NATIONAL RADIO INSTITUTE

WASHINGTON, D.C.

PRACTICAL DEMONSTRATIONS OF RADIO-TV FUNDAMENTALS

INSTRUCTIONS FOR
EXPERIMENTS 31 TO 40

4W

PIONEER HOME STUDY RADIO SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

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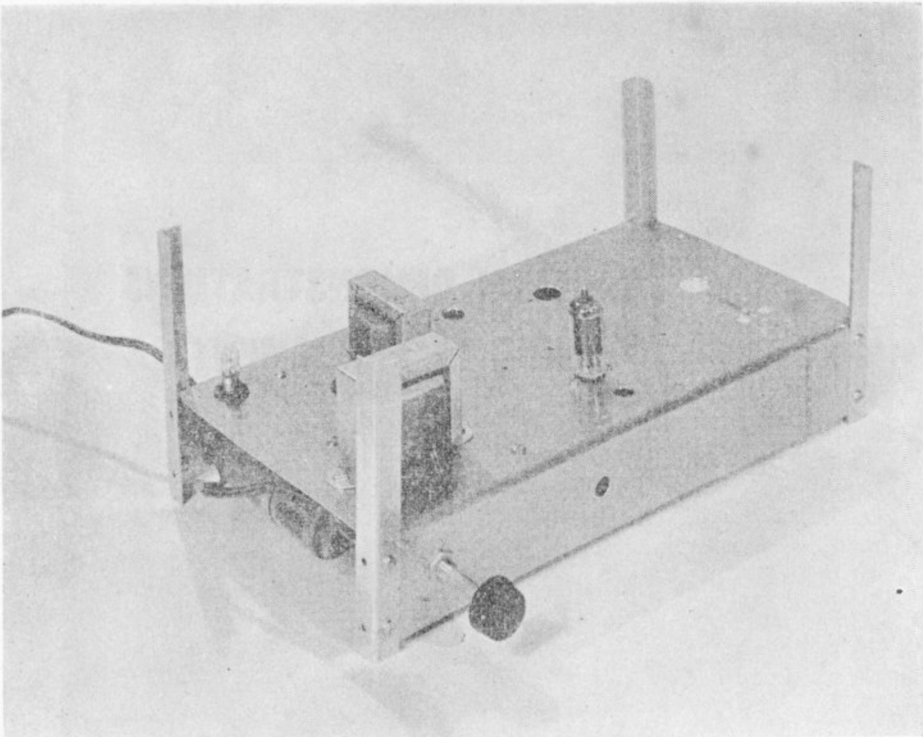

This is the power supply you will build and experiment with in this kit.

INDEX OF SECTIONS

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INSTRUCTIONS FOR PERFORMING RADIO-TV EXPERIMENTS 31 TO 40

IN ANY radio or TV receiver, the power supply must furnish not only the operating filament voltage for every tube in the receiver, but also dc voltages, either directly or indirectly, for the tube electrodes.

The electrodes of some tubes get their operating voltages directly from the power supply, while other tubes, such as the diode detector, operate on the signal voltages. A receiver stage of this type is indirectly dependent upon the power supply, because if a power supply defect interrupts the operation of the preceding stages that supply the signal to the diode detector, the detector will not get the signal it needs.

Thus, if the power supply is defective, the entire receiver may be inoperative. Diagnosing the trouble in a completely dead receiver (when no section or stage is working), therefore, is relatively simple. You know that it is probably a power supply failure, and a few tests will usually disclose the defective part or parts.

Common power supply defects are: failure to furnish voltages, furnishing too much or too little voltage, and poor filtering of the dc, allowing ac to be mixed with it. In this kit you will learn how components in a power supply fail, how to identify such failures by simple measurements, and how to check the suspected parts.

Many radio and TV receivers require higher voltages than rectification of the power line voltage will give. Rectifiers can be arranged to double the voltage. You will build and analyze voltage doublers in this kit.

HOW TO AVOID ELECTRICAL SHOCKS

As you get farther along in your Practical Demonstration Course, it becomes more and more important to take precautions to avoid electrical shocks.

An electrical shock is the result of current flowing through a part of your body. The stronger the current, the more severe the shock will be.

Current will flow through your body only when your body *completes* an electrical circuit. Remember, in any circuit there must be a source of voltage, electrical connections, and a load. If you touch both terminals of the source voltage, either at the source or at the load, you will be shocked. If a connecting wire is open, and you touch its broken ends, the circuit is completed through your body. Also, if you touch both ends of a resistor in a voltage divider, the current divides, part going through your body and part through the resistor. The important thing to remember is not to touch *both* sides of a circuit nor to bridge yourself across an open in an otherwise complete circuit.

One side of almost every power line is grounded. When you stand on the earth, you are at the same potential as everything else in contact with the earth, including the grounded side of the power line. So if you touch the other side of the power line, your body will complete the circuit to ground. If you are insulated from the earth, you can touch the other side of a power line and not get shocked. However, you should not touch a water pipe, a radiator, or a concrete floor at the same time, because they are at ground potential with respect to the high side of the line.

You have undoubtedly noticed birds perching on high-voltage power lines. They are not shocked, because they are touching only one side of the line. If the bird is big enough to touch both sides of a power line, however, it will be electrocuted immediately.

In many ac receivers that contain a power transformer, one side of the power line is connected to the receiver chassis through a capacitor. *If* you stand on ground and touch the chassis of such a receiver and *if* the capacitor is connected to the ungrounded side of the line, you can be shocked.

In ac-dc receivers, which operate on either ac or dc power line voltages, the ungrounded side of the power line connects to the receiver circuits, and in some cases directly to the chassis. Here a ground must not be fastened to the chassis. The power cord plug may be inserted into the wall outlet so that the chassis is connected to the high side of the power line. A ground wire connected to the chassis, therefore, would short-circuit the power line and cause a house fuse to blow out.

You must not touch the chassis of an ac-dc set unless you are insulated from the ground. If you are not insulated, the effect is the same as standing on ground and touching the ungrounded side of the power line. Usually such shocks are not fatal, since there is enough resistance between your feet, shoes, and ground to limit the current flow. However, shocks of this sort can be very unpleasant.

A power line is not the only source of electrical shocks. The B supply in a receiver may be even more dangerous, since in ac sets there may be several hundred volts between B+ and the chassis. You must observe the same precautions in working with the B supply as with a power line. Touch only one thing at a time. If you must touch a terminal that is connected to B+, make sure that your body is not in contact with a ground or with the chassis. Better still, do not touch any terminals or uninsulated parts while power is applied to the receiver. When there is a reason for you to touch parts directly with your hand or with a metal tool such as a pair of pliers or side cutters, turn off the set.

Just turning off a set, however, is no guarantee that you will not be shocked. The filter capacitor in the receiver may retain a charge for a few minutes after the receiver is turned off. If you don't want to wait while these capacitors discharge, you can short their positive and negative leads either with a piece of wire or with a screwdriver.

Make your work space safe. If you have provisions for an antenna and

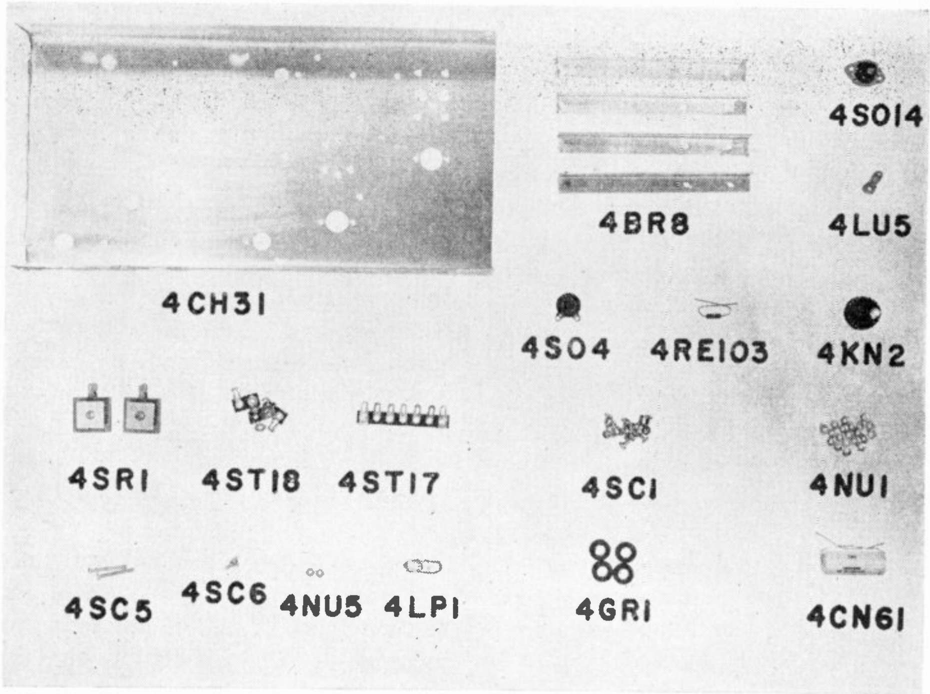

FIG. 1. The parts for this kit are pictured above, and described in the list below.

Quan.	*Part No.*	*Description*
1	4CH31	Metal chassis
4	4BR8	Chassis support bracket
4	4GR1	⅜" rubber grommet
1	4SO4	Pilot lamp socket with grommet
1	4SO14	Miniature 7-pin tube socket
1	4LU5	Solder lug
2	4SR1	Selenium rectifier
3	4ST18	1-lug terminal strip
1	4ST17	7-lug terminal strip
14	4SC1	6-32, ¼" machine screw
20	4NU1	6-32 hex nut
2	4SC5	6-32, 1" machine screw
2	4SC6	4-40, ¼" machine screw
2	4NU5	4-40 hex nut
1	4LP1	Pilot lamp
1	4RE103	27-ohm, ½-watt resistor
1	4CN61	20-mfd, 150-volt capacitor
1	4KN2	Round knob

NOTICE

You may receive either of two types of selenium rectifiers. One type has a mounting stud attached to it. If you receive that type, you will not receive the two 1-inch, 6-32 screws, part 4SC5, and you will receive 18 instead of 20, 6-32 hex nuts.

ground at your bench, the ground should be out of the way where you will not accidentally touch it. If water pipes are nearby, cover them with asbestos shields so you cannot accidentally hold on to one while working with a chassis. If the floor is concrete, provide a platform of dry boards, without nails going through the boards to the concrete. Do not use a stool with metal legs on the concrete floor without putting glass casters under each leg.

Don't probe around a live receiver unless you know what you are doing; and even then, keep one hand in your pocket out of harm's way. Discharge filter capacitors before touching circuits with your hands or metal tools. When using your vtvm as a voltmeter, do not let your fingers touch the tip of the probe. Keep your hand on the plastic probe handle. If the ground clip of the vtvm is to be connected to any point in the receiver except the chassis, turn off the set while attaching the ground clip.

Do not touch the metal chassis of the vtvm and the receiver chassis or circuits at the same time. Actually there is no danger of shock when doing this with the Model W, because the chassis is not connected to its circuits or to the vtvm ground clip. However, you may use another vtvm or other test equipment that does not have this safety feature, so you should make it a habit not to touch both at once.

Do not be afraid of electricity, but respect it. Beginners almost never get shocked. Only when you grow over-confident and disobey safety rules, is there a real danger of your being shocked. Keep alive your respect for electricity and its effects, and you will have nothing to worry about.

CONTENTS OF THIS KIT

The contents of this Kit are illustrated in Fig. 1 and are listed in the caption below it. Check the parts you received against this list to be sure you have all of them. Do not discard any of these parts, or the parts from previous kits, until you have finished your NRI course; you will use them over and over again in later experiments.

IMPORTANT: If any part of this kit is missing, look for a substitute part. If any part is obviously defective or has been damaged in shipment, return it immediately to NRI as directed on the packing slip accompanying this kit.

Assembling A Basic Power Supply

Before you begin the experiments, you are to mount a number of parts on the chassis. Then you are to wire a simple rectifier circuit for use in the first experiment.

Gather the parts listed below from the parts sent you with this kit, and from those left over from other kits.

One Metal chassis.
Four Chassis support brackets.
Four ⅜" rubber grommets.
One Pilot lamp socket with grommet.
One Power transformer.
One 7-pin tube socket.
One 500K-ohm potentiometer with On-Off switch.
Two Solder lugs.
One Iron-core choke coil.
Two Selenium rectifiers.
Three 1-lug terminal strips.
One 7-lug terminal strip.
One Round knob.
Fourteen 6-32 x ¼" screws.
Two 1", 6-32 screws.
Twenty 6-32 hex nuts.
Two 4-40 x ¼" screws.
Two 4-40 hex nuts.
One 20-20 mfd 150-volt electrolytic capacitor.

The power transformer and the iron-core choke coil are the ones you used in the last kit. Fig. 2 shows the chassis with all the holes identified that will be used in the experiments in this kit. Refer to Fig. 2 to identify the holes as you mount the various parts.

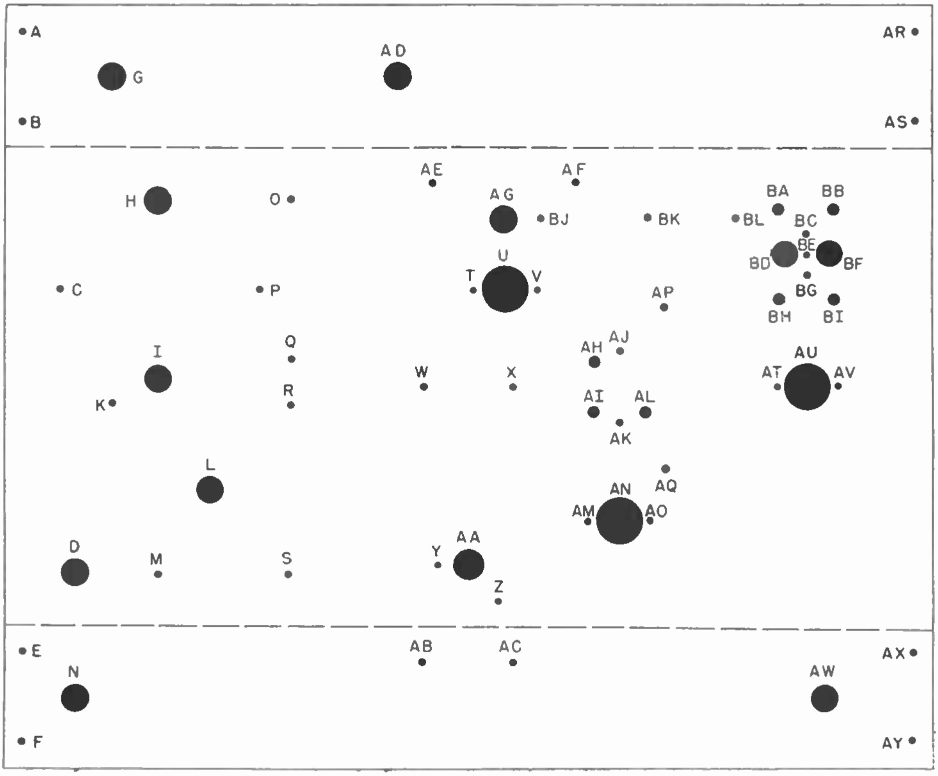

FIG. 2. This is your chassis with all the holes identified. Have it in this position to carry out the experiments.

First you are to mount the four chassis support brackets (right-angled pieces). These will be used to hold the chassis level when you turn it upside down to perform the experiments. Each support has four holes punched in one end. Fasten the brackets to the four corners of your chassis using holes A, B, E, F, AR, AS, AX, and AY, as shown in Fig. 3. Notice that each bracket fits around the corner and projects considerably above the top surface of the chassis. Use two 6-32 screws and nuts to fasten each bracket in place. Tighten the nuts securely.

Now turn the chassis upside down, and in the position shown in Fig. 2. Insert rubber grommets in holes H, I, L, and N. To do this, squeeze the grommet into an oval shape with the thumb and forefinger of one hand, then place it in the hole so that the chassis will fit into the groove in the grommet. Push the grommet into the chassis hole until half the grommet is on each side of the chassis, and the chassis fits into the groove in the grommet at all points.

Mount the pilot lamp socket in chassis hole D as shown in Fig. 4. First remove the large rubber grommet from the socket, and install it in the chassis hole in exactly the same way you installed the other grommets. Be sure the chassis does not cut through the rubber insulation in the groove of the grommet, because the purpose of this grommet is to insulate the pilot lamp socket completely from the chassis. Grasp the pilot lamp socket near its terminal lugs, and push the threaded part gently into the grommet from the bottom of the chassis as far as it will go without forcing. Then screw or rotate the socket in a clockwise direction until one of the lugs touches the grommet. Rotate the socket a bit more, if necessary, to bring the lugs into the position shown in Fig. 4.

Now mount the power transformer

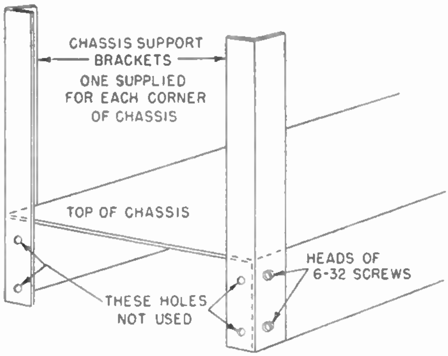

FIG. 3. Fasten the chassis support brackets to the four corners of the chassis as shown here. Although there are four holes punched at one end of each bracket, only one pair of holes is used to fasten each one to the chassis. As shown above, the support brackets project above the *top* of the chassis.

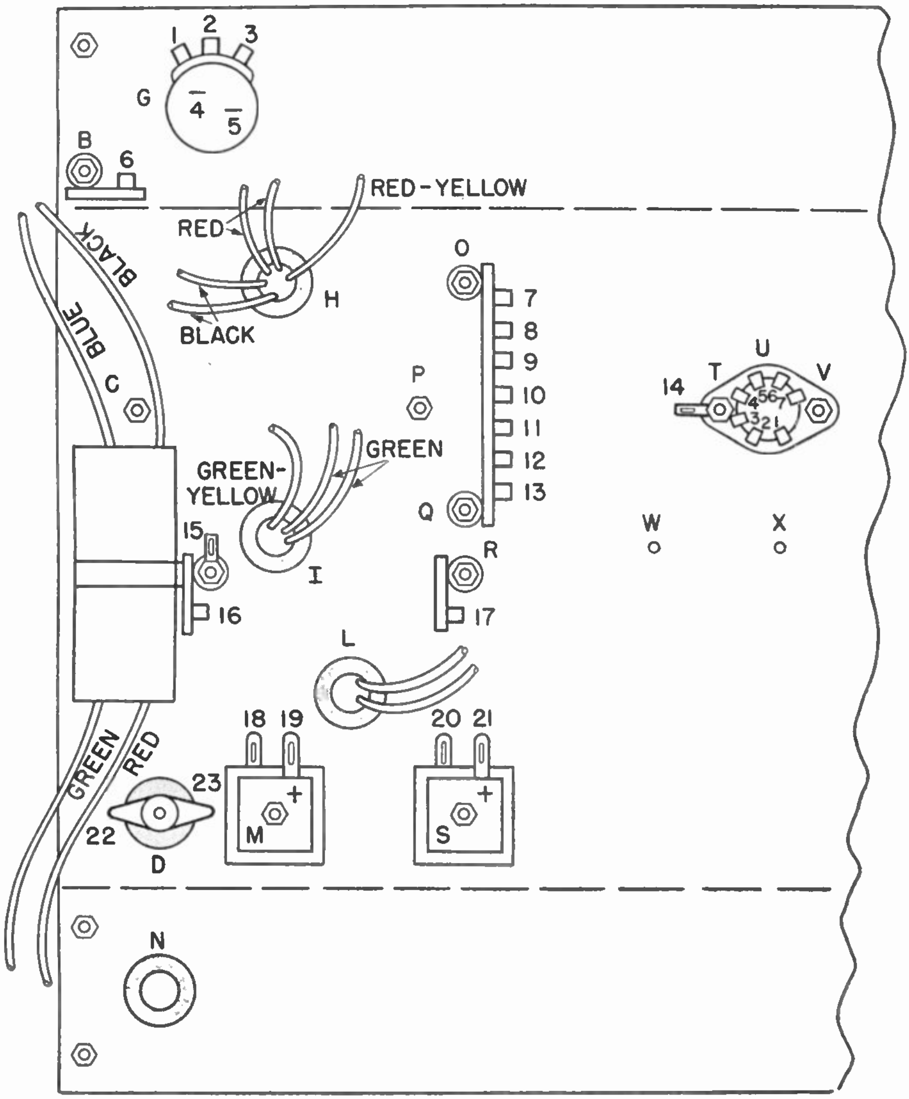

FIG. 4. This is the chassis with the preliminary parts mounted, and the terminals identified by number.

on top of the chassis. Place the transformer with its mounting feet over holes C and P so that the black, red, and red-yellow leads come through hole H, and the green and green-yellow leads come through hole I, as shown in Fig. 4. Use 6-32 screws and nuts. Pass the screws through the transformer and chassis from the top of the chassis. Draw the nuts up tight to fasten the power transformer securely in place.

Next, mount the 7-pin miniature socket in hole U. Be sure to place it so that the space between pins 1 and 7 is toward hole V, as shown in Fig. 4. Use 4-40 machine screws and nuts to hold the socket in place.

Insert one screw in hole V from the top of the chassis, and place a 4-40 hex nut on the screw. Do not tighten it yet. Before you put the screw in hole T, put a solder lug (the lug that you received in this kit) between the socket and the chassis, and position it as shown in Fig. 4. Bend the lug up away from the chassis so that you can make connections to it. Insert the screw through the chassis, the solder lug and the socket. Put a nut on the screw, and tighten both nuts. Gently bend the tube socket pins outward until they are approximately parallel to the chassis.

Mount the potentiometer with the on-off switch in hole G from inside the chassis with the shaft projecting out. The lugs should point upward as shown in Fig. 4. Place the nut on the threaded part of the shaft and draw it up tight.

To mount the knob on the potentiometer shaft, you will need a screwdriver with a small blade. Insert the screwdriver blade into the small hole in the side of the knob, and loosen the set screw, but do not remove it. Then, put the knob on the potentiometer shaft so that the set screw, when it is tightened will touch the flat side of the shaft. Tighten the set screw.

Mount the iron-core choke on top of the chassis over holes R and S, with its leads through hole L. First, pass a ¼″, 6-32 screw through the mounting hole in the choke and through hole R. Before you put on the nut, put a one-lug terminal strip over the screw, and position the terminal strip as shown in Fig. 4, then put on a 6-32 hex nut. Hole S is to be used to mount one of the selenium rectifiers under the chassis as well as the choke on top of the chassis. You may have received either of two types of selenium rectifiers. One type has a built-in mounting stud bolt, the other type does not. If you received the type that does have a mounting stud, put a 6-32 nut on it, and screw it all the way up. Then put the stud through hole S from underneath the chassis, and through the mounting ear of the choke, with the terminals pointing as in Fig. 4. Put another 6-32 nut on it, and tighten it, without forcing it.

If you received the type of selenium rectifier without a built-in mounting stud, put a *1-inch* 6-32 screw through the other mounting foot of the choke from the top and through hole S. Put a 6-32 nut on the screw and tighten it. Then put another 6-32 nut on the screw, and run it part way down.

Then put the selenium rectifier on the screw, with the side marked + *away* from the chassis, and with the lugs pointing toward the center of the chassis as shown in Fig. 4. Put a third nut on the screw. Run the second nut far enough down so there is room for the third nut above the rectifier.

Mount the second selenium rectifier in the same way in hole M. If it has no mounting stud, run a 1″, 6-32 screw through hole M, put a nut on the screw to hold it in place, and tighten the nut. Run a second nut part way down on the screw, mount the rectifier, and then put on the third nut. Be sure the positive side of the rectifier is away from the chassis and that the lugs are pointing toward the center of the chassis as shown in Fig. 4. The nuts holding the rectifier should be drawn up tight, but do not force them.

Now mount a 7-lug terminal strip over holes O and Q, using 6-32 screws and nuts. Mount a 1-lug terminal strip over hole B. You already have a screw and nut in this hole to hold the support bracket; remove the nut, and add the terminal strip . Then put the nut back on.

Now mount the 20-20 mfd, 150-volt electrolytic capacitor with the hole in the mounting strap over hole K in the chassis. Put the larger solder lug between the chassis and the mounting strap, and bend the lug up and away from the chassis. Put a 1-lug terminal strip over the strap as shown in Fig. 4. Insert a 6-32 screw in hole K, and pass it through the solder lug, through the hole in the capacitor mounting strap and through the 1-lug terminal strip over hole K. You should have three parts mounted on this screw: The solder lug, the capacitor, and the 1-lug strip. After you have the parts positioned as shown in Fig. 4, put a 6-32 nut on the screw and tighten it. Be sure the capacitor is placed as shown, with the blue and black leads at the end toward the power transformer, and the red and green leads toward the pilot lamp.

This completes the preliminary mounting of the parts. Check the positions of all your parts carefully against Fig. 4. See that the heads of all mounting screws are on the outside of the chassis; this gives your work a more professional appearance.

Identify each of the terminals as shown in Fig. 4. Use a sharp lead pencil, your metal-marking crayon, or marked pieces of adhesive tape, and place the terminal numbers near the corresponding lugs. Keep the numbers small, clearly legible and close to the terminals. Check your work carefully to be sure that you have numbered all the terminals correctly.

The first circuit you will build is a simple half-wave rectifier. Before you wire this rectifier circuit, however, let us learn something about the power transformer and tube.

THE POWER TRANSFORMER

The power transformer you received in Kit 3 is known as a "combination" transformer, because it furnishes both high and low ac voltages from a given ac line voltage. The symbol used to represent this transformer in schematic diagrams is shown in Fig. 5.

As the diagram shows, there are three separate windings on this transformer. The primary winding, which is wound for 115-volt, 60-cycle ac power, is terminated in the two black leads. Under no circumstances should you connect the primary of this transformer to a dc power line or to an ac

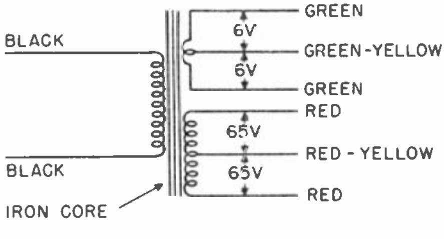

FIG. 5. The schematic symbol of your power transformer.

power line having a frequency of 25 or 40 cycles. The low-voltage winding is the one with green leads. It is center-tapped with a green-yellow lead. Each section, between either of the green leads and the center tap, supplies approximately 6 volts; the voltage between the two green leads is approximately 12 volts.

The third winding, having the leads colored red, is also center-tapped. This winding, which is commonly called the high-voltage secondary winding, supplies the high ac voltage needed for the plates of the rectifier tube. It is designed to have a no-load output of approximately 130 volts between the red leads. Variations in line voltage, however, may make the actual no-load output of your transformer anywhere between 100 and 140 volts. The center tap is brought out to the red-yellow lead.

THE RECTIFIER TUBE

The rectifier tube we will use in the first experiment is the 6X4 tube that is now in your vtvm. This tube contains two plates and two cathodes. The plates are independent of each

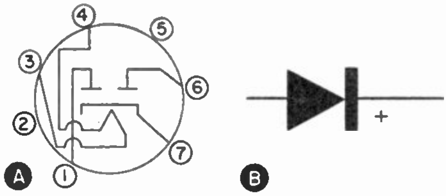

FIG. 6. A schematic diagram of the tube showing the internal connections of the electrodes to the tube pins as shown at A. The symbol used to represent a selenium rectifier is shown at A. The bar represents the cathode, and the arrow the plate.

other and are brought out to separate pins. There is only one cathode pin, however, since the two cathode sections are connected internally. The filament requires approximately 6.3 volts at .6 ampere for normal operation.

The 6X4 tube fits a standard 7-pin miniature socket. Pins 1, 3, 4, 6, and 7 on the base of the tube are connected to elements within the tube. Pins 2 and 5, although they are on the tube base, are not connected to anything. In factory-made radio and television receivers, the lugs on the tube socket that correspond to these blank pins are frequently used instead of terminal strips as tie points.

The schematic symbol for a 6X4 rectifier tube is shown in Fig. 6A. This diagram shows the elements within the tube, and indicates the pins to which they are connected. It identifies the terminals as they appear when you are looking at the bottom of the socket or the base of the tube.

The symbol used for a selenium rectifier, which you will also use in these experiments, is shown in Fig 6B. The selenium rectifier has no filament, but it does have sections that operate similarly to the cathode and plate of a vacuum tube. In fact, they have the same names. In Fig. 6B, the arrow is the plate, and the bar is the cathode, the cathode is the side of the rectifier that is marked with a + sign. Use this + sign as a means of identifying the cathode, but remember that before current will flow through a selenium rectifier, the voltage applied to the plate must be positive and greater in amplitude than the voltage on the cathode.

WIRING A HALF-WAVE RECTIFIER CIRCUIT

To wire the half-wave rectifier circuit shown schematically in Fig. 7, you need the following parts:

One 5′ power cord.
One roll hookup wire.
One 100K-ohm, ½-watt resistor.

In building this circuit and in doing the experiments in this kit, *do not cut* the leads on any of the parts. You will use them again in later kits. If the leads are too long, simply bend them out of the way.

Plug in your soldering iron, and clean and retin the tip if necessary. Proceed as follows:

Step 1: Wire the primary circuit. Connect the power cord, the on-off switch, and the primary winding of the power transformer in series. To do this, push the power cord through the rubber grommet in hole N in from the outside of the chassis. Pull enough of the cord through to reach the switch terminal 4 on the potentiometer in hole G. Then, tie a knot in the cord on the inside of the chassis to prevent it from being pulled back through the grommet, and to prevent strain on the terminals to which the power cord is soldered. Position the power cord as shown in Fig. 8. Your wiring will be neater if you push the power cord under the capacitor. Then, split the cord back far enough so that you can connect one side to terminal 4 on the switch, and the other to terminal 6. The ends of the power cord are already cut and tinned. Insert the end of one lead in switch terminal 4 and solder the connection.

Run the other power cord lead to terminal 6, as shown in Fig. 8, make a hook in the bare wire, and insert it in the terminal. Do not solder this connection yet. One of the primary leads from the transformer is also to be connected to this terminal.

Now, to connect the transformer primary winding into the circuit, attach one of the black leads of the power transformer to terminal 6. Solder the connection. Connect the other black lead to terminal 5 on the on-off switch, and solder the connection.

Step 2: Wire the pilot lamp circuit and rectifier filament circuit as shown in Figs. 7 and 8. Note that the pilot

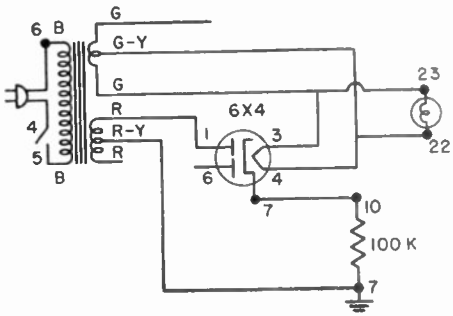

FIG. 7. This is the half-wave rectifier circuit you are to wire first.

lamp and the filament of the 6X4 are in parallel. Since the filament of this tube requires 6 volts, you will use only half of the low-voltage filament winding. As shown in Fig. 5, you can obtain the correct voltage by using the green and yellow transformer lead, and one of the green leads. It does not matter which green lead you use.

Connect the green-yellow lead of the power transformer to pin 4 of the tube socket, and the green lead to pin 3 of the tube socket. Do not cut the leads, and do not solder the connections yet. Now run a length of hookup wire between terminal 22 on

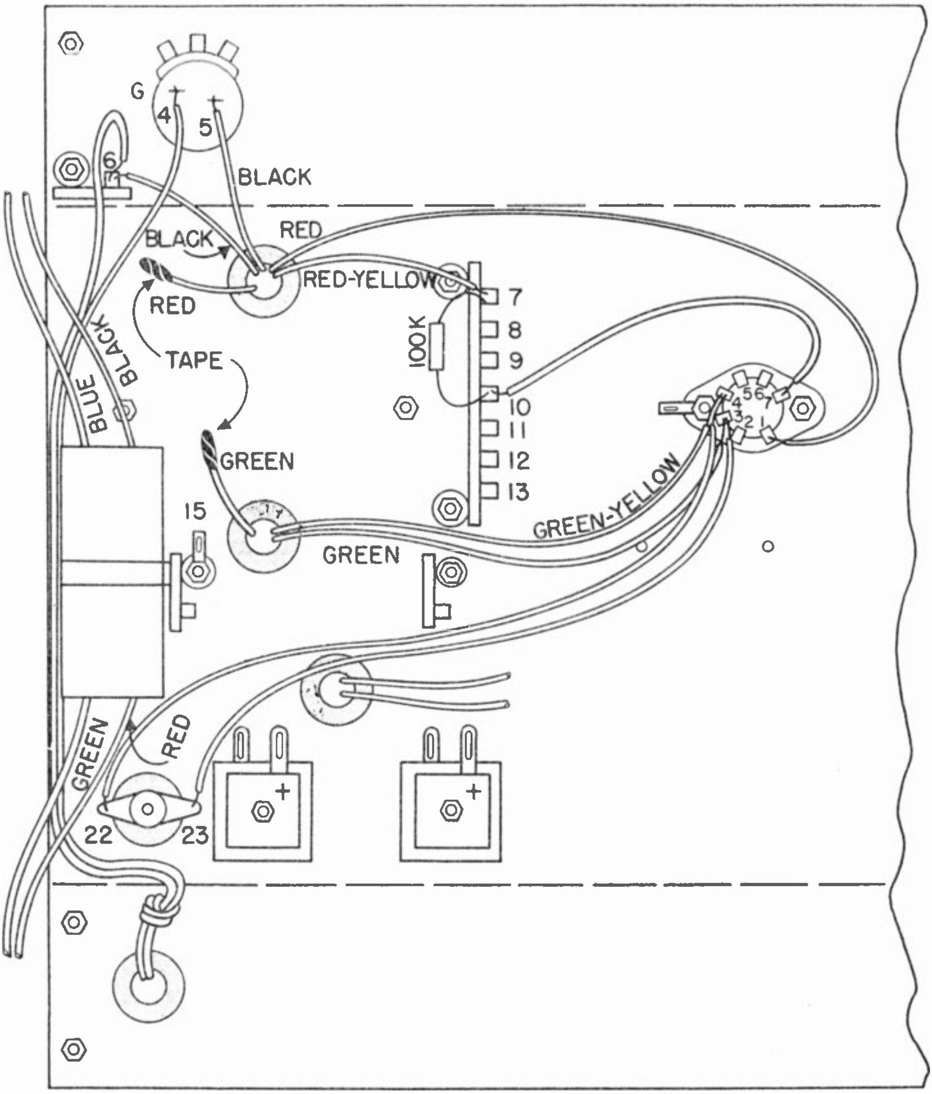

FIG. 8. This is how your chassis will look for the circuit in Fig. 7.

the pilot lamp socket and tube pin 4, and another length of hookup wire between terminal 23 of the pilot lamp socket and tube pin 3. Position the wires as shown in Fig. 8. Solder all four connections.

Step 3: To wire the rectifier circuit. Solder either of the red leads of the power transformer to pin 1 of the tube socket, and connect the red-yellow lead to ground terminal 7 on the terminal strip. Solder socket pin 1, but do not solder terminal 7 of the terminal strip yet. (Remember not to cut the transformer leads.)

Now, connect pin 7 on the tube

socket to terminal 10 on the terminal strip with a piece of hookup wire, and connect the 100,000-ohm resistor between terminal 10 and terminal 7 on the terminal strip. Solder all connections, and check the soldered joints. The circuit is now completely wired.

Check your work carefully against Figs. 7 and 8 to make sure the parts are connected electrically as shown. There are two unused leads on the power transformer. Tape the ends of these leads so that they cannot short to the chassis or to any terminal lugs.

Finally, dress down the leads to give your chassis a neat appearance. Push the transformer leads back through the grommets so that the excess lengths are on the top of the chassis where they will be out of the way.

TESTING THE HALF-WAVE RECTIFIER CIRCUIT

Radio-TV parts may look perfectly all right and yet be defective. An important part of every assembly procedure is to make resistance tests to be sure that there are no shorts or opens. If the results of these tests are satisfactory, then it is safe to apply power and make voltage measurements.

Continuity Tests. For a power supply like the one you have wired, you should check the continuity of the circuits and be on the lookout for a short between the cathode terminal of the rectifier tube and the chassis. A short of this type could not only ruin the tube, but it could also damage the power transformer.

You will use the ohmmeter section of your vtvm to carry out the continuity tests. Therefore, plug the line cord of the vtvm into the wall outlet, and turn the Function switch to Ohms. Do *not* plug in the line cord of the half-wave rectifier circuit until you are instructed to do so.

First, turn off the switch on the power supply. To do this, turn the knob on the 500K-ohm potentiometer shaft all the way in the counterclockwise direction until you hear a click. If the switch is already in the Off position, proceed with the continuity tests.

To test the line cord, switch, and primary transformer winding, turn the Range Selector switch to the R x 10K position, and connect the ohmmeter probes to the prongs of the power cord plug. You should get no reading on the ohmmeter, indicating that no continuity exists in the circuit. Now with the ohmmeter test probes still connected to the prongs, turn the power supply switch on. Immediately the meter pointer should drop over to the zero position and remain there until you turn the Range Selector switch of the ohmmeter to the R x 1 position. When you do this, the meter should indicate between 20 and 40 ohms, the resistance of the primary power transformer winding.

Next, connect your ohmmeter leads to pins 3 and 4 of the tube socket. With the Range Selector switch still in the R x 1 position, you will measure about .6 ohm. This indicates continuity in the circuit. Now, turn the Range Selector switch to the highest range, R x 1M, and check between the chassis and pin 3 or pin 4 of the tube socket. You should not get a reading.

To measure the resistance of half of the high-voltage winding of the power transformer, connect the ohmmeter probe to tube socket pin 1, and the ground clip to the chassis. With the Range Selector switch in the R x 1 position, your reading should be approximately 50 ohms. Next, measure the resistance from tube socket pin 7 to the chassis. Here you should get a reading of approximately 100,000 ohms, measured on the R x 10K ohmmeter range. A very low reading indicates a short. Look for solder that may have dripped down and shorted to the chassis, or for improper wiring.

Voltage Tests. If the results of the continuity tests are satisfactory, you can now check the voltages of the power supply. Plug the supply into a 115-volt, 60-cycle wall outlet, and be sure the on-off switch is still in the ON position. Set your voltmeter up for ac measurements, and turn the Range switch to the 120-volt position. Measure the voltage between the chassis and pin 1 of the miniature socket. Since you are measuring half of the high-voltage winding of the power transformer, you should get a reading of approximately 65 volts.

Now set the Range switch to the 12-volt position and measure the voltage between pins 3 and 4 of the tube socket. Then measure the voltage between terminals 22 and 23 of the pilot lamp socket. You should get a reading between 6 and 7 volts in both cases. When the tube and the pilot lamp are put into their sockets later, the voltage will drop somewhat.

To measure the line voltage, remove the line cord plug from the wall outlet, and connect the vtvm test probes between terminal 6 of the 1-lug terminal strip and terminal 4 on the on-off switch. Turn the Range Selector switch to the 300-volt range, and plug the line cord back into the wall outlet. You will get a reading of approximately 120 volts, although it may vary from 105 volts to 130 volts.

When you have finished making these measurements and found that the continuity of the supply and the ac voltages are correct, you are ready to go ahead with the experiments. If any readings were not correct, be sure to find out what is wrong before proceeding with the experiments. If you need help, write us giving the results of all your measurements. Turn off the power supply, and unplug it from the wall outlet.

Instructions for Performing the Experiments

Here are some general instructions that you are to follow in performing all of the experiments in this kit and in future ones.

1. Follow these steps for each experiment:

(a) Read the entire experiment, paying particular attention to the discussion.

(b) Perform each step of the experiment, and record your results.

(c) Study the discussion carefully, then analyze your results.

(d) Answer the Statement in the manual and on the Report Sheet.

2. If, when you read through an experiment, you think you won't have enough time to finish it, spend one work period doing any preliminary construction and wiring work. Leave the actual measurements, circuit changes, etc., until you have time to do them all at once.

3. If you do not get acceptable results from any experiment, stop right there and find the trouble before going any further. Do the very best you can to solve the problem yourself, because doing so helps you to develop the troubleshooting techniques you'll need later on. Check over the wiring instructions, test every connection, and, if necessary, test each part if effect-to-cause reasoning fails to lead you to the trouble. Be sure to check the circuit against the schematic. If all these procedures fail, write to us on the special Kit Consultation Blank provided, and tell us which experiment and step you're working on. Give us a complete description of the symptoms that indicate trouble, and list the results of your tests. Go ahead with your regular lessons while waiting for our answer.

4. One object of these practical experiments is to develop your ability to wire a circuit with only a schematic diagram as your guide, just as an experienced serviceman does. Begin now to think in terms of tube and circuit elements rather than specific terminal numbers. For example, instead of thinking of the 100,000-ohm resistor as being between terminals 7 and 10 on the 7-lug terminal strip, think of it as being between the cathode of the rectifier tube and the center-tap of the high-voltage winding of the power transformer. This will soon teach you to visualize circuits so that you can work from a schematic diagram with ease. Because we want to encourage you to develop this ability, there will be few pictorial sketches in this manual.

5. As in the previous kit, we have omitted the color code listing for the resistors. If you have not yet learned the RETMA color code, we urge you to do so immediately. Knowing the code thoroughly is a big time saver in your assembly work, and it helps reduce errors in wiring. If you are in doubt as to the value of a particular resistor, or if you forget the color code, look it up in the chart in your first kit.

6. From now on, we shall not indicate what tools you need to wire circuits. You know that you have to use hookup wire, pliers, screwdrivers, etc. If there is any soldering or unsoldering to be done, you know that you will have to heat your soldering iron and must use ROSIN-CORE solder. Therefore, in any experiment in which you are to make circuit changes, get out the tools you will need, and heat your soldering iron before beginning the assembly or disassembly of that experiment.

7. From now on, there will be very little said about how to use your vtvm. Remember to check its calibration occasionally, and to turn it off after each work period. A complete summary of the calibrating and operating instructions is in Data Sheet B that you received in Kit 2. If you forget any detail of how to use the instrument, refer to these instructions. You are going to make all kinds of measurements, resistance as well as ac and dc voltages. You must use your vtvm properly to get the correct results.

8. When you are taking measurements with your vtvm, turn the experimental chassis on-off switch off while connecting and disconnecting the test leads. When making wiring changes, turn the switch off and unplug it from the wall outlet. Be sure to remember to do this every time, because we may not always mention it specifically.

EXPERIMENT 31

Purpose: **To show that when an ac voltage is applied to a rectifier and a resistor in series, a dc voltage will be produced across the resistor; and to show that the polarity of the voltage drop across the resistor depends on how the rectifier is connected into the circuit; and**

To show that the voltage across the load resistor in a full-wave rectifier is approximately twice that measured across the load resistor in a half-wave rectifier.

Introductory Discussion: The circuit you will use to show that there is a dc voltage across the load when an ac voltage source, a rectifier, and a load (in this instance, a 100,000-ohm resistor) are connected in series, is shown in Fig. 31-1. This circuit is similar to the one that you have built, except that we have used a selenium rectifier in place of the 6X4 tube. To simplify the discussion, we

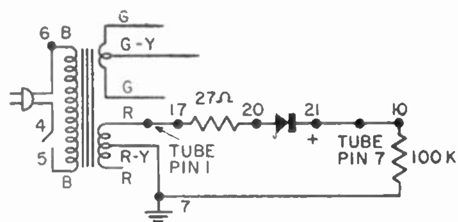

FIG. 31-1. Half-wave rectifier circuit for Experiment 31.

will consider the power transformer to be the ac source. Actually, of course, power is drawn from the power line to excite the primary winding of the power transformer.

To show that the voltage drop across the 100,000-ohm load resistor is a dc voltage, you will make use of the fact that under ordinary conditions, your vtvm will not respond to any ac voltage when the Function switch is in the dc position.

You will also use the Function switch of your vtvm as a polarity indicating device. When the meter pointer deflects to the right, the polarity of the terminal to which the probe is being touched is the same as that shown on the Function switch.

Experimental Procedure: The parts needed for this experiment, besides the power supply assembly you have constructed and the vtvm, are:

One 27-ohm resistor.
One Pilot lamp.
One 6X4 tube.

Wire the selenium rectifier into the circuit. To do this, connect the 27-ohm resistor between terminal 20 of the selenium rectifier in hole S and terminal 17 on the 1-lug terminal strip in hole R. Since you will not disconnect this resistor later on, place it between the terminals and cut the leads to the correct length. Do not cut any other leads unless you are instructed to do so. This resistor is used to protect the selenium rectifier from high current surges when the supply is turned on or off.

Connect a piece of hookup wire between terminal 17 and tube socket pin 1. Connect another piece of hookup wire between terminal 21 of the selenium rectifier and tube socket pin 7. Since there is no tube in the socket at present, we are simply using the tube socket pins as "tie" points, and the circuit is wired as shown schematically in Fig. 31-1. This is a half-wave selenium rectifier circuit.

With the power supply chassis turned upside down, clip the ground lead of your vtvm to the chassis. This is the same as clipping it to the 100,000-ohm resistor lead that goes to terminal 7 of the terminal strip, since terminal 7 is grounded.

Insert the power cord of the vtvm into the wall outlet, and set the Function switch to the +DC position. You are now ready to proceed with the first step.

Step 1: To prove that there is a dc voltage across the load resistor when it is in series with a selenium rectifier and an ac source. Insert the plug of the power supply cord into your 60-cycle ac wall outlet, and turn ON the on-off switch. Now touch the positive probe of your vtvm to the end of the 100,000-ohm resistor that is connected to terminal 10. Remember, you are measuring dc voltage here, so set the Function switch on the vtvm accordingly. Adjust the Range switch to the 30V range, and record your reading in the first line of the table in Fig. 31-2. Turn off the power supply.

STEP	CIRCUIT	VOLTAGE ACROSS LOAD RESISTOR
1	HALF-WAVE SELENIUM RECTIFIER	35
2	HALF-WAVE TUBE RECTIFIER	100
3	CONNECTIONS REVERSED ON TUBE RECTIFIER	100
4	FULL-WAVE RECTIFIER	8

FIG. 31-2. Enter your readings for Experiment 31 here.

Step 2: To show that a vacuum tube rectifier will give essentially the same results as a selenium rectifier. First, unsolder and remove the leads connecting terminals 17 and 21 to the miniature tube socket. Do not, however, disturb the other leads on tube socket terminals 1 and 7, and do not remove the 27-ohm resistor from the circuit.

Now remove the 6X4 tube from your vtvm. Grasp the tube with a handkerchief if it is hot, and insert it in the socket on your experimental

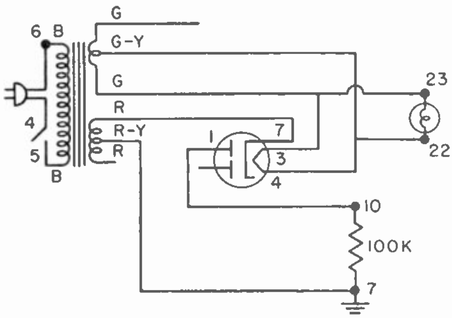

FIG. 31-3. Half-wave rectifier circuit with plate and cathode connections reversed.

chassis. Also insert the pilot lamp in its socket, and screw it up tight. Your circuit is now like Fig. 7. Again turn the power supply upside down, and turn on the power supply switch. The pilot lamp and the filament of the 6X4 rectifier tube should glow. Incidentally, this tube can be operated in any position, so it does no harm to turn the chassis upside down.

The ground lead of your vtvm should still be clipped to the chassis. Measure the dc voltage across the load resistor by touching the positive probe to terminal 10 on the terminal strip. Read the meter carefully, and record your reading in the second space in Fig. 31-2. Turn off the power supply.

Step 3: To show that the polarity of the voltage drop across the load resistor depends on how the rectifier is connected in the circuit. Set up the circuit shown in Fig. 31-3, in which the plate and cathode connections are the reverse of those in the circuit you just used. Unsolder the leads from socket terminals 1 and 7. Connect the red transformer lead that was on terminal 1 to terminal 7, and solder the connection. Then, solder the lead that was on pin 7 to pin 1. The circuit will now be like Fig. 31-3.

To show that the polarity of the voltage drop across the load resistor has changed, turn on the supply, connect the ground clip of the vtvm to the power supply chassis, and touch the positive probe to terminal 10 on the terminal strip. Note that with the Function switch in the +DC position you will get a downscale reading.

Turn the Function switch to the —DC position. Now you should get an up-scale reading. This indicates that the point to which the probe is touched is negative with respect to the point to which the ground lead is clipped. The reading you get should be just about the same as the one you got in Step 2, since the only difference between the circuits is that the connections to the rectifier are reversed. Record your reading on the third line of Fig. 31-2 as a minus (—) value, and turn off the power supply.

Step 4: To convert the half-wave rectifier circuit to a full-wave rectifier circuit. Wire the circuit as shown in Fig. 31-4. Disconnect the leads to pins 7 and 1 of the tube socket, and change them back to the way they were in Fig. 7. Turn on the equipment and check the load voltage to see that the change has been made correctly, and that the voltage you measure is approximately the same as you measured before for this half-wave rectifier.

Turn off the power supply switch, and remove the line cord to the experimental chassis from the wall outlet. Remove the tape from the other red power transformer lead, and solder this lead to tube socket pin 6. The circuit is now wired for full-wave rectification as shown in Fig. 31-4. When plate 1 is positive and conducts, plate 6 will be negative, and there will be no current flow from the cathode to this plate. On the next half cycle, plate 1 is negative and does not conduct, but plate 6 is positive, and does conduct. Thus, regardless of the polarity of ac voltage applied, we have current flowing in the same direction through the load resistor.

Now turn the Range Selector switch to the 120V position, check the voltage across the load resistor, and record your reading for Step 4 in Fig. 31-2.

Discussion: The fact that a direct current flows through the load in the circuits you have set up is based on a fundamental property of a rectifier—current will flow more easily through a rectifier in one direction than in the other.

In a rectifier tube, current can flow only from the cathode to the plate. Electrons cannot flow from the plate to the cathode. In a selenium rectifier, the terminal at which electrons enter is also called the cathode, and the one from which they leave is called the plate. When electrons are flowing from the cathode to the plate, they meet very little resistance. But when they attempt to flow from the plate to the cathode, the resistance is extremely high. Although some current flows in a selenium rectifier in the opposite direction, it can be ignored because it is small as compared to the current flow from the cathode to the plate.

In each of the circuits you set up in this experiment, the plate is alternately positive and negative during each ac cycle, and current flows through the rectifier and load as a series of pulses. Since the voltage drop across the load is in direct proportion to the current flowing through it, the load voltage is also a series of pulses. If you were to connect a cathode ray oscilloscope across the

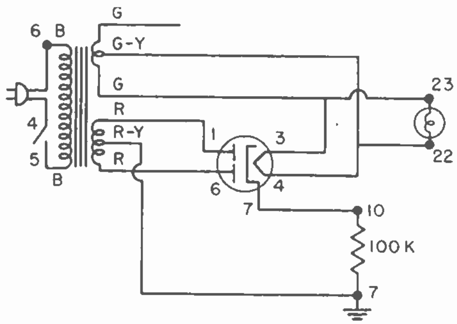

FIG. 31-4. Full-wave rectifier circuit.

load, you would get a pattern somewhat like that shown in Fig. 31-5.

As you can see, each voltage pulse extends in the same direction from the zero reference line. Therefore, the series of pulses contains a dc component that we can measure.

The rectifier circuit you used in the first part of this experiment is known as a half-wave rectifier because it passes current during only half of the ac cycle. When there is no filter capacitor in the circuit (the effect of a filter will be shown later), the dc component that the meter indicates is much less than the peak value of the voltage pulses. The pulses reach a peak nearly equal to the peak value of the ac source voltage, but the vtvm is capable of measuring only the average of the positive pulses, which is about one-third of the peak value.

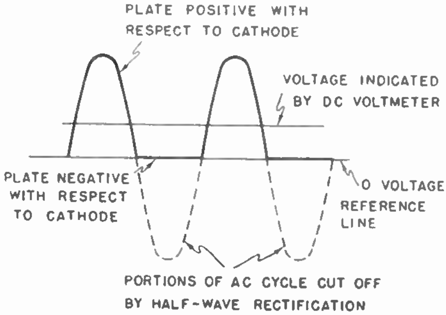

FIG. 31-5. The heavy line indicates the shape of the voltage across the load of the half-wave rectifier circuit.

The value of the ac voltage developed across each half of the high-voltage secondary winding is fixed by the design of the transformer. With half of the high-voltage secondary of this particular transformer connected in a half-wave rectifier circuit, the maximum no-load dc output voltage we can measure is approximately 30 volts. The voltage you measured in the experiment should not be much lower than this value, because of the high value load resistor used in the circuit. We can compute the no-load output voltage of this half-wave circuit by remembering that the peak value of a sine-wave voltage is 1.4 times the rms value. Since the rated rms output of half of the high-voltage winding on this transformer is about 65 volts, the peak output must be about 90 volts. One-third of 90 volts is about 30 volts.

If your ac source does not produce a true sine wave, the dc output you measure may be somewhat higher or lower than these values, depending on the exact shape of your ac voltage.

When you connected the circuit as a full-wave rectifier, you should have noticed an increase in the output voltage. With full-wave rectification, the spaces between the half-wave rectified pulses are filled in, as shown in Fig. 31-6. The two diodes conduct on alternate halves of the ac cycle. Thus, at all times there is some dc voltage across the load resistor, and we measure approximately twice as high a voltage with a full-wave recti-

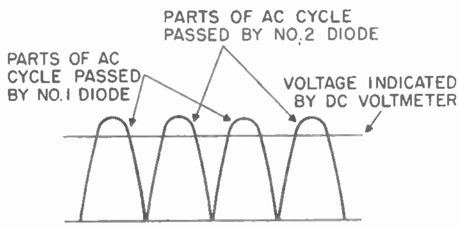

FIG. 31-6. In a full-wave rectifier, the two diodes conduct on alternate halves of the ac cycle, so the spaces between the half-wave rectified pulses are filled in as shown here.

fier as with a half-wave rectifier. Actually, the strength or magnitude of the voltage has not increased. The peak values in both cases are the same.

Several important radio and TV servicing principles are shown by this experiment. First, as you know, you must set the Function switch of your vtvm to the proper polarity to make the instrument indicate voltages correctly. By the term "proper polarity" we mean that the Function switch must be set so that the positive probe will connect to the point in the circuit under test having the same polarity as that indicated by the Function switch setting.

If the meter pointer moves to the right when you make a voltage measurement, you know that the probe polarity is the same as that of the Function switch. The opposite is also true, of course. If the meter pointer moves to the left, the Function switch polarity must be incorrect for the voltage source being measured.

In any device in a circuit, except the source, the terminal at which the electrons enter is the negative one. This fact lets you find the direction of electron flow by examining the diagram. If there are tubes in the circuit, electrons always flow from the cathode to the plate, and this establishes the direction of electron flow through any parts in series with the tubes. Knowing the direction of electron flow, you can determine the polarity of the voltage drops across the parts.

Instructions for Statement No. 31: For your Report on this experiment, you will change your full-wave rectifier circuit back to a half-wave circuit, and put the load between the plate of the rectifier and the ungrounded side of the high-voltage winding. The circuit is shown in Fig. 31-7. You are to measure the dc voltage drop across the load, and compare it to the voltage drops you measured in Steps 2 and 3 of the experiment.

To change the circuit, proceed as follows: First, disconnect the red transformer lead from tube socket terminal 6, and again tape the end to prevent shorts. Unsolder the 100,000-ohm resistor from the terminal strip. Then, disconnect from terminal 10 of

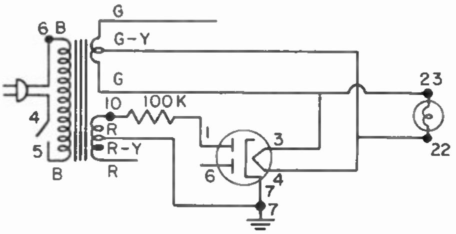

FIG. 31-7. This is the circuit you will use in answering Statement No. 31.

the terminal strip the lead that goes to terminal 7 on the tube socket. Move this lead to terminal 7 on the terminal strip, and solder the connection.

To connect the 100,000-ohm resistor in series with the plate of the rectifier tube, disconnect the red transformer lead from tube socket pin 1, and move it to terminal 10. Then, connect the resistor between terminal 10 of the terminal strip and tube socket pin 1. Solder both connections. Your circuit should now be like Fig. 31-7.

Connect the ground lead of your vtvm to tube socket pin 1, plug the power supply into the wall outlet, and turn it on. Then carefully consider the direction of electron flow through the load resistor, and set your Function switch to give an upscale reading. Touch the positive probe of your vtvm to the junction of the red lead from the power transformer and the 100,000-ohm resistor. Make a note of your reading. You now have sufficient information to complete the Statement.

Statement No. 31: When I measured the dc voltage across the 100,000-ohm resistor, I found that it was:

(1) *much lower than*

(2) *considerably higher than*

(3) *essentially the same as*

the dc voltage I measured in Steps 2 and 3.

EXPERIMENT 32

Purpose: **To show that a capacitor can be charged to approximately the peak ac voltage with both a full-wave and a half-wave rectifier; and to show that the voltage stored in the capacitor can be used to send current through a load.**

Introductory Discussion: There are two disadvantages to the rectifier circuits used in the last experiment. One is that the dc voltage at the output is not constant; pulsating voltage of this type would not be suitable for any electrical circuit requiring a relatively pure dc supply. The other disadvantage is that the circuits are very inefficient; the load voltage is not nearly as high as the ac voltage applied to the rectifier.

There are two ways in which the dc load voltage can be increased. One way is to increase the ac supply voltage by using a transformer with more secondary turns. This method may not be practical, however, because of limitations on the physical size or the cost of the power transformer. Of course, the output voltage will still be pulsating dc rather than pure dc.

Another way to increase the output voltage is to use the rectifier to charge a capacitor. By using this method, we can then get a dc voltage that is approximately equal to the peak of the ac voltage. The voltage stored in the capacitor is applied to the load resistor between the pulses of the rectified voltage. This removes most of the pulsating components, so that an almost pure dc appears across the load.

As you will prove, the capacitor may hold a charge for some time after the power has been turned off. For this reason it is important not to touch a capacitor until it has had time to discharge, or you may be shocked. You can discharge the capacitor with a screwdriver blade, as you learned in the last kit, to remove this danger.

Experimental Procedure: In addition to the parts mounted on the

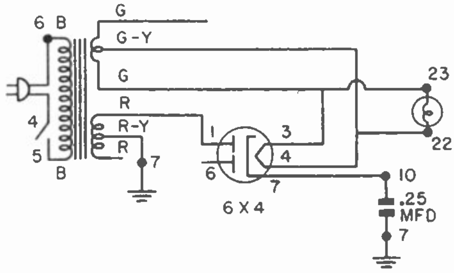

FIG. 32-1. Half-wave rectifier circuit for Experiment 32.

power supply and your vtvm, you will need for this experiment:

One .25-mfd capacitor.
One .1-mfd capacitor.

We will use the half-wave rectifier circuit shown in Fig. 32-1. It is the same as that shown in Figs. 7 and 8, except that you install a .25-mfd capacitor in place of the 100K-ohm resistor.

To build this circuit, check the schematic in Fig. 32-1 carefully against your circuit, and make any changes necessary to make your circuit agree with it. It is a good idea to do this systematically.

For example, let us start with the power cord. We see from the schematic that one side is connected to one black transformer lead at terminal 6, and the other side of the power cord is connected to terminal 4 on the on-off switch. The other black transformer lead is connected to terminal 5. These connections are the same as before, and should already be made on your chassis.

Next let us check the filament supply circuit. The green-yellow lead is connected to tube socket pin 4 and pilot lamp terminal 22. One of the green leads is connected to tube socket pin 3, and pilot lamp terminal 23. The unused green lead should still be taped.

The red-yellow center tap of the high-voltage secondary winding should be grounded to terminal 7, and one of the red transformer leads should be taped. These connections are also the same as before.

Now let's check the tube socket. Here you will have to make some changes. The other red transformer lead is to be connected to socket pin 1 of the 6X4 tube. So take out the 100K-ohm resistor, and move the red lead from terminal 10 to tube pin 1. The cathode terminal, tube socket pin 7, is to be connected to terminal 10, so move the wire connecting it to terminal 7 to terminal 10. Finally, connect the .25-mfd capacitor between terminals 10 and 7. Your circuit should now be like Fig. 32-1.

STEP	MEASUREMENT	VALUE
1	DC VOLTAGE ACROSS CAPACITOR IN HALF-WAVE RECTIFIER	36V
2	DC VOLTAGE ACROSS CAPACITOR IN FULL-WAVE RECTIFIER	72V
3	DISCHARGE TIME	INST.
4	PEAK OF AC VOLTAGE	100 8V

FIG. 32-2. Fill in your readings for Experiment 32 here.

After making the changes, check the circuit. You are now ready to proceed. Slip the alligator clip over the tip of the vtvm probe so you can make connections with both leads, and still have your hands free if necessary. Turn the Function switch to +DC and the Range switch to 120V, and let the vtvm warm up.

Step 1: To measure the voltage across the .25-mfd capacitor in a half-wave rectifier. Connect the ground clip of the vtvm to the chassis of the power supply, and clip the positive probe to a point in electrical contact with the cathode of the rectifier. This may be directly at tube socket pin 7 or any place on the lead of the .25-mfd capacitor connected to terminal 10. Insert the plug of the power supply chassis into a wall outlet, and turn on the power supply.

Carefully read the voltage, and record it in Fig. 32-2.

Step 2: To measure the voltage across the .25-mfd capacitor in a full-wave rectifier. With the power supply turned off, and the line cord removed from the wall outlet, remove the piece of tape from the end of the unused red transformer lead. Solder the bare end to socket pin 6. The circuit is now arranged for full-wave rectification. Using the same setup as before, plug in the power-supply line cord, turn the switch on, and measure the dc voltage across the .25-mfd capacitor. Record your reading in Fig. 32-2.

Step 3: To show that the charge stored in the capacitor will continue to send current through a circuit after the rectifier is turned off. Without changing the circuit or the voltmeter connections in any way, again measure the dc voltage across the .25-mfd capacitor. Leave your voltmeter connected, and turn the power supply off. Note that the meter pointer moves slowly toward zero. This shows that the capacitor is discharging through the meter resistance. This is a very high resistance, and does not require much current. Now estimate how long it takes for your maximum voltage to drop to 20 volts. At the instant you turn off the switch, start counting each second at a steady rate, one hundred and one, one hundred and two, etc. Put down the number of seconds it takes for the capacitor voltage to drop from its maximum to 20 volts. Record your results in the space provided in Fig. 32-2.

Step 4: To show that the capacitor charged up to the peak value of the ac. Remove the 6X4 tube from your power supply chassis, and put it back into your vtvm. Recalibrate the instrument if necessary, and set the switches to measure the maximum of 120 volts ac. Clip the ground lead onto the power supply chassis, turn on the power supply, and touch the probe to either plate of the rectifier. The voltage measured here is the ac voltage that was rectified. Make a note of this value. The peak value of an rms voltage is the rms value multiplied by 1.4, so multiply the voltage you just measured by 1.4 and enter this value in Fig. 32-2. Turn off the power supply.

Discussion: Compare the voltage you just entered in Fig. 32-2 with the values you measured in Steps 1 and 2. You will find that the capacitor did charge up to approximately the peak ac voltage. You should also have found that the voltage was the same for both half-wave and full-wave rectification. The only difference is that the full-wave rectifier charges the capacitor a little more rapidly.

Because there is no load resistor at the output of the power supply, the dc voltage across the capacitor is a pure dc like that obtained from a battery. However, if the capacitor is leaky, that is, if it has some internal resistance between its plates, it will discharge through the internal resistance path. The rectifier, of course, recharges the capacitor, but the discharging and recharging of the capacitor causes the voltage to vary. Thus, if the capacitor is leaky, the output voltage is not a pure dc.

Although a capacitor can hold a charge even when the power supply has been turned off, it cannot be used like a battery. It discharges very quickly when a load is placed across its terminals. However, if the capacitor is constantly recharged, only a small variation occurs in its voltage, so it can be used to deliver voltage to a load requiring dc. The next few experiments will show how this is done, and the troubles which are sometimes encountered because of defects in the capacitors or in other parts.

Instructions for Statement No. 32: In Step 3 you saw how long it took for the .25-mfd capacitor to discharge to a point where there was approximately 20 volts across it.

For this Statement you will see how increasing the capacity affects the discharge time. To do this, solder the .1-mfd capacitor in parallel with the .25-mfd capacitor by connecting one lead of the .1-mfd capacitor to terminal 10, and the other lead to ground terminal 7 on the terminal strip. Now, remove the 6X4 tube from the vtvm and put it back into the socket on the experimental chassis. Turn on the power supply, and measure the dc voltage across both capacitors. The value should be the same as that for Steps 1 and 2 of the experiment.

Connect the ground clip to the chassis, and touch the positive probe to the capacitor lead at terminal 10 or to tube socket pin 7. Turn the power supply off, and count as you did before to see how long it takes the voltage across the capacitors to drop to 20 volts. Jot your answer down in the page margin near Fig. 32-2. Answer the Statement below and on the Report Sheet.

Statement No. 32: **I found that** when the capacity was increased, the time it took for the capacitor voltage to drop to 20 volts after the power supply was turned off was:

(1) *the same as*
(2) *longer than*
(3) *shorter than*

the discharge time in Step 3.

EXPERIMENT 33

***Purpose:* To show that the output of a full-wave rectifier is higher than that of a half-wave rectifier with the same value of load resistance; and**

To show that for a given load resistance, increasing the shunt capacity increases the dc load voltage.

Introductory Discussion: We have frequently used the terms "load" and "loading." These terms can be rather confusing, so you should get a clear understanding of what they mean. Load and loading are used interchangeably to mean the amount of current drawn from a supply, and also to mean any device connected across a voltage source that draws current from it. In an electric circuit, the more you have connected across the line, the heavier the load, that is, the more current that will be drawn.

Let us consider as an example an electric light bulb. When you apply power to the bulb to light it, the bulb is a load on the power line. If you connect a second bulb across the line, it also is a load; now the total load on the power line is greater than before; you have two light bulbs. If you plug a toaster into the line, you have added still more load. From this you can see that the load is made up of the devices connected across the power line. The devices are connected in parallel across the line, so as each one is added, the total resistance decreases, and the current increases.

In a radio or TV receiver, the load on the power supply consists of the tubes connected across the power supply output.

The term load is also applied to the part or parts connected in the plate circuit of the individual tubes in a receiver. Remember that each tube acts like an ac generator. The ac output voltage from the tube is developed across a resistor, a coil, or a transformer connected in the plate circuit. The part in the plate circuit is called the load. Changing the value of the part in the plate circuit changes the load on the tube just as changing the number of electric bulbs connected across a power line changes the load on the power line.

Some confusion is created because the terms are applied either to the parts connected across the source or to the current drawn from the voltage source. If we say the load is increased, we mean that the current drawn from the voltage source is increased. However, when we say the *load resistance* is increased, we mean the current is decreased. You know that increasing the resistance will reduce the current, and therefore, the load, or loading is actually decreased.

The ideas of load and loading are important. Make sure you understand them before you leave this section.

In the preceding experiment, you saw that a charged capacitor could act as a voltage source for a short time, even when not being constantly recharged by a rectifier. When you measured the dc voltage with the power supply turned on, you found that the voltage across the capacitor was almost equal to the peak of the ac supply voltage. This was possible because no load resistor was connected across the capacitor, and the input resistance of the vtvm is so high that it did not load the power supply.

In this experiment, we will see what happens to the voltage when a small load resistance is used. You will find that the voltage will drop, because

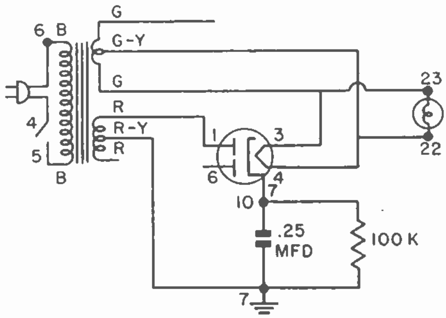

FIG. 33-1. Half-wave rectifier circuit for Experiment 33.

the rectifier cannot work fast enough, even on full-wave rectification, to keep the capacitor charged to its peak value. However, you will see that the voltage will be higher with a full-wave rectifier than with a half-wave rectifier, because it recharges the capacitor twice as often as the half-wave rectifier does.

You will also see that if we can store more energy in the capacitor, the load voltage will increase. The load will not have time to drain the capacitor of as much voltage as when the capacity was smaller.

tor that is in parallel with the .25-mfd capacitor.

Before you attach the load resistor, make certain the rectifier is still functioning normally. To do this, proceed as follows:

Step 1: To measure the voltage across the .25-mfd capacitor. Connect your dc voltmeter across the .25-mfd capacitor, and turn on the power supply. When we tell you to use your dc voltmeter, we mean to set your vtvm for dc measurements. If we say use your ac voltmeter, it means to set it for ac measurement, and if we say

STEP	CIRCUIT	DC VOLTAGE
1	NO LOAD	36 ✓
2	NO SHUNT CAPACITY	29 V ✓
3	HALF - WAVE 100K-OHM LOAD .25-MFD CAPACITY	66V
4	FULL - WAVE 100K-OHM LOAD .25-MFD CAPACITY	79 V ✓
5	FULL - WAVE 100K-OHM LOAD .35-MFD CAPACITY	82 ✓

54 ✓

FIG. 33-2. Record your readings for Experiment 33 here.

Experimental Procedure: In addition to the parts mounted on the power supply chassis, you will need:

One 100K-ohm resistor.
Two 22K-ohm resistors.

Again we will start the experiment with a half-wave vacuum-tube rectifier circuit. The circuit we will use is shown in Fig. 33-1. Your power supply is now wired as a full-wave rectifier. Change it to a half-wave rectifier by unsoldering the lead going to plate terminal 6 of the rectifier tube socket. Tape the bare end of the lead. Also, remove the .1-mfd capaci-

use your ohmmeter, it means to set the vtvm for resistance measurements. Measure the voltage, and record it in the space provided for Step 1 in Fig. 33-2.

Step 2: To measure the load voltage with no shunt capacity. Connect a 100,000-ohm resistor between terminal 10 and terminal 7 on the terminal strip. Disconnect one end of the .25-mfd capacitor so that it is no longer electrically in the circuit. Now measure the voltage across the 100K-ohm resistor, record it in Fig. 33-2, and turn off the power supply.

Step 3: To measure the load voltage in a half-wave rectifier circuit using a 100,000-ohm load resistor and a .25-mfd shunt capacitor. Connect the .25-mfd capacitor in parallel with the 100K-ohm resistor. Connect your voltmeter to measure the voltage across the combination, and turn on the power supply. Carefully read the meter, and record your reading in the space provided in Fig. 33-2. Turn off the power supply after taking the measurement.

Step 4: To show that more load voltage is obtained with full-wave rectification than with half-wave rectification with the same value of load resistance. With the power supply turned off, remove the tape from the end of the red transformer lead and solder this lead to the unused plate pin 6 of the rectifier socket. Then, connect your dc voltmeter between the chassis and the cathode of the rectifier. This is pin 7 or any point in direct electrical contact with pin 7. Turn on the power supply, and record the voltage you measure in Fig. 33-2. Then, turn the supply off.

Notice that in both cases loading the capacitor with a 100,000-ohm resistor has caused a decrease from the no-load value. With the load connected, you should find that you obtained more voltage with full-wave rectification than with half-wave rectification.

Step 5: To show that increasing the shunt capacity results in greater load voltage for a given value of load resistance. With the power supply turned off, shunt the .25-mfd capacitor and the 100,000-ohm resistor with a .1-mfd capacitor. Solder the connection. If you solder the leads of the .1-mfd capacitor to those of the .25-mfd capacitor, you will not disturb the present connections at terminals 7 and 10.

When the capacitor is securely soldered, connect your voltmeter from the chassis to the cathode of the rectifier. Turn on the power supply, and after the capacitors have been fully charged, measure the voltage. Record the reading in Fig. 33-2.

Turn the power supply off, and remove the .1-mfd capacitor and the 100,000-ohm resistor from the circuit. Leave the .25-mfd capacitor connected between the cathode of the rectifier and the chassis.

Discussion: Now look over the voltages you recorded in Fig. 33-2. The voltage value for Step 1 should be the highest, followed by Step 5, Step 4, Step 3, and finally Step 2. The voltage in Step 2 should be the smallest.

These voltages definitely show that when the capacitor is loaded, the load voltage is considerably less than the no-load voltage. It also shows that with full-wave rectification, the voltage does not decrease as much because the rectifier is charging the capacitor twice as often as when half-wave rectification is used. Step 5 showed that increasing the capacity increased the load voltage.

In radio and TV receivers, small-capacity paper capacitors are not used in the B-supply circuit because they will not store enough energy. Furthermore, because they cannot be kept fully charged, there will be a considerable variation in the dc voltage across them. In most cases we

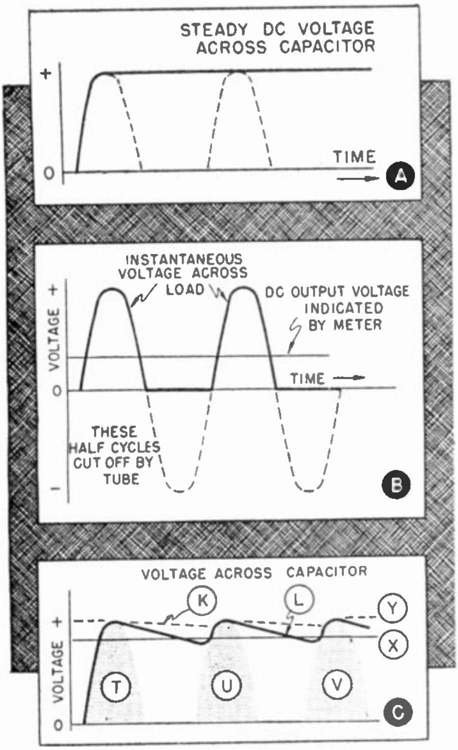

FIG. 33-3. Voltage waveforms at the output of a half-wave rectifier. A, a capacitor alone is used; B, a resistor alone is used; C, the resistor is shunted by the capacitor.

want the dc supplied to the receiver circuit to be as pure as possible. Thus, large value capacitors are used in power supply circuits. We will use capacitors of this type later in this kit.

The actions you have observed may be more easily understood by studying the waveforms of the rectified voltage for various load conditions. In each sketch in Fig. 33-3, the instantaneous voltage across the load is plotted against time.

When a capacitor alone was connected across the output of the rectifier, as in Step 1, the capacitor charged up in a short time to a value equal to the peak value of the ac supply voltage. This is shown in sketch A. After the capacitor was fully charged, no further current flowed through the rectifier because the voltage stored in the capacitor is always equal to or greater than that applied to the rectifier plate. Thus, there is no difference in potential between the plate and the cathode, and no current can flow.

The waveform in sketch B of Fig. 33-3 illustrates the output voltage you measured across the load resistor of a half-wave rectifier in Step 2. Notice that it is similar to that illustrated and discussed in an earlier experiment. Remember that we said that the dc voltage indicated by the meter is the average, or one-third of the peak value of the pulses.

If a capacitor is placed across the load resistor, as in Step 3, conditions change radically. This is shown in sketch C of Fig. 33-3. The shaded areas T, U, and V represent the output of a half-wave rectifier. On each of these pulses, the capacitor charges to a voltage equal to the peak value of the pulses. Between the pulses, when the capacitor is not receiving energy from the rectifier tube, it discharges through the load resistance.

The amount the capacitor can discharge before it is recharged by another pulse from the tube, depends on its capacity and the resistance of the load. If the load resistance is small, causing more current to be drawn from the capacitor, the voltage across the capacitor drops lower before recharging takes place. On the other hand, if the capacity is higher, the voltage does not decrease as much, and there is not as much variation in the voltage across the capacitor.

Instructions for Statement No. 33: In this experiment we have indicated that the value of the load resistance will affect the dc output voltage. For the Statement, you will install a 44,000-ohm load resistance across a half-wave rectifier circuit, and see what the effect will be.

Remove the red transformer lead from pin 6, and tape the end. Now you should have the half-wave rectifier circuit with only the .25-mfd capacitor connected from the cathode of the rectifier to the chassis.

Connect the two 22,000-ohm resistors in series, and connect one end of this combination to the cathode of the rectifier, and the other end to the chassis. Any grounded lug will be satisfactory. Connect your dc voltmeter from the cathode to the chassis, and turn on the power supply. Note the reading and jot it down beside the reading for Step 3 in Fig. 33-2. Answer the Statement below and on the Report Sheet.

Statement No. 33: When I decreased the load resistance from 100,000 ohms to 44,000 ohms, I found that the load voltage was:

(1) *less than half that for Step 3.*
(2) *half that for Step 3.*
(3) *more than half that for Step 3.*

Testing and Using Electrolytic Capacitors

You have studied electrolytic capacitors in your regular lessons and may remember a great deal about them. Let us review them now.

As you will recall, electrolytic capacitors have polarity. This means that the capacitor must be used only on dc. If ac is present, the dc must be greater at all times than the ac. The capacitor must be wired into the circuit so that its positive lead connects to the positive side of the circuit and its negative lead to the negative side of the circuit. If this polarity is not observed, the dielectric of the capacitor will break down, and it may become shorted.

When electrolytic capacitors are made, a voltage of the correct polarity and equal to the capacitor working voltage is applied across the capacitor terminals to polarize the dielectric film. If a capacitor lies on a dealer's shelf for several months, it may deteriorate slightly; but when it is installed in the receiver, the voltage from the set applied to it soon brings the dielectric film back to normal.

Servicemen usually check electrolytics for leakage with their ohmmeters before installing them. Test your dual electrolytic capacitor now. This is the large capacitor mounted in hole K. Turn on your vtvm, set the Function switch to the Ohms position, and the Range switch to the R x 10K position. Since your ohmmeter uses a battery, its leads have a small voltage across them. This voltage should be applied to an electrolytic with the correct polarity.

The ground clip is the negative lead of your ohmmeter, and it should be connected to the negative terminal of the capacitor. The black lead is the negative terminal of one section of your capacitor, and the blue lead is the negative terminal of the other section. Connect the ground clip of the vtvm to the blue capacitor lead. Touch the positive probe to the green capacitor lead. It is the positive lead of that capacitor section. When you first make connection, the meter pointer will swing all the way over to the left, indicating zero ohms. Then it will climb slowly to the right as the capacitor charges.

If the electrolytic capacitor has a measured resistance of greater than 100,000 ohms, it can be considered to be in good condition as far as leakage is concerned. A leakage resistance of less than 100,000 ohms indicates that the capacitor is in doubtful condition, and it would be best to replace it. Be sure you hold the positive probe in contact with the bare end of the green lead for several minutes when you make this test. Your ohmmeter will probably indicate well over 200,000 ohms.

When you are certain that this section of the capacitor is good, connect the ground clip to the bare end of the black lead, and touch the positive probe to the bare end of the red lead. The action should be the same as for the first section.

This leakage test does not indicate deterioration of the dielectric film, which may occur if the capacitor is out of use for any length of time. However, even if it has deteriorated, the dielectric of a capacitor soon reforms when operating voltage is applied to the capacitor sections. It would be a good idea to reform the dielectric of your capacitor now, following the instructions below.

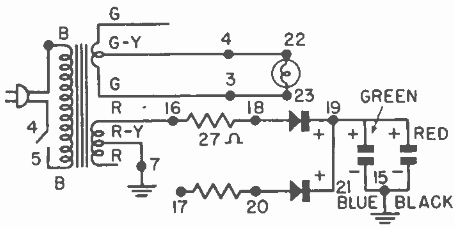

FIG. 9. Circuit to use to reform the dielectric of the electrolytic capacitor.

Because we are going to make ac measurements in the next experiment, we will need the 6X4 in the vtvm. Return it to your vtvm now. Disconnect the .25-mfd capacitor and the two 22K-ohm resistors that were in the circuit in the last experiment, and remove the red lead of the power transformer from the plate pin 1 of the rectifier.

You are to use the circuit shown in Fig. 9. Connect the red transformer lead to terminal 16, and connect a 27-ohm resistor between terminal 16 on the 1-lug strip and terminal 18 on one of the selenium rectifiers. This re-

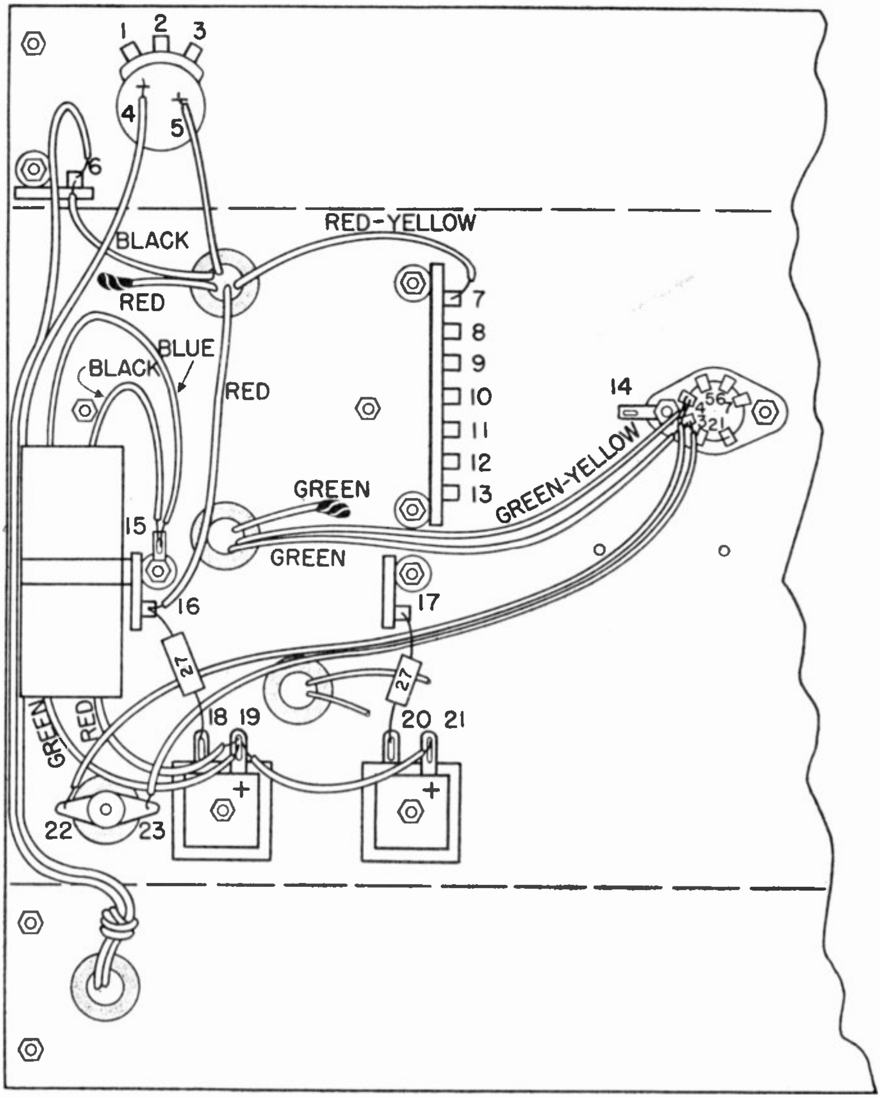

FIG. 10. Chassis layout for the circuit shown schematically in Fig. 9.

sistor will stay in the circuit; so place it between terminals 16 and 18, cut the leads to the correct length, and solder the connections. Remember—cut leads *only* when told to do so. Connect a wire between terminals 19 and 21 of the two seleniums. You will not use the second selenium rectifier now, but you will need this wire later.

Now, connect the black and blue leads of your dual electrolytic capacitor to solder lug 15, and solder them in place. Solder the red and green leads of the capacitor to terminal 19 of the selenium rectifier in hole M. Your chassis should now look like Fig. 10.

Set your voltmeter to measure

positive dc voltages on the 120-volt range, clip the ground lead of the vtvm to the power supply chassis, and clip the positive probe to selenium rectifier terminal 19. Turn on the power supply. Note that the voltage measured is rather low, but that it slowly increases.

Leave the power supply and the vtvm connected together and turned on while you carefully study the material in Experiment 34. When you have completed this pre-study of the experiment, your capacitor should have formed sufficiently so that it will not change while you are performing the experiments. After you have read through Experiment 34, turn off the power supply. Discharge the capacitors by touching a screwdriver blade between terminal 19 and the chassis. Disconnect the green and red leads of the electrolytic from selenium rectifier terminal 19, but leave the black and blue leads connected to the solder lug. Also leave the red transformer lead on terminal 16 of the 1-lug strip. You will then be ready to start the experiment.

EXPERIMENT 34

Purpose: **To show that there is a ripple voltage across the capacitor shunting the load at the rectifier output; and, to show that this ripple can be filtered out with a choke and a capacitor, leaving almost pure dc.**

Introductory Discussion: So far we have considered only the pure dc across the load. However, if you connect an ac voltmeter across the load, you will find that there is also an ac voltage. This voltage is the ac component of the pulsating dc output of the rectifier. That is, it is not an ac voltage in the sense that its polarity is alternately positive and negative with respect to the zero reference level, but it is a rise and fall in the dc voltage value. For all practical purposes, however, it acts like any other ac voltage.

A capacitor connected across the load will have a definite effect on the ac component, which is called the "ripple voltage." In this experiment you will measure the ripple voltage and see how it can be reduced to a very small value so it will not affect the operation of the load.

Since we are going to make ac measurements, we will need the 6X4 tube in the voltmeter. We will use a selenium rectifier for our experimental circuit. The circuit you will use first is shown in Fig. 34-1A.

Experimental Procedure: In addition to your vtvm and the parts mounted on your power supply, you will need the following parts:

One .25-mfd paper capacitor.
Two 22K-ohm resistors.

Heat your soldering iron, and carefully examine its tip. Clean and retin it if necessary. Plug in your vtvm, allow it to warm up and check the calibration.

To wire the circuit in Fig. 34-1A, first run a lead from selenium rectifier terminal 19 to lug 10 on the terminal strip. Do not solder yet.

Connect the two 22K-ohm resistors in series. Then, connect one lead of the 44K-ohm combination to terminal 10 and the other lead of the series group to terminal 13. Do not solder either connection until you have in-

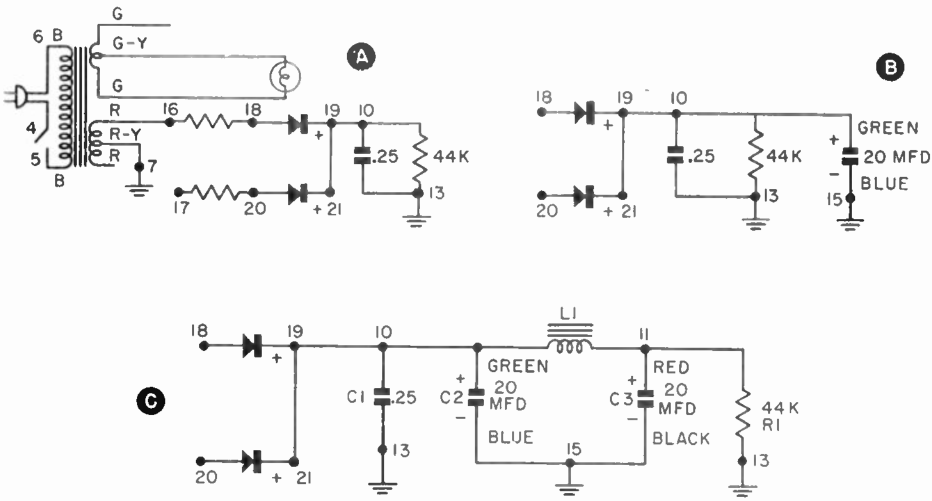

FIG. 34-1. Circuits for Experiment 34.

stalled the .25-mfd capacitor between terminals 10 and 13. After making this final connection, solder terminals 10 and 13, and you are ready to take measurements.

Step 1: To measure the ac ripple voltage and the dc voltage across the load resistor shunted by the .25-mfd capacitor. Set the Function switch of your vtvm to AC, and the Range switch to the 120-volt position. Clip the ground lead of the vtvm to the power supply chassis. Turn on the power supply, and touch the positive probe to terminal 10 of the terminal strip. If your reading is less than 30 volts, set the Range switch to the 30-volt range. Observe the reading carefully, and record it in Fig. 34-2.

Now set your vtvm to measure the dc voltage across the load resistor, make this measurement, and record your value in Fig. 34-2. Turn off the power supply.

You will probably notice that the dc voltage is less with the selenium rectifier than it was with a vacuum tube rectifier. This is normal.

Step 2: To measure the ac ripple voltage and the dc voltage across the load shunted by an electrolytic capacitor. The change to make in the circuit is shown in Fig. 34-1B. It is only necessary to connect the green lead of the 20-mfd electrolytic capacitor to terminal 10. The blue lead of the electrolytic capacitor, which is the negative lead, should be connected to solder lug 15 on the chassis.

You are now ready to make your voltage measurements. Turn the power supply on, and measure the ac ripple voltage across the load resistor. Record your reading in Fig. 34-2. Notice that the ac ripple voltage is extremely small compared to that obtained in Step 1, showing that the use of a larger capacitor at this point reduces the ripple.

When you are measuring ac voltages on the 3V range, you may notice that the meter pointer moves upscale, even when the probe is disconnected from the circuit. This is normal. It is due to stray voltage pickup. If the meter reads zero when the ground clip is shorted to the positive probe, the meter will read accurately when it is connected into a circuit.

Now set your vtvm to measure the dc voltage across the load, make this measurement, and record your result in Fig. 34-2. Turn off the power supply. Notice again the change between the readings in Step 1 and Step 2. Obviously, the large capacitor in the circuit caused the increase in the dc voltage.

Step 3: To show how the ripple voltage at the output of the rectifier can be reduced by a filter so that almost pure dc is applied to the load resistor. The changes to be made are shown in Fig. 34-1C. Disconnect the load resistor from terminal 10, and connect it to terminal 11 on the terminal strip. Connect the red lead of the electrolytic capacitor to terminal 11 and, also one of the leads of the choke. These are the leads that are coming through hole L. Solder this connection. Use either lead, as the choke has no polarity. Solder the other choke lead to lug 10 on the terminal strip. The green lead of the electrolytic should already be soldered to this terminal. You are now ready to make your measurements.

Set up your voltmeter for ac measurements, and measure the ac ripple voltage across the load resistor, at terminal 11. If you cannot measure any ripple voltage, simply make a dash in the space provided. Now reset your vtvm, and measure the dc voltage across the load resistor, recording your results in Fig. 34-2. Turn off the power supply switch.

Discussion: Now, look over the readings you have recorded. Note that the dc voltage in Step 3 is not a great deal more than in Step 2. However, the ac ripple voltage is far less than the ac voltage in Step 1 or Step 2. Let us see why this is so.

As you have learned, the voltage in a circuit divides between the loads in accordance with the resistance of the devices making up the loads. Also, we have two voltages in this circuit as you proved when you measured the ac ripple voltage from the positive terminal of the selenium rectifier to the chassis, and when you measured the dc voltage between these points.

The load in this circuit consists of the choke and the parallel combination of R1 and C3. For dc, the choke has little resistance, so most of the voltage is dropped across the parallel combination of R1 and C3. In a capacitor, the only path for dc is through the leakage resistance. Since the leakage resistance of C3 is high, we can consider the resistance of the combination to be practically the same as the resistance of R1.

STEP	CIRCUIT	VOLTAGE MEASURED	
		AC	DC
1	44K LOAD SHUNTED BY .25 MFD	32V	56V
2	44K LOAD AND .25 MFD SHUNTED BY 20 MFD	.02V	94V
3	CHOKE AND 20-20 MFD FILTER	—	92V

FIG. 34-2. Record your readings for Experiment 34 here.

On the other hand, the choke offers a very high impedance to the ac voltage in the circuit, while capacitor C3 offers an extremely low impedance. This means that most of the ac will be dropped across the choke, and very little of it will appear across the parallel combination of the capacitor and the resistor. Therefore, the voltage across the load is almost pure dc.

In Step 3, we used a choke and capacitor combination to filter the power supply voltage. In a circuit such as this, the capacitor section that is connected to the cathode of the rectifier is called the input filter capacitor, and the second section, connected across the load, is called the output filter capacitor.

switch to the 120-volt position. Measure the ac ripple voltage at selenium rectifier terminal 19. If necessary, you can reduce the setting of the Range switch to a lower range. Now measure the output ripple voltage across the load by touching the positive probe of the vtvm to terminal 11 on the terminal strip. Reduce the setting of the Range selector switch as necessary to get a reading. Now, divide the output ripple voltage into the input ripple voltage. The number you get as the answer is the ripple reduction factor. Turn off the power supply, and answer the Statement below and on the Report Sheet.

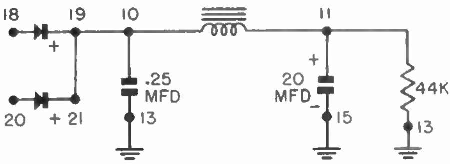

FIG. 34-3. Circuit to use in completing Statement No. 34.

Instructions for Statement No. 34: For this Statement, we are going to determine the ripple reduction factor of the filter. To do this, we divide the amount of ripple voltage across the input filter capacitor by the amount of ripple voltage across the output filter capacitor. For example, if you had 3 volts at the input and .1 volt at the output, you would divide 3 by .1, and obtain a ripple reduction factor of 30.

The circuit we will use is shown in Fig. 34-3. The .25-mfd capacitor is used as the input filter capacitor, so disconnect the green lead of the electrolytic from terminal 10.

Set up your vtvm for ac voltage measurements, and turn the Range

Statement No. 34: The ripple reduction factor I figured, was:

(1) *approximately 10.*
(2) *more than 100.*
(3) *between 20 and 80.*

EXPERIMENT 35

Purpose: **To show that the 120-cycle ripple produced by full-wave rectification can be more efficiently filtered out than the 60-cycle ripple produced by half-wave rectification.**

Introductory Discussion: As you have demonstrated, there is a ripple voltage across the input filter capacitor in a power supply. The input filter capacitor will discharge through any load placed across the output of

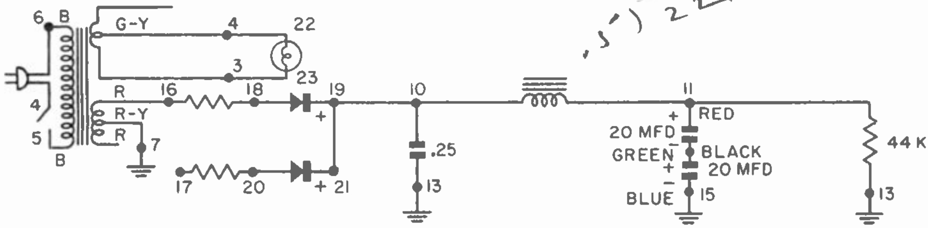

FIG. 35-1. Half-wave rectifier circuit for Experiment 35.

the power supply. When the rectifier is conducting, it supplies current directly to the load, and at the same time recharges the input capacitor. In a half-wave rectifier, recharging occurs sixty times a second, if the power-line frequency is 60 cycles. In a full-wave rectifier, one rectifier conducts on the negative pulses, and the other conducts on the positive pulses. Thus, with full-wave rectification, the input capacitor is charged twice as often as with a half-wave rectifier. The ac ripple voltage has a frequency of 120 cycles instead of 60 cycles per second.

In this experiment, you will demonstrate that the same filter parts are more effective in eliminating the ripple from a full-wave rectifier output than from a half-wave rectifier output. In order to be able to measure the ac ripple voltage at the output of the filter, we must use a smaller capacity than 20 mfd. To do this, we will use the two sections of the electrolytic in series. The circuit you will use for half-wave rectification is shown in Fig. 35-1.

Experimental Procedure: For the experiment, you will need your vtvm, the power supply chassis, and:

One .1-mfd capacitor.
One .25-mfd capacitor.

First we will wire the two 20-mfd electrolytic capacitors in series. The blue lead, which is the negative lead of one section, is already connected to the chassis at solder lug 15. The red lead, which is the positive lead of the other section, is already connected to terminal 11. Therefore, all you have to do is unsolder the black lead from terminal 15, and connect it to the green lead. Solder the connection, and tape it to prevent shorts. Push the leads out of the way where they will not interfere with the rest of the circuit.

The two capacitors are now in series and have a combined capacity of approximately 10 mfd. The 44K-ohm load resistance and the .25-mfd capacitor are already in place. You are now ready to start the experiment.

Step 1: To measure the ac ripple voltage from a half-wave rectifier at the input of the filter. Set your vacuum tube voltmeter up for ac measurements with the Range switch in the 120-volt position. Connect the ground clip of the vtvm to the chassis of the power supply, and turn on the power supply. Touch the positive probe to terminal 10. If necessary, turn the Range switch to a lower range to get a usable reading. Record the reading in Fig. 35-2.

Step 2: To measure the ac ripple voltage at the output of the filter.

CIRCUIT	VOLTAGE MEASURED		
	AC INPUT	AC OUTPUT	DC OUTPUT
HALF-WAVE RECTIFIER	26 V ✓	1 V ✓	67 V ✓
FULL-WAVE RECTIFIER	28 V ✓	.07 V ✓	60 V ✓

FIG. 35-2. Record your readings for Experiment 35 here.

Place the positive probe on terminal 11. Reduce the setting of the Range switch on the vtvm until you can get a definite reading. Record your reading in Fig. 35-2.

Step 3: To measure the dc output voltage for a half-wave rectifier. Change the Function switch of your vtvm to +DC, and set the Range switch to the 120-volt position. With the ground clip still connected to the chassis of the power supply, touch the positive probe to terminal 11 of the terminal strip. Turn off the power supply, and record the dc output voltage in Fig. 35-2.

Step 4: To measure the ac ripple voltage from a full-wave rectifier at the input of the filter. Change your circuit for full-wave rectification. Remove the tape from the unused red lead of the high-voltage secondary winding of the power transformer. Carefully solder this lead to terminal 17 of the 1-lug strip. You now have a full-wave rectifier.

Since the object of this experiment is to compare the effect of a filter on a 120-cycle ripple with the effect of this same filter on a 60-cycle ripple, we will have to change the circuit so that the 120-cycle ripple voltage will be approximately the same amplitude as the 60-cycle ripple voltage we have measured. To do this, we will change the input filter capacitor from .25 mfd to .1 mfd. Remove the .25-mfd input filter capacitor, and in its place install the .1-mfd capacitor. You now have the circuit shown in Fig. 35-3.

Again turn on the power supply, and measure the ac input filter voltage between the chassis of the power supply and terminal 10. It should be approximately the same as the voltage you measured in Step 1. Record it in Fig. 35-2.

Step 5: To measure the output ripple voltage for a full-wave rectifier. Turn the Range switch to a lower range, and measure the ac output voltage between the power supply chassis and lug 11 on the terminal strip. Record the reading in Fig. 35-2. If the voltage is so low that it cannot be measured, just place a dash in the space provided.

Step 6: To measure the dc output voltage for a full-wave rectifier. Set the Function switch of the vtvm to measure positive dc voltage, and place

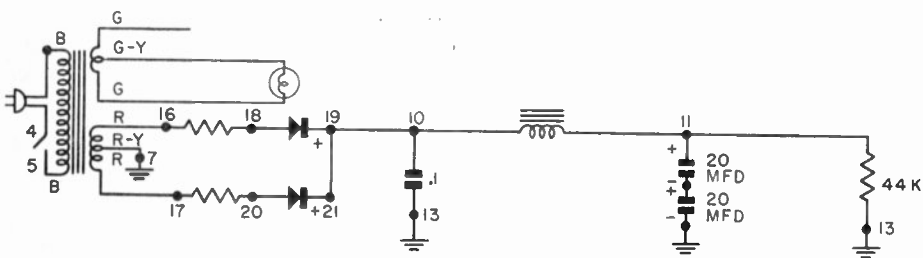

FIG. 35-3. Full-wave rectifier circuit for Experiment 35.

the Range switch in the 120-volt position. Measure the voltage between the power supply chassis and terminal 11. Record the reading in Fig. 35-2, and turn the power supply off.

Discussion: The ripple voltage at the output of a half-wave rectifier is 60 cycles, and of a full-wave rectifier is 120 cycles. As you learned in the last experiment a filter circuit acts as a voltage divider. For ac, the choke has a high reactance and the capacitor a low reactance; almost all of the ripple voltage is dropped across the choke, and very little is dropped across the capacitor and the load it shunts.

Doubling the ac ripple frequency by going from half-wave to full-wave rectification, doubles the choke reactance and halves the capacitor reactance. Even more of the ripple voltage is dropped across the choke and less across the capacitor and load resistor. Thus, an ordinary choke-capacitor filter is more efficient for full-wave rectification than for half-wave rectification. This means that smaller and less expensive filter parts can be used with a full-wave rectifier to achieve the same degree of filtering that more expensive parts give in a half-wave rectifier.

Instructions for Statement No. 35: The ac ripple voltage division in the filter circuit depends entirely upon the impedances of the various components in the circuit. If we increase the impedance in one part of the filter circuit, there will be less voltage dropped across another part. On the other hand, if we reduce the impedance of one part, the voltage drop across the other parts in the circuit will increase.

For this Statement, we will connect a .5-mfd capacitor across the choke coil, and see what happens to the voltage across the load. To show this, we will return to the half-wave rectifier circuit shown in Fig. 35-1, but we will use the .1-mfd capacitor as the input filter. This capacitor is already in the circuit, so it is only necessary to disconnect the red transformer lead from terminal 17 of the 1-lug strip. Tape up the end of the lead to insulate it.

After you have made this change, measure the ac ripple voltage from terminal strip lug 11 to the chassis. Now turn the power supply off, and solder two .25-mfd capacitors in parallel between lugs 10 and 11 of the terminal strip. Turn on the power supply, and again measure the ac ripple voltage from terminal 11 to the chassis. Answer the Statement here and on the Report Sheet. Be sure you turn the supply off when you have completed the Statement.

Statement No. 35: When I connected the capacitors across the filter choke, I found that the ripple voltage at the output of the filter:

(1) *increased.*
(2) *decreased.*
(3) *remained the same.*

EXPERIMENT 36

Purpose: **To show that a resistor can be used in a filter network in place of a filter choke.**

Introductory Discussion: In this experiment you will see that a filter resistor can be used in place of the choke to give equal filtering action, but that the resultant dc output volt-

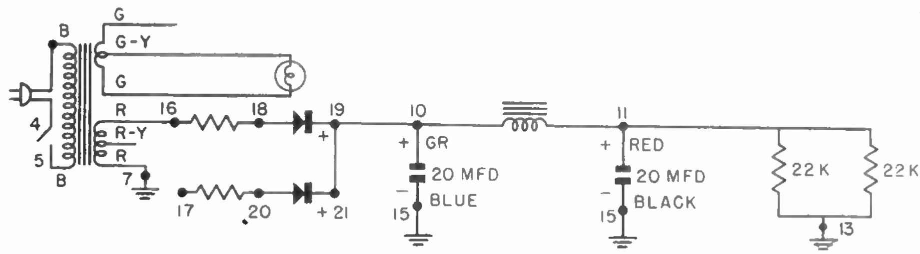

FIG. 36-2. Half-wave rectifier circuit with the full voltage of the high-voltage secondary winding of the transformer applied to it.

age will be less than when a choke is used.

To see why this is so, let us look at the circuit shown in Fig. 36-1. Notice that at the power-line frequency of 60 cycles per second, the reactance of the 20-mfd filter capacitor is only 100 ohms, but the **reactance of the choke is approximately 3000 ohms.* This means that when an ac ripple voltage is applied across the filter network, there will be approximately thirty times as much ripple voltage across the choke as across the capacitor.**

If we replace the choke with a resistor having a value of 3000 ohms,

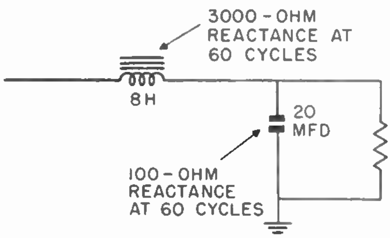

FIG. 36-1. In this filter, at 60 cycles, the reactance of the coil is 3000 ohms, and the reactance of the capacitor is only 100 ohms.

*You may remember that in Kit 3W we found that the inductance of the choke was about 11 henrys. This value was measured with only ac flowing through the coil. When dc as well as ac is flowing through the coil, the dc has the effect of lowering the inductance of the coil. In this circuit its inductance is about 8 henrys and its reactance is about 3000 ohms.

the division of the ripple voltage between the resistor and the capacitor will be the same as for the choke and the capacitor. Therefore, we will get just as good filtering. However, the dc resistance of the choke is only 400 ohms. This means that when the dc voltage divides between the choke and the load resistance, only a very small dc voltage drop appears across the choke as compared to the dc voltage across the load resistor. If we install a 3000-ohm resistor in place of the choke, then considerably more dc voltage will be dropped across it than was dropped across the choke. The resistor offers the same opposition to ac as it does to dc.

In many circuits, the lower dc voltage from the supply does not matter. It is possible to eliminate the costly filter choke and to substitute an inexpensive resistor in its place.

For this experiment we must have a higher voltage than we have used previously. We can readily achieve this by connecting the supply as a half-wave rectifier, and using the full voltage of the high-voltage secondary winding. The first circuit you are to use is shown in Fig. 36-2.

Experimental Procedure: In conducting this experiment, you will of course use the power supply chassis

STEP	FILTER USED	VOLTAGE MEASURED	READING
1	CHOKE	DC OUTPUT	1.80V
		AC OUTPUT	—
2	500-OHM RESISTOR	DC OUTPUT	170V
		AC OUTPUT	.03
3	3000-OHM RESISTOR	DC OUTPUT	135V
		AC OUTPUT	—

FIG. 36-3. Record your readings for Experiment 36 here.

and your vtvm. You will also need:

Two 1000-ohm resistors.
One 3K-ohm resistor.

To prepare for the experiment, remove the two .25-mfd capacitors which shunted the filter choke, and the two 22K-ohm resistors. Also disconnect the .1-mfd capacitor from terminals 10 and 13 of the terminal strip. Unsolder the red-yellow center-tap lead of the high-voltage secondary winding from terminal 7. Tape the end of the wire to insulate it.

Remove the tape from the unused red lead, and solder the bare end of this lead is lug 7.

Remove the tape covering the joint of the black and green leads of the filter capacitor. Unsolder this connection, and solder the black lead to lug 15 on the power supply chassis. Solder the green lead to lug 10 on the terminal strip. The green lead is now the positive terminal of the input filter capacitor.

Connect the two 22K-ohm resistors in parallel, and place the 11K-ohm combination between terminal lugs 11 and 13. You now have the half-wave rectifier circuit shown in Fig. 36-2, and are ready to proceed.

Step 1: To measure the dc and ac output voltages when a filter choke is used. First, measure the dc voltage across the 11K-ohm load resistor. Record your value in the space provided in Fig. 36-3. Now measure the ac ripple voltage across the 11K-ohm load resistor. If you measure no voltage, put a dash in the space. Now, turn off the supply.

Step 2: To show that substituting a resistor having the same ohmic value as the dc resistance of the choke will result in the same dc output voltage but increased ripple. To make this change, disconnect the choke coil lead from lug 10 on the terminal strip. The filter choke is now out of the circuit. The choke coil lead connected to terminal 11 will not affect the circuit operation. Just make sure the free lead that was connected to terminal 10 does not short to the chassis.

Connect the two 1000-ohm resistors in parallel between terminal 11 on the terminal strip and terminal 10. This gives a resistance of 500 ohms. This is slightly higher than the dc resistance value of the choke. However, it is close enough for our purpose in this experiment. The circuit is now wired as shown in Fig. 36-4.

Now measure the dc voltage across the 11K-ohm load resistor (the two 22K-ohm resistors in parallel), and record your reading in the space provided in Fig. 36-3. Also measure any ac ripple voltage across the 11K-ohm

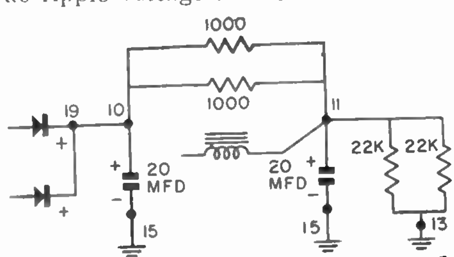

FIG. 36-4. Substituting a 500-ohm resistance for the filter choke.

resistor, and record this in the space provided in Fig. 36-3.

Step 3: To show that a resistor having approximately the same value as the choke reactance will filter the ripple satisfactorily, but the dc output voltage will be reduced. To make this change, remove the two 1000-ohm resistors, and in their place solder the 3000-ohm resistor to terminal 10 and terminal 11. Be sure the power supply is turned off when you change the circuit. You now have the circuit shown in Fig. 36-5.

Measure and record in Fig. 36-3, the dc voltage across the 11K-ohm load resistor. Also measure the ac ripple voltage and record its value, if you obtain a definite reading. If the reading is too small to be read with any accuracy, make a dash in the space provided for the reading. Turn off the supply.

Discussion: Now let us look over the readings you have made. You should have found that the dc output voltages in Step 1 and Step 2 were practically identical, but that there was a perceptible ripple voltage in Step 2.

In Step 1 and Step 3 you probably were not able to measure any ripple voltage, but in Step 3, the dc output should have been lower than in Steps 1 and 2.

A resistor cannot be used in place of a filter choke in some receivers, because the lower voltage at the output of the supply would be insufficient to operate the various stages. One way we can get around this is to divide the load. The part of the load where hum can be tolerated, such as the plate circuit of a pentode output tube, is put ahead of the filter resistor, and the part where pure dc is needed is put after the filter resistor. This arrangement is often used in ac-dc receivers. Reducing the dc through the filter resistor causes a decrease in the voltage drop across it. Thus, there is a higher voltage at the output to operate the other stages in the receiver.

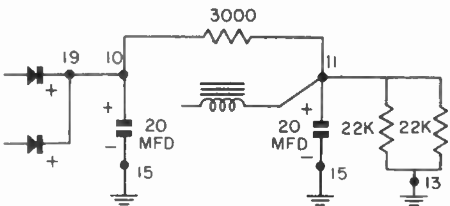

FIG. 36-5. Substituting a 3000-ohm resistance for the filter choke.

Instructions for Statement No. 36: For this Statement, you will demonstrate what happens when the load is split.

The power supply is now wired as shown in Fig. 36-5 with a load consisting of two 22K-ohm resistors in parallel. Disconnect one of the 22K-ohm resistors from terminal 11, and solder the free lead of this resistor to lug 10. The load still consists of the two 22K-ohm resistors. However, one is supplied ahead of the filter where there is some ac ripple, and the other is supplied at the output of the filter.

Set up your vtvm for ac measurements and measure the ripple voltage across the 22K-ohm load resistor connected from lug 11 of the terminal strip to the chassis. Then measure the dc voltage across this resistor.

CAUTION: Do not leave your power supply turned on any longer than necessary to measure the voltage, because the 22K-ohm resistor connected across the input filter capacitor will get quite warm. Compare your ac and dc measurements to those you measured in Step 3. You are now ready to answer the Statement here and on the Report Sheet.

Statement No. 36: When I split the load, by connecting part of it ahead of the filter resistor and part at the output of the filter resistor, I found that the dc voltage at the output compared to the voltage in Step 3:

(1) *increased,*
(2) *decreased,*
(3) *remained the same,*

and the ac ripple voltage:

(1) *increased,*
(2) *decreased,*
(3) *remained the same.*

EXPERIMENT 37

Purpose: **To show that the filter choke or filter resistor can be placed in either the positive or the negative side of the circuit, and the filtering action will be the same.**

Introductory Discussion: In a filter circuit, the ac ripple voltage divides between the filter resistor or filter choke and the load. In this experiment, you are going to demonstrate that this voltage division occurs whether the voltage-dropping leg (the choke or resistor) of the filter is in the positive or in the negative side of the filter circuit.

First you will put the choke in the positive side, and measure the ac ripple across the choke and across the load. Then, you will put the choke in the other side of the circuit, and repeat the measurement.

In all of the power supplies you have constructed in this kit, one side of the high-voltage winding on the power transformer and the negative leads of both filter capacitors were connected directly to the chassis. To put the voltage-dropping leg of the filter in the negative side of the circuit, we must unground the negative lead of the input capacitor and the high-voltage secondary lead, and connect them to the ungrounded side of the filter choke or resistor. The other side of the resistor or choke is connected to the chassis. The first circuit you will use is similar to the ones you have used in the previous experiments, with the filter in the positive side of the circuit. It is shown in Fig. 37-1.

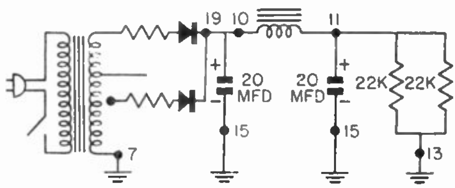

FIG. 37-1. Half-wave rectifier with filter in positive side of circuit.

Experimental Procedure: In this experiment, in addition to your vtvm and the parts mounted on the power supply chassis, you will need:

One 1-megohm resistor.
One .25-mfd capacitor.

First disconnect the 22K-ohm resistor from terminal 10 of the terminal strip, and the 3000-ohm resistor from between terminals 10 and 11. Solder the free lead of the 22K-ohm resistor to lug 11, so that the two 22K-ohm resistors are again in parallel. Finally, connect the free lead of the choke coil back to terminal 10. The circuit is now wired as shown in Fig. 37-1, and you are ready to take measurements to show the ac ripple voltage division in the circuit.

STEP	CIRCUIT	AC VOLTAGE ACROSS FILTER CHOKE	AC VOLTAGE ACROSS LOAD
1	FILTER CHOKE IN + SIDE	2.45V	—
2	FILTER CHOKE IN – SIDE	2.5V	—
3	FILTER RESISTOR IN – SIDE	.5 V	—

FIG. 37-2. Record your readings for Experiment 37 here.

✓ *Step 1: To measure the ac voltage drop across the filter choke.* Set up your vtvm for ac voltage measurements, clip the ground lead to the power supply chassis, turn on the power supply, and measure the ac ripple voltage across the input filter capacitor. Make a note of the voltage in the margin of the page.

Now turn off the power supply, connect the ground clip of the vtvm to terminal 11, turn on the power supply, and touch the hot probe to terminal 19 of the selenium rectifier. You are now measuring the ac ripple voltage across the filter choke. Record it in Fig. 37-2. You will see that it is essentially the same as the ripple voltage across the input filter capacitor, proving that the ripple voltage is dropped across the filter choke, and that practically none appears across the load resistor.

Check this by measuring the ac ripple voltage across the load resistor (between the power supply chassis and lug 11 on the terminal strip). Turn off the supply before you change the meter connections. Record the value in Fig. 37-2. You may not get a readable voltage when you take this measurement. If the voltage value is too small, make a dash in the space provided in Fig. 37-2.

Step 2: To measure the ac voltage with the filter in the negative side of the circuit. Rewire the circuit as shown in Fig. 37-3. To make the change, proceed as follows: Unsolder the red lead connected to terminal 7. Then, disconnect the choke leads from terminals 10 and 11. Remove the lead from terminal 10 that comes from selenium rectifier terminal 19, and connect this lead to terminal 11. Unsolder the green capacitor lead from terminal 10, and connect it to terminal 11 also.

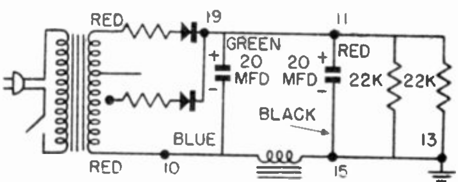

FIG. 37-3. Half-wave rectifier with filter in negative side of circuit.

Unsolder the blue lead of the filter capacitor from solder lug 15, but leave the black lead soldered to this lug. Three leads are to be connected to terminal 10 of the 7-lug strip. These are the red transformer lead, one lead of the choke coil, and the blue lead of the filter capacitor. After you have made these connections, solder the remaining choke lead to terminal 15, and the circuit will be wired as shown in Fig. 37-3.

After making the changes, carefully examine your work. Look at both sides of the terminal strip to make certain that solder has not dripped down and shorted a terminal to the chassis. If it has, remove the excess solder with your soldering iron. If the connections are all right, connect the ground clip of your vtvm to the power supply chassis, turn on the power supply, and measure the ripple voltage across the load and across the filter choke. To measure the voltage across the choke, touch the positive probe to lug 10 on the terminal strip. Then, to measure the ripple voltage across the load, touch your positive probe to terminal 11 on the terminal strip.

The ac ripple voltage that you are measuring does not have a true sine wave shape. Therefore, you may notice that these ripple voltage values are not exactly the same as those you obtained in Step 1. Reverse the test leads—that is, connect the positive probe to the chassis and touch the ground clip first to terminal 10 and then to terminal 11—and repeat the measurements. You must hold the ground clip by the black plastic part of the clip. If the readings you obtain this time are closer to those you obtained in Step 1, enter them in Fig. 37-2. Take the ripple voltage measurements with the meter connections that give you the most accurate readings in the remaining steps of this experiment. Your readings still may not match exactly, but they should be close.

Step 3: To measure the ac voltages in a circuit with a filter resistor in the negative side. The circuit you will use is shown in Fig. 37-4. To make the necessary changes, unsolder the filter choke lead from terminal 10, and connect the 3000-ohm resistor between terminals 10 and 13 of the terminal strip.

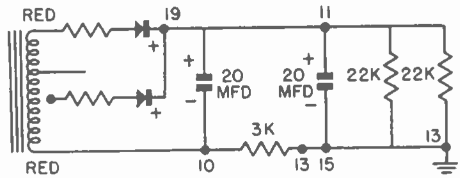

FIG. 37-4. Filter resistor in negative side of circuit.

Connect the ground clip of your vtvm to the power supply chassis, turn on the power supply, and measure the ripple voltage across the resistor by touching the positive probe to lug 10 of the terminal strip. Reverse the test leads if necessary. Record your reading in Fig. 37-2. Now touch your positive probe to lug 11 on the terminal strip and see if any ripple voltage is present across the load resistor. Again record the value you measure in Fig. 37-2. If there is no ripple voltage, indicate this by a dash in the space.

Step 4: To measure the dc voltages in the circuit shown in Fig. 37-4.

2.5V 155

Connect the ground clip of your vtvm to the power supply chassis, turn on the power supply and set the Function switch of the vtvm to the +DC position. Set the Range switch to an appropriate range, and measure the dc voltage between the chassis and terminal 11. Remember, you are to reverse the probe and ground clip only when taking ac ripple voltage measurements, not for dc measurements. Connect the ground clip to the chassis, and touch the probe to terminal 11.

Now measure the dc voltage between the chassis and terminal 10. To get an upscale reading you must set the switch in the —DC position. This capacitor between terminals 9 and 7. Now measure the dc voltage between terminal 9 and the chassis, and the ac voltage between terminal 9 and the chassis. Write your readings in the margin of this page.

Discussion: Now look at Fig. 37-2 and compare your readings. Your readings in Steps 1 and 2 should have been quite close. This shows that the filtering is the same, whether the filter choke is in the negative or the positive side of the circuit. In Step 3 you substituted a filter resistor for the choke. As in Experiment 36, the filtering action was the same, since the 3000-ohm resistor equaled the ac re-

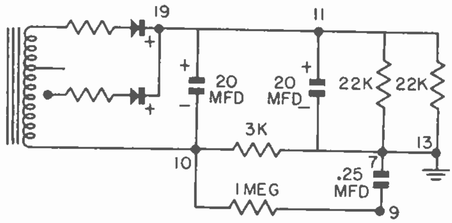

FIG. 37-5. Circuit to use to filter the dc voltage across the filter resistor to get pure negative dc.

shows that the voltage is negative with respect to the chassis. A negative dc voltage can be used to bias a tube, but there is also ac ripple between the chassis and terminal 10. Thus, this negative voltage must also be filtered before it can be applied to the grid of a tube. We can obtain a pure dc voltage by using the simple filter circuit shown in Fig. 37-5.

Step 5: To show that the dc voltage across the filter resistor can be filtered so that pure negative dc can be obtained. The circuit is shown in Fig. 37-5. Connect a 1-megohm resistor between terminals 10 and 9 on the terminal strip. Connect a .25-mfd

actance of the choke. However, more dc was dropped across the resistor than was dropped across the choke, because the dc resistance of the choke is only 400 ohms.

In Step 5 you showed how a pure dc voltage can be obtained from the filter resistor by using a second filter. This dc voltage is negative with respect to the chassis and could be used to bias a tube.

When the choke or resistor is in the negative side of the circuit, the positive leads, rather than the negative leads, of the electrolytic capacitor are connected together. Therefore, when replacing filter capacitors

150V — 150DC .3AC

in a receiver using such a circuit, you must get capacitors with separate negative leads, or else use two separate capacitors. Always examine the circuit to determine the lead arrangement necessary on the replacement capacitors.

Instructions for Statement No. 37: For this Statement you will disconnect the lead of the .25-mfd capacitor from terminal 7 and note the effect on the voltage between terminal 9 and the chassis. Do this now. Be sure the lead does not short to the chassis. Measure the dc voltage between terminal 9 and the chassis, and check to see if there is any ac voltage between 9 and the chassis. If necessary, use the 3-volt range of the vtvm. Compare this reading with the reading you made in Step 5, and then answer the Statement below and on the Report Sheet.

Statement No. 37: When I opened one lead of the .25-mfd capacitor, I found that the ac voltage between terminal 9 and the chassis, as compared to that in Step 5:

(1) *increased.*
(2) *decreased.*
(3) *remained the same.*

EXPERIMENT 38

***Purpose:* To show the effect of high power factor in the filter capacitors on the ac ripple voltage and the dc voltage at the output of a filter, and to show how servicemen check a capacitor for high power factor.**

Introductory Discussion: Electrolytic capacitors are used almost exclusively in radio and TV power supplies. An electrolytic capacitor, like all other capacitors, has two purposes. It acts as a high resistance for dc and like a low resistance for ac.

As you have learned from your regular lessons, a perfect capacitor acts as an open, or offers an infinite resistance to the flow of dc. Also, in a perfect capacitor there is no loss during charge and discharge when ac is

FIG. 38-1. Leakage in a capacitor has the effect of a resistor shunted across the capacitor as shown at A. Power loss has the effect of a resistor in series with the capacitor as at B.

applied. In practice, these desirable results cannot be obtained. All capacitors have some leakage, and there is always some power loss.

A practical capacitor can be pictured as shown in Fig. 38-1. Fig. 38-1A shows the effect of leakage, and Fig. 38-1B shows the effect of power loss. In practical circuits, some leakage or some power loss can be tolerated. However, if the resistance of the leakage path becomes too small, circuit operation is affected, and we say that the capacitor is leaky or entirely shorted.

If the series resistance in Fig. 38-1B becomes too large, circuit operation is affected, and we say that the capacitor has developed a high power factor or has lost capacity. A high power factor is the result of an increase in the resistance between the capacitor plates themselves, or of drying out of the dielectric.

We will use the circuit shown in Fig. 38-2 to demonstrate the effects of high power factor in both the input and output filter capacitors.

Experimental Procedure: In addition to your vtvm and the parts mounted on the power supply, you will need:

One 20-mfd, 150-volt electrolytic capacitor.

Proceed as follows. First, remove the 3000-ohm resistor, the 1-megohm resistor, and the .25-mfd capacitor from the terminal strip. Then disconnect the red transformer lead and the blue capacitor lead from lug 10 of the terminal strip, and connect the transformer lead to terminal 7, and the capacitor lead to terminal 15. Disconnect the lead from terminal 11 that goes to terminal 19 of the selenium rectifier. Connect this lead and the free choke lead to terminal 10. Remove the green capacitor lead from terminal 11 and connect it to terminal 10. Finally, remove the choke lead from terminal 15 and connect it to terminal 11. Solder the connections.

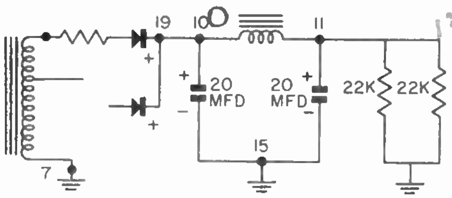

FIG. 38-2. Circuit for Experiment 38.

Your circuit should now be wired as shown in Fig. 38-2. Check it over carefully, comparing it to Fig. 38-2. Examine both sides of the terminal strip to make certain that solder has not dripped down and shorted to the chassis.

Also, check for a short in the B supply with your ohmmeter, before applying power. To do this, set your vtvm for ohmmeter measurements with the Range switch in the R x 1K position. Put the ground lead on the power supply chassis, and touch the positive probe to selenium rectifier terminal 19. The capacitors will slowly charge up and should eventually give a reading of 11,000 ohms. This is the resistance of the load composed of the two 22K-ohm resistors in parallel. If the resistance is considerably less than this, there is a short or incorrect wiring, which you should find and correct before going on.

Step 1: To measure the normal dc and ac output voltages in the circuit shown in Fig. 38-2. Set your Function switch to +DC and the Range switch to the 300-volt position. Clip the ground clip to the power supply chassis, turn on the power supply and touch the positive probe to terminal 11. Record the reading as the dc output voltage for Step 1 in Fig. 38-3.

STEP	CIRCUIT CONDITIONS	OUTPUT VOLTAGE DC	OUTPUT VOLTAGE AC
1	NORMAL	135	—
2	HIGH POWER FACTOR IN INPUT CAPACITOR	95	15
3	DEFECTIVE INPUT CAPACITOR SHUNTED BY GOOD CAPACITOR	135	—
4	HIGH POWER FACTOR IN OUTPUT CAPACITOR	135	1V

FIG. 38-3. Record your readings for Experiment 38 here.

Now set up your vtvm for ac measurements, and measure the ac voltage between terminal 11 and the chassis. If no perceptible voltage is present even on the 3-volt range, make a dash in the space provided, or record any reading you obtain. Turn off the supply.

Step 2: To determine the effect of

a high power factor in the input filter capacitor on the dc output voltage and the ac ripple voltage. To simulate a high power factor in the input filter capacitor, disconnect the green capacitor lead from terminal 10. Solder one end of the 3000-ohm resistor to terminal 10, and then solder the green capacitor lead to the other end of the 3000-ohm resistor. Arrange these two leads so that they will not touch the chassis. You can now imagine that the resistor is actually inside the capacitor, in series with the green lead and the capacitor plates. You can consider the end of the 3000-ohm resistor connected to terminal 10 as the capacitor lead. Now we will measure the dc and ac output voltages with a defective input capacitor to see what has happened.

Set up your vtvm to measure dc voltages as you did before, with the switch in the 300-volt position. Measure the dc voltage between terminal 11 and the chassis. Reduce the Range switch setting if necessary to a lower range, and record the reading for the dc output voltage in Step 2.

Now measure the ac output voltage between the chassis and terminal 11. If there is no perceptible reading, indicate this by a dash; but if you do get a reading, show the value in the space for ac output voltage in Step 2 in Fig. 38-3. Turn off the supply.

You should find that the dc output voltage has dropped considerably, and you should have been able to measure an ac output voltage, showing that the ripple voltage at the input of the filter has increased considerably.

Now let us see how a serviceman would test a defective capacitor by using a good one of the same size.

Step 3: To determine the effect of shunting a suspected capacitor with one of approximately the same size known to be in good condition. Connect your dc voltmeter between the chassis and terminal 11, using the slip-on alligator clip over the positive probe. Turn the power supply on, and note the voltage reading. Then pick up your 20-mfd, 150-volt electrolytic capacitor, *holding it by the case.* Note carefully the positive and negative markings. Hold the capacitor with the negative lead touching the chassis and move the capacitor around until its positive lead touches selenium rectifier terminal 19. You may notice a snap or spark when the connection is made. Hold the capacitor firmly in place, keeping your fingers off the hot lead. Notice the effect on the output voltage. It should increase almost to its original value. Record this value in Fig. 38-3 as the dc output voltage for Step 3.

Then, still holding the capacitor carefully by its case, lift it up and touch both leads to the power supply chassis. The capacitor will discharge with a sharp snap and spark. Always discharge a capacitor, because if you don't, you might get an unpleasant shock later. There is no danger as long as you hold the capacitor by its cardboard case.

Leave your voltmeter connected to the output of the power supply, turn off the power supply, and set up the voltmeter switches for ac measurements. Turn the power supply back on, and note that you still get the same reading as in Step 2 for the ac output voltage. Now, again hold the negative lead of the 20-mfd capacitor against the chassis, and allow the positive lead to touch lug 19 of the selenium rectifier. Notice that when the capacitor makes contact across the defective capacitor, the ac output voltage drops to the same value as in Step 1 for ac output voltage. Record this in Fig. 38-3.

Thus, you have seen what happens when an input capacitor develops a high power factor, and you have seen that you can check the capacitor by shunting it with a good one of about the same size. In a test like this, you must be sure to use the proper polarity. If you were to reverse the polarity on the test capacitor, you would probably ruin the capacitor. Even if it did not damage the part, the test would be worthless with the capacitor connected in this manner.

While your equipment is still set up to measure the ac voltage at the output of the supply, make one more test. Turn the equipment on again, and note the ac reading. Now hold your test capacitor so that its negative lead touches the chassis and so that its positive lead touches terminal 10. Notice that the effect is exactly the same as when you hold the positive lead of the test capacitor to terminal 19. This shows that the test capacitor does not have to be connected to the same physical points as the one under test. For example, points 21, 19, and 10 are all at the same potential electrically, and you can make the connection to any one of these points. The negative lead of the test capacitor can be in contact with any point on the chassis rather than with the particular point to which the negative lead of the capacitor being tested is connected.

You have now finished the tests with the input filter capacitor; so remove the 3000-ohm resistor from the circuit, and unsolder the green lead of the input capacitor from the resistor lead. Resolder the green lead to terminal 10. The circuit is now the same as in Fig. 38-2.

Step 4: To show the effect of a high power factor in the output filter capacitor. Disconnect the red lead of the electrolytic capacitor from terminal 11. Solder one lead of the 3000-ohm resistor to lug 11. Then, solder the red capacitor lead to the free resistor lead. Place the two leads so they cannot touch the chassis.

Connect the ground clip of the vtvm to the chassis of the power supply, and connect the positive probe to lug 11 on the terminal strip. Set your vtvm to measure the dc voltage across the load resistor, and turn the Range switch to the 300-volt position. Turn on the power supply, and record the reading in the space for dc output voltage for Step 4 in Fig. 38-3.

The voltage should be the same as that in Step 1 in Fig. 38-3. This shows that a high power factor in the output filter capacitor has no effect on the dc output voltage. Now turn off the power supply.

Set your Function switch to AC, and turn on the power supply. Reduce the Range switch setting a step at a time until you get an easily read ac output voltage. Record this voltage in the space provided for ac output voltage in Step 4 of Fig. 38-3. Note that this voltage is considerably higher than in Step 2, showing that the filter action has definitely been affected.

Now, with the equipment still turned on and your meter indicating the ac output voltage, take your 20-mfd test capacitor, touch the negative terminal to the chassis, and the positive terminal to terminal 11 or to any point in electrical contact with lug 11. Good contact is necessary. The ac output voltage should drop to zero. Discharge your capacitor by touching both of its leads to the chassis of the power supply, and turn off the supply.

Discussion: From the tests you have made, you have learned that a defect in the input capacitor does not affect the circuit in the same way as one in the output capacitor. You have learned the following facts:

(1) A high power factor in an input filter capacitor decreases the dc voltage and increases the ac ripple voltage at the output.

(2) A high power factor in the output filter capacitor has no effect on the dc operating voltages but increases the ac ripple voltage across the load considerably.

In both cases, the capacitor can be easily tested by shunting it with a good one of about the same size. If the symptoms clear up, the one being tested is definitely bad, and should be replaced. The test capacitor does not need to have exactly the same capacitor, I found that the ac voltage voltage at least equal to that of the one under test. Also remember that you must observe the proper polarity when making these tests. Immediately after making the test, discharge the test capacitor by touching its two leads to the chassis.

Instructions for Statement No. 38: You have seen the effect of a high power factor in both the input and the output filter capacitors. The lead connecting to the foil inside the case may break, thus opening the capacitor. We are going to simulate this by disconnecting one of the capacitor leads and checking the ripple voltage. You are to find out the results of an actual open in the output filter capacitor compared to the results of a high power factor that you simulated by using the 3000-ohm series resistor.

Disconnect the red capacitor lead from the 3000-ohm resistor, remove the 3000-ohm resistor from the circuit, and arrange the red capacitor lead so that it cannot short to the chassis. Clip your vtvm to the chassis and to terminal 11. Set your vtvm for ac measurements, turn on the power supply, and note the reading. You will then be able to answer the Statement.

Statement No. 38: When I simulated an open in the output filter capacity, but should have a working across the load resistor was:

(1) *less than*

(2) *more than*

(3) *the same as*

the ac output voltage for Step 4.

EXPERIMENT 39

***Purpose:* To show the effect on the dc supply voltage of leakage in the input and output filter capacitors; and to show how the leakage can be found by analyzing voltage and resistance measurements.**

Introductory Discussion: Shorted

and leaky filter capacitors in radio and TV receiver power supplies are very common. You saw in the previous experiment that the symptoms of high power factor in input and output filter capacitors were quite different. In this experiment, we will show how leakage in an electrolytic capacitor affects the operation of the supply. You will see that the symptoms of leaky input and output filter capacitors also differ. The exact symptoms depend upon the amount of leakage. A complete short, for example, may ruin several parts. A small amount of leakage, on the other hand, may not cause any trouble.

Leakage is a progressive defect. Once an electrolytic capacitor starts to become excessively leaky, the dc resistance of the capacitor will decrease until symptoms become noticeable in the operation of the receiver. If the dc resistance drops to zero, the capacitor is said to be shorted.

In this experiment, we are going to take an average example, in which the capacitor has developed a leakage resistance of 10,000 ohms.

Before introducing excessive leakage, you will measure the normal power supply voltages and the normal point-to-point resistance values. Then you will shunt the filter capacitors, one at a time, with a 10K-ohm resistor and measure the voltages and resistances again.

These measurements will not only show you what to expect when you check the voltage and resistance values in equipment having leaky capacitors, but they will also give you practice in locating the defective parts. In the discussion of this experiment, you will see how the results of your measurements can be analyzed to point out the leakage path.

Experimental Procedure: The power supply to be used in this experiment is shown in Fig. 39-1. In addition to your vtvm and the parts mounted on the power supply, you will need:

One 10K-ohm resistor.
One 3K-ohm resistor.

First, disconnect the leads of the choke from terminals 10 and 11, and connect the 3000-ohm resistor be-

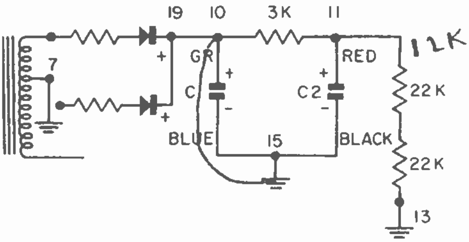

FIG. 39-1. Circuit for Experiment 39.

tween 10 and 11. Connect the red lead of the electrolytic capacitor to terminal 11. Disconnect the red transformer lead from lug 7 of the terminal strip, and tape up the end to insulate it. Remove the tape from the end of the red-yellow lead, and connect it to terminal 7. Connect the two 22K-ohm resistors in series between terminals 11 and 13 of the terminal strip. Your power supply should now be wired as shown in Fig. 39-1, and you are ready to make measurements.

Step 1: To measure the normal dc operating voltages and point-to-point resistance values. Turn on your power supply, and measure the dc voltage across input filter capacitor C1, by measuring between the chassis and selenium rectifier terminal 19. Record the reading in Fig. 39-2. Now measure the dc voltage across filter capacitor C2, which shunts the load resistor. This measurement should be made between the chassis and terminal 11. Again record the value in Fig. 39-2.

Now, turn off the power supply and disconnect it from the wall outlet so you can make point-to-point resistance measurements. Wait a minute or so for the electrolytic capacitors to discharge, or short them to the chassis with a screwdriver blade.

Set up your vtvm for resistance measurements, and check the resistance between the chassis and terminal 11. Wait long enough for the electrolytic capacitors to charge, and record your final reading in Fig. 39-2. Now measure the resistance between the chassis and lug 19. Record the value in Fig. 39-2.

Step 2: To show the effect on dc operating voltages and point-to-point resistance values when the input filter capacitor is leaky. Let us suppose that capacitor C1 has become leaky, and that the leakage resistance is approximately 10,000 ohms. We can

STEP	CIRCUIT CONDITION	DC VOLTAGE		RESISTANCE	
		ACROSS C1	ACROSS C2	11 TO GND	19 TO GND
1	NORMAL	72V	59V	3K	1K
2	C1 LEAKY	56V	46V	12K	4K
3	C2 LEAKY	64V	15V		

FIG. 39-2. Record your readings for Experiment 39 here.

simulate this condition by soldering a 10K-ohm resistor in parallel with C1. Connect the resistor between terminal 10 and any convenient ground point on the chassis. Terminal 7 is probably the easiest one to use. Before plugging the power supply back into the wall outlet, check the leakage resistance values. Measure the leakage resistance between lug 11 and the chassis. Record the reading in the correct space in Fig. 39-2. Now measure the resistance between lug 19 and the chassis. Record this reading in Fig. 39-2.

Now, set up your vtvm for +DC voltage measurements, plug the power supply into the wall outlet, and turn it on. Measure the dc voltage across capacitor C1 between terminal 10 or 19 and the chassis, and record the value in Fig. 39-2. Measure the dc voltage across capacitor C2, between lug 11 and the chassis, and again record your reading in the correct space. Turn off the power supply, and unplug it.

Step 3: To show the effect on dc operating voltages and point-to-point resistance values when the output filter capacitor is leaky. Disconnect the lead of the 10K-ohm resistor from terminal 10, and solder it to terminal 11. Leave the other end grounded. The resistor is now in parallel with C2.

Now, while the power supply is disconnected from the line, measure the resistance values from terminal 19 to the chassis and from terminal 11 to the chassis, being sure to discharge the capacitors before making the measurements. Wait long enough to get a steady reading on your ohmmeter. Record the two readings in the correct spaces in Fig. 39-2.

Set up your voltmeter for measuring +DC voltages, plug the power supply into the power line, and turn it on. Measure the dc voltage across input filter capacitor C1, and then across output filter capacitor C2. Record the measurements in Fig. 39-2. Turn off the supply.

Discussion: Let us analyze the voltages and then the resistances you measured. In Step 2 you should have found that the voltage drops across the input and output filter capacitors were less than those you measured in Step 1. There is a decrease in the voltage across the input capacitor because the rectifier cannot keep the capacitor charged as much as it did before. This causes an increased voltage drop in the rectifier and in the windings of the power transformer because of the increased current flow. The drop across the 3000-ohm resistor, which is the difference between the voltage across C1 and the voltage across C2, is the same as in Step 1.

Now look at the resistance measurements. You should have found a large change in resistance between Steps 1 and 2. Looking at Fig. 39-1, you can see that the resistance normally between terminal 11 and the chassis is composed of the load resistance, which should be about 44,000 ohms (the actual value depends upon the tolerance of your parts). The resistance between terminal 19 and the chassis consists of the load in series with the 3000-ohm resistor. Therefore, the resistance you measured at this point should be about 3000 ohms more than you measured between 11 and the chassis.

When we connected a 10K-ohm resistor across capacitor C1, the resistance between point 11 and the chassis became higher than between point 19 and the chassis.

Now examine the values recorded in Step 3 of Fig. 39-2. The voltage across the input filter capacitor should be slightly higher than in Step 2, because the short across C2 is isolated from C1 by the 3000-ohm filter resistor. Thus, the rectifier can recharge the capacitor to a higher value than if the short were directly across C1. The voltage across C2 has dropped considerably, to a value much lower than in Step 2, because the short has caused extra current to flow through the 3000-ohm resistor. This increases the voltage drop across the resistor and leaves less voltage for the output capacitor and the load.

The resistance you measured between terminal 11 and the chassis (across the load and the output filter capacitor) should be considerably less than the resistance across the input capacitor. This is a very important fact. When two points such as 19 and 11 are isolated from each other by means of a resistor, such as the 3000-ohm resistor in Fig. 39-1, you can easily locate the approximate position of a short or a leakage path with an ohmmeter. The end of a filter resistor that shows the lowest resistance is connected to the short. Thus, if the resistance between 19 and the chassis is lower than between 11 and the chassis, you know that the short is in some part connected between the resistor and the rectifier. On the other hand, if the resistance between terminal 11 and the chassis is lower, you know that the short is on the load side of the 3000-ohm resistor, and you would check the parts in that side of the circuit.

Ordinarily, a good electrolytic capacitor has a leakage resistance of at least 100,000 ohms; it is usually considerably higher. An electrolytic capacitor with a leakage resistance of only 10,000 ohms is definitely defective.

The resistance may become even lower, in which case so much current will flow through the capacitor that it will become noticeably hot to the touch. If you find such a capacitor in a receiver, turn the set off at once to prevent damage to other parts. A capacitor that feels hot may break down and short completely at any time. Generally, excessive heat is more readily apparent in metal-clad electrolytics than in the cardboard ones.

Let us see what happens if a capacitor shorts completely (has zero or only a few ohms resistance between its terminals).

Suppose capacitor C2 in Fig. 39-1 were shorted. All of the voltage would be dropped across the 3000-ohm filter resistor, and there would be none across the load. The 3000-ohm resistor would become quite hot, its colors might burn off, its body might crack, and it could burn out. The 3000-ohm resistor would limit the current drawn from the rectifier and power transformer so they probably would not be damaged.

If capacitor C1 became shorted, there would be no voltage across the capacitor; all of it would be dropped in the selenium rectifier. This would overheat the rectifier and ruin it if the equipment is turned on for any length of time.

An overheated selenium rectifier has an odor like sulphur or bad eggs. If you notice such a smell in a receiver, look for a shorted filter capacitor before trying a new rectifier.

If the input filter capacitor breaks down in a circuit using a vacuum tube rectifier, so much current will flow that the rectifier plates may become red hot. Material may be torn off the cathode and fly over to the plates. This looks like bright sparks flying around inside the tube. After the rectifier tube has lost its emission, it is worthless.

Instructions for Statement No. 39: Disconnect the power supply from the wall outlet, and *do not* plug it in until you have completed all work on the Statement.

Remove the 10K-ohm resistor, and the 3000-ohm resistor from the circuit. Wire the leads of the filter choke to terminals 10 and 11 of the terminal strip, and solder a short piece of hookup wire between terminals 7 and 10. You are ready to take the necessary measurements for the Statement.

First, measure the resistance between terminal 11 and the chassis. Then, measure the resistance between lug 19 and the chassis. Make a note of your readings. Now, remove the piece of wire from terminals 7 and 10.

From the information we gave you in this experiment, you should be able to answer the Statement. Make sure you enter your choice on the Report Sheet also.

Statement No. 39: The tests I made show that:

(1) *the short was on the rectifier side of the filter choke.*

(2) *the short was on the load side of the filter choke.*

(3) *there was no short.*

EXPERIMENT 40

Purpose: **To show how two rectifiers can be connected to a voltage source to give twice the voltage that can be obtained from a single rectifier; and to show how they can be used for either half-wave or full-wave rectification.**

Introductory Discussion: Tubes used in ac-dc receivers today are designed to operate on power supply voltages of 90 to 100 volts dc. A half-wave rectifier that is capable of sup-

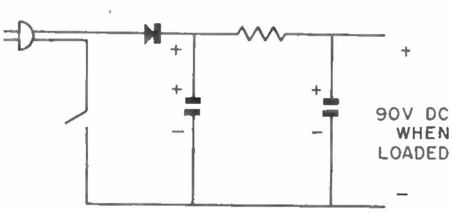

FIG. 40-1. A half-wave rectifier circuit that can supply 90 volts.

plying this voltage is shown in Fig. 40-1. It is the type of rectifier circuit that is usually found in ac-dc receivers. The tubes used in early ac-dc receivers required 180 volts dc or more. Therefore, vacuum tube rectifier circuits that could double the line voltage were used in these receivers. They are not often found in today's inexpensive ac-dc sets, except where the audio output tubes must deliver high power to the loudspeaker, as in many radio-phono combinations.

Voltage doublers, however, are widely used in TV sets, where eliminating the power transformer gives a much greater saving than in a radio receiver. You are likely to have to work on one at some time in your servicing career. For this reason, the study of how the voltage-doubler power supply operates is important to you.

The voltage-doubler power supplies are divided into two types—the full-wave and the half-wave. The full-wave doubler is generally used in supplies where the current demands are heavy. Its output voltage has a frequency of 120 cycles. Therefore, it can be more easily filtered than the output voltage of a half-wave voltage doubler, which has an output ripple of 60 cycles per second.

The half-wave voltage doubler is most often used in TV high-voltage supplies because in the high-voltage supply the current demands are very low. Hence, filtering is not a problem. In fact, a 1-megohm resistor can be used as the filter without dropping the voltage appreciably.

Instead of using the power line directly as a source of voltage in this experiment, we will use half of the high-voltage winding of the power transformer. This gives protection from the power line, and permits us to experiment with somewhat lower voltages. Regardless of the source

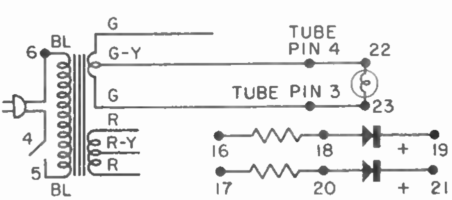

FIG. 40-2. Before you begin Experiment 40, take off all the wiring except the wiring shown here.

voltage used, the basic principles are the same.

Experimental Procedure: In addition to your vacuum tube voltmeter and the power supply parts, you will need:

One 20-mfd, 150-volt electrolytic capacitor.
One .25-mfd capacitor.

Examine your soldering iron tip to be sure it is clean and well tinned.

You must first partially dismantle your power supply. Remove the two 22K-ohm resistors from terminals 11 and 13. Unsolder the two choke leads, and the red-yellow transformer lead from terminal 7. Remove the lead between selenium rectifier terminals 19 and 21, and between terminal 19 and terminal 10 on the terminal strip. Unsolder all four electrolytic capaci-

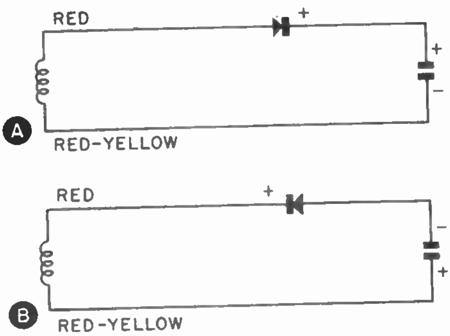

FIG. 40-3. A, how a rectifier can be connected to produce a positive rectified voltage; B, how it can be connected to produce a negative rectified voltage.

tor leads. Remove any excess solder on the terminal strip, and make certain that no solder has bridged from the lugs to the chassis.

When cleaning lugs on the terminal strip, turn the chassis on its end so the terminal strip is farthest from the table top. Then the solder will come off easily. Work from the bottom lug, 13, toward the top. Also examine the selenium rectifiers to see if any solder has spattered between the plates. Such solder can ordinarily be removed with a sharp knife, but be careful not to scar the plates. If such solder will not come out easily, the rectifier should be dismounted and re-installed after the job is done. Your circuit should now be like Fig. 40-2. Check your wiring against this figure.

Fig. 40-3A shows how a rectifier can be connected to an ac voltage source to produce a rectified voltage that is positive with respect to the red-yellow side of the voltage source. Fig. 40-3B shows a rectifier connected to produce a rectified voltage that is negative with respect to the red-yellow side of the voltage source. We will combine these two circuits to make a full-wave voltage doubler. The circuit is shown in Fig. 40-4.

Connect a red transformer lead to terminal 16, then connect a bare wire between terminals 16 and 21 and solder the connections. Solder a piece of hookup wire to terminal 17, and connect the other end to terminal 12 of the terminal strip. Connect the blue capacitor lead to 12, and then solder the connection.

Solder the red capacitor lead to terminal 19. Then, connect the red-yellow transformer lead, the green capacitor lead and the black capacitor lead to terminal 9, and solder the connections.

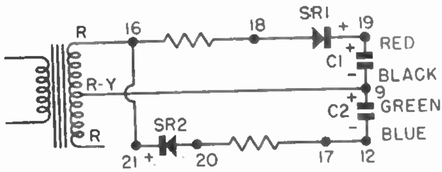

FIG. 40-4. A full-wave voltage doubler.

Check the connections carefully, because when more than two leads are soldered to a single terminal, it is very easy for one of the leads, usually the one on the bottom, to come loose. The circuit is now wired as shown in Fig. 40-4, and you can proceed with the experiment.

Step 1: To show that the circuit in Fig. 40-4 gives twice the voltage that a single rectifier would. Measure the ac source voltage between terminals 9 and 16. Record your measurement in Fig. 40-5. Turn off the supply after each measurement.

Now measure the dc output voltage of selenium rectifier 1, by measuring across capacitor C1. Connect the ground clip of the vtvm to terminal 9, and the probe to terminal 19. Note the polarity marked on the electrolytic capacitor in Fig. 40-4 so you will know how to set the Function switch on the vtvm. Record your reading in Fig. 40-5.

VOLTAGE MEASURED	READING
AC SOURCE	63 V
DC OUTPUT OF SR1	82 V
DC OUTPUT OF SR 2	78 V
DC OUTPUT WITHOUT LOAD	160 V
DC OUTPUT UNDER LOAD	150 V

FIG. 40-5. Record your readings for Step 1 here.

Measure the dc voltage developed by selenium rectifier 2 by measuring the voltage across C2. Leave the ground clip of the vtvm on lug 9, note the polarity of the voltage to be measured as shown on the electrolytic capacitor in Fig. 40-4, and set your Function switch accordingly. Touch the positive probe to terminal 12, and record the voltage you measure in Fig. 40-5.

As you can see from Fig. 40-4, capacitors C1 and C2 are in series, so that the voltages across them add. Measure this voltage by clipping the ground lead of the vtvm to terminal 12, note the polarity so you can set the Function switch properly, and put the Range switch in the 300-volt position. Touch the probe to terminal 19, and record your voltage in Fig. 40-5 as the dc output without load. You should get approximately twice the voltage that you got across either C1 or C2. Notice that the dc voltage is much higher than the peak of the rectified ac source voltage. Turn off the power supply. As a final measurement in this Step, let us see how much the voltage drops between terminals 12 and 19 when a load is applied. Connect the two 22K-ohm resistors in series, and connect the outside leads of the 44K-ohm resistor between terminal 12 of the terminal strip and terminal 19 of the selenium rectifier. Solder the connections. Now measure the dc voltage between terminals 12 and 19, and record the value in the space provided in Fig. 40-5. Note that the voltage dropped when the load was applied just as you have observed in the various rectifier circuits with which you previously experimented.

Before starting to disassemble this circuit, you should discharge the filter capacitors. To discharge the capacitors, strip a quarter of an inch or so of insulation from both ends of a 6-inch piece of hookup wire. Unplug the power supply chassis from the power line, and holding the wire by the insulation, short terminal 19 to terminal 9. You may see a spark as the capacitor discharges. Do this several times. Now discharge capacitor

C2, by touching the ends of the hookup wire to terminals 9 and 12. When the capacitors have been discharged, it will be safe to touch the circuits without danger of shock.

Step 2: To show that in a half-wave voltage doubler, the rectified voltage stored in one capacitor is added to the line voltage so the sum of the two voltages acts as the source for the second rectifier. The circuit that you will use is shown in Fig. 40-6. First, remove the 44K-ohm load resistor (the two 22K-ohm resistors in series) from terminals 12 and 19. Then, unsolder the red and yellow transformer lead from terminal 9, and solder it to terminal 12.

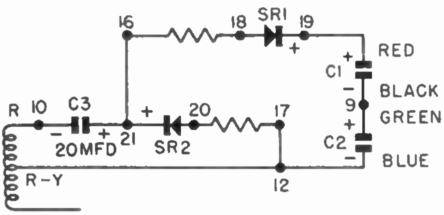

FIG. 40-6. Circuit for Step 2 of Experiment 40.

Unsolder the red transformer lead from terminal 16 of the 1-lug strip, and connect it to terminal 10 of the 7-lug strip. Finally, solder the — (negative) lead of the separate 20-mfd, 150-volt electrolytic capacitor to terminal 10, and the + (positive) lead of this capacitor to terminal 16. You are now ready to make measurements to prove that the voltage has doubled.

To measure the ac source voltage, set up your vtvm for ac voltage measurements, and connect the ground clip to terminal 10. Turn on the power supply, and touch the positive probe to terminal 12. Record the ac voltage measured in Fig. 40-7.

Now, set your vtvm for positive dc voltage measurements. With the ground lead connected to terminal 10, touch the positive probe to terminal 21. The voltage you measure is that developed across C3, the separate 20-mfd, 150-volt capacitor in Fig. 40-6. Record the value in Fig. 40-7.

To measure the voltage at the output of selenium rectifier SR1, turn off the power supply, connect the ground lead of the vtvm to terminal 12, set the Range switch to the 300-volt range, turn on the power supply, and touch the probe to terminal 19. Record the voltage you measure in Fig. 40-7. Note that it is approximately the same as the dc output voltage in Step 1 of Fig. 40-5.

Discussion: In Fig. 40-4 the selenium rectifiers function on alternate cycles of the power line, so the ripple voltage developed in the circuit between terminals 12 and 19 is 120 cycles.

When the red transformer lead is positive with respect to the red-yellow lead in Fig. 40-4, we have current flow through rectifier SR1, which charges capacitor C1 with the polarity shown. **(Remember that the side marked + on the rectifier is actually the cathode).** When the ac across the power transformer has this particular polarity, rectifier SR2 will not conduct. On the

VOLTAGE MEASURED	READING
AC SOURCE	6.3 V
VOLTAGE ACROSS C3	81 V
VOLTAGE OUTPUT	155 V

FIG. 40-7. Record your readings for Step 2 here.

next half cycle, the red-yellow lead is positive with respect to the red lead. Then rectifier SR1 will not conduct. However, rectifier SR2 conducts, and in doing so, charges capacitor C2 with the polarity shown. The two capacitors of course retain their charges, and since they are in series with the correct polarity, the voltage between terminals 19 and 12 is twice that of either capacitor.

In the half-wave voltage doubler in Fig. 40-6, there is a 60-cycle ripple between terminals 19 and 12. When the red lead in Fig. 40-6 is negative with respect to the red-yellow lead, selenium rectifier SR2 will conduct, charging up capacitor C3 to the polarity shown. This time selenium rectifier SR1 will not conduct. On the next half cycle, the red lead becomes positive with respect to the red-yellow lead and the voltage across C3 is added to the transformer voltage. The polarity is incorrect for conduction through SR2, but SR1 will conduct, and its output capacitor will charge up to the peak of this voltage. As you have seen, it is roughly equal to the output voltage of the full-wave rectifier.

Voltage doubler circuits, such as those in Figs. 40-4 and 40-6, are able to double the source voltage only when operated on ac voltage. They will not act as doublers if the line voltage is dc. This is of little importance because there are few areas today where dc power line voltage is available.

Voltage doublers have the same difficulties as ordinary power supplies. The filter capacitors become leaky or develop a high power factor and the rectifiers may fail. Where a high power factor is suspected, the capacitors can be checked by shunting them with others of about the same size known to be in good condition. Where you suspect leakage, the capacitors are checked with an ohmmeter.

Instructions for Statement No. 40: In the high-voltage supplies of TV receivers, voltage triplers are often used. You will build such a system to get the information to answer the Statement.

Remove the 6X4 rectifier tube from your vtvm, and insert it in the socket on the power supply. Disconnect the power supply from the ac line. Run a lead from pin 7 of the 6X4 socket to terminal 10 and solder both connections. Make certain that the connections already on terminal 10 do not come loose.

Connect a .25-mfd capacitor from socket pin 1 of the 6X4 tube to terminal 12, again taking care that the leads already connected to terminal 12 do not come loose, and solder does not drip down and short to the chassis. The circuit should now be wired like that shown in Fig. 40-8.

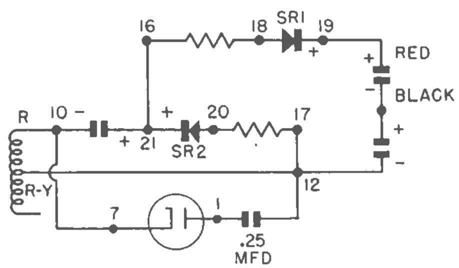

FIG. 40-8. Circuit for Statement No. 40

Connect the ground clip of your vtvm to the .25-mfd capacitor lead that goes to pin 1 of the 6X4 tube. Clip the positive probe of the vtvm to terminal 19. Plug the power supply in, and turn it on. Note that the voltage goes up to approximately 170 volts, and then drops down as the .25-mfd capacitor slowly discharges. As the 6X4 tube heats up, the voltage will start to rise rather rapidly, and will soon come to a stop. Carefully record the voltage you measure on the margin of this page. You are now ready to answer the Statement.

Statement No. 40: The voltage I measured between pin 1 of the 6X4 rectifier and terminal 19 was approximately:

(1) *twice*
(2) *three times*
(3) *the same as*

that across C3 in Step 2.

LOOKING AHEAD

This completes your experimental work on power supplies. After you have answered all the Statements on the Report Sheet, send it in for grading. While waiting for your next kit, remove the circuits you used here.

Remove the 6X4 tube and reinstall it in your vtvm. Disconnect the leads from the + terminals of the selenium rectifiers. Now, disconnect all the leads from the 7-lug terminal strip, and the piece of hookup wire and the 20-mfd capacitor lead from terminal 16. Disconnect the lead from tube socket terminal 7, and the .25-mfd capacitor lead from tube socket terminal 1. Finally, remove the piece of hookup wire from terminal 17 of the 1-lug strip.

Clean up all lugs and make sure that there is no excess solder remaining on them. Examine the selenium rectifiers and clean up any pieces of solder that have spattered between the plates. Clean up your solder iron and retin the tip so you will be ready for your experiments in Kit 5. The parts left over are listed in Table I. Be sure to save them for future use.

TABLE I

2	Flashlight cells
1	.1-mfd paper capacitor
2	.25-mfd paper capacitors
3	120-ohm, ½-watt resistors
1	220-ohm, ½-watt resistor
3	1K-ohm, ½-watt resistors
1	3K-ohm, ½-watt resistor
1	10K-ohm, ½-watt resistor
1	18K-ohm, ½-watt resistor
2	22K-ohm, ½-watt resistors
1	47K-ohm, ½-watt resistor
1	100K-ohm, ½-watt resistor
1	220K-ohm, ½-watt resistor
1	470K-ohm, ½-watt resistor
1	1-megohm, ½-watt resistor
1	1.8-megohm, ½-watt resistor
1	10-megohm, ½-watt resistor
1	4-lug terminal strip
1	1K-ohm potentiometer
1	20-mfd, 150-volt capacitor
1	Potentiometer mounting bracket
	Assorted hookup wire

250 V

SOFT SPOTS

Just as a soft spot in an apple or a melon makes it unfit for sale, so a soft spot in a man's character makes it difficult for him to sell himself. An employer, looking for men to promote, to take over his work when he is ready to retire, looks for sound men —men without any spots in their characters.

How about us—do we have any soft spots that might interfere with our success?

This soft spot may be a streak of laziness, a tendency to shirk responsibility, to pass the buck, to pity ourselves, to put off until tomorrow what should be done today, to put pleasure before work—to name but a few.

Be honest with yourself. Don't blind yourself to your "soft spot." It is no disgrace to have *had* a soft spot, the disgrace comes only when the soft spot is allowed to grow, only when you make no attempt to eradicate it.

FREQUENCY MODULATED SIGNALS

THE FM RECEIVER

34B

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Study Schedule No. 34

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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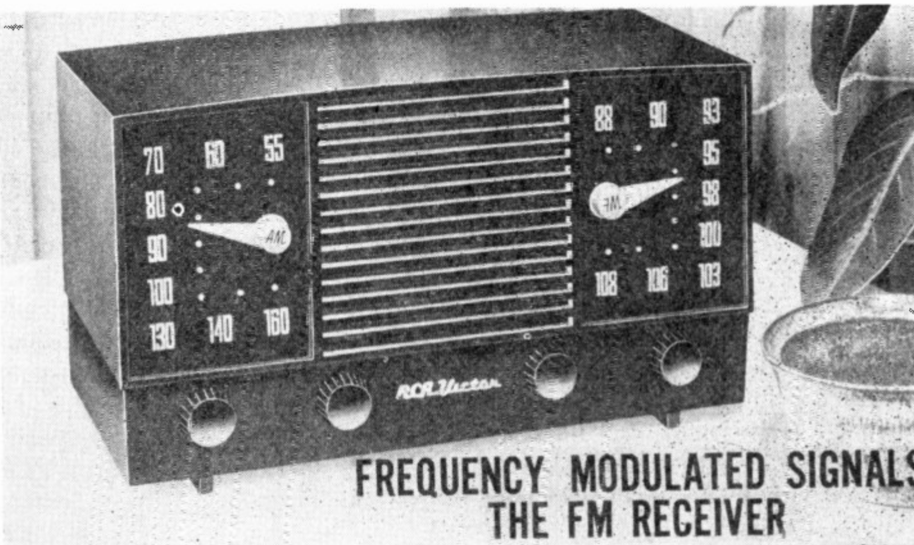


FREQUENCY MODULATED SIGNALS
THE FM RECEIVER

SERVICEMEN today must know frequency modulation and the circuits used in FM receivers. You will work on FM not only in FM and combination FM-AM radios, but also in TV sets, because the sound part of the TV program is frequency-modulated.

In this lesson, you will study the FM signal and learn how it differs from the AM signal. Then, you will learn that all the stages in an FM set except the FM detector, operate in much the same way as the corresponding stages in an AM set. You will not have to learn a lot of new circuits. What you already know about rf amplifiers, converters, and i-f and audio amplifiers can be applied to the stages in an FM receiver.

However, the operation of an FM detector is considerably different from that of an AM detector. Therefore, we will give a detailed description of the three types of FM detectors most often used in FM and TV receivers. Some FM detectors must be preceded by an additional stage, called a limiter, to remove noise and other interference that may be on the signal. You will also study limiters.

Much of what you learn in this lesson about FM receiver operation, especially FM limiters and detectors, also applies to the sound part of a TV set, although the sound in a TV set is amplified in the TV tuner and i-f amplifiers along with the picture information. A defect in any of these stages will affect both the sound and the picture. A defect between the loudspeaker and the point at which the sound signal is separated from the picture signal will affect only the sound. You will learn trouble-shooting in a TV set in a later lesson.

ADVANTAGES AND DISADVANTAGES OF FM

FM broadcast stations cover the full audio frequency range up to 15 kc. The upper audio frequency limit on AM stations is from 5 kc to 8 kc. Thus, FM gives more faithful sound reproduction than AM. It would be possible for an AM station to cover as wide a range; if its band width were increased from its usual 10 kc to 30 kc, that station would be able to broadcast audio signals up to 15 kc, and the reproduced sound would be just as faithful as that from an FM station. AM broadcast stations can get permission to do this if they have the facilities to handle the wide audio frequency range and there are no stations nearby with which they can interfere, but the usual AM band width is 10 kc.

One of the most important advantages of frequency modulation broadcasting is its low noise level compared to that of AM broadcasting. The sound from an FM set is usually clear and noise-free even during an electrical storm, when the sound from an AM set would probably be almost useless. Thus, FM is used where communication must be reliable.

Many police forces, utility companies, and large industries use FM in their mobile and point-to-point communications. This is a profitable field that you may want to get into as a source of extra money, or even as a full-time business.

In AM broadcasting, the audio level must be kept within limits to prevent over-modulation and distortion. Loud passages in music and other similar loud sounds must be suppressed at the transmitter, and the soft sounds must be increased to get them above the noise level. As a result, the very loud and very soft audio signals are not in true proportion to each other. This is not so in FM broadcasting. The reproduced sound is more lifelike—we say the sound has a fuller "dynamic range."

Still another advantage of FM is that a strong FM station can dominate a weak one. If two FM stations are received, and one signal is only three or four times as strong as the other (in a well designed system even twice as strong is enough), the stronger station will entirely obscure the weaker one. In AM, the weak station would still be heard in the background.

FM has some disadvantages, however. Because FM broadcast stations are in the vhf band, their signals are not reflected from the ionized layers in the sky, and long-distance reception is not possible, except under very unusual conditions. Another disadvantage is the much wider frequency band required for FM stations than for AM stations. The channels in the FM band are 200 kc wide; those in the AM band, only 10 kc. The AM broadcast band is from 550 kc to 1700 kc. As you can see, it would be possible to have only five FM stations in this band, but there can be over a hundred AM stations in it.

Now that we have seen some of the advantages and disadvantages of FM, let us learn how the FM signal is formed.

How Signals Are Modulated

Although in this lesson we are dealing mainly with frequency modulation, you will understand it better, if we compare AM and FM signals. This will not only help you to understand AM and FM, but it will also help you understand the more complex color television signal when you study it later in the course.

As you have learned in your study of AM, an audio signal alone cannot be transmitted over any distance; it soon becomes too weak to be heard. The audio signal must be combined with a higher frequency signal called a "carrier" before it can be sent from the transmitter to the receiving antenna. The method of combining the audio and rf carrier signals is called "modulation." The unmodulated rf carrier signal is a continuous stream of high-frequency sine waves having a constant amplitude. The way in which these sine waves are changed, or "modulated" by the audio signal is the difference between AM and FM.

Fig. 1 shows the basic differences between the two types of modulation. Fig. 1A shows the audio signal and the rf carrier that are to be combined. Fig. 1B shows how they are combined in AM, where the *amplitude* of the rf carrier signal varies according to the amplitude of the audio signal.

Fig. 1C shows how they are combined in FM, where the *frequency* is varied according to the amplitude of the audio signal. As you can see in Fig. 1, the carrier in an AM wave has a constant frequency but a varying amplitude; the carrier in an FM wave has a constant amplitude but a varying frequency.

Let us now look more closely at an AM signal and study its characteristics. Then we will discuss the FM signal later in this section, and compare the two methods of modulation, so you can see the differences.

FORMING AN AM SIGNAL

When an audio signal amplitude-modulates an rf carrier, as in Fig. 2, the amplitude of the rf carrier increases and decreases on both sides of the center line (the zero axis) according to the strength or amplitude of the audio signal.

In Fig. 2A, the peak amplitude of the audio modulating signal is one-

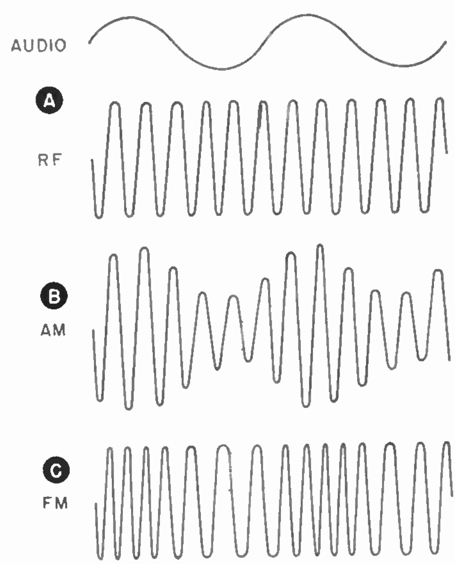


FIG 1. The audio signal waveform and the rf carrier to be modulated are shown at A; B shows the two combined by amplitude modulation; C shows how the two are combined by frequency modulation.

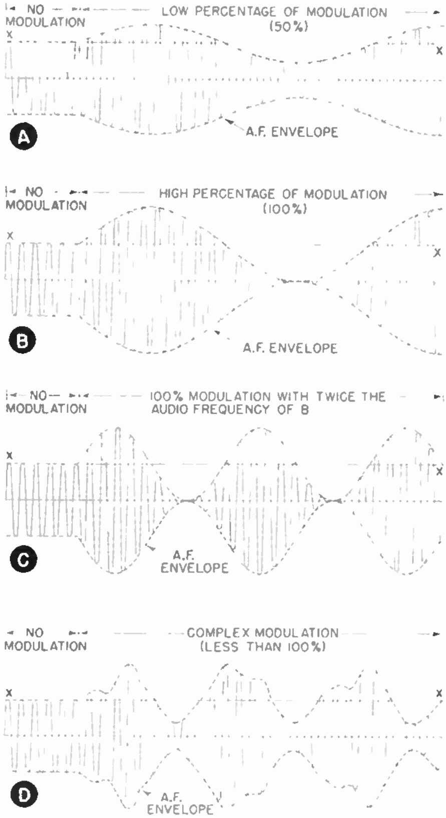


FIG. 2. Example of amplitude-modulated signals.

half the peak amplitude of the rf carrier signal, and we have 50% modulation. In Fig. 2B the peak amplitude of the audio modulating signal is equal to the peak amplitude of the rf carrier signal, and we have 100% modulation. This is the modulation percentage that can be used on an AM wave without distorting the audio signal.

If the frequency of the modulating audio signal increases, as shown in Fig. 2C, the rate at which the rf carrier rises and falls increases. This is still 100% modulation. Therefore, you can see that in amplitude modulation, the amplitude of the modulated carrier signal is determined by the strength or amplitude of the audio signal, and the rate at which the rf carrier amplitude varies is determined by the frequency of the audio signal.

The audio signal fed to the transmitter is seldom a pure sine wave signal. It usually has a very complex waveform and results in an rf signal such as the one in Fig. 2D. Although this waveform varies considerably, it is formed the same way as waveforms A, B, and C in Fig. 2.

The envelope of an AM signal (the broken line drawn through the peaks) is a combination of a number of modulating components. When an rf carrier signal is amplitude-modulated by a single fixed-frequency sine wave, the modulated signal is made up of three separate frequencies. One is the constant amplitude rf carrier, and the other two are the sideband frequencies which are above and below the carrier frequency an amount equal to the audio frequency.

For example, if the audio frequency is 5000 cycles and the carrier frequency is 1000 kc, the rf signals after modulation will be 1000 kc, 995 kc, and 1005 kc. In other words, the audio information appears 5000 cycles above and below the carrier frequency as the upper and lower sidebands.

When a complex audio signal, having many frequencies in the range from 100 cycles to 5000 cycles, is used to modulate the rf carrier, the transmitted modulated carrier will contain the 1000-kc rf carrier and two sidebands for each of the many, many frequencies that make up the voice or music information. The rf and i-f systems in the AM receiver must be able to amplify this entire frequency range uniformly, so that the carrier and the side frequencies will be applied to the second detector.

FORMING THE FM SIGNAL

A frequency-modulated signal is also made up of the rf carrier and upper and lower sidebands. The frequency-modulated signal as you saw in Fig. 1C has a constant amplitude; the audio signal causes the frequency of the carrier to vary.

The carrier frequency of the FM signal, called the "center" or "resting" frequency, is the frequency of the carrier when no audio modulation is being applied, as shown in Fig. 3. When an audio signal is applied, the frequency of the carrier increases and decreases as shown in Fig. 3A. This frequency variation is called deviation. When the audio signal crosses the center line, corresponding to zero audio voltage, the center carrier frequency is transmitted.

In the illustration we show, the frequency of the carrier increases on the positive peaks of the audio signal (larger number of cycles in the FM signal) and decreases on the negative peaks (fewer cycles). FM transmitters can be designed either this way or so that the frequency decreases on the positive peaks.

When a higher amplitude audio frequency (a loud sound) is used to modulate the FM carrier, the frequency of the FM carrier increases and decreases more. This is shown in Fig. 3B. Notice that the modulated carrier frequency at the positive peaks of the audio wave contains a larger number of cycles than for the lower amplitude audio peaks in Fig. 3A.

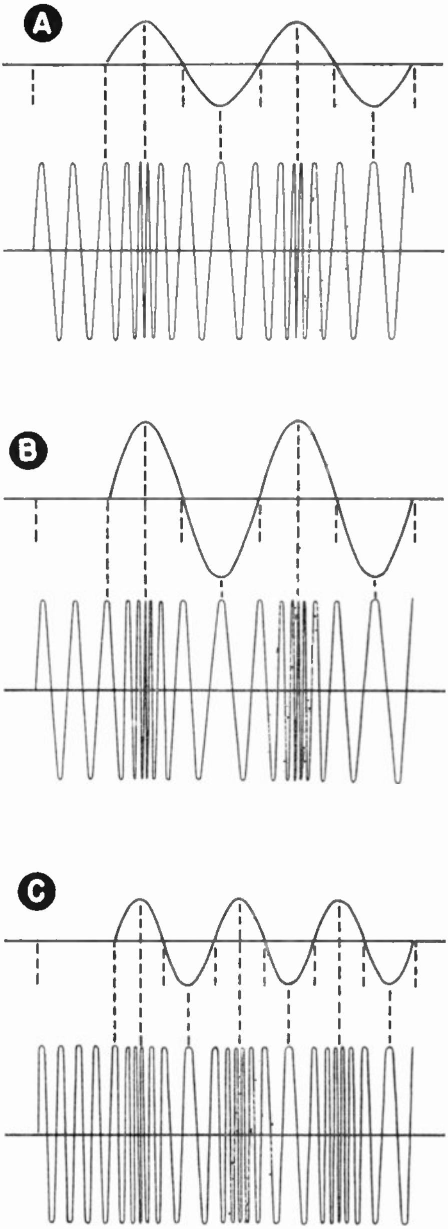


FIG. 3. Examples of frequency-modulated signals.

When the frequency of the modulating audio signal increases (higher pitched sound), the rate at which the FM wave deviates above and below the center frequency increases. This is illustrated in Fig. 3C. Thus, the amplitude of the audio signal controls the *amount* of frequency deviation in the FM carrier signal, and the frequency of the audio signal controls the *rate* of frequency deviation. The *amplitude* of the FM signal always remains constant.

FM Band Width. The FM band is in the vhf range between television channels 6 and 7, and extends from 88 mc to 108 mc. This band of frequencies is divided into channels 200 kc wide. In the center of each channel is the carrier frequency for that channel.

The FM broadcast station is not permitted to use the entire 200-kc channel. According to the FCC regulations, the highest amplitude audio signal that may be applied as modulation to the FM transmitter is one that causes a frequency deviation of 75 kc on each side of the resting frequency—a total of 150 kc. The 75-kc limit corresponds to 100% modulation limit in AM broadcasting. The extra 25 kc on each side acts as a guard band to prevent interference between stations.

In the sound portion of the television signal, the maximum deviation permitted is only 25 kc on each side of the FM resting frequency. Thus, the deviation is less for FM sound transmission in television than it is for the FM broadcast band.

Sidebands. Like the AM signal, the FM signal is made up of the carrier frequency and a number of sidebands. In AM, when a single-frequency audio tone is transmitted, two sidebands, one above and one below the carrier frequency, are formed. The amplitude of these sidebands changes when the audio level changes, but regardless of the amplitude there are always two, and only two, sidebands. The center carrier amplitude never changes with modulation.

When a carrier is frequency-modulated there will be at least two, and usually there will be more than two sidebands. The sidebands are always in pairs. One sideband of each pair is at a frequency higher than that of the carrier, and the other sideband is at a frequency lower than that of the carrier. The amplitude of each pair of sidebands and the number of sidebands changes when the audio level changes. The number of sideband pairs increases as the audio level increases. The number of sideband pairs also changes when the audio frequency changes. There are more sidebands for a low audio frequency than for a higher frequency of the same amplitude.

An increase in audio level will increase the amount of power in the sidebands, and decrease the amplitude of the center carrier; the carrier even disappears at some audio levels then reappears at higher levels. The different sideband pairs also change in amplitude and even disappear at some amplitudes. The total power, however, contained in the carrier and all of the sidebands never changes, no matter what the audio level or modulating frequency.

Here then is a major difference between an AM signal and an FM signal. Amplitude modulation changes the total power of the signal, with the additional power going into the sidebands. Changing the audio level changes the amount of power added to the signal. Frequency modulation, on the other hand, does not change the total power. Therefore, the power that appears in the sidebands must come from the carrier. Frequency modulation causes the available power to divide between the carrier and the sidebands. Changing the audio level changes the way in which this power is divided.

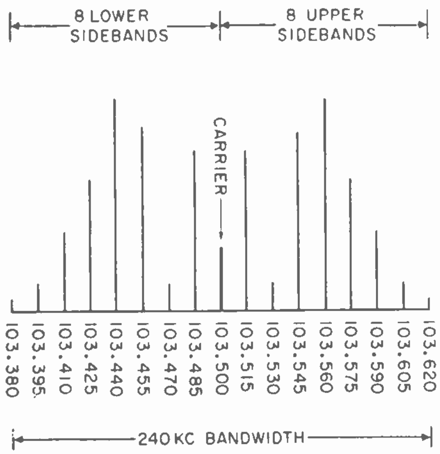


FIG. 4. An FM band, showing the carrier or center frequency and the sidebands for a 15-kc audio modulating frequency.

The illustration in Fig. 4 shows the number, positions, and amplitudes of the sideband pairs that might be produced when the FM carrier is modulated by a very loud, 15-kc audio signal. This is the highest frequency audio signal that is used in FM broadcasting.

In Fig. 4, the FM carrier is deviating 75 kc above and below the center or resting frequency of 103.5 mc. At the audio modulating frequency of 15 kc, there are eight upper and eight lower usable sidebands spaced 15 kc apart. The amplitudes of the sidebands are indicated by the lengths of the lines. There are actually more than eight sideband pairs above and below the carrier, but the sidebands beyond these eight usable ones have such low amplitudes that they contain very little information.

To find the band width needed to transmit these usable sideband pairs, multiply the number of sideband pairs by the audio modulating frequency. In this case, 8 x 15 kc = 120 kc on each side of the resting frequency. This is a total band width of 240 kc. A 5-kc audio signal, of the same amplitude, will produce nineteen usable sideband pairs. In this case, the signal band width will be 190 kc (19 x 5 kc = 95 kc above and below the carrier frequency). Thus, the lowest frequency sound requires the smallest band width but contains the most sideband pairs.

If the amplitude of the modulating signal is reduced, the amplitudes of the sidebands will also be reduced. In fact, if the signal amplitude is very low, the sideband pairs at the extreme ends may disappear, or drop to a very low value. The fewer the sideband pairs, the narrower the band width. However, the signal that is broadcast will contain all the information that is needed to produce good fidelity sound.

In Fig. 4, we show that the band width of a 15-kc audio signal is 240 kc. Actually the FCC restricts the band width of FM stations to 200 kc. Sideband components beyond the 200 kc limit are not broadcast. The i-f amplifier section of the FM receiver should have a band pass of at least 200 kc. A narrower band pass will produce frequency distortion in the audio output signal because some of the usable sidebands contained in this signal will be cut off.

From the preceding discussion, you can see that the number of usable sidebands contained in the frequency-modulated signal depends on the frequency and amplitude of the audio signal used to modulate the carrier. The lower the audio modulating signal, the larger the number of sideband pairs. Also, the number of usable sideband pairs will decrease when the amplitude or strength of the audio signal decreases.

A BASIC FM MODULATOR

We can demonstrate how an FM signal can be produced by studying the basic FM modulator circuit shown in Fig. 5.

The modulator is made up of a Hartley oscillator and a condenser microphone. The frequency of this oscillator is determined largely by the values of coil L and capacitor C in the oscillator resonant circuit. Of course, it can be tuned to higher or lower frequencies by changing the value of the inductance or the capacity. If the frequency change of the oscillator is not great, it is not likely to affect the amplitude of oscillation.

A condenser microphone is connected across the resonant circuit. Sound waves striking the movable diaphragm of the microphone cause its capacity to vary. These changes in the capacity of the microphone

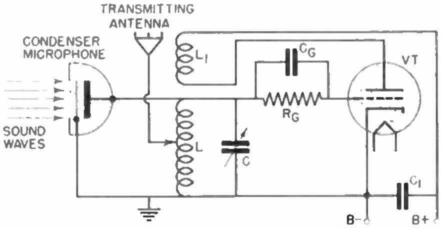


FIG. 5. A simple modulator having a condenser microphone across the tank circuit of a tuned-grid rf oscillator.

vary the effective capacity in the resonant circuit, which raises and lowers the frequency of the oscillator, forming a frequency-modulated signal. A louder sound will cause a greater movement of the diaphragm, which will cause a wider frequency deviation; a softer sound will cause a smaller movement and a smaller deviation.

This is a crude and impractical method of frequency modulation, but it does demonstrate the principle of producing an FM signal.

SUMMARY

In this section of the lesson, you learned that in an FM system, the audio modulating signal causes the frequency of the carrier to vary, and the greater the audio amplitude the greater the variation. This is in contrast to an AM system in which the audio signal causes the amplitude of the rf carrier to vary.

When the modulating audio frequency increases in an FM system, the rate at which the frequency varies or deviates increases. In AM, an audio frequency increase causes the rate at which the rf carrier signal amplitude changes to increase. Therefore, the chief difference between AM and FM is that the FM signal has a constant amplitude but a varying frequency, while an AM signal has a constant frequency but a varying amplitude.

Noise rejection is an important feature of the FM system of broadcasting. Therefore, in the following section of this lesson, you will learn how noise is removed from the FM signal.

Eliminating Noise And Interference

The FM signal picked up by the FM receiving antenna usually contains some amplitude modulation in the form of noise or interfering signals. If the signal containing the amplitude variations were fed directly to certain types of FM demodulators, the noise would be reproduced in the loudspeaker just as in an AM set. These amplitude variations must be removed before the signal is demodulated. This is done by a circuit called a "limiter."

Fig. 6 shows the block diagram of an AM receiver at A, and of two FM receivers at B and C. In Fig. 6B, the limiter precedes the FM demodulator. It, in effect, clips off the positive and negative peaks of the FM signal so that the limiter output signal is constant in amplitude but varying in frequency. The receiver shown in Fig. 6C uses a ratio detector. The limiting operation is done in this detector without the use of a separate limiter circuit.

Except for the limiter and demodulator, the FM receiver is similar in many ways to an ordinary AM receiver. Both the AM and the FM receivers are superheterodynes; they each have a mixer-oscillator, i-f amplifiers, and audio amplifiers. The FM receiver often uses an rf ampli-

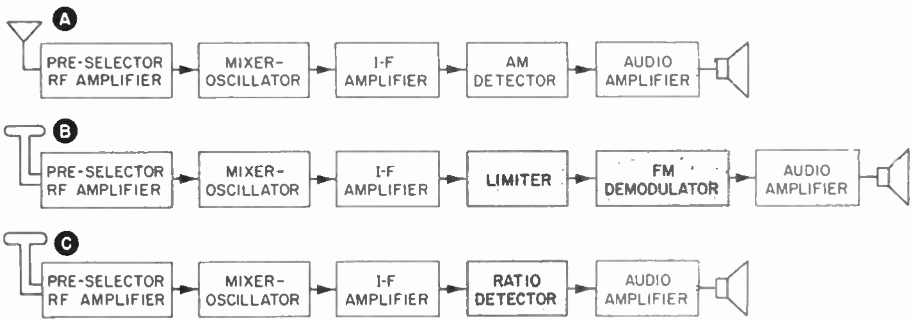


FIG 6. Block diagrams of (A) an AM receiver, and (B) and (C) two FM receivers.

fier in the pre-selector. The AM receiver does not need this.

There are some differences between AM and FM sets besides the differences in the sections used to convert the modulated signal to the audio signal. For one thing, the intermediate frequency used in an FM set is much higher than that used in the AM set. It is usually 10.7 mc compared to 456 kc in AM. Also, the i-f amplifiers must have a band pass of at least 200 kc; the band pass of an AM set is usually 10 kc. Also, the preselector in an FM set operates at a much higher frequency—from 88 mc to 108 mc, compared with 550 kc to 1700 kc in an AM set.

The operation of FM and AM receivers is essentially the same until the FM signal reaches the demodulator. The FM demodulator must change the frequency deviation of the rf carrier back into the amplitude variation of the original audio signal. After the signal has been filtered, it is fed to the audio amplifier and then to the loudspeaker.

In a TV set, the FM sound part of the signal is amplified along with the picture information in the i-f stages of the set. The FM sound signal is removed from the output of the i-f amplifier section and fed to the sound section. Here the FM signal is amplified and detected in the same type of circuits as in an FM receiver.

Now let us see how a limiter is used to eliminate the amplitude variation in an FM signal, caused by noise such as from atmospheric disturbances, electrical appliances, and auto ignition systems. If these were not removed, the FM detector would reproduce them just as an AM detector would.

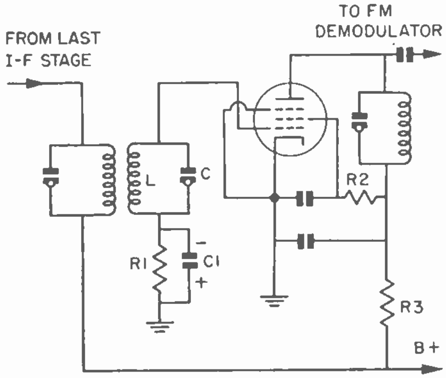


FIG. 7. A single-stage limiter circuit.

FM LIMITERS

The desired information in an FM signal is in the frequency variations rather than in the amplitude variations. Therefore, if we get rid of the amplitude variations by clipping off the positive and negative peaks, we will eliminate the interfering noise. This operation is called amplitude limiting.

The limiter stage removes the interference signals without destroying

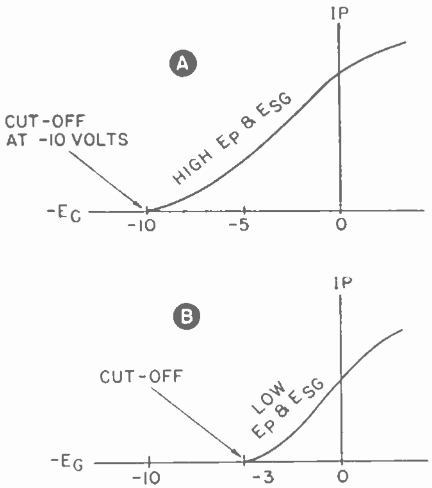


FIG. 8. (A) normal operation of an amplifier; (B) operation of a limiter.

the desired intelligence in the FM signal by removing the positive and negative peaks of the FM signal so that the output signal is again constant in amplitude but varying in frequency.

Let us study some typical limiter circuits used with an FM detector like that shown in Fig. 6B, and find out how they are able to eliminate interference signals on the frequency-modulated signal. We will discuss limiter action in a ratio detector when we study that circuit later in this lesson.

Limiter Operation. The most common form of a limiter is shown in Fig. 7. At first glance, the circuit seems the same as any other i-f amplifier except for the addition of R1 and C1 in the grid return circuit. However, the values of resistors R2 and R3 are much larger than would be expected, and the plate and screen voltages are low.

Parts values and voltages are not given in Fig. 7, since they will depend upon the tube type, the B+ supply voltage, and the signal level at the input to the stage. In average sets, the plate voltage is between 50 and 110 volts, and the screen voltage may be as low as 10 volts.

The operating curve of grid voltage and plate current for a typical i-f amplifier tube at normal plate and screen voltage is shown in Fig. 8A. The negative alternation of the incoming signal can cause the grid to be as much as 10 volts negative with respect to the cathode before clipping will take place. Fig. 8B shows the operating characteristics of the same tube with reduced plate and screen voltages. Now the negative alternation of any signal that drives the grid 3 volts negative with respect to the cathode will cut off the plate current.

The positive alternations are clipped in the grid circuit. Fig. 9 shows the equivalent grid circuit of the limiter. The grid and cathode form a diode with the grid acting as the diode plate.

A signal voltage appears across the secondary of the i-f transformer. This voltage divides between the diode and R1. When the grid (plate of the diode) is negative with respect to the cathode, no current flows through the circuit. There is no voltage drop

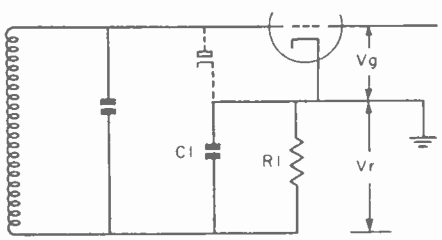


FIG. 9. Equivalent grid circuit of a limiter.

across R1 and the entire signal voltage appears across the grid and cathode of the tube. When the positive alternation of the incoming signal causes the grid to become positive with respect to the cathode, the grid will conduct. The current flowing through the grid-cathode circuit also flows through R1. The voltage drop across R1 reduces the voltage between grid and cathode. Capacitor C1 charges to the voltage across R1 and sets the bias on the tube.

When a diode conducts, its internal resistance goes down as the voltage across it increases. Therefore, the current increases more rapidly than the applied voltage, and the voltage drop across R1 increases more rapidly than the voltage between grid and cathode of the tube. In this way the grid-cathode voltage is held constant at a slightly positive voltage during the entire positive alternation. Fig. 10 shows how this grid clipping removes noise and amplitude variations from the positive alternations of the signal.

The RC circuit should have a fast time constant to permit a fast change in average bias when strong impulse noises are received. If a strong noise

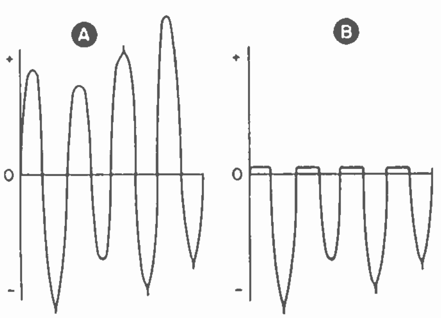


FIG. 10. Wave shape of signal across (A) tuned circuit; (B) grid-cathode circuit of a limiter.

signal is applied to the limiter grid, the voltage across the capacitor changes quickly so that a high negative bias is applied to the grid, and the impulse noise does not appear in the plate circuit. This fast time constant also permits a rapid recovery of the limiter circuit to normal operation at the end of the noise pulse. However, too fast a time constant (a time constant equal to the time of one cycle of the rf wave) is not desirable because the capacitor voltage will follow the individual rf cycles and grid limiting will not take place.

The grid may be acting as a diode plate in the grid-cathode circuit, but it still controls the current in the plate-cathode circuit of the tube. The plate current still follows the grid-cathode voltage. However, the low cut-off bias clips the positive alternations of the signal and results in the pulse output shown in Fig. 11. As you can see, all amplitude variations and noise are removed from the signal by these two types of clipping action. These pulses pass through a tuned output circuit which converts them to sine waves of a constant amplitude.

For full limiter action, the signal from the preceding amplifier stages must be high enough to drive the limiter into grid current and plate current cut-off. In Fig. 8B the signal applied to the limiter must swing more than 3 volts peak-to-peak. In a practical circuit, the limiting levels may be reached with a 4- or 5-volt signal. The circuit is designed usually so that the applied signal will be 10 to 20 volts. This makes sure that noise will not get through to the discriminator.

When a very weak signal is received, we cannot get full amplitude limiting, and the amount of background noise will increase. It is possible to bias and design the limiter to move the limiting levels nearer to each other to accommodate a weaker applied signal. However, if we make the limiting levels too low, the output will not be high enough to operate the following FM demodulator.

A defect in the set can also cause the noise to increase. For example, a defect causing higher than normal voltage on the limiter plate and screen grid will cause the limiting levels to move further apart. The background and impulse noise signals from auto ignitions, motors, etc., will be heard in the output. When servicing an FM set having this complaint, check the limiter plate and screen grid voltages. If the voltages are higher than normal, you will have to check the B+ circuit and find out what caused the voltage to increase.

An open in capacitor C1 in the grid-leak circuit (R1-C1 in Fig. 9), will also cause the noise from the receiver to increase. In this case, grid limiting will not take place and

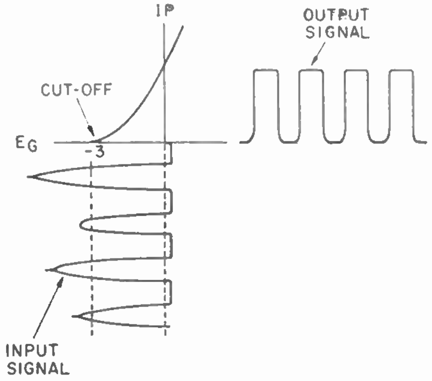


FIG. 11. Clipping of negative alternations by plate current cut-off.

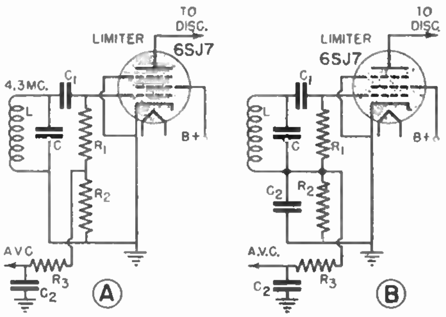


FIG. 12. Two ways of getting avc voltage from a limiter stage.

the positive alternation of the incoming signal will be amplified by this stage.

Cascade Limiters. Some FM receivers use two limiter stages in cascade. On the negative alternation of the incoming signal, the first limiter grid is driven to plate current cut-off. The signal phase is reversed 180 degrees in the tube so that the positive alternation of the original signal now drives the second tube to plate current cut-off. Thus, both alternations are clipped in the cascade limiter circuits by cut-off action alone. Neither tube need be driven into grid current to have good limiting action. Also, the action of the two stages together permits more effective limiting of a weak signal that may be present at the output of the i-f amplifier section.

Obtaining AVC Voltage from the Limiter. It is possible to use the limiter circuit as a source of avc voltage. In the practical circuit in Fig. 12A, capacitor C1 and resistors R1 and R2 serve as the limiter time constant network like R1 and C1 in Fig. 9. Using low capacity and resistance values gives the proper fast time constant. Part of the dc voltage developed across the limiting resistor R2, after being filtered by resistor R3 and C2, is used for avc.

It is possible to have dual RC limiter time-constant networks as shown in Fig. 12B. In this circuit, resistor R1 and capacitor C1 can have a fast time constant (not much longer than the time required to transmit a few rf cycles). The fast time constant provides a rapidly changing bias for fast limiter action and suppression of noise surges that occur at a rapid rate. The network made up of resistor R2 and capacitor C2 has a longer time constant and shifts the limiter bias voltage in accordance with the average strength of the incoming signal. This network takes care of the large changes in signal amplitude when the receiver is tuned from a weak FM station to a strong one. Because it has a longer time constant, it is a better source of avc voltage because the avc system must handle slow changes in bias.

Limiting is not the only method used to reduce the effects of noise on the FM signal. Circuits are used in both the FM transmitter and the receiver to change the frequency response in the audio frequency range where the noise is the most pronounced. Let us find out how changing the frequency response can reduce the noise on the FM signal.

PRE-EMPHASIS AND DE-EMPHASIS

The noises you have just studied cause amplitude variations that can be removed in the limiter. There are also noises that cause frequency deviation just as the desired signal does. These cannot be removed by the limiter.

These are chiefly high-frequency noises added in the transmitter and receiver vacuum tube circuits. Therefore, they can be minimized by emphasizing the high frequencies of the desired signal before these noises are added so that they will be stronger than the noise.

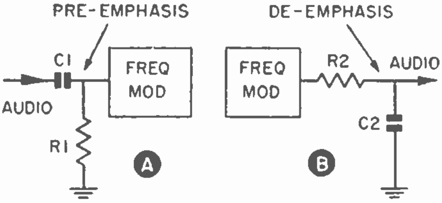


FIG. 13. Circuit used for (A) pre-emphasis of high frequencies at transmitter; (B) de-emphasis of highs at receiver.

Emphasizing the highs also improves the over-all frequency response because the high-frequency components of the program material are most likely to be distorted because their amplitude is lower.

Pre-emphasis. The circuit used to emphasize the higher audio frequencies at the transmitter has characteristics similar to those of the equalizer circuits you studied in an earlier lesson. A typical pre-emphasis network is shown in Fig. 13A. It consists of a series capacitor and a shunt resistor. The value of capacitor C1 is rather small, so its reactance is high at the low audio frequencies. Thus, the amplitude of the lows is reduced, and they do not appear at full level across R1 at the input of the modulator. The capacitive reactance presented to the high frequencies is much lower, and they appear almost at full amplitude at the input of the modulator.

De-emphasis. At the output of the demodulator stage in the receiver, of course, the highs and lows are not in true proportion. The highs must be de-emphasized to put them back in the proper proportion with respect to the lows. This is done by a de-emphasis network like that shown in Fig. 13B. Notice that in this case, the resistor is in series and the capacitor is in parallel with the demodulator output. The low reactance of capacitor C2 on the high audio frequencies has a shunting effect on the highs, but its much higher reactance to the lows prevents them from being shunted.

Now let us see how pre-emphasis can improve the signal-to-noise ratio. The high frequency noise signals are added to the FM signal after the desired audio signal has passed through the pre-emphasis network. These noise signals, therefore, will cause a much smaller frequency deviation in the FM signal than will the desired high frequency audio signal. The de-emphasis network is located at the output of the FM discriminator. When the audio signal passes through this RC circuit, all the high frequencies will be decreased in amplitude. Since the noise signals have much smaller amplitudes than the desired high frequency audio, the noise will be reduced to a very low value by the de-emphasis circuit.

If the product of C1-R1 equals that of C2-R2, the response of the two networks is equal but opposite. That is, the rate of high frequency pre-emphasis at the transmitter will be the same as the rate of high-frequency de-emphasis at the receiver. Thus, exact compensation occurs. The product of R and C is referred to as the "time constant", and when we equalize the time constant of two opposite networks, the over-all frequency response becomes linear.

Now let us study the demodulator or detector, itself. First we will take up those that require a separate limiter stage, and then we will take up those that do not require a separate limiter.

FM Demodulators Used With Limiters

The purpose of the FM demodulator or detector is to convert the frequency deviations in the signal back into the original audio variations. In this section, we will discuss the basic types of FM detectors.

The type we will discuss first is called the "slope" detector. Although they are no longer used in commercial receivers, they do demonstate the method of frequency demodulation.

THE SLOPE DETECTOR

The slope detector is a true FM demodulator because the audio variations in its output are a direct result of the frequency deviation in the FM signal applied to its input. Some of the FM detectors we will discuss later respond to phase variations rather than frequency deviations to produce the audio output signal. However, the diode circuits in both types of FM detector operate in the same way. A discussion of slope detector operation here will

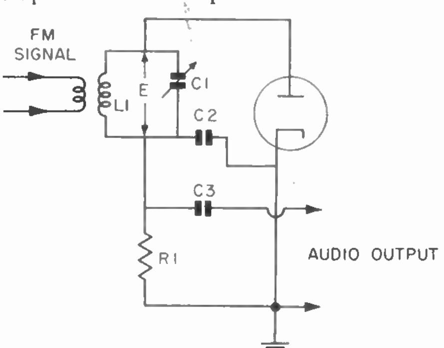


FIG. 14. Basic FM demodulator using a slope-tuned resonant circuit and a diode detector.

help you understand how the more complicated and practical circuits work.

The basic slope detector circuit is shown in Fig. 14. In this simple circuit, the frequency deviations in the i-f signal from the limiter are first changed to amplitude variations by the resonant circuit L1-C1. Then, the amplitude variations are demodulated by the diode detector. The resonant circuit, instead of being peaked at the center frequency of the i-f signal, is tuned so that the center frequency is at some point on the slope of the resonant response curve —hence the name "slope detector".

Fig. 15 shows the response curve of the L1-C1 resonant circuit. The 10.7-mc i-f is at point A, and the slope is wide enough to permit a frequency deviation of 75 kc on either side of the i-f from point A to B and A to C.

As the frequency of the incoming i-f signal increases, the i-f signal moves further up on the response curve toward point B. As you have learned, the voltage across an L-C circuit is highest at the resonant frequency (the peak of the curve). Since the frequency at point B is nearer the resonant frequency of the L1-C1 circuit than that at point A, a higher signal voltage will be applied to the diode.

A frequency decrease places the operating point further down on the response curve toward point C, and a lower voltage will be applied to the

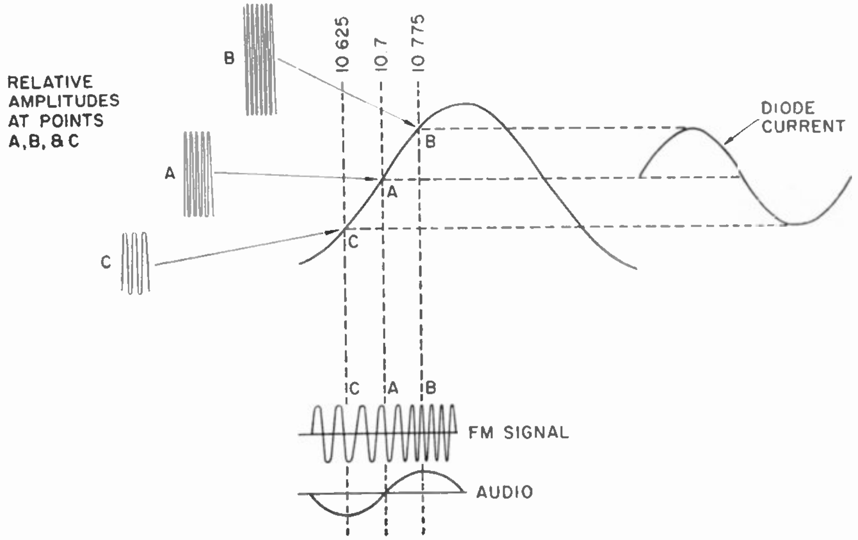


FIG. 15. Demodulation with a slope detector.

diode. In this way, the signal between the cathode and plate of the diode is amplitude-modulated instead of frequency-modulated. This signal merely has to be demodulated and filtered as in a conventional AM receiver to get the original audio signal.

The slope detector, although it clearly demonstrates the process of frequency demodulation, is not a good detector for commercial use. The amount of deviation is limited because the response curve of a simple resonant circuit does not have truly linear sides. The peaks of the audio signal produced when the FM signal swings into the non-linear portion will be distorted. Also, the slope detector is as sensitive to amplitude variations as it is to frequency variations. Therefore, it does not bring out one of the chief advantages of frequency modulation—keeping amplitude-modulated noises from interfering with recepiton.

THE TRAVIS DISCRIMINATOR

A more practical FM detector circuit, called the Travis discriminator, is shown in Fig. 16. It is really a balanced slope detector. The balanced arrangement gives a more linear reproduction of the original audio information than the simple slope detector just discussed.

Instead of a single resonant circuit feeding a diode amplitude detector, the signal from the L1-C1 resonant circuit is fed to two resonant circuits and detectors. The L2-C2 resonant circuit is tuned below the center

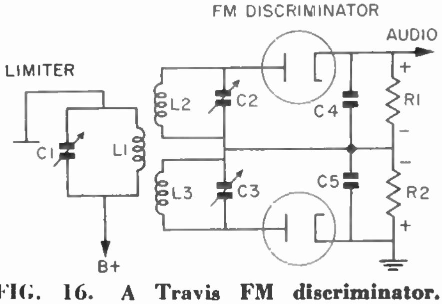


FIG. 16. A Travis FM discriminator.

frequency of the primary circuit and the L3-C3 resonant circuit is tuned above the center frequency.

The dashed curves in Fig. 17 show the response curves for the two resonant circuits. When the two curves are added algebraically, they produce the solid S curve. Notice that the central portion is essentially linear.

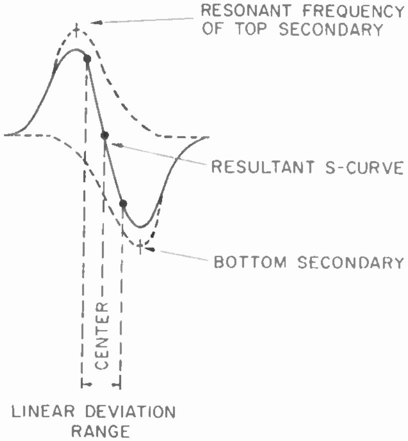


FIG. 17. Over-all response curve of the secondary resonant circuits of the Travis discriminator.

The diodes in Fig. 16 are connected so that the polarities of the output currents through resistors R1 and R2 oppose each other. At the center frequency, the current through R1 equals the current through R2; and because they have opposite polarities, the total current through the resistors is zero.

When the incoming i-f signal deviates below the center or resting frequency, the current drawn by the upper diode is higher than the current drawn by the lower diode, and a positive alternation appears at the audio output. When the frequency of the i-f signal deviates above the center frequency, the current drawn by the lower diode and resonant circuit is higher than the current drawn by the upper diode. Now the output of the detector swings negative, forming the negative alternation of the original audio information. Capacitors C4 and C5 connected across the diode load resistors act as filters to remove the rf signal components before the demodulated audio signal is fed to the audio amplifier.

Notice that although the individual response of each resonant circuit and diode is non-linear, the resultant response of the two sections working together is essentially flat. Linearity can often be obtained in electronic circuits in this way; by properly using non-linear responses that are equal but opposite in polarity.

The balanced slope detector is no longer used in commercial receivers because it is hard to align and the transformer design is critical. We will now discuss the various FM detectors that are used today. The most popular types are the Foster-Seeley discriminator and the ratio detector. We will discuss the Foster-Seeley discriminator which requires a limiter, first. Then we will take up the ratio detector, and other types that have been used by FM and TV receiver manufacturers that do not require limiters.

THE FOSTER-SEELEY DISCRIMINATOR

The Foster-Seeley discriminator, instead of converting frequency changes into amplitude changes as the slope detector does, converts phase changes into amplitude changes. As with slope detectors, a limiter must be used ahead of this

FM detector because it is as sensitive to amplitude changes in the incoming signal as it is to frequency changes.

A diagram of the discriminator is shown in Fig. 18. Notice that in some ways this circuit resembles the balanced slope detector shown in Fig. 16. The biggest difference is that the Foster-Seeley discriminator uses a single-tuned, center-tapped secondary winding in the transformer instead of the double-tuned type. In both circuits two diodes and two load resistors are used and the polarities of the voltage drops across these resistors in Figs. 16 and 18 are the same. Also, the over-all response curves of the two FM detectors have the same characteristic S shape.

There is a considerable difference in the operation of the two circuits, however. The primary and secondary resonant circuits L1-C1 and L2-C2 in Fig. 18 are both tuned to the i-f resting frequency. This frequency is usually 10.7 mc in an FM broadcast set, and 4.5 mc in a TV set. The i-f signal voltage, EP, at the output of the limiter stage is applied to the secondary of the resonant circuit in two ways. It is applied inductively by magnetic lines of force produced by the current flowing through winding L1, and capacitively through capacitor C3 to the center tap of the transformer secondary winding.

The voltage induced in the secondary causes a current flow, which in turn develops a voltage drop EO across the resonant circuit. This voltage divides between the center tap and either outside terminal to produce voltages E1 and E2. Notice that there is also a voltage drop E3 across coil L3 which is connected to the center tap of the secondary winding. Capacitors C3, C5, and C6 have practically no reactance at the frequency of the incoming signal. If you trace the circuit from the plate of the limiter, through C3, L3, and C5, to ground, and then through C6 and L1 back to the limiter plate, you will find that coils L1 and L3 are connected in parallel as far as the rf signal voltage is concerned. Therefore, voltage E3 across coil L3 is the same as the input voltage EP.

Let us now trace the individual diode circuits. The signal circuit of the upper diode D1 is from the plate, through the upper part of the trans-

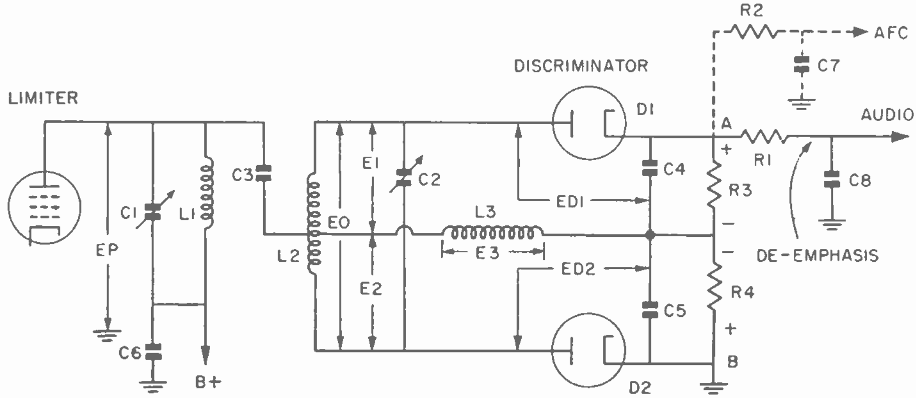


FIG. 18. Foster-Seeley discriminator.

former secondary winding to the center tap, through coil L3 and capacitor C4 to the cathode. The lower diode signal circuit (D2) is from the plate, through the lower half of the transformer secondary to the center tap, through coil L3 and capacitor C5 to the cathode. Resistors R4 and R3 provide dc return paths for D1 and D2.

Coil L3, therefore, is common to both diode circuits, as is the voltage drop E3 across it. Thus, voltages E1 and E3 operate diode D1 and voltages E2 and E3 operate diode D2. These operating voltages are shown as ED1 and ED2 in the diagram. The rectified signals produce voltage drops across resistors R3 and R4 with the polarities shown.

When the voltage drops across the diode load resistors are equal in value, the net output voltage between points A and B is zero. As in the balanced slope detector, this occurs when the i-f resting frequency is fed to the discriminator input.

We can understand how the Foster-Seeley discriminator demodulates the FM signal by studying the vector diagrams in Fig. 19 for each of the three operating conditions. The diagram in Fig. 19A shows the phase relationships between the circuit voltages and currents when the incoming signal is at the resting frequency (at resonance), Fig. 19B when the incoming signal is below the resting frequency, and Fig. 19C when the incoming signal is above the resting frequency. Let us take up each condition.

Incoming Signal at Resonant Frequency. As we said before, resonant circuits C1-L1 and C2-L2 in Fig. 18 are tuned to the i-f resting frequency. When this frequency is fed to the discriminator input, the circuit is said to be at resonance, and the various circuit voltages will have the phases shown in Fig. 19A.

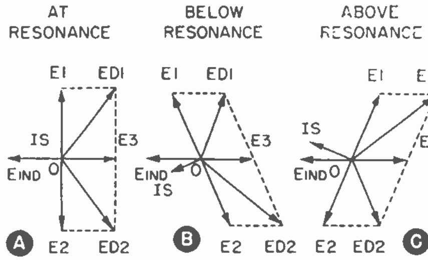


FIG. 19. Vector diagram for Foster-Seeley discriminator.

Voltage E3 across coil L3 is the same as the input voltage, so E3 is in phase with EP. The voltage induced in the secondary winding (Eind) will be 180 degrees out of phase with the voltage E3 because of the transformer action. These phase relationships are shown in Fig. 19A. We can use them as the reference vectors because their values and phases will not change regardless of the amount of frequency deviation.

Now that we have established our

reference vectors, let us study the phase relationships between the other circuit voltages and currents. At resonance, a series resonant circuit acts like a resistance. (L2-C2 is a series resonant circuit because the voltage is induced in the coil.) The voltage and current in a purely resistive circuit always have the same phase. This is shown in Fig. 19A where the secondary current IS is in phase with the induced voltage Eind.

The center-tapped secondary winding operates the diodes in push-pull. The voltage drops, E1 and E2, across the individual sections from the center tap to either outside transformer terminal are equal in amplitude and 180 degrees out of phase with each other, and 90 degrees out of phase with the induced current. Voltage E1 lags the induced current IS by 90 degrees, and voltage E2 leads the induced current by 90 degrees. These phase relationships between E1, E2, and IS remain the same regardless of the frequency deviation.

Voltages E1 and E3 operate the upper diode D1, while voltages E2 and E3 operate the lower diode D2. We can find the voltages that operate each of the diodes by getting the vector sum of voltages E1-E3 and E2-E3. These are shown as the vectors ED1 and ED2. The vectors ED1 and ED2 are equal in length. This indicates that the voltages on the two diodes are equal, and the voltage drops across the diode load resistors R3 and R4 are equal in value but opposite in polarity. The output voltage between points A and B at resonance, therefore, will be zero.

Incoming Signal Below Resonant Frequency. When the incoming FM signal deviates below the resonant frequency of the discriminator, the series resonant circuit L2-C2 becomes capacitive. The induced current and induced voltage are no longer in phase, as shown in Fig. 19B. The induced current IS will lead the induced voltage Eind a certain amount, depending on the amount of frequency deviation.

We said previously that the amplitude and phase relationships between E1, E2, and IS always remain the same. Thus, when the phase of current IS changes, the phases of voltages E1 and E2 also change, and the vector sums of E1-E3 and E2-E3 are no longer equal. Since vector ED2 is longer than ED1, you know that the voltage applied to diode D2 is higher than that applied to diode D1, which will produce unequal voltage drops across resistors R3 and R4. The *difference* between the voltage drops across the resistors will appear between points A and B. In this case, the output voltage will be negative because the voltage across R4 is greater than that across R3.

Incoming Signal Above Resonant Frequency. The vector diagram in Fig. 19C shows the phase relationships between the circuit voltages and currents when the incoming signal is above the resonant frequency of the series circuit L2-C2. The circuit impedance is now largely inductive, so the induced current lags the induced voltage. Again the phase difference between IS and Eind will depend on the amount of frequency deviation from the resting frequency.

The vector sum of voltages E1 and E3 is greater than the sum of voltages E2 and E3 (ED1 is longer than ED2). Therefore, diode D1 conducts more than diode D2, and the positive voltage drop across R3 is greater than the negative voltage drop across R4. The net voltage between A and B, then, will be positive.

In summary, as the FM signal frequency deviates above and below the resting frequency, the vector sums of the voltages applied to the diodes (voltages ED1 and ED2) will vary accordingly. Since the amplitude of the audio modulating signal determines the *amount of deviation* and the frequency of the audio signal determines the *rate of change* of the FM deviation, the difference in the voltage drops across the two diode load resistors will be the audio signal varying in frequency and amplitude with the original audio signal.

The output of the discriminator is coupled through a de-emphasis network, resistor R1 and capacitor C8, which de-accents the high-frequency components of the audio signal the proper amount to compensate exactly for the pre-emphasis of the highs with respect to the lows at the transmitter.

In addition to the audio information at the output of the discriminator, there is a dc component of the voltage developed between points A and B which keeps the resonant frequency of the discriminator tuned circuit and the center frequency of the incoming FM signal in the proper relationship to each other. Any change in the frequency relationship between the center and resonant frequencies of the discriminator circuit causes the dc component of the output voltage to change. This dc component can be used to control afc action in the FM receiver.

Other methods can and have been used in the FM discriminator like that in Fig. 18 to get the proper phase relationships between the various voltages. Basically, however, all the circuits operate in the same way.

Now let us look at the discriminator from a servicing viewpoint. Suppose the output sound is distorted. The first thing you would check is the i-f alignment. You will study alignment in a later lesson. Next, check the emission of each section of the duo-diode tube. Low emission in one diode section can cause distortion, but this is unlikely to happen because both sections are contained in the same tube envelope. Low emission in both sections will cause poor sensitivity (low output) rather than distortion.

A defect in the limiter stage will allow the interference and noise signals to come through. Since the Foster-Seeley discriminator, like the Travis discriminator, is as sensitive to amplitude variations as it is to frequency variations, the noise will be demodulated and will appear in the output.

FM Demodulators Not Requiring Limiters

Some types of demodulators act as limiters as well as detectors and therefore do not require a separate limiter stage. Let us study them now.

THE RATIO DETECTOR

The ratio detector is perhaps the most common type of FM demodulator used in FM and TV sets today. It not only acts as an effective demodulator but also as a limiter, thus permitting the last i-f stage to operate as a high-gain amplifier stage instead of a low-gain limiter stage. The ratio detector also has a lower noise level than a discriminator when no signal is being received and is more sensitive to weak signals because of its self-limiting abilities. Some receiver manufacturers use a limiter ahead of the ratio detector to get even better noise-free reception.

In appearance, the ratio detector circuit in Fig. 20 is similar to the conventional discriminator, except that the diodes are connected in series instead of in parallel. This is one way that you can tell from a schematic diagram whether the FM detector is a discriminator or a ratio detector. Other differences are in the RC stabilizing circuit (resistors R1, R2, and capacitor C3) at the output, and the point at which the audio signal is taken off. Notice that the audio signal is taken off between capacitor C1 and C2 rather than between points A and B.

The primary and secondary tuned circuits are resonant at the i-f resting frequency, and the input circuit and voltages E1, E2, and E3 have the same relationships with respect to each other as in the conventional discriminator. The diodes are excited in the same way by the E1 and E3 voltages applied to the top diode, and E2 and E3 voltages to the lower diode. Therefore, the vector diagrams in Fig. 19 hold for the three operating conditions in the ratio detector the same as in the discriminator.

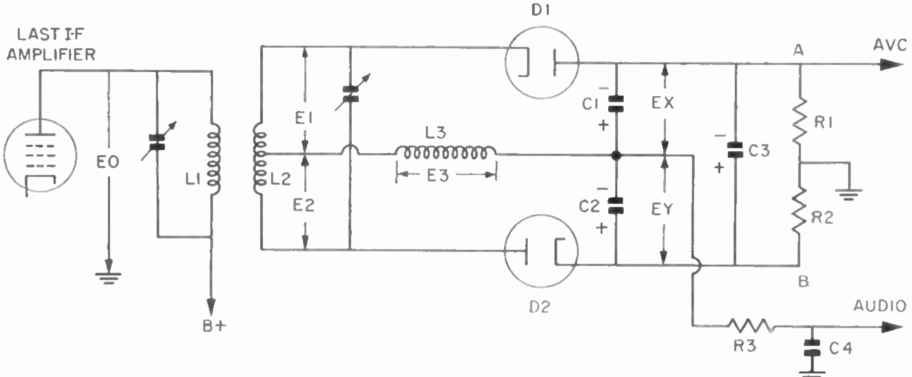


FIG. 20. Ratio-detector

Since the diodes are connected in series aiding, direct current will flow in only one direction through the circuit. Beginning at the plate of diode D1, the dc path through the circuit is through resistors R1 and R2 to the cathode of diode D2, and from the plate of D2 through the transformer secondary winding to the cathode of D1. The polarity of point A, therefore, is always negative with respect to point B.

The ac path for D1 is from the plate, through capacitor C1, through coil L3 and the upper half of coil L2 to the cathode. Similarly, the ac path for diode D2 is from the plate, through the lower half of L2, through coil L3 and capacitor C2 to the cathode.

The ac flow through the capacitors produces voltage Ex across capacitor C1 and voltage Ey across capacitor C2 with the polarities shown in the diagram. Since the voltages are in series aiding, the ac voltage measured between points A and B will always be the *sum* of voltages Ex and Ey. Remember that the voltage measured across the output of the discriminator was the *difference* between the voltage drops across the diode load resistors.

Now, let us find out the purpose of the electrolytic capacitor C3. Resistors R1 and R2 plus capacitor C3 form an RC stabilizing circuit across the detector output. The values of R1, R2, and C3 are chosen to provide a long time constant at frequencies above the lowest audio frequency to be reproduced. The current flow through the circuit will charge capacitor C3 to the average level of the incoming signal. Any undesired amplitude variations or impulse noise above this average value will have no effect on the audio output because the voltage on capacitor C3 cannot change fast enough to follow the voltage variation. Thus, the circuit acts as its own limiter.

When the i-f signal fed to the ratio detector input is at the resting frequency, capacitors C1 and C2 will be charged to the same value so that voltage Ex is equal to Ey. If the average voltage between points A and B is 10 volts, the voltage across each of the capacitors C1 and C2 will be 5 volts.

When the incoming signal deviates above the resting frequency, the circuit reactance will change so that the top diode will conduct more than the bottom diode. Therefore, there will be a greater voltage drop across C1 than across C2—Ex will be greater than Ey. The voltage at the audio take-off point between capacitors C1 and C2 will be positive. This voltage, however, instead of being the difference between Ex and Ey as in the discriminator, will be the *ratio* between them. In other words, if voltage Ex is 8 volts and voltage Ey is 2 volts, the positive voltage at the audio take-off point will be 4 volts $(8 \div 2 = 4)$.

Likewise, when the incoming signal deviates below the resting frequency, diode D2 will conduct more than D1, and a negative voltage will appear at the audio take-off point. This time voltage Ey will be greater than Ex, and the voltage at the audio take-off point again will be the ratio of the two voltage drops. Voltage ratios containing the positive and negative alternations of the audio signal are fed through the de-emphasis network, R3 and C4, to the audio amplifier.

The foregoing explanation shows one of the disadvantages of the ratio detector over the discriminator. Because the audio output voltage is the ratio of the two voltage drops rather than the difference between them, the audio voltage at the output of the ratio detector is less than that of a discriminator. The chief advantage of the ratio detector is that a limiter stage is not needed to eliminate the noise and interference signals.

The R-C time constant of the R1-R2-C3 output circuit holds the voltage between points A and B constant at the average level of the incoming signal. If the carrier level of the incoming signal decreases, the voltage between points A and B will decrease accordingly. Of course, the carriers of different FM stations, either local or distant, do not have the same strength. The RC stabilizing circuit, therefore, will automatically adjust to the average level of the incoming signal.

If the electrolytic capacitor becomes open, limiting action will not occur, and the noise on the incoming signal will be reproduced in the output. This is a point to look for when servicing a receiver using a ratio detector with the complaint of noisy reception.

Since the voltage between points A and B varies only with the carrier level of the incoming signal and point A is negative with respect to point B, the voltage at point A can be used for avc purposes. When a strong signal is received, the higher avc voltage from point A places a higher negative bias on the grids of the i-f stages. This, of course, lowers their gain and prevents them from being overloaded.

As with the discriminator circuits, there are many variations in the design of ratio detector circuits. However, all of them operate in essentially the same way as that in Fig. 20.

THE GATED-BEAM DEMODULATOR

The gated-beam tube and its associated circuit can also be used as an FM demodulator, serving as both a limiter and an FM detector. Its operating principle is different from the circuits we have discussed previously.

A diagram of the electrodes of the gated-beam tube is shown in Fig. 21. In addition to the cathode and the plate, there are two electrodes called the "signal" or "limiter" grid and the "quadrature" grid that control the electron flow between the cathode and the plate. Notice also that there are various shields surrounding the electrodes. The accelerator is operated at a positive potential, and the shields surrounding the plate, the

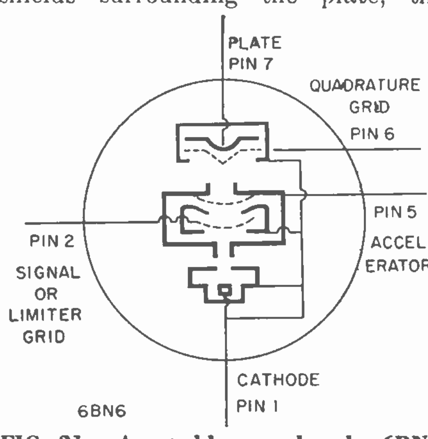


FIG. 21. A gated-beam tube, the 6BN6.

quadrature grid, the signal grid, and the cathode are operated at cathode potential.

Now let us see the effects of the control electrodes on the electron flow between the cathode and the plate. The electrons from the cathode must flow through the openings in the accelerator and past the signal and quadrature grids to reach the plate. The positive potential on the accelerator electrode attracts the electrons away from the cathode, and the first opening in the accelerator concentrates the electrons into a narrow, vertical beam.

Fig. 22 shows the circuit in which this tube is used.

The bias on the signal and quadrature grids is adjusted by potentiometer R3 so that a very small signal voltage will drive either grid between cut-off and plate current saturation. Thus, if the signal grid is more than a few volts negative, the beam will not pass through the accelerator, but will be reflected back to the accelerator itself. On the other hand, if the signal grid bias is somewhere between plate current cut-off and plate current saturation, the electrons will pass through the first and second accelerator openings and pass on toward the quadrature grid.

The quadrature grid can also cut off the electron flow to the plate when it is driven a few volts negative. Again the electrons will be forced to return to the accelerator. Therefore, each grid can be considered as a gate to control the flow of electrons between the cathode and the plate, because only a small voltage change on either grid can change the plate current from cut-off to saturation.

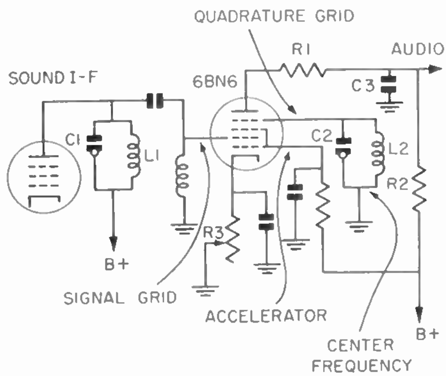


FIG. 22. The gated-beam FM detector.

When the gated-beam tube is connected as a demodulator, as shown in Fig. 22, it acts as both a limiter and a detector. Since only a very small signal voltage variation, usually about 1.25 volts, is needed to drive the tube between cut-off and saturation, amplitude variations on the positive and negative peaks of the incoming signal will be removed. A constant amplitude signal appears at the output.

Now let us see how the FM signal is demodulated in the gated-beam de-

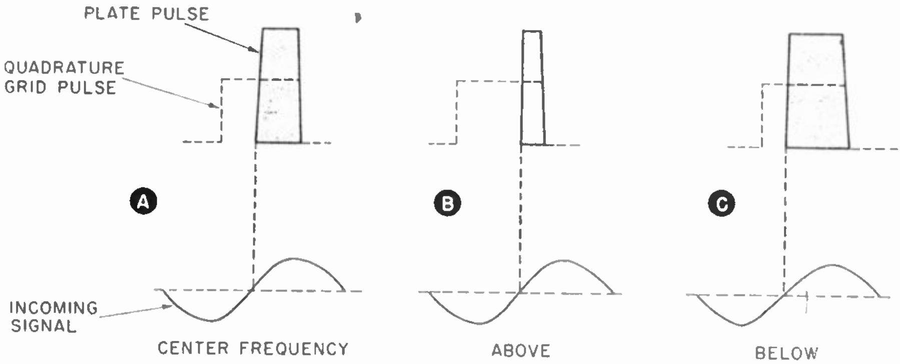


FIG. 23. Phase relationship between the incoming signal and the square-wave pulse on the quadrature grid of the gated-beam tube when the input signal is at the resting frequency (A); above the resting frequency (B); below the resting frequency (C).

tector. The resonant circuit L1-C1 in the signal grid is tuned to the center frequency of the incoming i-f signal. The sharp cut-off characteristics of the signal grid cause the plate current of the tube to vary from cut-off to full current and back once each rf cycle. The plate current then is in the form of pulses. These current pulses passing through the tube shock-excite the circuit L2-C2. This circuit is also tuned to the center frequency of the i-f signal. Because of the method of exciting this circuit, the voltage across capacitor C2 is 90 degrees out of phase with the current passing through the tube. The voltage in this tuned circuit lags the current in the tube and hence the voltage on the signal grid. It is because of this 90-degree phase difference between the voltage signals on the two grids that the second grid is called a quadrature grid. The quadrature grid also has a very sharp cut-off characteristic.

Both the signal grid and the quadrature grid are capable of swinging the tube between cut-off and saturation on each rf cycle. Therefore, no current can pass from the cathode to the plate of this tube unless both the signal and the quadrature grids are positive at the same time.

The waveforms in Fig. 23A show the phase relationships between the incoming signal and the square-wave pulse on the quadrature grid (shown in dashed lines) when the input signal is at the resting frequency. Notice that the quadrature grid pulse lags the incoming signal by 90 degrees. This means that the signal on the quadrature grid goes through a part of its positive alternation during the interval that the current pulse is arriving from the signal grid and the accelerator. Therefore, it is possible to get a current flow to the plate during only half of each positive cycle of the incoming signal, shown by the shaded area in Fig. 23A. The bursts of electrons flowing to the plate cause a specific average plate current flow in the output circuit of the gated-beam tube.

When the FM signal deviates

above the center frequency, the quadrature resonant circuit becomes reactive, and the signal in the quadrature grid lags the input signal by less than 90 degrees, as shown in Fig. 23B. Plate current will flow for less than half of the quadrature square-wave pulse. The higher the signal deviates above the center frequency, the less the plate current flow in the output circuit.

When the FM signal deviates below the center frequency as in Fig. 23C, the phase difference between the signals on the signal and quadrature grids is more than 90 degrees, and plate current will flow for more than half the square-wave pulse.

Let us see how the audio signal is produced in the plate circuit. The plate current pulses across the plate load resistor R2 charge capacitor C3 to the average of the pulse peaks, and the average voltage varies according to the frequency deviations in the incoming signal. The average of the plate current pulses at the resonant frequency is used as the zero audio signal. Deviations above the center frequency produce shorter plate current pulses, and therefore, the voltage at the output is less than at the center frequency. This produces the negative alternation of the original audio signal. The FM deviation below the center frequency produces a longer plate current pulse. This develops the positive voltage alteration of the audio information.

Capacitor C3 in the output circuit also serves as the rf filter capacitor, and this capacitor together with resistor R1 provides proper de-emphasis.

SUMMARY

The Foster-Seeley discriminator, the ratio detector, and the gated-beam demodulator are the three most common FM detectors used in FM and TV receivers today. There are other types of FM demodulator circuits that have been used and developed by the various receiver manufacturers. Examples of these are the locked-oscillator demodulator used in some of the older Philco receivers and the Fremodyne demodulator. The locked-oscillator demodulator uses the frequency deviations in the incoming FM signal to produce variations in the frequency of an oscillator circuit. Some of its operations are similar to the gated-beam detector discussed in this lesson. The Fremodyne is a type of super-regenerative demodulator. The signal circuits are detuned slightly in receivers using this detector in such a way that the frequency distortions are converted to amplitude variations.

Demodulators of these types have not been used much in either FM or TV receivers, but you may find them used in some of the sets you service. If you do service a receiver using an FM demodulator other than those discussed in this lesson, get the manufacturer's service information on the set and follow the instructions in the service sheet.

Lesson Questions

Be sure to number your Answer Sheet 34B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. What is the basic difference between a frequency-modulated signal and an amplitude-modulated signal? AM the amplitude of the RF carrier signal varies according to the amplitude of the audio signal & FM the frequency is varied according to the amplitude of the signal

2. What are the limits of the frequency range used by FM broadcast stations?
200 KC.

3. Which type of noise, tube noises in the transmitter or atmospheric noises, is removed from an FM signal by the limiter?
atmospheric noises.

4. What effect will an increase in the plate and screen voltages on the limiter stage in Fig. 7 have on the sound from the loudspeaker?
Noise signals from motors, ignitions etc will be heard in the output.

5. What is the purpose of the FM demodulator in an FM receiver?
convert frequency deviations in the signal back to the original audio wave

6. Why must a limiter stage be used with a Foster-Seeley discriminator?
because it is as sensitive to amplitude changes in the incoming signal as it is to frequency changes

7. In aligning a Foster-Seeley discriminator what frequency would be used in aligning the C1-L1 and C2-L2 resonant circuits?
10.7 mc

8. How does the output voltage between points A and B in Fig. 18 differ from that between points A and B in Fig. 20? In Fig. 18 the voltage measured across the output was the difference & Fig 20 are always the sum across the diode load resistors.

9. Suppose you are servicing a receiver using a ratio detector like that in Fig. 20, and the complaint is noisy reception. Which part would you suspect is defective and what is wrong with it? electrolytic capacitor open causing the limiting action to cease

10. Why is it possible to use the dc voltage at the output of the ratio detector for avc purposes? because the voltage varies only with the carrier level

SHALL I CHANGE JOBS?

Before you can answer this question, you must set your goal in life. With a goal in mind, apply these three questions to your present job: 1. Does it give reasonable pay for the present? 2. Does it give knowledge, training or experience which will be worth money to you in the future? 3. Does it give you prestige, or bring you in touch with men who can help you to attain your goal?

Judge each new job opportunity also by these three questions. Hold each job only long enough to learn what is needed for the next job. Then, if a vacancy up ahead is unlikely, you are justified in changing to a corresponding job somewhere else.

The important thing is to keep going ahead. Learn something every day. When you reach the point where you are no longer learning, no longer progressing ahead, then you are already moving backward, and it's time for you to change jobs.

First, though, be sure you really are prepared for a better job. Be sure your training is complete, and be sure you are able to apply it.

J.E. Smith

MAGNETIC TAPE AND WIRE RECORDERS

35B

RADIO—TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL

NATIONAL RADIO INSTITUTE

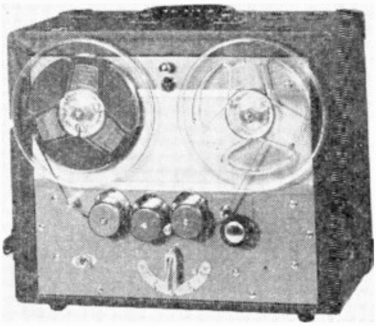
WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE No. 35

For each study step, read the assigned pages first at your usual speed. Reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind, then answer the Lesson Questions for that step. Study each other step in this same way.

JDL4M558 1958 Edition Printed in U.S.A.



MAGNETIC TAPE AND WIRE RECORDERS

RECENTLY, inexpensive and even semi-professional tape recorders have become very popular in the home, office, and shop. Tape recorders can be useful as well as entertaining. Many professional men and business men find them indispensable in their work.

A good tape recorder is also a part of many high-fidelity installations. It can be used to tape special programs or recordings, family concerts, recitations, etc. These can then be played back on the high-fidelity system. Prerecorded high-fidelity tapes can also be purchased and played through the system.

Many of the tape recorders now on the market are very versatile. Some have inputs for taping directly from a microphone or from the output of a tuner; others can be used as public address amplifiers. These recorders have an external speaker jack for attaching a remote speaker on playback position. The taped information can be interrupted at any time and a microphone can be switched in to make special announcements. Such an arrangement is ideal for talks in small halls and auditoriums not equipped with public-address systems.

Tape recorders come in various shapes and sizes from the very small battery-operated portables to the elaborate recorders used for transcribing high-fidelity tapes. Small stenographic tape recorders are also available as well as small, almost pocket-size wire recorders.

Most of this lesson will be devoted to tape recorders because they are now more popular than wire recorders. The wire recorder has many disadvantages. Some of its main drawbacks are that the wire will break easily when kinked, it is difficult to edit, and its frequency response is poor compared to the tape recorder. To edit tape, all you have to do is cut out the section you don't want with a pair of scissors, and connect the two free ends together with cellophane tape. When wire is edited, a square knot must be used to tie the ends of the wire together.

Another disadvantage is that when the magnetized wires are wound on the spool, magnetism will be induced in the surrounding wires, producing noise and echoes in the reproduced sound. This is not found in tape recordings because the magnetized areas are isolated from one another. However, you may have to service a wire recorder at some time, so we will give enough information so that you will know how they work.

In the following section of this lesson, you will learn how the audio frequency information is recorded on tape, how it is played back, and how all the information is removed so that the tape can be used again. Then, you will study the various types of tape-transport mechanisms—the mechanical section of the recorder.

As with all electronic devices, the recorder must contain an amplifier and a control system; you will study several types. Finally, you will find out how to adjust the electrical and mechanical sections of typical recorders, and how to trouble-shoot the mechanical failures that may occur in them.

The number of tape recorders in use has increased tremendously in the past several years, and you will undoubtedly be called on at some time to repair or adjust these units. Your service work need not be devoted exclusively to radio and television receiver repair, although most of your work will probably be in this line. If you know how to repair tape and wire recorders, you will be able to add to your income. This also applies to maintaining and repairing high-fidelity systems, record players, PA systems, and many other subjects that are taken up in your Radio-TV Servicing course.

How Magnetic Recordings Are Made

The three major operations performed by a tape recorder are to record, to play back, and to erase. We will discuss each of these operations in this section.

A block diagram of a typical tape recorder is shown in Fig. 1. Notice that a single head is used for both recording and playback operations.

Separate record and playback heads are found in some semi-professional and higher-priced recorders. The erase operation, which removes the magnetic information from the tape, is

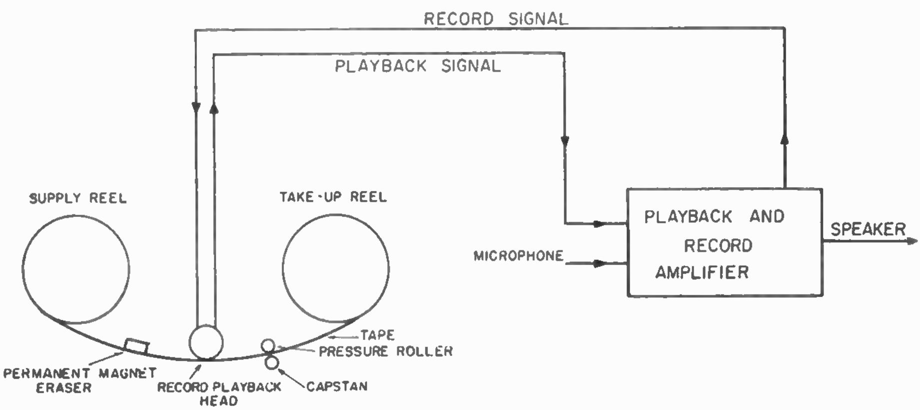


FIG. 1. Basic tape-recorder system.

performed by a permanent magnet in the recorder in Fig. 1. In higher priced recorders, a separate head, similar to the record-playback head, performs this operation.

Notice in the block diagram that the signal from a microphone is fed into the playback and record amplifier. When the recorder is in the record position, the signal at the output of the amplifier is fed into the record-playback head. During playback, the magnetic head feeds the signal that has been recorded on the tape to the input of the amplifier, and the sound is reproduced in the loudspeaker. Two cylindrical pieces called the capstan and the pressure roller pull the tape at a uniform speed past the record-playback head. More will be said about the mechanical operation of the recorder in a later section.

The magnetic tape used in the recorder is made of either plastic or paper. Most of the tapes today are plastic, because it is more durable. One side of the tape contains a coating of very fine particles of iron oxide. Each particle acts as a tiny magnet that can be easily magnetized and demagnetized when exposed to a magnetic field. The oxide coating on some magnetic tapes extends over the entire surface, as shown in Fig. 2A. This tape is called single track. Another magnetic tape, shown in Fig. 2B, contains two tracks, each of which can be recorded separately. A dual-track tape can be used to record twice as much information as a single-track tape. In the dual-track tape, the tracks are separated by a non-conducting area. The width of each tape is only one-quarter of an inch.

When information is recorded on the tape, the tape is not changed physically in any way. In disc recording, as you know, small grooves must be cut in the disc by the recording stylus, and the recorded information is obtained by passing a playback stylus through these grooves. In recording on tape, however, the iron oxide coating is magnetized in accordance with the varying magnetic field produced by the audio signal variations in the record head. In the playback process, the varying magnetism on the tape produces a varying voltage in the playback head, which is then fed to the amplifier system.

Let us see how the tape is magnetized by the record head.

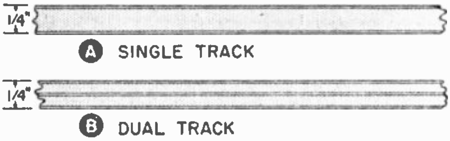


FIG. 2. Recording tape may have one track or two as shown above.

MAGNETIZING THE TAPE

A diagram of a record-playback head used in tape recorders is shown in Fig. 3. The audio signal is fed into a coil of wire that is wound around a ring. The ring is made of a metal that can be easily magnetized and demagnetized. When the audio signal passes through the coil of wire, it produces a varying magnetic field between the pole pieces. As the tape passes the pole pieces, the magnetic flux produced by the current flow through the coil magnetizes the oxide coating on the tape.

A very strong magnetic field is produced between the pole pieces because of the small spacing between them. The iron oxide coating on the tape offers a low reluctance path for the magnetic field to flow from one pole to the other. (Reluctance is the overall opposition offered by a material to magnetic flux lines.) The iron oxide offers less opposition to the magnetic flux than air does. The direction in which the coating is magnetized, of course, depends on the direction of the flow of the magnetic lines produced by the varying audio current flow through the coil of wire in the record head; the amount that the tape coating is magnetized depends on the density of the flux lines. The stronger the magnetic field, the more magnetized the tape coating becomes as it passes the pole pieces.

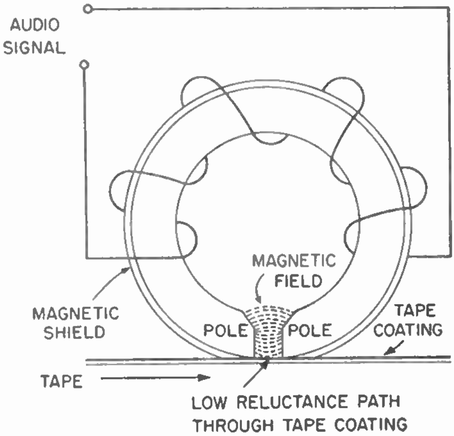


FIG. 3. Record-playback head.

Fig. 4 shows how the magnetic field magnetizes the oxide coating. The arrows indicate the directions in which the various small magnetic areas on the oxide coating are polarized. In Fig. 4A, the arrows are pointing in all directions; we can say that the tape is completely demagnetized. The magnetic tape must be demagnetized in this way before it passes in front of the recording head; otherwise, the sound produced by the loudspeaker will be noisy.

If the signal applied to the recording head is weak, a few of the magnetic areas in the oxide coating will be lined up in the direction of the applied field, as in Fig. 4B. When a stronger field is applied, more of the magnetic areas will be lined up, as shown by the arrows in Fig. 4C. A strip of tape completely saturated by an intense erase field is shown in Fig. 4D. The way in which the tape is erased will be explained in more detail in a later section.

Of course, the magnetic areas on the tape are much smaller than the arrows used in Fig. 4 to indicate the direction of magnetization. However, the important thing to note is that each small area acts as a tiny magnet having a north and a south pole. When a magnetic tape passes through the changing magnetic field between pole pieces, the tiny magnets in the iron-oxide coating align themselves in accordance with the direction and strength of the magnetic field. As the field varies at an audio rate, the audio information is transcribed on the tape. Later, the same tape can be passed in front of the playback head, and the small magnetic fields produced by the magnetized areas on the tape will induce a voltage in the playback head. In this way, we can get the audio information out again.

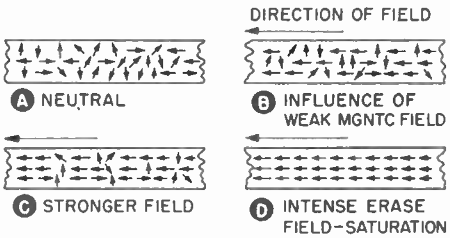


FIG. 4. How oxide coating on tape is magnetized by magnetic fields.

To understand how an audio signal can be recorded on tape, refer to Fig. 5. In this illustration, we are assuming that a sine wave signal is being applied to the record head.

When the sine wave shown in Fig. 5B is passing through zero at point 1, the record head for that moment is not magnetized, and there are no flux lines extending across the tape between the pole pieces, as shown in the first illustration of Fig. 5A. Thus, at that instant, the tape coating is not magnetized.

When the ac signal voltage applied to the record head swings positive to point 2, the core becomes magnetized and the lines of force flow from the south magnetic pole, through the tape, to the north magnetic pole. The tiny areas in the magnetic coating align themselves parallel with the flux lines between the pole pieces. The number of areas that are aligned depends on the strength of the magnetic field.

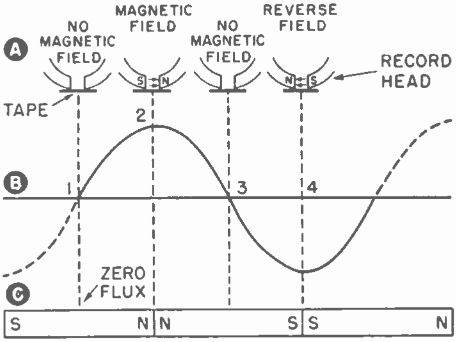


FIG. 5. Recording a sine-wave audio signal. A shows the effect on the magnetic field in the head; B shows the sine-wave signal; C shows the effect on the tape, which is like bar magnets placed end to end.

Thus, as the voltage between point 1 and point 2 in the sine wave rises higher and higher in the record coil, the magnetic lines between the pole pieces and through the tape become stronger. More of the magnetic areas are pulled into alignment with the magnetic lines, and magnetization of the tape becomes higher. Since the tape is moving past the pole pieces at a constant speed, the amount that the individual segments of the tape are magnetized depends on the strength of the flux lines at the particular moment the tape spans the gap.

After the magnetic field reaches the positive peak of the sine wave, it declines to zero at point 3, and begins the positive alternation. On the negative alternation, the flux lines reverse their direction of flow between the pole pieces of the record head. They pass through the tape in the opposite direction from those indicated on the positive alternation, and therefore align the magnetic areas on the tape in the opposite direction. The more negative the applied sine wave voltage, the stronger the magnetic field becomes.

The manner in which the tape is magnetized can also be represented as a group of bar magnets placed end-to-end, as shown in Fig. 5C. Each magnet represents the polarity of the magnetized areas on the tape. The two north poles represent the crest of the positive alternation, and the two south poles the crest of the negative alternation. The zero axis of the sine wave occurs at the mid-point of a bar magnet when there is zero flux.

AC BIASING

Tape recording is not just a simple matter of applying a varying magnetic field to the iron oxide coating on a piece of tape. The magnetization of the tape and the ease with which the areas can be magnetized is not linear with respect to the amplitude of the magnetizing force. The oxide coating on the tape, as with all magnetic materials, will resist a force tending to magnetize it. Also, if the coating is magnetized, it will oppose any demagnetizing force. This opposition to change in the magnetization is called hysteresis. You can easily see the opposition by studying the shape of the curve in Fig. 6.

The curve shows the amount of magnetism (magnetic flux) that will be induced in the oxide coating for different values of the applied magnetizing force between the recording head pole pieces. Beginning at the intersection of the horizontal and vertical lines, which we will call the origin,

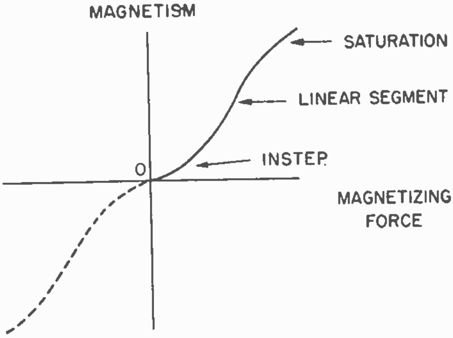


FIG. 6. Magnetization curve.

notice that the curve rises slowly to form what is called the "instep" of the magnetization curve. This shows that a large amount of magnetizing force is required for just a small increase in the magnetism (flux density) in the tape surface. In other words, the oxide coating opposes the magnetizing force over this part of the range.

Above the instep, the curve becomes linear; the tape surface becomes magnetized in direct proportion to the applied magnetic force. It is in this portion of the curve that the magnetic recording must be made. If the amplitude of the flux lines becomes too great, the tape coating will become saturated and, as shown by the curve, the response will again level off and become non-linear. If a tape is recorded so that a part of the signal extends down into the instep region or into the saturation region of the curve, the reproduced signal will be distorted. Therefore, a bias voltage or signal must be applied to the record head to raise the audio signal into the linear portion of the curve to prevent amplitude distortion. This is similar to biasing a vacuum tube on the linear portion of its transfer characteristic curve.

There are two methods that can be used to bias a record head. It can be biased by applying a high-frequency ac signal to the head along with the audio signal, or it can be biased by applying a constant dc voltage. DC bias, which was used in early tape recorders, magnetizes the tape at a specific constant level so that the ac signal is recorded on the linear portion of the magnetization curve. However, the constant magnetization results in a high noise level that is not present when the ac bias method is used. As a result, the ac bias system is now used almost universally.

The ac bias method uses a supersonic bias signal having a frequency somewhere between 30 kc and 150 kc. As shown in Fig. 7, the ac bias signal from an oscillator and the audio signal from the amplifier are both fed into the record head. Fig. 8 shows how the bias signal raises the magnetizing level of the audio signal into the

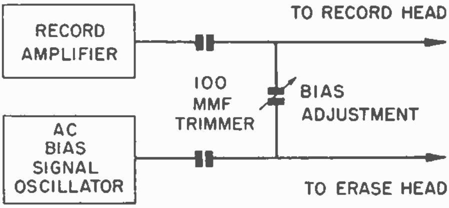


FIG. 7. AC bias method.

linear portion of the magnetization curve. Notice that the audio signal, in fact, modulates the bias signal.

The amount of bias required depends upon the characteristics of the tape and of the recorder. If the bias is too low, distortion and reduced signal output result. If the bias is too high, peaks of the audio signal will be recorded in the saturation region, again increasing distortion and reducing signal output. Inexpensive recorders use a fixed bias level that is set for a particular recording head and type of tape to be used with the recorder. In more expensive models, the bias level can be adjusted to compensate for variations in tape characteristics.

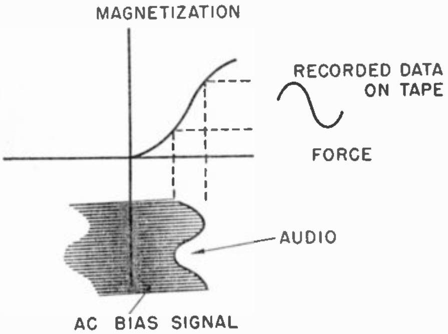


FIG. 8. How the bias signal raises the magnetization level of the audio signal to the linear part of the curve.

The bias component in the diagram in Fig. 7 is supplied through an adjustable trimmer capacitor so that the ac bias signal can be set to the proper level. Generally this amounts to setting the trimmer to obtain maximum output when a specific ac signal is applied to the input of the recorder.

The high-frequency bias signal has almost an erasure effect because with no audio signal applied, and just the ac bias signal, the tape is demagnetized almost completely as it leaves the recording head. This increases the signal-to-noise ratio. The bias signal must be a pure sine wave. If it is not, the unbalanced wave form will produce a dc component of magnetization which will cause a decrease in the signal-to-noise ratio.

The demagnetizing effect occurs because of the high frequency of the supersonic bias compared to the speed at which the tape travels between the two poles of the recording head. In the time required for a segment of the tape to pass from one pole to the second pole, the ac bias signal has passed through a number of complete cycles. As it does so, the magnetized areas on the tape return to their original random polarity positions. Notice also in Fig. 7 that the output of the bias oscillator can be fed to the erase head to completely demagnetize the tape. The primary function of the high-frequency signal, however, is to supply bias signal to the record head. How the signal is used for erase purposes will be discussed in more detail later in this lesson.

In the next section, we will find out what effect the width of the recording head gap and the tape speed have on the quality of the tape magnetization.

FREQUENCY RESPONSE

There are a number of factors that influence the frequency response of a record and playback tape system. Fig. 9 shows the response curves for two

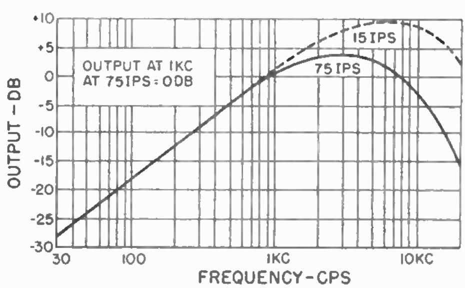


FIG. 9. Response of record-playback head.

standard tape speeds—15 inches per second, and 7.5 inches per second. Notice that the slower moving tape has a poorer high-frequency response than the fast tape.

Recording Process. One cause of high-frequency recording losses is demagnetization. As you saw in Fig. 5C, a sine-wave modulating signal on the tape can be considered to be a number of individual bar magnets, with each magnet representing a half wavelength of the frequency. With the tape moving at a constant speed past the record head, the higher the frequency of the modulating signal, the shorter the individual magnetic bars become. Thus, there is a shorter distance between the north and south pole of each magnetized segment on the tape. This causes a cancelling effect between the opposite poles, that reduces the actual magnetism induced in the tape. Thus, the higher the frequency, for a given input signal amplitude to the record head, the weaker the magnetic field induced in the tape.

When the tape speed is increased, the high-frequency signal components develop a larger magnetized area or bar, because in the time taken by one complete cycle, more tape has passed between the two poles. Thus, as shown in Fig. 9, the high-frequency response is better with a tape speed of 15 inches per second than with a tape speed of 7.5 inches per second. Of course, the higher the tape speed, the more tape required for a given recording time.

Most tape recorders have two or more individual speed settings. When a high-fidelity tape is to be made, the fastest tape speed should be used. For voice recordings and other recordings of limited frequency response, the slower tape speeds can be used and more information can be transcribed on a given tape. The speeds and durations for dual-track tapes of various lengths are given in Table I.

A second cause of high-frequency loss is bias erase. As mentioned previously, the bias signal erases itself as it leaves the recording field. It also has some erasure effect on any magnetic fields that have been induced in the tape, particularly the smaller wavelength fields of the high audio frequencies. Consequently, the highs are affected more than the lows.

The record head itself has a frequency-discriminating effect. The record amplifier and the recording head must be matched to obtain the proper frequency characteristic. Because the record head is largely inductive, its impedance, or opposition to ac current flow, increases with frequency. As a result, the coil current and the strength of the magnetic field between the pole pieces decreases at high frequencies. However, this effect is overcome with proper equalization in the record head and proper match between the plate circuit of the recording amplifier output stage and the recording head. With proper design, a nearly constant current can be made to flow through the head regardless of the frequency of the applied signal at the input of the recording amplifier.

Tape Length	Speed in Inches per Second			
	1⅞	3¾	7½	15
150′	30 min.	15 min.	7.5 min.	3¾ min.
600′	2 hr.	1 hr.	30 min.	15 min.
900′	3 hr.	1½ hr.	45 min.	22½ min.
1200′	4 hr.	2 hr.	1 hr.	30 min.
1800′	6 hr.	3 hr.	1½ hr.	45 min.

TABLE I. Running time for tapes of different lengths at different speeds.

Playback Process. In the recording process, a magnetic field is induced in the tape. In the playback operation, this magnetic field on the tape induces a signal voltage in the coil of the playback head. Thus, the playback process is the reverse of the record process. However, an understanding of the playback operation again depends upon a knowledge of the principles of magnetic induction. In the playback process, the voltage induced in a coil depends on the rate of change of the magnetic flux lines as the tape passes in front of the playback head. When we associate this principle with frequency, we can understand the frequency response characteristic of the playback process.

The speed of the tape as it passes between the poles of the playback head must be constant, regardless of the frequency of the induced audio signal. However, a high-frequency tone of a given amplitude occupies a shorter length of tape than a lower-frequency tone of the same amplitude. Thus, as the tape travels between the pole pieces, the change of flux lines at a high frequency is at a faster rate than at a low frequency.

The playback head is said to have a "constant velocity" characteristic. In other words, the voltage induced in the playback coil varies with the rate of change (or velocity) of the flux lines. Since the rate of flux change is greater at the higher frequencies, a greater voltage is induced in the playback coil per given flux density at a high frequency than at a low frequency. Thus, as shown in the curve of Fig. 9, the output is greater as the frequency becomes higher, until we reach a high-frequency range at which the over-all response begins to decline. This decline is due to the high-frequency losses in the record-playback head and at other points. To get a linear frequency response in a tape recorder system, there must be equalizing and frequency-compensating networks in the amplifier systems. These will be discussed in the following section.

Still another consideration in the playback head is the width of the gap between the pole pieces. The wider the gap, the poorer the high-frequency response. Therefore, the high frequencies are attenuated not only at the recording head, but also at the playback head.

You can see how the gap width and the flux density between the pole pieces influence the frequency response of the playback head by referring to Fig. 10. Notice in Fig. 10A and 10B that the difference in the flux density in the gap depends on the wavelength (frequency) of the signal on the tape, the lower-frequency signal having a greater wavelength occu-

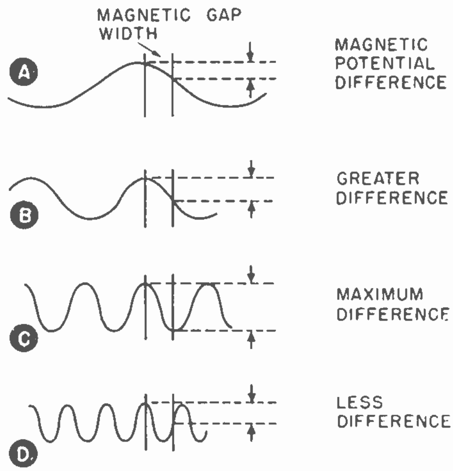


FIG. 10. Influence of frequency on magnetic potential. A shows the effect with a low-frequency having a long wavelength; B shows a somewhat higher frequency; C shows maximum magnetic potential when gap width equals ½-wavelength; D shows that a higher frequency decreases the difference again.

pies a greater length of tape than the higher frequency signal. Thus with a gap of a specific fixed width, the actual difference in flux density between the gap edges is always less for the longer wavelength (the lower frequency).

The magnetic gap width is always somewhat greater than the actual physical gap width because it is not possible to machine a gap with absolutely sharp edges. However, at the frequency where the magnetic gap is exactly one-half wavelength as in Fig. 10C, there is the greatest difference in flux density between the gap edges. Therefore, the response at this frequency is maximum. At a frequency higher than this limit, the response begins to decline again (Fig. 10D) because the actual flux density between gap edges begins to fall off.

Thus, the high-frequency limit depends on both the gap width and the tape speed. When the gap width is reduced, the frequency corresponding to a one-half wavelength dimension must be higher. If the width of the gap is made smaller, the difference in the flux density between the gap edges is less for the low frequency signal as it goes through its cycle, and the low-frequency response decreases accordingly. The gap width, therefore, must be a compromise to obtain an adequate response at both low and high frequencies. Generally, the gap for the combination record-playback head is 0.0005 inch or less. If a separate record head is used with ac bias, the gap of the record head can be nearly 0.001 inch wide.

Equalization. To obtain a flat response curve, circuits called equalizing circuits are used. The subject of equalization is very important in tape recorder systems. The curves of Fig. 9 indicate that to obtain a flat frequency response, we must increase the amplitudes of the frequencies at both the high and low ends of the audio range. So much correction is required that there are usually two equalizing circuits; the high frequencies are usually compensated for in the record amplifier, while the lows are boosted in the playback amplifier, as shown in Fig. 11.

As you have learned, the highs are attenuated by the demagnetizing effect of the bias signal, when they are recorded on the tape. Thus, we can obtain better results if we emphasize the higher frequencies before they are applied to the recording head. This step makes certain that the highs are emphasized above tape noise and hiss. Without pre-emphasis, the signal-to-noise ratio at the high audio frequencies would be poor.

The weak highs could be boosted in the playback amplifier, but tape noise and hiss would also be boosted and result in a much poorer signal-to-noise ratio than with high-frequency pre-emphasis.

Many tape recorders use a two-stage recording amplifier with high-frequency pre-emphasis circuits in both stages. In other recorders, the highs are also boosted a small amount in the playback amplifier.

Low-frequency boost is taken care of largely in the playback amplifier, and is referred to as post-emphasis

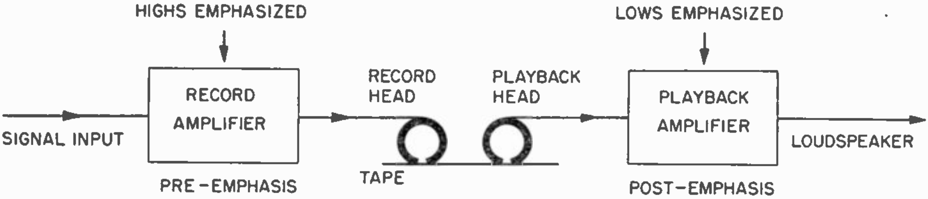


FIG. 11. Equalization method in a tape-recorder.

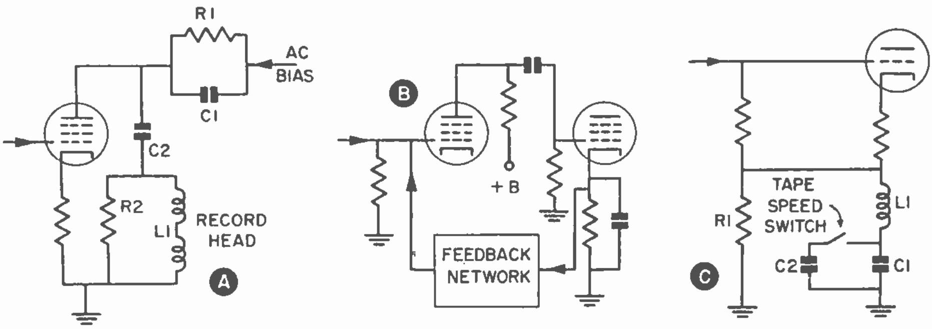


FIG. 12. Pre-emphasis compensation.

because it occurs after the audio information has been transcribed on the tape. The lows cannot be boosted in the recording amplifier, because the high energy content of the pre-emphasized lows in the record head will drive the magnetic induction into the distorted regions near saturation. If the recording level is reduced to prevent overdriving on lows, the highs will then be at such a low level that they will be obscured by tape noise and hiss. It is best, therefore, to boost the lows in the playback amplifiers.

The post-emphasis of lows presents a problem because of the sensitivity of the input of the playback amplifier to hum pick-up. Any hum that enters the playback amplifier is further emphasized by the bass boost system. For this reason, all hum fields from the motors and transformers used in the tape recorder must be properly shielded. The record and playback heads also are shielded, except for the small area around the gap.

To reduce hum pickup further, many tape recorders introduce a controlled amount of pre-emphasis of the "very lows" in the record amplifier. In this arrangement, the record pre-emphasis curve tapers off in the 60 to 120-cycle range to introduce stronger signal components of this frequency to the record heads. Signal amplitudes are not as great in this very low frequency range as they are in the peak energy range around 400 cycles. As a result the very low frequencies enter the playback amplifier at a higher level, and ride above the hum components. In addition, no emphasis or just a small amount of post-emphasis has to be introduced by the playback amplifier over this range. Hence, any hum components in the amplifier are not increased by the network.

Three typical record pre-emphasis circuits are shown in Fig. 12. In Fig. 12A, capacitor C2 is in series with the recording head across the output of the amplifier tube. Because the reactance of capacitor C2 decreases as the frequency increases, a high-frequency signal will produce a higher current flow in the coil of the recording head than a low-frequency one will. At low frequencies, the coil current is limited by the increasing reactance of capacitor C2.

A frequency-discriminating feedback amplifier can also be used to pre-emphasize the highs. In the feedback arrangement in Fig. 12B, the low and the middle ranges of frequencies are fed back to the input through the cathode feedback link. However, at high frequencies, the low reactance of the cathode capacitor provides an efficient high-frequency filter, and therefore there is no feedback. The high-frequency gain of the stage is maximum, and the highs are emphasized over the middle and low ranges.

Another method of getting a correctly shaped pre-emphasis curve is to use a series resonant circuit in the cathode of one of the pre-amplifier stages, as shown in Fig. 12C. At low frequencies, a degenerative voltage is developed across resistor R1, which feeds back an out-of-phase signal to the grid of the amplifier. At higher frequencies, coil L1 and capacitor C1 (or C1 and C2 in parallel) have an increasing shunting effect on resistor R1, which decreases the amount of feedback. At high frequencies, coil L1 and capacitor C1 place a very low-impedance shunt across resistor R1 and there is no feedback. Again full amplification is given to the highs; the gain decreases with lower and lower frequencies. Since the frequency response also depends on the tape speed, proper compensation is made by switching capacitors C1 and C2. The capacitors are connected in parallel at high tape speeds, but C1 is used alone, by opening the switch, at lower speeds.

Two typical post-emphasis circuits are shown in Fig. 13. In the circuit in Fig. 13A, the bass response is boosted by the series network consisting of capacitor C2 and resistors R2 and R3. The reactance of capacitor C2 is so high at low frequencies that the series network of C2 and R2 has no shunting effect, permitting the lows to pass unattenuated to the grid of the next stage. As the frequency increases, the shunting effect of the two components also increases. Thus, a higher and higher percentage of the high-frequency signal appears across resistor R3 instead of at the grid of the next stage. The taper of this

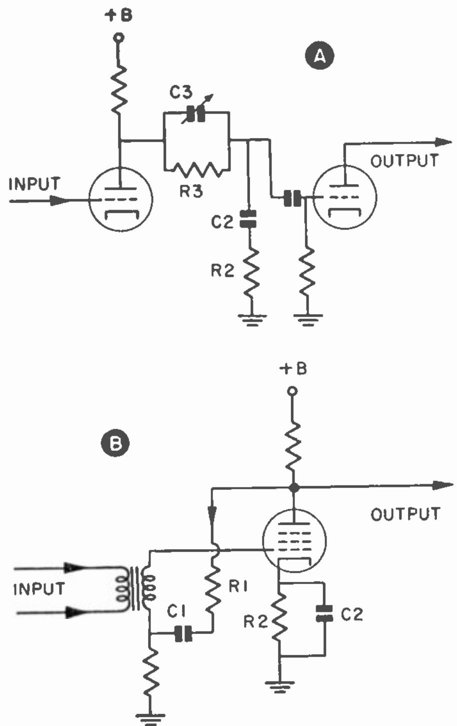


FIG. 13. Post-emphasis circuits.

response is the opposite of the constant velocity response of the playback head.

The resistor-capacitor network also provides some high-frequency peaking in the form of an adjustable treble control, capacitor C3. The reactance of this capacitor becomes low at very high frequencies and, therefore, shunts some of the highs around resistor R3 and directly to the grid of the next stage. This control is adjustable to correct for the very high-frequency losses in a tape recorder system.

The feedback arrangement of Fig. 13B can also be used in the playback amplifier to boost the low-frequency response. In this circuit the middle range of frequencies is fed back to the input circuit through resistor R1 and capacitor C1. There is no feedback of lows because of the rising reactance of capacitor C1. Again the parts values are chosen so that the gain of the amplifier stage decreases with increases in frequency to counterbalance the high-frequency boost of the playback head.

The values of resistor R2 and capacitor C2 in the cathode circuit can also be chosen to provide a small amount of boost at the very high frequencies. If the value of capacitor C2 is small, its low reactance at very high frequencies prevents cathode feedback and increases the high-frequency gain. Capacitor C2 can be made adjustable to obtain the proper amount of additional treble boost sometimes used in the playback amplifier system.

In lower-priced tape recorders, particularly those using the same head for record and playback, the same amplifier is used for both operations. In changing between record and playback, equalization networks and components are also switched in the amplifier stages. For the record position, a suitable pre-emphasis network must be inserted into the amplifier; for playback, a proper post-emphasis network must become a part of the reproducing amplifier system.

It is apparent that the tape recorder is a combination of mechanics, magnetism, and electronics. Each is important for good tape recording.

TAPE ERASURE

The function of the erase head in a tape recorder is to remove the magnetic information that has been transcribed on the tape so that the tape can be used again to record new information. The erase operation is usually done automatically during the recording process by passing the tape in front of the erase head. This demagnetizes the tape so that new information can be transcribed on it when it passes the record head.

One method of erasing the tape is to use a strong, high-frequency magnetic field. This high-frequency signal is usually the same as that used for ac bias purposes, except that the full output of the oscillator is applied to the erase head.

To erase the magnetic information from a tape, the erase signal fed to the erase head generates an intense magnetic field that alternately drives the oxide coating on the tape rapidly between the two saturation levels. This is shown by the hysteresis curve in Fig. 14. Hysteresis, as you learned earlier, is the property of a magnetized material to retain its magnetism and to oppose any change by an external force. If we apply a very strong magnetic field to a magnetic tape, the field will saturate the tape to the level shown at point A. Now, suppose we decrease the magnetic field to zero. The magnetism in the tape, because of hysteresis, will decrease to point B instead of the demagnetized point (where the vertical and horizontal lines cross). There, to completely demagnetize the tape and overcome the hysteresis, we must apply a signal that alternately drives the magnetic coating between two saturation levels of opposite polarity.

Because the ac bias signal has a very high frequency, the signal will

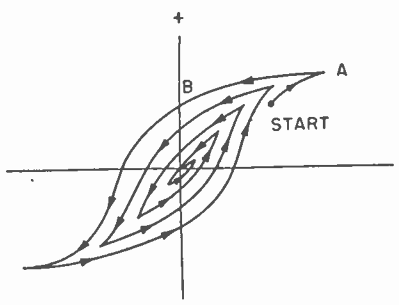


FIG. 14. Hysteresis path of erase field.

go through several complete cycles before any particular area on the tape has had time to pass completely by the gap in the erase head. Thus, as shown by the hysteresis curve, each small area on the tape is alternately magnetized first in one direction and then in the other. Then, as the tape moves away from the erase head, the alternating field decreases in intensity, as shown in the smaller loops on the diagram in Fig. 14. The magnetism finally decreases to zero. The tape is demagnetized, and the magnetic areas on the tape are again aligned in a random fashion as you saw in Fig. 4A. The tape can now be used to record new information.

The erase head generally has a much wider gap than the record and playback heads so that the tape is under the influence of the erase field for a longer time. A typical gap width is about .02 inch. For single-track tapes, the erase head gap must be made large enough to span and demagnetize the entire tape surface. For a dual-track recorder, the record and playback heads span only half the tape width. Thus, in the record and playback position, there is no interference between the two oxide-coated tracks on the tape. The erasure gap, too, must erase only the half of the tape on which new information is to be recorded. The width of the gap, however, is slightly more than the gap for the record and playback heads to make certain that there is complete erasure of each track.

Using DC for Erasure. DC can also be used to demagnetize tape, although it is not as satisfactory as ac. When a strong dc erase field is used, it applies a saturated magnetic field that aligns all the magnetic areas in a given direction, thereby erasing any audio information that was present on the tape. As the tape leaves the field of influence of this magnetic field, the magnetism in the tape declines toward zero from point A to point B in Fig. 14. However, an object cannot be demagnetized completely unless a demagnetizing field of opposite polarity is also applied. With a dc field, then, the tape is not completely demagnetized. Rather, it is uniformly magnetized at a specific level. Thus, when recording new information on the tape, some residual magnetism is present when the tape moves in position across the gap of the recording head. If the residual magnetism is high enough, it can cause any new information recorded on the tape to be distorted because the recording level will be near the saturation region instead of in the linear portion of the curve. Therefore, the dc erase method is not widely used.

Permanent - Magnet Erasure. Magnetic tape can also be erased by using several small permanent magnets. Although a single magnet will give reasonably satisfactory erasure, with two magnets, it is possible to approach the type of erasure obtained with an ac erasure signal.

In a typical arrangement, shown in Fig. 15, the tape first comes under the influence of a strong field from the south pole of a permanent magnet. This strong field saturates the tape, and thereby removes all of the sound information. A second magnet is placed almost at right angles to the first. As the tape travels between A and B, the flux lines from the first magnet decrease, and the tape be-

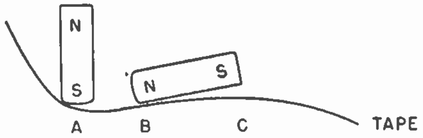


FIG. 15. Permanent magnet tape erasure.

comes almost completely demagnetized.

The north pole of the second magnet, at position B, functions as a reversing field, and therefore magnetizes the tape with the opposite polarity. The field at B is considerably weaker than the field at A and contributes just the required amount of reversed magnetic force. The small amount of magnetism remaining on the tape, now with an opposite polarity, comes under the influence of a still weaker but opposite polarity field from the south pole of the second magnet at point C. Thus, as the tape travels between B and C, it is demagnetized further toward the origin, finally declining near to the origin after coming under the influence of the reverse field at point C. The magnetism trails off toward zero as the tape leaves the influence of the south pole of the second magnet.

Bulk Erasure. It is also possible to erase using a 60-cycle ac field. This type of erasure, called a bulk erasure, can be used to demagnetize an entire tape in less than a minute. The usual bulk eraser plugs into the 110-volt ac line, and generates a very strong magnetic field. The entire tape is placed on the eraser, so that when power is applied, the strong magnetic field saturates the tape. Now, the tape is moved slowly and evenly away from the bulk eraser, this gradually reduces the intensity of the field and approximates the changing magnetic field necessary to follow the hysteresis curve down to the origin. When the tape has been moved away from the eraser the specified distance, the power is turned off.

A bulk eraser is useful in restoring used magnetic tapes to a completely demagnetized level, thereby improving signal-to-noise ratio and effectively removing any information which the regular erasure circuit of the recorder has not been able to remove. A bulk eraser of this type will be very useful to you if you do any amount of tape recorder servicing. The bulk eraser, however, should be used carefully so that you never demagnetize any of the tapes that the customer may be saving. Also place the bulk eraser far enough away from the tape recorder so that its magnetic fields will not affect any of the component parts of the recorder itself. It is a good idea to keep your watch away from the bulk eraser, too.

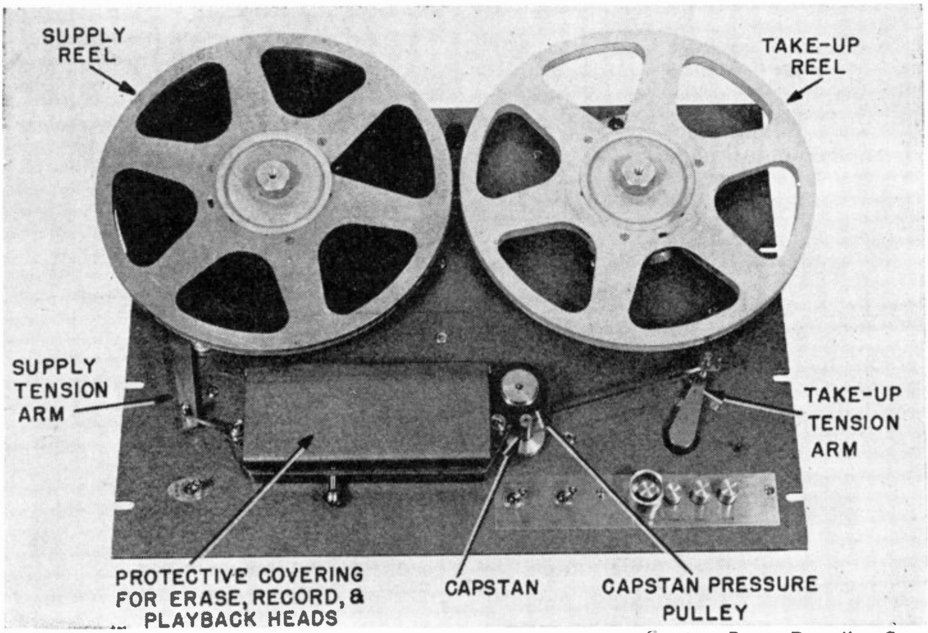
Tape-Transport Mechanisms

The mechanical section of the recorder is referred to as the tape-transport mechanism. It moves the tape at the proper speed in front of the record, playback, and erase heads. The transport mechanism consists of a driven supply reel, a take-up reel, and a capstan, all of which move the tape when driven by the proper motor arrangement. Separate motors can be used for each of the three driven axles. However, in a less expensive recorder, a single motor is used with a system of pulleys, belts, brakes, and shift plates to transfer power from a single motor to the various parts of the transport mechanism.

The mechanical parts of a tape recorder are shown in Fig. 16. Looking at the mechanism, you might at first assume that the tape can be moved in front of the various heads by connecting a motor to the spindle of the take-up reel. This is not satisfactory because the actual tape speed would increase as tape was wound up on the take-up reel. As the tape winds, the diameter of the roll of tape increases. Therefore, if the take-up spindle rotated at a constant speed, the speed of the tape would increase progressively as the tape piled up on the reel. Thus, a constant speed of rotation of the take-up spindle would cause a continuous change in the speed at which the tape passed the various tape recorder heads.

Suppose the supply reel were full, and the take-up reel were empty. If the supply reel rotated at the same speed as the take-up reel, tape slack would accumulate rapidly because the tape would run off the supply reel much faster than it could be taken up by the take-up reel. Once the take-up reel built up more tape than remained on the supply reel, the take-up reel would pull the tape from the supply reel at a faster rate than it could be released from the supply reel, and the tape would break.

It is apparent that if the tape is to be moved past the heads at a constant speed, there will have to be a mechanical system that will change the speed of the tape reels continuously as the tape divides between take-up and supply reels. A piece called a capstan, which is driven by the motor and is located between the two reels, supplies the pull that moves the tape at constant speed past the head. The capstan is rotated either by the drive shaft of a motor directly; or by a gear pulley, idler wheel, or flywheel arrangement. It can have a rubberized surface which will exert the necessary torque on the tape to pull it past the magnetic heads. A pressure wheel or



Courtesy Presto Recording Corp.

FIG. 16. Presto tape-transport mechanism.

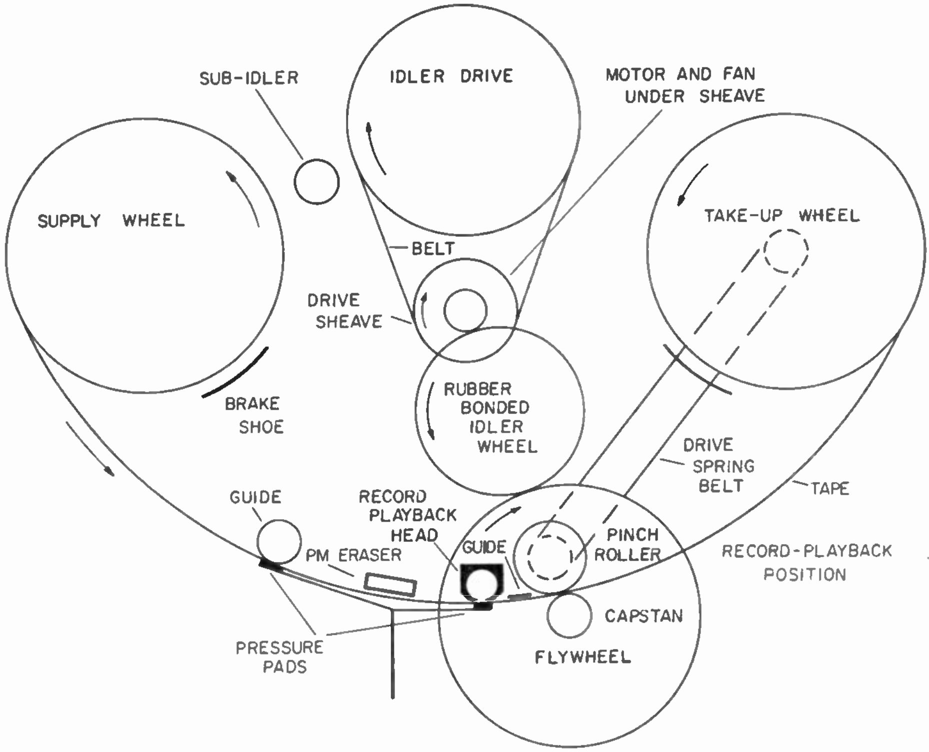


FIG. 17. Tape-transport mechanism in record position.

pad holds the tape against the capstan and minimizes the possibility of tape slippage or varying tape speeds.

Idler pulleys and posts guide the tape properly from the reels past the heads and onto the take-up reel. A slip clutch or automatic torque system is used to regulate the reel speeds. Pressure pads are used at various positions to make certain that the tape lies firmly against the magnetic heads.

In addition to moving at the regular forward rate from the supply to the take-up reels during record or playback operation, the tape can also be wound quickly on either reel. On the fast rewind or reverse setting of the tape recorder when the tape is rewound on the supply reel, the pressure roller is moved back away from the capstan. The pressure pads are also moved away from the tape. Thus, the tape can move freely and easily from one reel to the other. In this position, the motor operates the spindle of the supply reel and winds up the tape in a clockwise direction. A fast forward position is also possible. With this setting the capstan control is also disengaged and the take-up reel spindle exerts control of the tape to wind it up on the take-up reel in a counterclockwise direction.

SINGLE-MOTOR TAPE-TRANSPORT MECHANISM

You can see how a tape-transport mechanism works by studying the mechanism in Fig. 17. This is the type that is used in the Knight and Wilcox-Gay tape recorders. Notice that the mechanism uses only one motor for all the operations.

The mechanical operations are controlled by a row of pushbuttons, shown in Fig. 18. When a button is

FIG. 18. Push-button controls.

depressed, various levers, springs, shift plates, and engagements supply driving power to the proper mechanisms. To understand the various actions, let us consider each one.

Record. In the record position, shown in Fig. 17, a shift plate moves the erase magnet so that it touches the tape. Thus, since the tape passes the erase magnet before it reaches the record head, the tape is automatically erased just before the new information is recorded. Notice that two pressure pads hold the tape firmly against the left guide and against the record head. Likewise, the pinch roller presses the tape against the capstan.

The way in which the motor drives the capstan is illustrated in Fig. 19. The motor includes a cooling fan on one side of its shaft and the drive sheave on the other. The drive sheave has two segments of different diameters. The larger diameter segment drives a rubber-bonded idler wheel for the fast tape speed. When the tape recorder is set on slow speed, the idler wheel is moved, by means of a lever, into the next smaller diameter segment of the drive sheave, which rotates the idler wheel at lower speed. The direction of rotation for the various shafts and wheels is indicated by the curved arrows in Fig. 17.

In the record position, the idler wheel friction drives a large flywheel. The shaft of the large flywheel is the capstan of the tape recorder. As mentioned previously, it is the capstan that keeps the tape moving at constant speed.

The pinch roller also moves forward and holds the tape firmly against the capstan. The pinch roller rotates and is linked to the take-up reel with a spring-belt pulley arrangement. Of course, the torque of the take-up reel does not have as much pulling power on the tape as the capstan. It has just enough power to wind up the tape after the capstan pulls it through.

Stop. When the stop button is depressed, a number of things happen, as shown in Fig. 20. The erase head moves away from the tape, and the pressure pads release the tape from

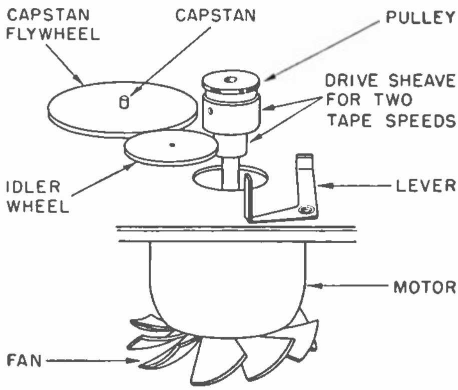


FIG. 19. Driving power for the capstan is transferred from the motor drive sheave to the capstan flywheel by means of an idler wheel.

the guides and the record playback head. In addition, the pinch roller moves away from the capstan, and the rubber idler wheel moves away from the drive sheave and flywheel. The motor itself continues to rotate along with the idler drive wheel, which is linked by a pulley to the motor. Whenever the stop button is engaged,

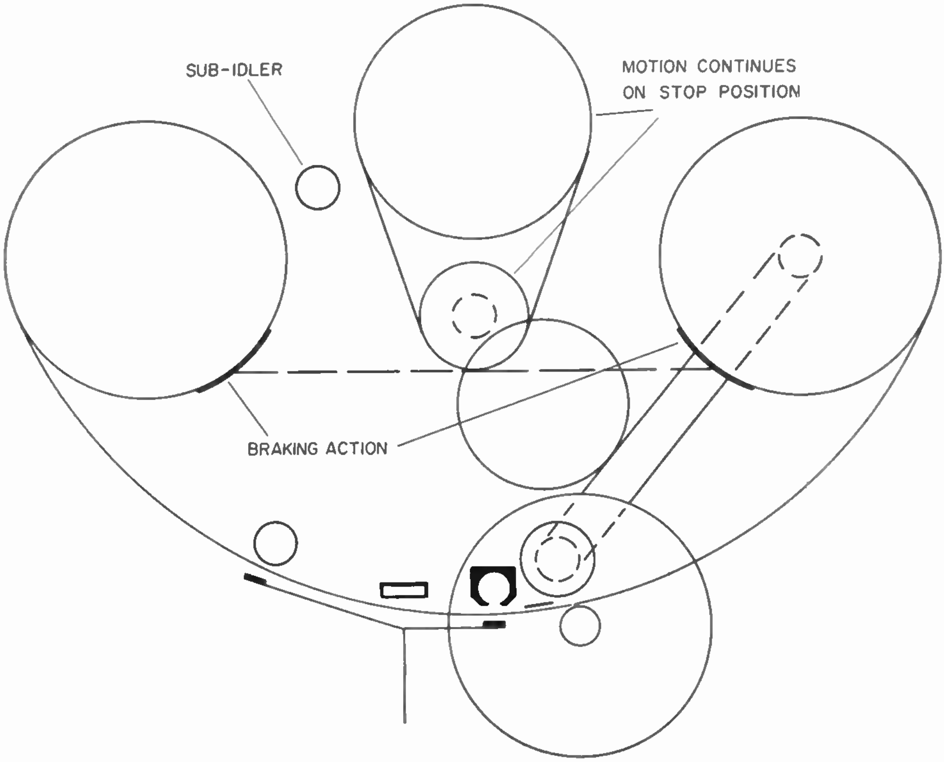


FIG. 20. Stop position of transport mechanism.

a lever moves two brakes against the supply reel and take-up reel drums. Thus, the tape motion is stopped quickly, preventing breakage or the accumulation of tape slack.

Playback. On playback position, the same motor activity occurs as shown in Fig. 17, with the capstan pulling the tape in the same direction and at the same speed from the supply to the take-up reels. In the playback position, however, the erase head remains separated from the tape, as shown in Fig. 21. The pressure pads hold the tape against the guide and against the playback head (record head and playback head are the same for this recorder).

Reverse. When the reverse button is depressed, it causes a shift plate to move the idler wheel against a sub-idler wheel, which in turn moves against the supply drum. The sub-idler wheel causes the reel to rotate in the proper direction. Thus, the tape is reeled up quickly from the take-up reel to the supply reel.

In this position, shown in Fig. 22, the brakes are released and the rubber-bonded idler wheel is moved

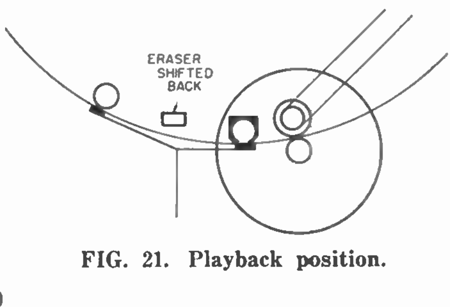


FIG. 21. Playback position.

away from the motor drive sheave and the capstan flywheel. Consequently, the capstan is not driven in the reverse operation. In reverse position, the pinch roller and capstan are also separated and the tape pressure pads are also released. The erase head, too, is moved away from the tape.

Forward. The fast forward operation is similar to the reverse operation, except that a shift plate moves the idler drive wheel in direct contact with the drum of the take-up reel. The take-up reel is now driven directly by the motor, and the tape is transferred quickly to the take-up reel. In this position, too, the capstan is not driven and the pinch roller and pressure pads release the tape to permit it to move rapidly and freely.

TWO- AND THREE-MOTOR MECHANISMS

An example of a more elaborate tape transport mechanism is the Presto unit that was shown in Fig. 16. As shown in Fig. 23, separate heads are used for erase, record, and playback. Individual motors are used to drive the capstan, take-up reel, and supply reel.

The capstan drive unit, illustrated in Fig. 24, is entirely self-contained and consists of a motor, motor pulley, and capstan shaft, which serves as the capstan. The capstan shaft, therefore, is belt-driven by the capstan motor.

The capstan motor is a hysteresis type with two sets of windings. The proper windings for the high or low

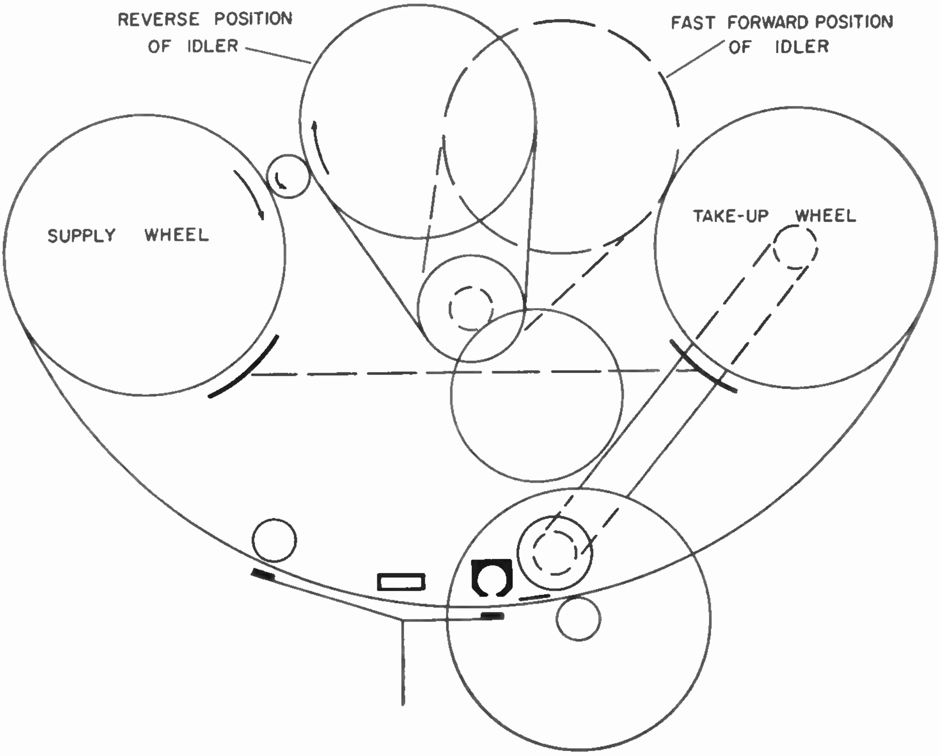
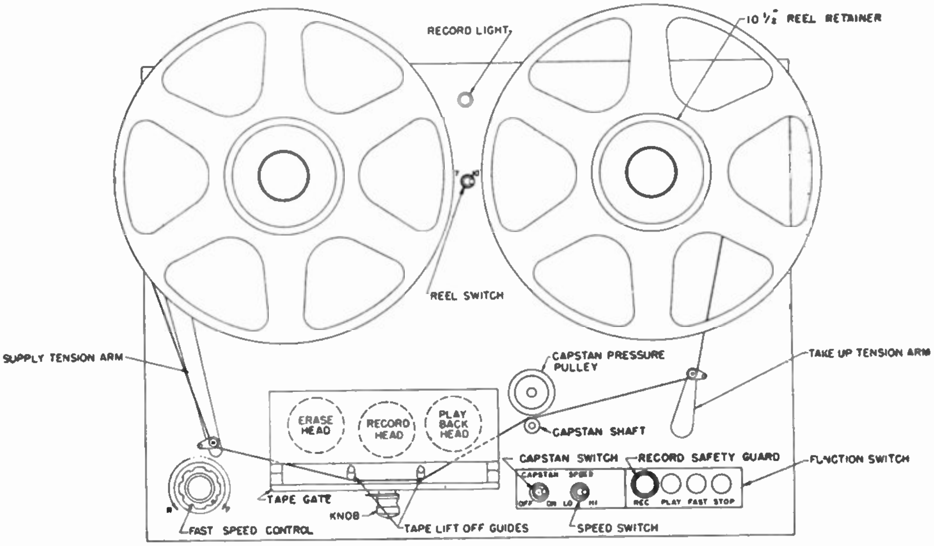


FIG. 22. Reverse and fast-forward positions.



Courtesy Presto Recording Corp.

FIG. 23. Presto tape-transport mechanism.

tape speed are chosen by the speed switch.

When the record or playback push-button is depressed, it closes a switch which energizes a solenoid. A solenoid is a coil of wire (an electromagnet) that has a movable iron core. When a current passes through the coil, the magnetic flux causes the core to move inward, toward the center of the coil. Thus, when the solenoid is energized, it causes the capstan pressure pulley, shown in Fig. 25, to move into contact with the rotating capstan shaft, and the tape is driven between them.

The supply and take-up motors are coupled directly to the reel tables. These motors keep the tape under constant tension while a uniform pulling force is being exerted by the capstan.

The reel tables are equipped with brake drums. A brake solenoid applies the brake bands to the drums on the stop setting of the recorder. During fast rewind, the brake system applies greater braking force to the reel that is unwinding. This keeps a more constant tension on the tape and prevents loops. If tape breaks or runs off, the take-up tension arm closes a micro-switch that energizes the brake solenoid to stop the reel tables.

There are two tension arms (supply and take-up) around which the tape

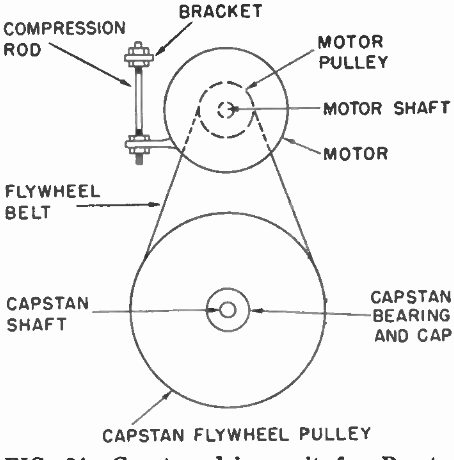


FIG. 24. Capstan drive unit for Presto recorder.

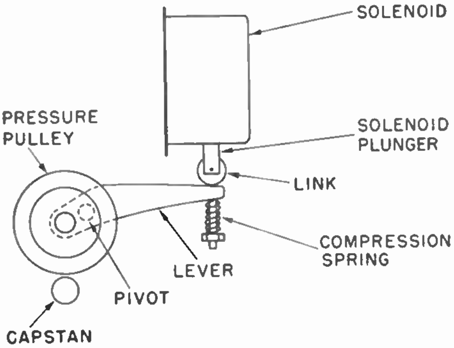


FIG. 25. When the solenoid shown here is energized, the solenoid plunger moves inward, causing the other end of the lever attached to it to move downward, bringing the pressure pulley into contact with the capstan.

must be threaded as shown in Fig. 23. For record and playback operation, the tape is threaded through the tape gate and under two tape lift-off guides. Function switches are at the lower right. Before the mechanism can be operated at fast tape speeds during rewind and fast forward, however, the tape must be withdrawn from contact with the heads by sliding the tape gate knob out. The speed of fast forward or reverse can be adjusted with the fast speed control.

The Presto tape-transport is separate from the main amplifier unit, but does include the bias and erase oscillator. Motor and solenoid control circuits are also included, and a neon bulb that lights up to indicate when the recorder is set on record position.

A third mechanical arrangement, such as used by Webcor, has two motors. It is designed to record and playback with the tape traveling in either direction. You can see the motor shafts and bushings in Fig. 26. The left and right reel drums, not shown in the illustration, are driven by the motor shafts through a slip clutch arrangement. Also, the motors drive the capstan flywheel. The direction of tape travel determines which motor

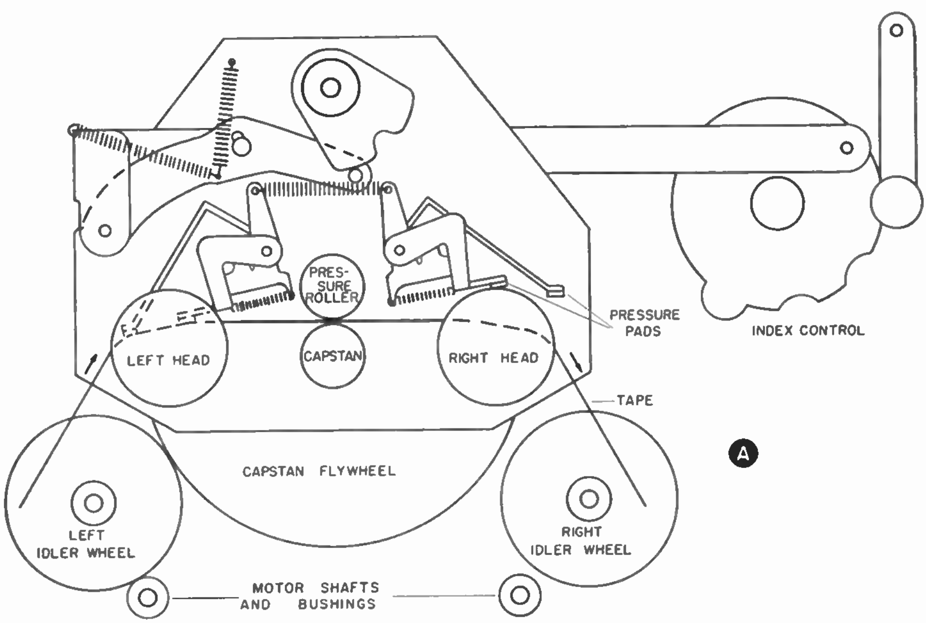
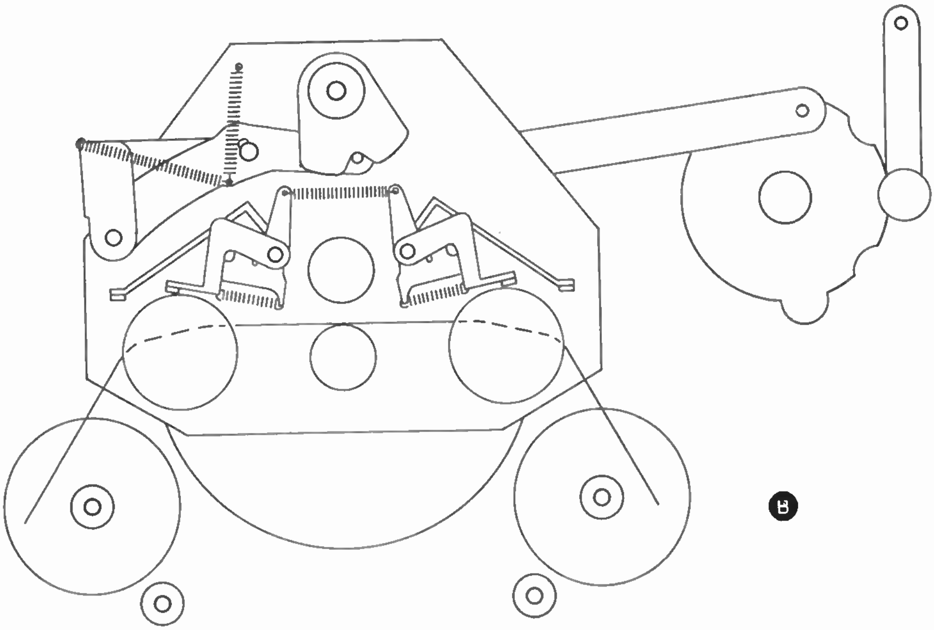


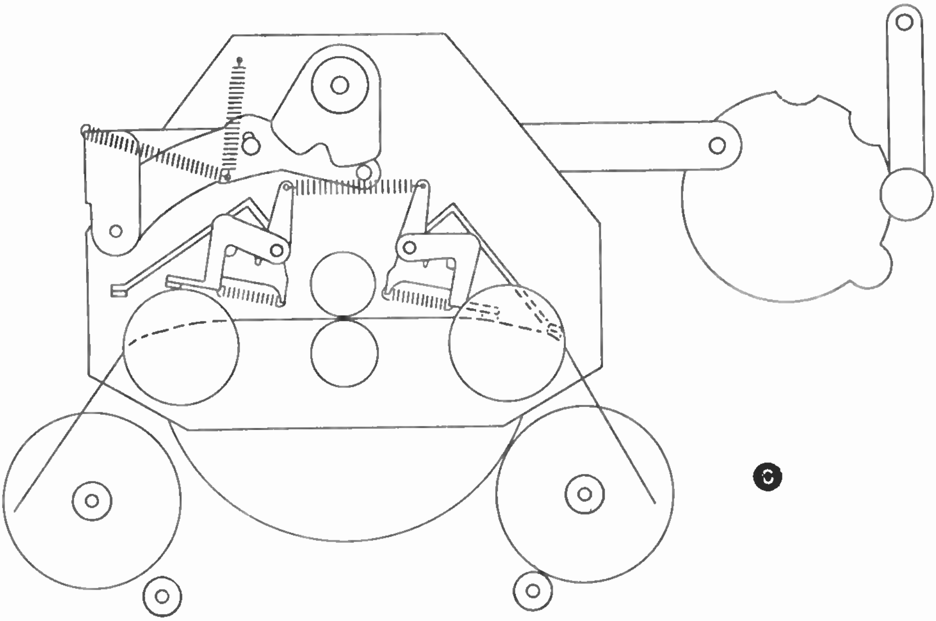
FIG. 26. Webcor transport plan. A, record or playback tape moves left to right. B (on opposite page), stop position. C, record or playback tape moves right to left.

and idler wheel operates the capstan and its flywheel.

The unit has two identical heads, left and right, which perform all three tape recorder functions of record, playback, and erase. The right head operates only when the tape moves from right to left, and the left head operates only when the tape moves from left to right.



B



C

In Fig. 26A the index control recorder is set on record or playback position with tape motion left to right. The left idler wheel (driven by the left motor) is shifted by a lever and cam arrangement into position where it can friction-drive the capstan flywheel. The pressure roller is moved against the capstan shaft, and pressure pads hold the tape against the left magnetic head.

In the stop position, as shown in Fig. 26B, the tape is released by the pressure pads, and the pressure roller moves away from the capstan. Although not shown, brakes are applied to both reel drums. The same conditions occur for rewind or fast forward settings, except that the brakes are released. Fig. 26C shows the arrangement that permits recording and playback operation with the tape moving right to left. Now the right-hand motor drives the capstan flywheel, and pressure pads hold the tape against the head on the right.

WIRE RECORDER

Magnetic recordings can be made on wire as well as on tape. The stainless steel recording wire must be manufactured carefully so that there are no irregularities in the wire diameter or impurities in the material. It must be clean and corrosion free. Wire diameter is approximately 0.004 inch. One hour of wire can be stored on a 2¾-inch diameter spool. Wire speed is faster than tape, usually 24 inches per second.

The method used to record magnetic information on wire is similar to that used in making tape recordings. As the wire passes the magnetic gap in the recording head, the wire is magnetized by the varying magnetic flux in the gap. The amount and direction of the magnetization depends on the strength and the polarity of the magnetic flux. During playback, the magnetized wire is again fed through the gap (the record head is also used for playback in most wire recorders), and the magnetized areas on the wire produce a varying voltage in the playback head. This is fed to the amplifier, which feeds the amplified signal to the loudspeaker.

The high-frequency response of a wire recorder, like the tape recorder, depends on the wire speed and the gap

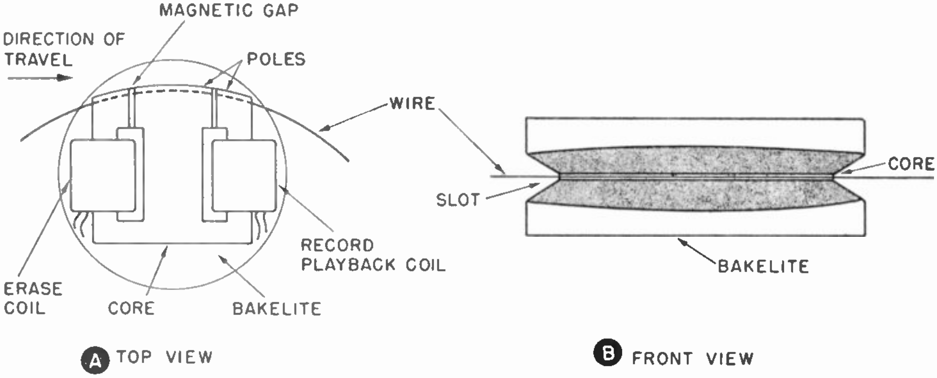


FIG. 27. Wire-recorder head.

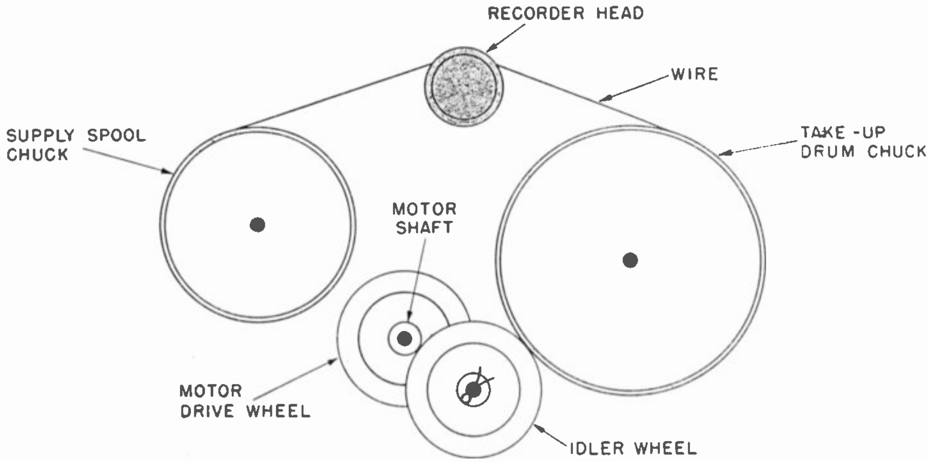


FIG. 28. Wire-recorder mechanism.

width. With the wire traveling at 24 inches per second, the high-frequency response can be as good as and often better than that of a tape moving at 7.5 inches per second. Faster tape speeds have a better response than wire.

The metal used to form the core in the record-playback head shown in Fig. 27 must have a high permeability at low flux density. In other words, it must be able to magnetize and demagnetize easily in a low flux field. Heads are generally constructed of mu-metal or molybdenum. The gap between the magnetic poles in the head is 0.001 to 0.002 inch, depending on the wire speed and frequency response.

The transport mechanism for an economy-type wire recorder does not require a capstan drive. Some of the more expensive and exacting wire recorders, however, do have a capstan drive. If a large diameter take-up spool and a small diameter wire is used, the change in wire speed is so slight that it has very little influence on the frequency response or wire tension.

A typical wire transport mechanism is shown in Fig. 28. With the control switch in the record position, cams and levers cause the motor shaft to press against the idler wheel, which in turn presses against the lower rim of the take-up drum, which is called the take-up drum chuck. The upper part of the drum is the take-up reel. Thus, when the chuck rotates, the reel rotates and pulls the wire from the supply reel, through the recorder head, and on to the take-up reel.

On rewind, the motor drive wheel is moved to the left until it contacts the supply spool chuck, and the idler wheel moves away from the take-up drum. Since the motor drive wheel is in direct contact with the supply chuck, the wire will be pulled back on the supply reel during rewind much faster than it was pulled during recording.

A wire recorder requires a level winding system so that the wire piles up on the take-up spool layer after layer. The head moves up and down vertically as the wire piles up on the take-up spool. As shown in Fig. 27, the wire passes through the head in a slot that is tapered on both sides. The taper aids in wire placement and permits use of a square knot wire splice. Because of the tapered edges, the head can move vertically without binding.

Amplifier and Control Systems

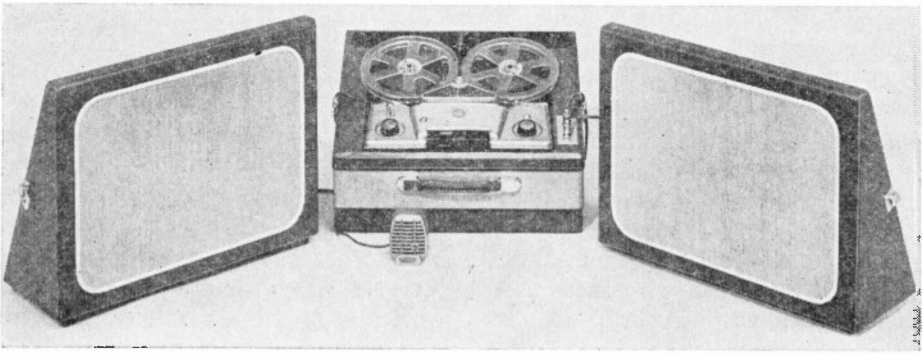
The amplifier and control system of a tape recorder is rather elaborate because of the many functions it must perform. In the record position the amplifier must have the proper sensitivity, frequency response, and output to drive the record head. A suitable switching arrangement must be included so that recordings can be made with a microphone or from the output of a tuner or high-fidelity amplifier system. In some recorders, using separate record and playback heads, the information being taped can be monitored at the same time by feeding the tape past the playback head to reproduce the sound through the speaker.

In the playback position, the amplifier must be able to build up the signal removed from the tape to a high enough level to drive the loudspeaker. In addition, it must have the desired frequency response to give a good quality reproduction of the taped information. The playback frequency characteristic, as studied earlier, is quite different from the record amplifier frequency response. Therefore, proper equalization circuits must be included in the change-over switching arrangement.

KNIGHT RECORDER

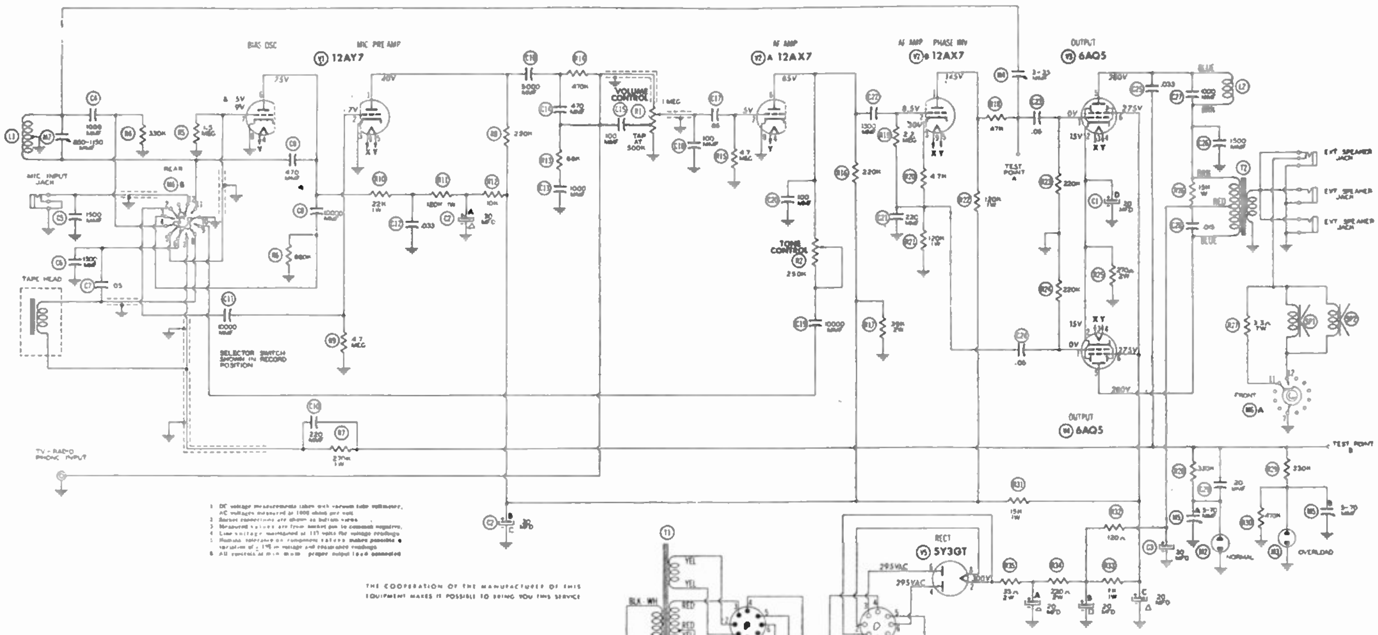
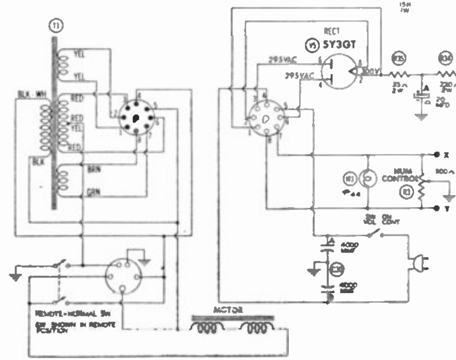
The Knight recorder, the mechanics of which were discussed in the previous section, is shown in Fig. 29, and a schematic diagram of the amplifier system is given in Fig. 30.

As you can see in the diagram, the Knight tape recorder contains a five-tube amplifier including the power rectifier. The main section of the audio amplifier consists of a triode input amplifier, a triode phase inverter, and a push-pull audio output stage, which is transformer-coupled to the speaker output section. The amplifier has an 8-watt output capable of driving



Courtesy Allied Radio Corp.

FIG. 29. Knight tape recorder with remote speakers.

THE COOPERATION OF THE MANUFACTURER OF THIS EQUIPMENT MAKES IT POSSIBLE TO BRING YOU THIS SERVICE

RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8	Pin 9
V 1	12AY7	†250KΩ	4.7Meg	0Ω	150Ω	150Ω	†170KΩ	▲1.6Meg 200KΩ	0Ω	150Ω
V 2	12AX7	†140KΩ	2.3Meg	125KΩ	150Ω	150Ω	†235KΩ	4.7Meg	0Ω	150Ω
V 3	6AQ5	220KΩ	270Ω	150Ω	150Ω	†500Ω	†1.2KΩ	220KΩ		
V 4	6AQ5	220KΩ	270Ω	150Ω	150Ω	†500Ω	†1.2KΩ	220KΩ		
V 5	5Y3	NC	50KΩ	TP	100Ω	TP	100Ω	TP	50KΩ	

▲ MEASURED IN "PLAY" POSITION
† MEASURED FROM PIN 8 OF V5
TP - TIE POINT
ALL MEASUREMENTS TAKEN IN "RECORD" POSITION UNLESS OTHERWISE DESIGNATED
NC - NO CONNECTION

Courtesy Howard W. Sams

FIG. 30. Knight tape recorder amplifier system.

two 12-inch public address accessory speakers. There are also two smaller self-contained speakers.

Recording Process. When making tape recordings of records, TV, or radio signals, the audio information is fed into the "TV-radio-phono input" jacks, and applied through the volume control R1 to the grid of the triode audio input stage. When recording from a microphone, the signal is fed into the "mic input" jack. It passes through the record-playback selector switch M6B to the grid of a microphone pre-amplifier stage, and then through the volume control to the grid of the first audio amplifier.

To understand the record process, let us trace the signal in Fig. 30, beginning at the microphone input jack. The selector switch is shown in the record position. The switch consists of two sections: M6A and M6B. One is immediately to the right of the input jack and the second is beneath the two speakers at the far right-hand side of the diagram. This latter section of the switch has only a single function; namely, to turn off the included speakers on the record position.

The microphone signal passes through the selector switch from contact 12 to contact 2, and then through capacitor C11 to the grid of the microphone pre-amplifier. From there the signal proceeds in conventional fashion through the volume control circuit and on to the grid of the first audio amplifier.

The resistor-capacitor network (resistors R13 and R14, and capacitors C13, C14, and C15) between the microphone pre-amplifier stage and the volume control has a dual function. It retains the desired frequency response regardless of the setting of the volume control. In addition, you will recall that in the record process, the highs are emphasized to correct for the severe high-frequency loss in the recording process. Thus, the network also functions as a compensator to provide proper pre-emphasis of the highs.

The audio output of the first amplifier is applied to the phase inverter. Equal amplitude but opposite polarity signals are developed across resistors R22 and R21 to apply correctly phased signals to the grids of the audio output tubes. Record information is taken from the plate of output tube V3 and is applied through capacitor C25 to the tape head, located on the far left-hand side of the diagram. Capacitor C10 and resistor R7, along with the tape head coil, supply proper constant current loading on the output stage.

The signal passing through capacitor C25 is also applied to the neon bulb recording level indicators, M2 and M3. Each neon bulb contains a suitable voltage divider network so that the "normal" bulb lights when proper signal level is being applied to the record head. If the signal level is too high for recording purposes, the "overload" bulb also lights and indicates improper recording level, and the possibility of distortion. In this way the operator can retain proper recording level conveniently.

You will recall from an earlier discussion that a high-frequency bias signal is necessary to raise the recording level of the audio signal in the record head to prevent distortion. The signal bias is developed by the Hartley oscillator at the far left of Fig. 30. Coil L1 is suitably tapped to provide a stable and proper amplitude bias signal, which is supplied through capacitor M4 to the grid of the audio output tube V3. Capacitor M4 is adjustable so that the correct level of bias signal can be applied. Capacitor M7 in the tank circuit of the bias oscillator permits that oscillator to be set on the proper supersonic frequency.

Let us next consider the function of the selector switch M6B. It is shown in the record position. The contact between terminals 4 and 5 functions as the grid return circuit from the oscillator tank circuit to the grid of the bias oscillator. With the switch in this position, the only other contacts besides 2 and 12 are between terminals 6, 8, and 10. Since terminal 10 is grounded, 6 and 8 are also grounded.

The grounding of terminal 8 shorts compensating capacitors C6 and C7 to ground, and grounds the top end of the tape head. Remember that the record signal from the audio output stage is applied to the bottom side of the tape head coil.

Playback. Let us consider the playback function next. In playback position, the selector switch connections are moved counter-clockwise. In this position, terminal 7 is grounded through terminal 10, which grounds the lower side of the tape head coil. Likewise terminal 9 is grounded through terminal 10. This connection grounds the bottom side of the tone control network consisting of potentiometer R2 and capacitors C19 and C20. The tone control circuit is in operation only in the playback position. In the record position, terminal 9 is open, and therefore the tone control is out of the circuit.

Terminal 8 on the selector switch opens on the playback position and, therefore, the ground is removed from the top of the tape head coil. Instead, the signal from the top of the tape head coil (same head is used in the playback position) is coupled through capacitor C7 to terminal 6. In playback position, terminal 6 connects to terminal 5, and supplies the playback signal to the grid of the bias oscillator, which functions as an audio amplifier in the playback operation. In the playback position, terminals 2 and 3 join, and, therefore, the plate circuit of the bias oscillator now is coupled through capacitor C8 and capacitor C11 to the grid of the microphone pre-amplifier stage, and so on through the remainder of the audio amplifier.

The bias oscillator ceases to be an oscillator, because on playback position the connection between the tank circuit through terminals 4 and 5 is broken. Thus, the bias oscillator becomes a conventional triode audio amplifier for playback operation.

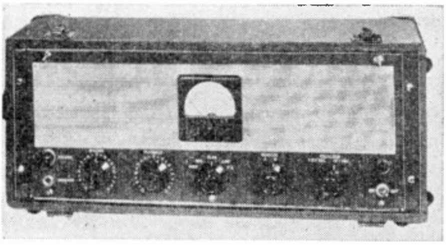
In the playback position the constant velocity characteristic of the tape head must be compensated for by proper emphasis of the lows. In using the bias oscillator as the initial audio amplifier for playback operation, suitable compensating networks can be switched into the circuit. Capacitor C12 and resistor R10 function as a load on the plate circuit. The values are chosen to provide a rising impedance characteristic with a decrease in frequency. This is opposite to the constant voltage characteristic of the tape head.

Notice that there are three external speaker jacks in addition to the two speakers contained in the recorder. The top jack on the schematic connects to the same line as the included speakers. Thus, when an external speaker is connected into this jack, the included speakers are disconnected. The second and third external speaker jacks, however, are connected directly to the secondary of the output transformer. Thus, speakers plugged into these jacks do not cut off the internal speakers. As a result, it is possible to use the tape recorder as a public address system when the selector switch is set on record. By changing the selector over to the playback position, any information on tape can be reproduced by the external loudspeakers.

Remote Control. The recorder also may be operated by remote control through a jack and cable arrangement to the power circuit. With the control switch set for remote control operation, the unit can be turned on and off from a remote control box.

PRESTO RECORDER

In more elaborate and semi-professional recorders, the amplifier and control section is often separate from the tape-transport mechanism. The amplifier section of a recorder of this type, shown in Figs. 31 and 32, has dual amplifier channels—one for record and one for playback. Separate three-stage pre-amplifiers are used for record and playback. A single-phase inverter and a push-pull output stage are used for both functions.



Courtesy Presto Recording Corp.
FIG. 31. Presto recording amplifier.

The selector switch sections, marked S101 in the diagram in Fig. 32, are shown in the bias positions. The bias oscillator in recorders of this type is usually a part of the tape-transport mechanism, rather than the amplifier section. Notice in the diagram that the outputs of both the record and playback amplifiers are disconnected from the phase inverter power amplifier stages by switch section S101-1A when the high-frequency bias signal is fed to the erase head.

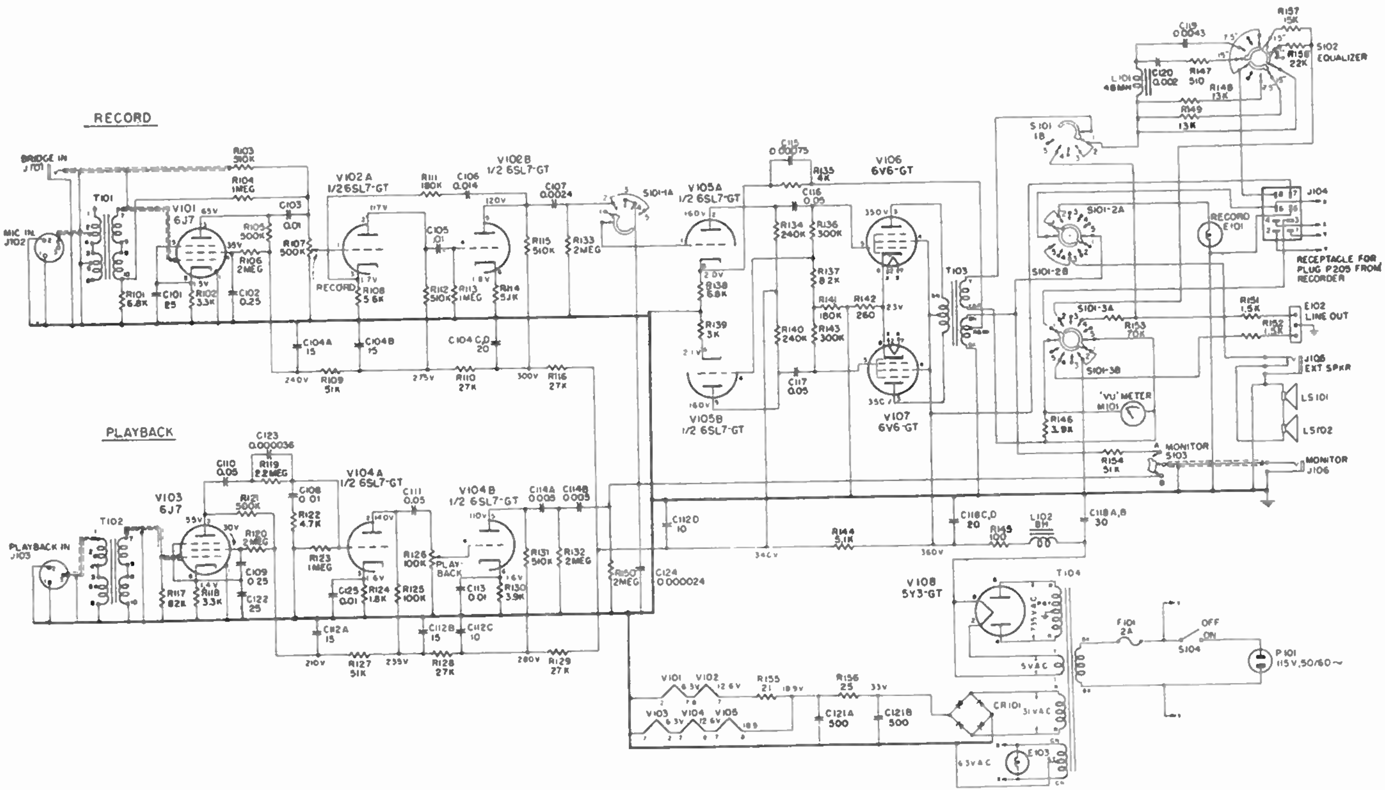
Recording. In the record position, the microphone signal is applied to the grid of the mike pre-amplifier, tube V101, through a matching transformer. The output of the pre-amplifier stage is fed to the grid of the triode amplifier through the record gain control R107. Resistors R104 and R101 form a feedback circuit to the input of the stage to establish a good signal-to-noise ratio.

When the recording signal is taken from an audio line, from a tuner or phonograph cartridge, it is applied to the bridge input jack. The signal is fed to the grid of the first triode amplifier through the record gain control.

The signal to be recorded is amplified by two triode stages (also employing feedback) and is applied through selector switch section S101-1A to the phase inverter. Signals of equal amplitude and opposite polarity are taken from across resistors R136 and R143, and applied to the grids of the push-pull output stage.

The record signal is removed from the top of the upper secondary winding of the output transformer, and fed through switch S101-1B to the pre-emphasis equalizer. The amount of pre-emphasis depends on the tape speed. Separate equalizer circuits are used for speeds of 7.5 and 15 inches per second. The recording signal is now sent by cable through pin 8 of jack 104 to the record head.

Playback. In the playback position the signal from the playback head is coupled through a cable and a matching transformer to the grid of the pentode amplifier, tube V103. Its output is applied to the dual-triode second amplifier stage through a post-emphasis network. Capacitor C108 and resistors R119 and R122 accent the lows by developing a propor-



Courtesy Presto Recording Corp.

FIG. 32. Presto tape-recorder amplifier.

S101 LEGEND	
POS. NO.	FUNCTION
1	BIAS
2	RECORD
3	PLAY
4	LINE
5	P A

NOTES

1-ALL RESISTORS ARE IN OHMS K=1,000 OHMS; MEG=MEGOHMS

2-ALL CAPACITORS ARE IN MICROFARADS

3-ALL D.C. VOLTAGES MEASURED TO GROUND WITH A 20,000 Ω/VOLT METER tionately greater percentage of the low-frequency signals at the grid of the first triode. Capacitor C123 provides some emphasis of the very highs.

The output at the plate of tube V104B passes through switch S101-1A to the audio output stages. Only one of the secondary windings of the output transformer is used at a time. The upper winding feeds either the recording head or a line. The lower winding feeds the speakers.

The signal can be monitored at the output of the recording amplifier or the output of the playback preamplifier by using switch S103. The monitoring is done with very high impedance heads.

The playback amplifier can also be used as a PA system. When the selector switch is set so the amplifier can be used as a PA system, the recording amplifier supplies signal to the audio output stage, which, in turn, drives the loudspeaker system.

A record light, E101, is included and a VU volume level meter indicates proper recording levels. When the selector switch is set to the bias position, the VU meter indicates the bias level.

Adjustment and Maintenance of Magnetic Tape Recorders

The average tape recorder is a surprisingly reliable device and generally operates for years without trouble. However, the number of recorders in use has increased tremendously in the last several years, so you can expect to be called on to service them more and more frequently. There are so many different models of magnetic recorders on the market that it would be impossible to give a detailed description of each one. In this section, therefore, we will discuss several representative types to show you how to proceed in making repairs and adjustments. If you have to service a magnetic recorder, get the manufacturer's service sheet on the recorder and follow the instructions.

The defects that you will find in magnetic recorders can be either mechanical or electrical. Most defects or improper adjustments can be isolated quickly by using a logical trouble-shooting procedure. An understanding of the multiple functions of a tape recorder and how the various switching and change-over actions occur is very important in isolating a defect quickly. By going through the various operations of the tape recorder and observing the functions, you will be able to localize the defect.

KNIGHT RECORDER ADJUSTMENTS

Let us first discuss some of the recommended adjustment procedures for the Knight recorder. Refer to Figs. 17, 30, and 33. Typical adjustment procedures involve three sections of the recorder: the tape head, the motor and drive mechanism, and the electronic circuit.

Tape-Head Section. In the tape-head section we are concerned with the proper motion and positioning of the tape as it is pulled past the erase magnet and record-playback head. In the Knight recorder the actual posi-

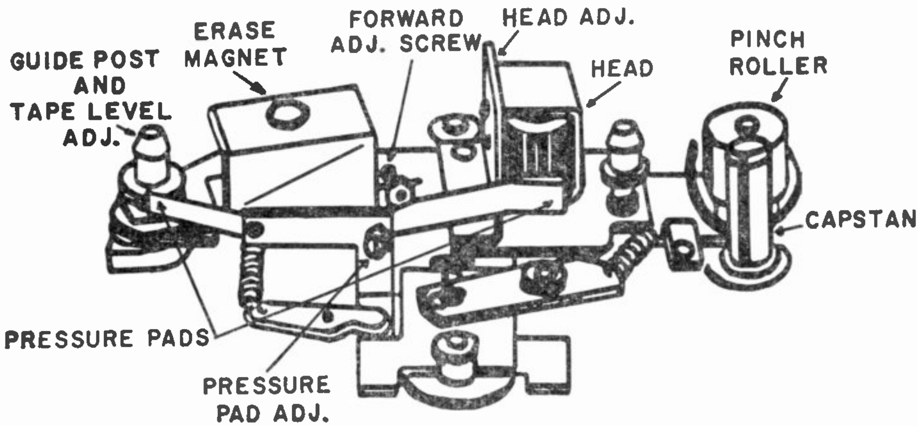


FIG. 33. Location of service adjustments for Knight recorder.

tioning of the record-playback head is taken care of by using a pair of pliers to rock the mounting bracket for the record head, shown in Fig. 33, from side to side until it is positioned correctly with respect to the tape motion. A test tape is run through and the head is set for maximum reproduction of the high frequencies. In some recorders the correct head adjustment is obtained by making precise measurements.

In this section of a tape recorder, there are various pressure pads and guide adjustments. These adjustments permit smooth motion of the tape and hold the tape firmly against the erase and record-playback heads. Typical adjustment points are shown in Fig. 33.

The record-playback head pressure pad is adjusted by a locked adjustment screw, and the pressure pad that holds the tape against the guide post is adjusted by bending the spring metal to which the pad is attached. There are also adjustments to make certain that the tape moves correctly with respect to the erase head. Again refer to Fig. 33. When the tape passes the erase head during recording, the top edge of the tape must coincide with the top end of the diagonal slot in the permanent magnet erase head. The level of the tape can be set with the guide post and its set screw. A forward adjustment screw is also provided so that the erase head can be moved forward with the proper pressure against the tape to obtain efficient erasure.

Similar adjustments are a part of most tape recorders. However, the actual adjustment procedures may differ. It is always advisable to follow exactly the procedures recommended by the manufacturer for each model.

Motor Mechanisms. A number of motor mechanism adjustments can be made when necessary. Refer to Fig. 17. The brake shoes must have proper clearance so that they will completely release the drums during the record, playback, reverse, and fast forward operation. Also, the brake shoes must have enough pressure to stop the drums quickly when the stop button is depressed. Adjustments are made by using a pair of pliers to bend the spring arm a small amount away from the drums.

A second adjustment involves the take-up reel. It must exert just enough torque to reel up the tape and must not in any way influence the operation of the capstan. Sometimes the take-up reel slows down and the tape is not wound up quickly enough. In the model shown, this is often caused by a stretched spring drive belt. The most effective solution then is to replace the belt. Improperly adjusted brake shoes also can cause the take-up reel to revolve more slowly than normal.

Electronic Adjustments. The electronic adjustments generally include adjusting the bias signal and various indicators so that the proper level audio signal is applied to the tape head during record. Refer to Fig. 30.

Proper bias signal is obtained for this recorder by connecting a vtvm as an rf voltmeter to the record head terminals. With proper bias applied, the voltage should be between 75 and 100 volts. Two bias level adjustments are provided. One is the trimmer capacitor M7, which tunes the bias oscillator to the correct frequency. The second trimmer adjustment is M4, which controls the amplitude of the signal applied to the grid of V3, the audio output tube.

The indicator trimmer capacitors M5A and M5B are set by applying a 1000-cycle audio note of specified amplitude to the input of the recorder. The trimmers are adjusted so that the "normal" bulb lights when proper signal level is applied, and the "overload" bulb lights when the amplitude of the applied signal is slightly more than desirable.

PRESTO RECORDER ADJUSTMENTS

Here we will discuss some of the recommended adjustment procedures for the Presto tape-transport mechanism shown in Figs. 23, 24, and 25.

Magnetic Heads. The playback head can be tilted by loosening an adjustment screw to give the maximum high-frequency response. The record head should not be adjusted. It should remain in the position set at the factory as a standard for aligning the other heads.

Tension Arms. The tension in the supply arm is controlled by a spring on the underside of the panel.

Capstan Pressure Pulley. The pressure against the capstan shaft is controlled by the small compression spring shown in Fig. 25. The large spring in the capstan solenoid should not be touched.

Capstan Flywheel Belt. The belt tension is regulated by a compression rod (see Fig. 24). To adjust, loosen the holding nuts and turn rod for desired belt tension. Do not make the belt too tight, as this will cause flutter.

Supply and Take-Up Brakes. Brake tension is controlled with knurled nuts on the brake tension screws. Tighten or loosen the nuts to the required tension. Do not tamper with the adjusting screw on the brake band strip which has been permanently set at the factory. Brake tension must be equal on both drums after adjustment.

Again it is important to emphasize that procedures and adjustments will vary from recorder to recorder. Do not make adjustments unless you have the manufacturer's information, or unless you have built up a considerable backlog of experience in servicing tape recorders.

TROUBLE-SHOOTING TAPE RECORDERS

Perhaps the most common tape recorder defect is some form of mechanical sluggishness. Often cleaning will remedy the condition. Dust will accumulate on the capstan and its pressure roller and record-playback head. Also, some of the magnetic material may wear off the tape as it passes the head. A soft cloth and alcohol can be used to clear the surfaces of the tape head, pressure roller, and capstan. A brush or metal object should not be used, because it will mar the pole pieces. Metal parts can be cleaned with a few drops of carbon-tetrachloride. Rubber is best cleaned with soap and water and then dried thoroughly.

Dust and dirt should be removed occasionally from the mechanical pushbuttons and levers. An occasional drop of oil on the sliding levers and cams is helpful in maintaining smooth and noise-free operation.

Mechanical lever defects can usually be found by inspection. Often they are in the form of a released, weakened, or broken spring. You can locate the defective section by determining what position the selector is in when the disturbance occurs.

For example, if the recorder will not work on fast forward or reverse, the defect can be isolated to the mechanical section of the recorder that controls these operations. Refer to Fig. 17 through 22. With no fast forward or reverse operation, the defect could be in the tension spring arrangement that moves the idler level and idler wheel into position against the supply drum or take-up drum (Fig. 22). The idler belt could also be broken or have slipped off the pulley.

When there is no motion on record or playback position (Figs. 17 and 21), the defect is probably in the components that transfer the power from the motor to the rubber idler wheel and to the flywheel and its capstan.

If the recorder operates on record and playback positions but the tape does not wind up on the take-up reel, look for the trouble in the transfer of power between the capstan, the pinch roller, and the take-up reel. If the pinch roller is operating normally, check the spring pulley that links the pinch roller to the take-up reel mechanism. Another possible cause of this trouble is that the brake may be rubbing against the supply reel or the take-up reel and causing it to revolve more slowly than it should.

A speed variation or wow in tape recorder reproduction is similar to wow sometimes found in a regular record player. It can be caused by an accumulation of dirt or uneven wear of one of the mechanical parts of the recorder, or by a warped take-up or supply reel. Parts, such as the capstan, pinch roller, idler wheel, motor pulley, and flywheel, should be cleaned with a good cleaning fluid. Make sure that the motor pulley on the motor shaft is not slipping and that the tension springs are holding the idler wheels in firm contact with the driving mechanism. Also look to see that there is no uneven wear of rubber idler wheels.

As the tape slides over the tape head, it may wear the surface so smooth that the tape will tend to stick to the head. In the beginning, it may cause a squeal. Later, the surfaces may stick together enough to stall the recorder and break the tape. Cleaning the head will not help; it will only make the condition worse. You must roughen the head surface slightly by rubbing it with crocus cloth. Then clean it with alcohol.

Electronic Defects. Regular signal tracing techniques can be used to locate defects in the vacuum tube section of the tape recorder. If you know what the various stages should do, you will be able to localize the circuit defect quickly. Only a few stages are usually involved in each operation.

Therefore, if you know the switching actions that occur, you should have no trouble tracing the signal through the stage.

Test Tape. There is a test tape that you can buy to make very exacting checks of tape recorder performance. The Dubbings test tape can be used to test wow and flutter, head alignment, frequency response, signal levels, and tape speeds. The wow check is made with a 3000-cycle tone recorded on the tape. The ear is very sensitive to variations at 3000 cycles. Therefore, if no variations can be heard, it is an indication that the wow level is less than 0.5 per cent. If the wow is abnormal, however, it indicates a defect in mechanical motion, such as a faulty capstan or a worn idler, or in some other eccentric motion of the drive mechanism. Tape binding or improper pressure pad adjustments can also be offenders.

To check the head alignment, the test tape includes a high-frequency tone of 10,000 cycles. Since improper head alignment causes the high-frequency response to fall off, the 10,000-cycle tone represents a good check. With the tape in operation, the head alignment adjustments can be made to get maximum output from the loudspeaker or for maximum indication on some type of audio output meter. You can also use the tone to check the pressure pads. The record-playback pressure pad must hold the tape firmly against the pole pieces for the best high-frequency output.

The test tape also includes frequency-response test runs in fourteen steps between 30 and 15,000 cycles. If the frequency response does not match the manufacturer's specifications for a particular model, there is a defect. Improper equalization or incorrect setting of adjustable equalizing circuits may be the fault. Worn tape heads and improper tape-to-head contact and pressure also can cause a loss of highs.

The test tape also includes a calibrated 400-cycle tone that can be used to check the signal levels and measure the gain of the tape-recorder amplifier system.

Calibrated timing beats on the test tape are used to check tape speed. The beats are spaced exactly five minutes apart on the tape when it is moving at correct speed. You can time the beats with a watch. If it takes longer than five minutes for the second beat to sound, the tape speed is too slow. Conversely, if the beat sounds in less than five minutes, the tape is moving too fast.

A test tape of this type is very important in checking the performance of high-fidelity tape recorders. These tapes are available for two tape speeds—7.5 inches per second and the high-fidelity 15 inches per second.

There are other tests that can be used as a basis for adjusting tape recorders. These tests, however, require test equipment that is not used in radio servicing. This test equipment and its use is described in a lesson on servicing high-fidelity equipment. There is little to be gained by using these tests on the lower priced home tape recorders. They are valuable only on the more expensive semi-professional tape recorders.

Lesson Questions

Be sure to number your Answer Sheet 35B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of lessons before new ones can reach you.

1. What is the purpose of the bias signal? To prevent amplitude distortion
2. What would be the result of the failure of the bias oscillator during recording? distortion + signal reduction.
3. Why do the more expensive recorders have adjustable bias? to compensate for variations in tape characteristics.
4. What influence does tape speed have on high-frequency response? poor high frequency
5. Which does a narrow gap in the core of the playback head favor, high frequencies, or low frequencies? high frequencies
6. Why is pre-emphasis used for the high frequencies? To make certain the highs are emphasized above tape noise & hiss.
7. Is erasure better with a wide gap or a narrow gap? wide gap
8. Do the bulk eraser and the erase head using a bias signal work on the same electromagnetic principle? yes
9. Why is a capstan instead of the take-up reel used to pull the tape? To maintain proper tape speed
10. What is the difference between the drive mechanisms on an economy wire recorder and a tape recorder? wire recorder has no capstan.

UNDERSTANDING

"Happy is the man that findeth wisdom,
and the man that getteth understanding.
For the gaining of it is better than the gaining of silver.
And the profit thereof than fine gold.
Understanding is more precious than rubies:
And none of the things thou canst desire are to be compared unto it.
Its ways are ways of pleasantness,
And all its paths are peace.
It is a tree of life to them that lay hold upon it.
And happy is every one that retaineth it."

— *Adapted from Proverbs.*

The world is yours. Stored in your subconscious mind is knowledge acquired through your own efforts, plus abilities bequeathed by all the centuries of the past. Once you truly understand the tremendous capacities which are within you—once you realize your responsibility to others in the world—once you acquire the knowledge needed for success in your own chosen field—*you can be as great as anyone who has ever lived before you!*

J. E. Smith

HOW TO MAKE EXTRA MONEY

FIXING RADIO AND TV SETS

NO. 11

HOW TO FIX WEAK AND INTERMITTENT RECEIVERS

SPARE-TIME MONEY-MAKING AIDS

PIONEER HOME STUDY RADIO-TV SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

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HOW TO FIX WEAK AND INTERMITTENT RECEIVERS

WEAK reception is quite a common complaint, and one that may be baffling to the radio mechanic. All that he can do is hopefully "poke around" in the set, wishing for a lucky solution. The professional radioman, on the other hand, can locate the trouble by a series of logical tests and measurements and cure it quickly. By observing how the set acts, he can find out just which circuit or stage is giving the trouble, and by making a few quick checks, confirm the diagnosis.

Intermittent defects are those that appear and disappear, and for this reason can be very troublesome. An intermittent defect usually takes longer to locate than a continuous defect. However, just remember that the same things that cause permanent defects can also cause intermittent defects.

In this book, we will give you the professional ways of finding out why a set does not deliver its normal performance. We will follow our regular plan of study. First we'll see what could cause the complaint, and then give you the methods by which the cause is located. In a later section, we will help you learn to recognize complaints that are not due to receiver defects, and finally, we will continue your Practical Training Plan to give you actual servicing experience.

Let us study weak reception, first.

CONFIRMING THE COMPLAINT

When you get a set with weak reception as the complaint, be sure the trouble is actually in the set, and not in the customer's imagination! This means you must know just exactly what *is* "normal reception" in your area for each type of set. How many stations can be picked up with how much volume for each type of set, portable, home radio, FM-AM radio, TV, etc. For instance, if you lived in Arkansas, and the customer had recently moved in from Washington, D.C., and was complaining that the set would not pick up New York stations that he had been used to getting, your task would be to convince him that the reception was actually normal, and the set was perfectly all right. This sometimes calls for a good bit of diplomacy, but you can handle it if you'll use a common-sense, polite approach.

Once again, we repeat that you must be able to recognize normal performance, in both radios and TV sets, in order to tell whether the set in question is actually weak. This will come to you as you get experience, and you may already be able to recognize it. Only when a set will not pick up stations normally heard, or will not deliver sufficient volume, or when a TV set is abnormally snowy, is the set definitely "weak" and requires servicing.

Once you have decided that a set is weak, take it to the shop for further testing. There, you can apply your regular service techniques, and usually locate the trouble in short order.

There are two basic causes for weak reception. Either some part has failed, interrupting the signal path through the set, or some part has changed value, altering the gain of some stage or stages. The first might be caused by such things as an open loop antenna, an open coupling capacitor, or a dead tube; the second might be due to low operating voltages, weak tubes, or improper alignment. Your first task is to locate the weak stage.

TESTING TUBES

Tubes cause most of the complaints. They are more apt to give trouble than many of the other parts. A tube normally deteriorates as the active material of the cathode is used up. Loss of emission results, causing lowered mutual conductance and gain.

Transistors have shown no sign of this particular trouble, although it is quite possible. Most transistor defects so far found have been from complete failure due to moisture penetration, excess heating, or application of wrong voltages. One common cause of this in a portable is that the customer puts the battery in backwards, breaking down the transistors by applying reversed voltages.

Therefore, the first step in checking a weak set is to operate the set on the bench, noting the performance carefully. Then, test the tubes. If one or more are weak, replace them. Recheck the performance. Replacing the defective tubes will often restore the set to normal.

CHECKING OPERATING VOLTAGE

If all the tubes test fairly good, the next step is to localize the trouble to a single stage. You can often do this by means of a circuit disturbance test made as a side effect while you are measuring the dc operating voltages. To do this, proceed as follows: Turn the set over, and measure all voltages, beginning with the rectifier, then going from the output stage back toward the antenna. In this case, since you are not looking for a dead stage, but a weak one, listen very carefully to the amount of "pop" when you apply the voltmeter probe to each plate and control grid. As you know, the "pop" should increase in strength as the probe is moved toward the receiver input. If you get a normal increase up to a certain point, and the next test point shows a *loss* in the amount of thud, click, or pop in the loudspeaker, you have just passed through the defective stage. In many cases the voltage measurement will also be low, which will help you in diagnosing the trouble. Low operating voltages are a major cause of weak reception, so read them carefully, comparing them mentally with what you know to be normal for a set of this particular type.

Causes of Weak Reception in the Power Supply and Audio Section

Let us go through the receiver and see what parts defects can cause weak reception. We will use the typical ac-dc receiver shown schematically in Fig. 1 for this discussion.

LOW VOLTAGE AT RECTIFIER CATHODE

Let us suppose we read only 75 volts dc at the output of the rectifier. In a good set, it should be 115 to 125 volts, whether it is a vacuum tube or a selenium rectifier. With 75 volts at the output of the rectifier, the voltage at the output of the filter will be 50 or 60 volts, which is low enough to cause a decided drop in the volume. Let us see what could cause this.

Defective Rectifier. Now you have a defect. What is causing it? Is the rectifier weak, or is there a partial short or leakage in the filter system? Temporarily replace the rectifier. If the voltage comes up to normal, then the rectifier tube is definitely weak, and must be replaced.

If this set has a selenium rectifier, temporarily disconnect one end, and hook a new rectifier across the circuit, being very sure to get the polarity right. The side of the rectifier with the printing on it is always positive, and goes to the filter capacitors. Now, recheck the voltage. If it has come back up to normal, replace the rectifier. This test rectifier can be connected across the circuit with two short leads ending in test clips.

Filter Capacitors. Now, let's take another case. We have replaced the rectifier, and the voltages are still low. Therefore, we have some other trouble. The next most common cause would be in one of the filter capacitors. If input filter capacitor C1 (the reservoir) is low in capacity or has a high power factor, the dc voltage goes down. C1 can be easily tested. Shunt it with a good capacitor having about the same capacity and rated at 150 volts or more. Be sure the test capacitor is connected so its polarity is the same as that of C1. If this brings the voltage back up, replace the entire filter capacitor. As you have learned, you should never replace only *one* of the capacitors in a multiple unit. Always replace the whole unit to avoid callbacks.

Now, if bridging this capacitor across the circuit doesn't get the voltage back up, we know that there is bound to be an excessive current drain on the circuit, loading it so that the voltage drops too much. To check this, we first turn the set off and take a reading from the rectifier cathode to B— with an ohmmeter. A normal reading here would be something over 50,000 ohms. From the filter output to ground (B-minus) you would read about the same. If you get a reading decidedly less than 50,000 ohms, say around 10,000-15,000 ohms, you know that you have a leakage somewhere in the B supply circuit. The most likely suspect is the output filter capacitor. Unhook it and remeasure the resistance of the circuit. If this goes up to normal, replace both capacitors.

By-Pass Capacitors. Suppose you find low resistance from the rectifier cathode to B— but removing the filter capacitor leads does not bring up the resistance reading. This shows that the filter capacitors are not defective, but that some other part between

B+ and B— has developed leakage. There could be a short in the wiring or excess solder from a previous repair job could be bridging across the circuit. However, the chances are that there is an actual part defect. Here is where the schematic is of value. Trace out the complete B+ wiring. When you come to the symbol for each part, stop. Form a picture of the part in your mind, and then decide if there is any way it could become defective to cause the trouble. At the start this is a little difficult, but as you gain experience you will do it automatically as you run your eye over the schematic. For practice, take your pencil and run it over the circuits we discuss.

Start at the lead coming from the positive side of C1, and run your pencil point over the wiring to the end of this circuit at the plate of VT4. You will go through the primary of the output transformer and pass by C13, the only two parts in the circuit. There is no defect that could occur in the transformer that would result in a low resistance path to B—. Leakage could develop between the primary and the transformer core, but the core is grounded to the chassis, and there is 470,000 ohms resistance (R1) between the chassis and B—. In sets where the chassis is B—, a primary-to-core short in the output transformer should not be overlooked. C13, as you can see from the diagram, is a possible source of trouble. If it develops leakage, there will be a low resistance path from the rectifier output to B— through bias resistor R13. Don't disconnect C13 yet for a check —go through the entire circuit to see if there is a more likely suspect. If there is, it is the first thing to check—this is the easy way to troubleshoot.

Now run your pencil point over the wiring from the + terminal of C2 to the plates and screens of all the other tubes. You will find another capacitor at the plate of VT3 connected directly to B—. However, even if this capacitor shorts out completely (has zero resistance), it will not result in a low resistance measurement from B+ to B—. This is due to the high resistance of R11, which would be in series with C11 if it broke down.

Tracing to the plate of VT2, you find only the primary of the 2nd i-f transformer and its trimmer as possible trouble makers. Difficulty here is also impossible because the only short that could occur is to the chassis rather than B—.

The tube itself could short between the plate and suppressor grid or between the screen and suppressor grid. Check for this possibility now by removing the tube to see if the resistance reading goes up to normal. A short is unlikely, but could occur in VT2 or VT1 because of the close spacing of the suppressor grid and the other electrodes. Such a short in VT4 is so unlikely that it is not considered except as a last resort.

Now run your pencil from B+ to the plate of the mixer VT1. Again you dismiss the possibility of trouble in the i-f transformer, and check the tube by pulling it out of its socket. Note however the presence of rf bypass capacitor C14. This part connects directly from B+ (through the wiring) to B—. Leakage in it will surely cause the condition we wish to correct. This capacitor is the most likely suspect. If C13 is leaky, it may burn out R13 and the set will be dead. If R13 is open, the resistance from B+ to B— will not be affected even with C13 shorted. C14 is such a likely suspect that the experienced serviceman will cut one of its leads loose rather than bothering to unsolder it. With the capacitor cut loose. the B+ to B— resistance is again checked. If it is now normal, C14 is

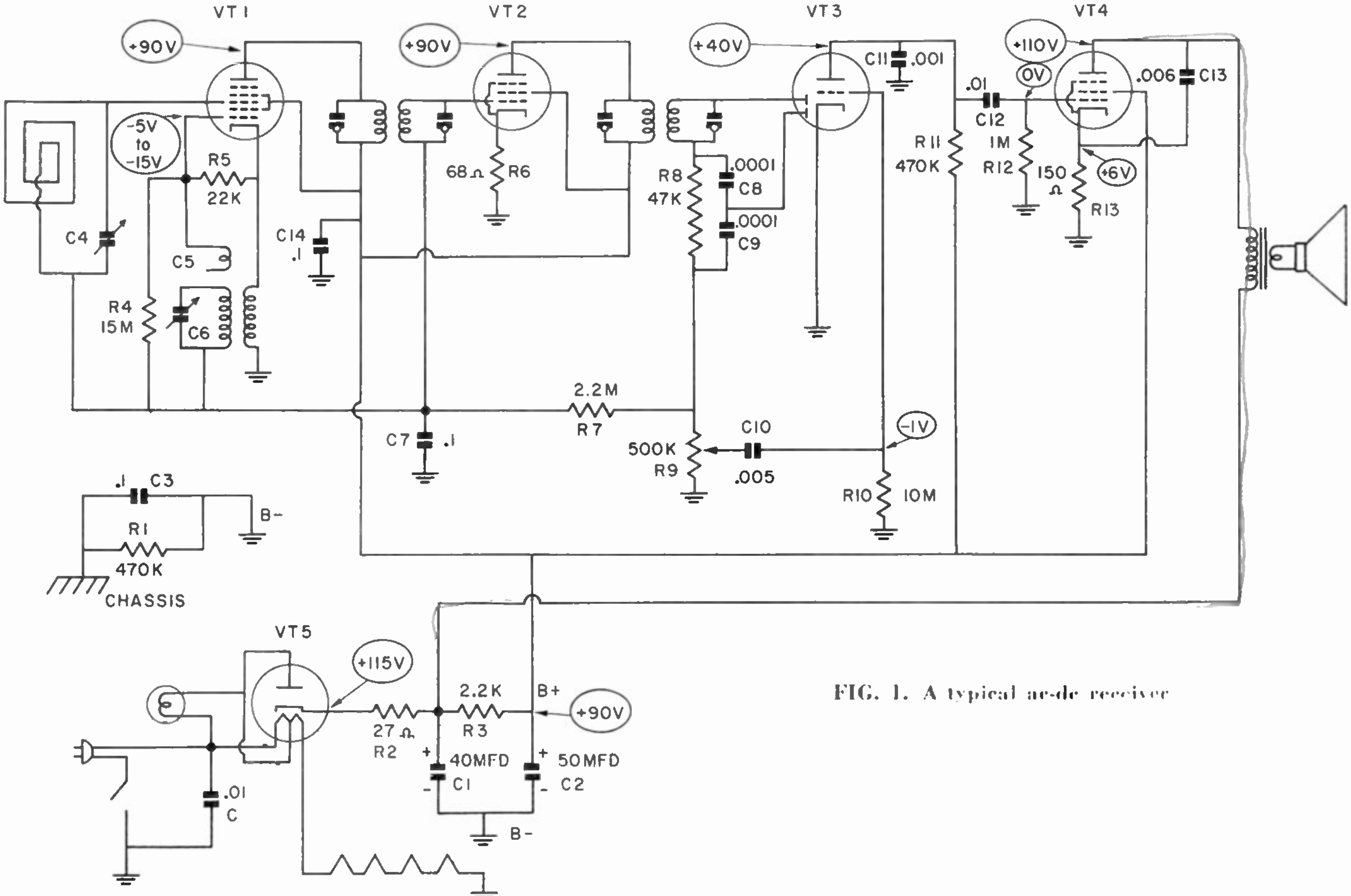


FIG. 1. A typical ac-dc receiver

removed entirely and replaced. If the capacitor is not at fault, the cut ends of its leads are bent so they are as close to each other as possible and are soldered together.

Since C13 is almost sure to be defective if the trouble is not in C14, you clip either one of its leads and again check the circuit. C14 is not found in every receiver, but is used in the better sets. If C2 ceases to be a satisfactory rf by-pass, the presence of C14 prevents oscillation and makes replacement of C2 unnecessary at that time. Thus C14 may lengthen the useful life of C2 by a year or more.

If neither C14 nor C13 is at fault, the circuit leads are disconnected one at a time to note the effect on the B+ to B— resistance. If, for example, disconnecting the B+ lead of the 2nd i-f transformer from the circuit causes the resistance to go up to normal, you know the leakage to B— is between the end of the disconnected lead and the plate socket or screen socket terminal of the tube. Examine each joint for excess solder or a leakage path and look for a break in the wire insulation. This is the way professionals operate.

Output Tube. Now, let's take another case in which the voltages are low as before, but this time, the filter capacitors are OK, and the resistance to ground is high enough. What now? Obviously, if we have an excessive current drain, something must be causing it, something which is not a part used in the actual production of the voltage. Instead you would suspect a bypass capacitor, a tube fed from the voltage supply, etc. VT4 in Fig. 1 is the only tube that could consume enough current to cause this type of trouble, so it is tested first. If the tube has gas in its vacuum, the ion flow in the tube cathode-grid path will upset the operating bias by producing a voltage drop across grid resistor R12 with such polarity as to make the control grid positive. This increases the tube cathode current several times its normal amount. This excess current will load the input filter capacitor C1, dropping the B supply voltage.

It takes a little time for the gas to ionize and the effect is not noticeable when the tube is cold, but appears after the tube has been in operation long enough for the parts to get hot enough for any gas clinging to them to be driven out into the electron stream. This will not be shown up on an emission type of tube tester. Therefore, to confirm the presence of gas in the tube, let the set run long enough for the trouble to show up, and then check for a voltage drop across resistor R12 with a vtvm. This voltage in the average set should be zero, as the grid is returned directly to B-minus. If you read a small positive voltage, say 1 or 2 volts on the grid, let the set run for another minute or two, and recheck. If this voltage has increased, the tube is probably gassy. Replace the tube, and remeasure the voltage. If it has gone back to zero with a new tube, you have probably found the trouble. Let the set run for five minutes or so with the voltmeter connected across the grid circuit, and see if the unwanted voltage shows up again.

Cathode-to-heater leakage in the output tube will also cause excess current flow through the rectifier and filter circuit with a resulting drop in the dc voltage. However, this trouble will also give you other confirming symptoms, such as a decided hum and quite perceptible distortion in the sound, due to the change in the power tube bias voltage across R13. In fact, the complaint will be hum rather than weak reception. Use these auxiliary symptoms to help you decide just where the defect lies.

Coupling Capacitors. If we have installed a new tube, and we still have a positive voltage on the grid, we can assume that coupling capacitor C12 is probably leaking. We test this in the same way; disconnect one end of the capacitor, remove it from the circuit, and measure the voltage again. If removing the capacitor eliminates the positive voltage on the grid, and allows the plate voltage to return to normal, we replace the capacitor. Remember, gas in a tube or a leaky coupling capacitor will, through the change in bias, produce distortion in the signal as well as low B supply voltages. In some cases the *main* symptom will be distortion caused by incorrect grid voltage, and in others the *main* symptom will be weak reception due to low B supply voltage on the mixer and i-f tubes. Always check the control grid voltage after a new tube is installed because only a slight amount of coupling capacitor leakage will cause the tube to become gassy. If caught quickly, no permanent damage will result.

DEFECTS IN THE AUDIO SECTION

Now suppose that the high voltage at the rectifier cathode or filter output is normal. Before you go on with your voltage measurements, one quick check at this point can bypass several detailed tests, and most professional technicians use it. They simply turn the volume of the set full on, and touch the grid of the first audio tube with a finger tip, or a small screwdriver. To do this, slide your fingertip down on the metal shank of the screwdriver, then touch the grid, or the top of the volume control. Listen for the "honk" produced, and judge the condition of the audio end of the set by the response. This is perfectly valid as a short cut. If you get a good loud honk from the audio grid, you can assume that the audio end of the set is in good shape, and that your troubleshooting should be done in the mixer and i-f stages. Incidentally, this test assures you that the power supply is all right. If there was any trouble in it, you would not get a loud honk, but a weak one. Many men make this their first test, as it saves quite a bit of time.

If you don't get a loud enough honk at the input of the audio section, then there is trouble in the audio stages. Make the voltage-circuit disturbance tests, starting at the power tube, and working your way toward the antenna, to find the defective stage and then concentrate on the parts in that stage.

Open Coupling Capacitor. An open coupling capacitor can cause a set to stop playing entirely, or to play very weakly on very powerful stations and is a common cause of trouble. Test for this by shunting another capacitor of approximately the same size, across the suspected unit. If it is open, the set will begin to play when the new capacitor is connected; at least, normal background noise will be heard if the set happens to be tuned off a station. Now and then, you'll find sets in which open coupling capacitors will not stop the signal completely because there is stray coupling between the wiring and other parts. The signal, instead of having an easy path through the capacitor, is forced to travel through the very small capacity offered by the wiring. Incidentally, check the action of the volume control itself if you find this trouble. It is possible for the volume control to become open, at the *top* end, thus opening the signal path, and not allowing the audio signal to get through to the slider, to be fed to the grid. In this case, you would have a very weak signal, and the volume control would have no effect upon it whatsoever. This, however, is quite rare. You can also have another kind of trouble, not in the weak department. If the control opens at the *low end*, you'll have maximum volume at all times, with no control over it at all.

When checking for open coupling capacitors in the audio end of the set, you can also make the circuit disturbance test with the probe of your voltmeter. If you touch a grid and hear a pop, then touch the plate, to which the other end of the coupling capacitor is connected, you should hear almost the same pop. A pop at one end of a coupling capacitor, with no pop at the other, is an almost certain indication that the capacitor is open.

Plate Load Resistor. Another cause of weakness can be the plate load resistor R11 of the first audio tube in Fig. 1. This resistor is usually high in value, from 240,000 ohms to .5 megohm, but if it decreases in value or opens, the volume of the set will be severely affected. A normal reading on a vtvm at the plate of common triode tubes used in this circuit such as the 12SQ7, 12AT6, etc. is 40-60 volts. Watch for a too high reading. If the tube is weak, or there is something wrong elsewhere, the tube will not draw enough plate current and the voltage will be too *high*. If you read a low voltage, 15-20 volts here, check the resistance of the load resistor and also check the tube. Substitution is probably the best and easiest way to test this tube.

Gassy Tube. Gas in this tube can also cause trouble by upsetting the grid bias. Common commercial circuits use a very large resistor in the grid circuit, as high as 15 megohms,

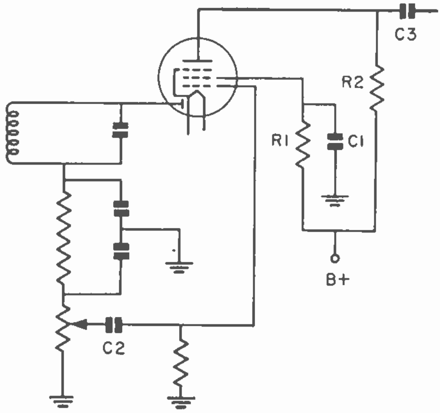


FIG. 2. First af stage in a modern battery or 3-way portable receiver.

and even very small gas currents flowing through this large resistor can upset the bias enough to affect the gain of the stage seriously.

If the tube is one of the pentode-diode types used in some circuits, such as 1S5 or 12SF7, shown in Fig. 2, and the volume is low, check both the screen resistor and the screen bypass capacitor shown as R1 and C1. This resistor is commonly as high as 3.3 megohms, which will give you a normal voltage reading of around 5-10 volts on the screen grid, even with a vtvm. As you can see, in a circuit with so much resistance, even a very small leakage in the screen grid bypass capacitor will cause a serious upset in the screen voltage. Often the screen resistor itself will open or increase in value without any defect in any other part. Watch this resistor. It is a very common source of trouble.

The plate resistor, R2, used with these tubes, runs around 1 megohm, and in some sets is as high as 2.2 megohms. Check the value from the color-code bands of the resistor, and measure the resistor to see if it conforms to its color-coded value.

Causes of Weak Reception in the RF-IF Section

Now, suppose when we made our quick check at the grid of the first audio tube we found that the audio section was OK.

From the audio stages, moving on up the circuit toward the antenna, we find the i-f amplifier stages to be our next possible source of trouble. Let us see what could go wrong there.

I-F STAGE

The first step here is the same as in the audio stages. Measure all voltages, plate, screen, and grid, and check all tubes. Here, too, we'll find that the pop at the grids and plates of the tubes is a good indication of the quality of the stage as far as its gain is concerned. If we get a good loud pop at the grid of VT2 and then a very small one at the plate of VT1, we can stop right there and look for trouble.

Checking the I-F Transformer. The only thing between the two points is the i-f transformer itself. Therefore, we test it first. With the set on, and receiving a station, however weakly, carefully turn the alignment adjustments just a little bit, first one way and then the other. As you will remember from the book on alignment, each one of these tuning adjustments, if normal, should be pretty sharp. That is, they should show a peak with only a *small* rotation of the adjustment control. In other words, if you have a signal, it should fade out rapidly as you turn the tuning adjustments, within a half turn if the transformer has trimmers, and within a full turn if it has core adjustments. If the transformer is all right, you will notice that the signal fades out as you go either way from the present setting. If there is trouble in the transformer, you'll find one of the adjustments that will have no effect or only a very slight effect upon the signal level. No matter how far you turn it, or which way, there will be no change in sound output level. This is *always* an indication of trouble in any tuned circuit.

Turn the set off, and check the resistance of the windings of the transformer. In an input transformer and in an interstage transformer, both windings should have the same resistance; in an output i-f transformer, you may find that the i-f filter resistor R8 is inside the can, in series with the output winding, making it impossible to connect your ohmmeter directly across the winding to check its resistance.

If you are still doubtful about the condition of the i-f transformer, set your signal generator to the i-f of the receiver and feed the signal generator output into the mixer grid. Carefully note the avc voltage. Now, move both alignment adjustments on the suspected transformer to see if each has the desired sharp peak. If one has a sharp peak, and the other is very broad, you can probably restore the set to normal by replacing the transformer.

Weak reception due to broad tuning of a transformer is often caused by electrolysis of the windings. A break in the enamel insulation of the fine wire has allowed an electrolytic action to start, which has eaten up the wire itself. Windings that have suffered this kind of damage will have a very high resistance, compared to a normal winding. Instead of the correct 15-30 ohms, they will read up to 1000 ohms. Readings of 100-200 ohms indicate electrolytic damage just beginning. At the start, electrolysis will produce intense noise in the receiver. In more advanced cases the set will be weak or dead.

Another cause of weak reception can occur in the small iron-core i-f transformers used in many late model sets. Most of these transformers are tuned by powdered iron cores and are resonated by small *fixed* capacitors. These capacitors are part of a base assembly, made of small plates of metal with plastic separators, held by small clips, brackets, etc. in the base of the transformer. This is very common in the output transformers, which use the small 100-mmf capacitors of the i-f filter, together with the actual resonating capacitors, as a part of this assembly. If moisture gets into this assembly, it will cause high resistance leakage between the capacitors, sometimes even a short between the primary and the secondary.

This last condition is easily spotted upon making voltage measurements as it causes a high positive voltage to appear on the grid of the following tube. Remember, in *any* radio receiver, *no grid* should ever show a positive voltage.

The best and final test, of course, for this trouble is to substitute another transformer. Fortunately, this is quite easy, as most of these are clip-mounted, with the wiring brought to lugs coming through the base. Both mechanical and electrical removal is easy and a new transformer may be slipped in place.

Tube. Sometimes weak reception is caused by a combination of defects. If the reception still seems weak after a defective transformer is replaced, the tube may be contributing to it. Even though the tube tested good in a tube tester, it might pay you to check it here, by checking the avc voltage. To do this, hook up the signal generator and connect the vtvm across the avc line. Set the signal generator to produce a reading of 3 volts. Now, replace the tube and read the avc voltage. If when the i-f amplifier tube is replaced, the avc reading immediately rises to double its former value, we can see immediately that the original tube was weak enough to affect the performance adversely. On the other hand, if we begin with a 3-volt reading, and a new tube causes a rise of only .2 volt, to 3.2 volts, this is not enough to be noticeable and the original tube is still OK.

After you replace a tube in a tuned circuit such as this, you should check the tuning adjustments to see if the maximum signal is being developed across the avc network because small variations in interelectrode capacity and mutual conductance might cause the tuning to be slightly off if the tubes are changed. The readjustment needed will always be very slight, but it should always be checked.

Misalignment. As you have learned, misalignment of the i-f amplifier stage can cause a loss of gain. This can give us weak reception. There will be no distortion, hum, or other indication of trouble. The tone will be fairly good, but the volume will be entirely too low.

Therefore, after checking the other causes, such as low voltages and weak tubes, the technician checks the alignment. He tunes in a station, and roughly checks the alignment by turning each of the i-f adjustments, either trimmers or slugs, to see if he can get any great rise in the volume. If he does find that he can increase the volume to any great extent by this procedure, he stops to give the set a complete realignment.

The first thing that he checks for in cases like this is the possibility that the i-f adjustments have been tampered with by the customer or by an inexperienced tinkerer. In most cases, there are obvious signs, such as scratched or damaged adjusting screws on i-f transformers, caused by the use of too large a screwdriver. Fortunately, most of the new sets use the iron-core i-f transformers, with recessed adjustments, which are not quite so conspicuous as the tuning screws of the capacity-tuned type. Hence, they are not as often tinkered with because the customer does not recognize them as adjustments. Thus, he unwittingly saves himself quite a bit of money. Any technician can tell you that 75% or more of the actual alignment work he is called upon to do is caused by the mistuning of adjustments by amateurs, rather than by natural causes. In sets with iron-core i-f transformers, actual drift off frequency is almost non-existent, and the only time realignment is required is after a transformer or tube has been replaced.

USING A SIGNAL TRACER

The signal tracer can be an invaluable aid in solving a problem of lack of gain somewhere in an i-f amplifier, for example. Let us see how we would use the signal tracer along with the signal generator to track down the cause. We will assume that the stages have been realigned.

First, we set the signal generator to the frequency the receiver is tuned to, and connect it to the grid of the mixer tube. Now we measure the output of the signal generator with the signal tracer by tuning it to the same frequency and connecting its probe directly to the mixer grid, where the signal generator is connected.

Note the setting of the gain control for reference, and then move the probe to the mixer plate, tuning the signal tracer to the i-f signal frequency. The gain shown here is the conversion gain of the mixer stage. Next, move the probe to the grid of the i-f amplifier tube. If the transformer is all right, you may see a small amount of gain or even a slight loss through the transformer itself; this varies with sets and circuits, and experience will be of great value in determining the normal amount of gain in such cases. In any case, you should not have a large loss. If you see quite a large loss in going through an i-f transformer, it would be wise to check it, possibly by substitution.

Next, go to the i-f amplifier plate and measure the signal voltage there. There should be quite a large gain through the tube, because most commercial i-f stages are designed so that the tubes provide the gain and the transformers give the selectivity, although there is often a certain amount of gain in the transformers themselves, if they are of the high-Q iron-core type. If you are dissatisfied with the showing, change the tube and touch up the alignment to see if you can get a perceptible increase in the gain.

Different circuits make different demands upon a tube. For instance, in many cases a tube that measures 2/3 of its rated output will cause trouble by low gain in i-f amplifier or mixer-oscillator stages, whereas a tube that measures only 1/4 or less of its rated output would be just as good as a new one in the first audio stage. In the first af stage, which has very high plate resistors, a great deal of the tube's emission can be lost before it will affect the performance; in the i-f amplifier, a tube with a loss of 1/2, will show a definite loss in sensitivity. When you get into TV work, you will find several circuits in which the gain is unimportant; for example, sync clippers and separators are very criti-

SECTION	WHERE MEASURED	MIN GAIN	MAX GAIN
RF	Antenna to 1st grid Antenna to 1st grid, auto sets RF amplifier, supers, broadcast	2 10 10	10 50 40
MIXER	Converter grid to 1st i-f grid (single i-f stage) Converter grid to 1st i-f grid (two-stage i-f)	30 5	60 30
I-F AMPLIFIER	I-F stage (single stage) I-F stage (two-stage i-f, per stage)	40 5	180 30
DETECTOR	Diode detector (a loss—depends on % modulation)	.2	.5
AUDIO AMPLIFIER	Triode (low gain) Triode (high gain)	5 22	14 50
POWER OUTPUT	Pentode and beam	6	20

TABLE I. Average gain data.

cal. In some cases, tubes that will not work at all in these stages will work perfectly in some other stage. Therefore, we say again, the final test of a tube's quality is its performance in the circuit in which it is used.

You can go all the way through the i-f stages with the signal tracer, taking a reading at each grid and plate, and watching for the gradual increase in the reading, until you get to the secondary of the last i-f transformer. Normally, with a tuned signal tracer, there will be an apparent drop in the i-f signal across this transformer. This may be as high as 3:1 in some sets. This is perfectly normal, and is due to loading of the transformer by the diode detector.

If you find any tube or transformer, as you work your way through the i-f stages, that shows a loss, or shows no gain where there should be a gain, stop and investigate it, and don't go on until you have found and corrected the trouble. It may be a weak tube, a defective or mistuned transformer, a leaky bypass capacitor, or something else. Whatever the defect is, it will invariably show up as a loss of gain where there should be an increase. Practical experience will soon let you recognize the different gains that you should find in the various stages, and you'll be able to determine quickly whether or not the gain is normal.

Of course you must have some idea of the gain to expect when passing from one stage to another. Many manufacturers include gain measurements in their service data. When such information is not available, you can use the gain values listed in Table 1. However, these are only average values. You may find some normal receivers with stage gains slightly outside these minimum and maximum values. Therefore, you can't rely on them absolutely. You will have to supplement them with what you learn from experience with actual receivers. Even when you get a reading within the average limits, you will have to be careful. It may be below normal for that particular set. That is, if you get a reading near the minimum value in Table 1, you won't always know whether this is natural for the receiver, or whether the gain for this particular stage should be near the maximum value. Be critical of any low gains when the customer's complaint is weak reception.

Exactly the same method can be used in audio stages, by feeding a signal at audio frequency into the volume control, and following it through the audio amplifier stages. Remember that there will be a decided loss in signal *voltage* across the output transformer, as we are stepping down here from a very high impedance circuit to a very low impedance one (10,000 ohms plate resistance to 3-4 ohms voice coil). This naturally causes a great loss in voltage, but permits a high current flow. You will also note that the voltage gain across the power tube itself is not large. *Voltage* amplification of the signal is used in the preceding stages, and here, in the power tube's plate circuit, we are changing to *power* amplification, with the result that we may not have as high a signal *voltage* as we might expect, but do have much more *power.*

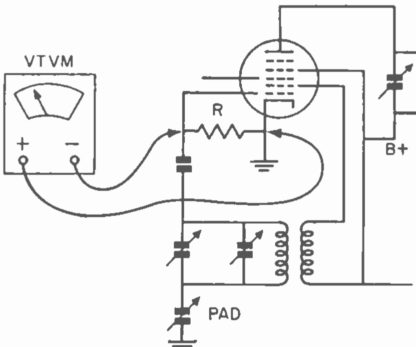


FIG. 3. Measuring the grid voltage of the oscillator with a vtvm.

RF SECTION

The "front end" of a radio set has many potential sources of weakness. Alignment adjustments are usually plainly visible, and are subject to tinkering, even more so than the i-f adjustments. The rf amplifier, if used, can be defective, or the mixer control grid circuit can be bad, or mistuned. Let's check the oscillator circuit first.

Oscillator. As you know, most of the tubes used in this circuit are a combination of oscillator and mixer tube, using several grids, two of which act as control grid and plate for the set's oscillator. If the emission of this tube falls off, even to a small extent, the performance of the oscillator suffers because the tube is unable to furnish the required amount of local oscillator voltage. This will result in a lowered heterodyne beat voltage (i-f signal) at the plate of the tube. Since a lower than normal signal is fed into the i-f amplifier, the output is below normal. Also, if the oscillator is weak, the mixer section will also be weak, contributing to the loss of gain. As before, substitution of a new tube is the best and easiest test to make here. If the new tube increases the output, bringing it back to normal, that was the trouble.

To check the operation of the set's oscillator, measure the grid voltage: this should be done with a vtvm, because of the high impedance of the circuit. Take this reading on the oscillator grid itself, across the grid resistor, as shown in Fig. 3. As you know, this dc voltage is developed across the resistor by the grid current drawn by the oscillator. The more efficient the oscillator circuit, the greater this current, hence, it may be used as an indication of the circuit condition. Normally you will measure from 6-8 volts at the low-frequency end of the dial, and from 12-30 volts at the high end, depending upon tube type, circuit constants, etc. It is usually sufficient to check only at the low-frequency end, as this is where most of the trouble shows up. If a set has a weak oscillator, its performance will be affected at the low end of the dial first, and the high end last. Stations at the low end will be weak, whereas the stations near the top of the band will have normal volume. Learn to look for this peculiarity, which is a good clue to possible oscillator trouble. Misalignment of the i-f amplifier increases the mixer-oscillator tracking error and results in the same symptom.

If the oscillator voltage is weak or entirely gone at the low end of the dial, try replacing the tube, even though the original tube checks fairly good. Because of peculiarities in this circuit of two tubes that check the same in a tube tester, one may oscillate and the other may not.

If there is still trouble after a new tube is put in, check the rest of the circuit consisting of the oscillator coil itself, the grid resistor and capacitor, and the tuning capacitor. Many of the older sets had trouble due to moisture absorption by the insulators of the stator section of the tuning capacitor resulting in leakage. This has the same effect as shorting a resistor across the tuned circuit. The Q of the circuit is reduced tremendously, and the output is also reduced. Because a coil is almost always connected across this capacitor, you will have to open the circuit by disconnecting the coil at one end in order to be able to take a resistance reading across the capacitor. Use the very highest range of your ohmmeter, as a leakage of even several megohms is enough to affect circuit operation.

Troubles in the oscillator coil are the same as in the i-f transformer windings. Look for electrolysis of the windings, mainly the primary or tickler winding, which carries the feedback current. Check the grid resistor for the proper value, as read from the color-coded bands. If this resistor changes in value, either up or down, the oscillator circuit will be affected. Measure the grid capacitor to see if it is leaking. Most of these are small mica capacitors, around 250 mmf, and give very little trouble, but now and then a defective one is found, so don't overlook it.

While we're on the oscillator circuit, let's mention one defect that is not common, but occurs often enough to be worth mentioning. This is found in the circuits of Fig. 4. Note that a very large resistor connects the return of the oscillator coil to the avc circuit. It feeds a small amount of the oscillator dc grid voltage back into the avc circuit so there will al-

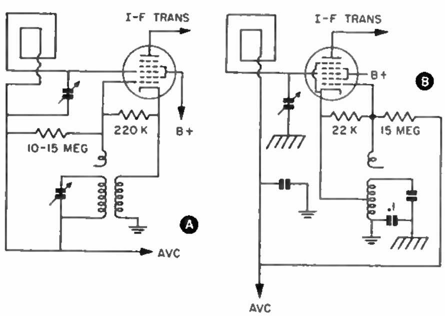


FIG. 4. Typical oscillator circuits where the oscillator bias is fed to the avc line to provide starting bias.

ways be a bias voltage for the avc controlled tubes even when a station is not being received. In this case, the resistor is connected to a terminal of the coil, used as a terminal lug. None of the coil wires are connected to it. If the coil develops leakage, quite a bit of the oscillator dc grid voltage is fed back into the avc circuit reducing the receiver sensitivity. This could occur only in the circuit shown in Fig. 4A where the rotors of the tuning capacitors connect to the avc circuit instead of the chassis. If the circuit shown in Fig. 4B is used, leakage in the oscillator grid coupling capacitor will simply reduce the oscillator grid voltage. If the leakage becomes low enough, the oscillator will stop working.

Input Circuit. Now, if you have sufficient oscillator voltage, check the input circuit, or the mixer grid itself. If the set has a stage of rf amplification, this would include the tuning capacitor, the secondary of the rf interstage transformer, the trimmer capacitor, and the wiring itself.

Check the resistance of the coil, to see if it is open or has suffered from electrolysis. Measure the grid voltage, to see if it is a very small negative voltage, which is normal. In some sets, the avc is not applied to the mixer grid. In that case, the dc grid voltage will, of course, be zero. Check the tuning capacitor, and the trimmer capacitor mounted on top of it, to see if it has any leakage across it, or if the small mica sheets have shorted out in the trimmer itself. If so, you can replace them with mica from a discarded trimmer. Also, check the alignment of this stage by feeding a signal into the antenna and checking the trimmer to see if it has a normal peak. If this trimmer is flat, with no peak, the stage is defective; check coils, etc. and the oscillator alignment. It is possible for the oscillator to be so far off that the rf stage will not track it properly, which will cause the trimmer to be flat, since its resonant frequency is too far away from the frequency for which it should be tuned.

If the set has no rf amplifier stage, the pentode section of the mixer tube serves as the rf amplifier. The loop antenna is connected directly to the mixer control grid. In the older sets in which a tube with a grid cap is used, the wire from the antenna section of the stator plates of the tuning capacitor goes directly to this cap. Modern single-ended tubes have the grid on the base, and the wire from the tuning capacitor to the grid goes from the bottom lug of the stator. However, the wire from the loop antenna usually is connected to the top stator lug, thus identifying the antenna section of the tuning capacitor. Also, as you have learned, these tuning capacitors are usually made with the two sections of obviously different sizes. The oscillator section is much smaller than the antenna section.

Tune in a station or a signal from your signal generator at the high end of the dial, around 1400 kc, and check the antenna trimmer for a proper peak. These trimmers may not have quite an exact peak, but will rise in output, as the trimmer is unscrewed from its maximum capacity position, until maximum output is reached, then level off, with no further increase in output as the trimmer is unscrewed. This is not normal, and is caused by aligning the receiver with the dial pointer set incorrectly. In such a case, complete realignment is required.

In everyday service work, one of the most frequent problems is actual misconnection of the loop wires by the owner or an inexperienced radio mechanic. With the very low gain of most loops, correct connections are essential, and a small misconnection can rob the set of almost all its signal input. These connecting wires are very small in most cases, and the instructions on the back cover generally specify "Remove this screw and fasteners and move loop back, to check tubes." However, the professional radioman generally removes the whole set from the cabinet, leaving the loop fastened securely to the chassis. He knows that this will give him much better access to the tubes, and at the same time prevent damage to the loop itself. Taking the set out of the cabinet is usually quicker than removing the loop, and working inside the crowded cabinet. The customer, however, is apt to follow the instructions, and remove the back and loop; while doing this, he usually manages to break one or more of the loop wires, and then is apt to put them back in wrong, merely wrapping them around the terminals, not soldering them in place.

For these reasons, one of the first things the professional technician does when checking a radio is to examine the loop wiring closely to see if it is all right. One common misconnection is for one loop wire to be fastened to the antenna tuning section, the other to the oscillator section. Incidentally, this usually makes a loud oscillation.

If the set in question is quite old, and a loop antenna is in obviously bad condition with several turns loose, insulation frayed, etc., you would be better off to replace it entirely with a "loopstick", one of the small high-Q iron-core loops available now. This will cure many sets with a complaint of weakness, as the higher gain of the Loopstick will increase the over-all volume, and since it is adjustable, you can make the antenna track much better by making padding adjustments at the low-frequency end of the dial, as explained in the book on alignment. If the cause of weakness is still not apparent, after you have checked everything else, try replacing the loop to see if that helps correct the trouble.

ALL-BAND, AUTO, AND TV SETS

In the more elaborate sets, such as the "all-band" sets, with several short-wave bands, auto radios, and portables, you may find troubles other than those we have already described, but in the majority of cases, the troubles are the same.

All-Band Sets. In the all-band sets, weakness traced to the antenna stage or rf stage may be due to bad connections in the band switch, which switches the different coils into the circuit for the different wave bands. If an rf secondary coil, for instance, were to remain open on a given band because of a dirty contact on the switch, the result would be the same as an open coil in a single-band set.

Battery Sets. The battery-operated sets used for farm reception are meant for use with a long outside antenna. Hence, most of them use a standard antenna coil in place of the common loop antenna just as the older ac sets did. This antenna coil has two windings, a primary which is connected to the antenna itself and to an external ground, and a secondary which is connected from the grid of the rf amplifier tube to the avc. It was quite common to find these sets with the primary of the antenna coil open because of lightning, physical damage, or corrosion. This can be quickly checked with an ohmmeter, and the normal average resistance of this winding should be from 50-100 ohms, measured from the antenna lead to chassis. If the coil is open, take a very close look at it, using a high-powered magnifying glass to see if you can spot the broken ends of the fine wire. If so, you can often clean them and solder them back together. The breaks are usually in the leads from the coil winding to the terminal lugs, and you can simply unwind a turn or two, and make a new connection. This can be done even on the tuned secondary, without too much trouble, and it will have no measurable effect.

Auto Sets. In the auto radio, if you get a complaint of weakness, you must check practically everything in the set, just as outlined before, and in addition, before making any tests upon the radio itself, even before removing it from the car, you should check the battery voltage and the antenna. The voltage must be within its normal range; for 6-volt cars, not less than 5.5 volts, and for 12-volt cars, not less than 11 volts, at the set fuse, with the set turned on.

The antenna must be checked for continuity and freedom from short circuits or leakage; both of these will tend to make the set weak by shunting off to ground a part of the signal voltage. A complete discussion of this will be found in your regular lessons.

Let us take up one more typical trouble in auto radios. If the set will receive a local station at about 1/3 normal volume, but will get no others, look for a burned-out rf amplifier tube. Here's the reasoning on this: you can hear the local station, therefore, the oscillator, i-f, and audio stages are working. It is quite possible that the power supply is all right, especially since you can hear the station, even though it is fairly weak. Therefore, the signal is probably coming into the set, but instead of being amplified by the rf stage, it is merely leaking through the stray capacity of the wiring, socket, etc. You can quickly check this without even pulling the set from the car, in most cases. Simply remove the lid of the case and look for the rf tube. Even though it is lit, replace it. It may have an internal short or leakage. The same symptoms can be caused by open coils, etc., in the rf stage. To check these you must remove the set. Therefore, since tubes furnish almost 90% of this type of trouble, it is certainly worthwhile to check them before removing the set from the car.

TV Sets. Although it is a little too early to try to do much TV work, we will briefly mention a few minor causes of weak reception that can be easily remedied. The symptoms in TV are quite different from those in radios. Weakness will show up in the picture first, unless there is a weak tube in one of the sound circuits, such as the discriminator, sound i-f, or audio amplifier. In that case, substitution will readily show the trouble. Most complaints of weakness in a TV set will show up first as "snow" in the first picture.

The first thing to do is to find out whether there is an actual defect or whether the signal in that area is simply too weak to be picked up. You can check this by comparing it with reception on other sets in the same area. The trouble may lie in the antenna, especially in outlying suburban and fringe areas. A low signal level will always result in a large amount of snow.

This can be caused by several things. It is a good idea to check the signal level before doing any work on the set itself. The only way of doing this is to measure the signal strength, using a TV "Field Strength Meter", which is merely a calibrated vtvm with a TV tuner and amplifier, whose output is fed to an indicating meter. Take a reading of the signal strength on the desired channel; if it is well below normal, check the lead-in for broken wires, and see that the antenna is pointed in the right direction if it is a directional type, as most secondary and fringe-area antennas must be.

Practically all modern antennas in primary signal a eas use some variation of the folded dipole. In this type of antenna, there is always continuity between the bottom ends of the two conductors in the twin-lead used for connecting the antenna to the set. With this arrangement, you can check the antenna lead-in and its connections to the antenna for continuity by taking an ohmmeter reading at the set. For ordinary lengths of line, up to 100 feet, you will get a very small reading, only a few ohms. If the line is open, you will get no reading at all. Look for places where the lead-in may have been sharply bent, such as under a window, over the eaves, etc., as these are the most likely spots for a break.

Another and very unhandy place is at the terminals of the antenna. Often, because of careless installation, the line is left unsupported, and wind pressure causes the line to bend and break loose up there. Lowering the antenna and repairing the break is the only remedy for this condition. When the antenna is down, install a stand-off insulator within five or six inches of the antenna terminals, and use terminal lugs on the ends of the wires to take up the strain of the connection and avoid future breakages.

This continuity test is of no use on Yagis or plain dipoles because they do not have continuity. With experience, you will be able to tell by looking up at the antenna whether or not there should be continuity. Often a good pair of binoculars will save you from having to climb the antenna to look.

If the antenna is OK, the next thing is to check the tubes. If the picture is quite snowy, but the sound is fairly good, there is probably trouble in the rf amplifier. In fact, this one tube gives more trouble than all the rest combined. It should be replaced first, and the picture checked. If this does not make any perceptible difference, put the original tube back in, and change the mixer-oscillator. Continue changing tubes, one at a time, in this order: rf amplifier, mixer-oscillator, first video i-f, second video i-f, third video i-f, fourth video i-f, video detector. It is also possible for the video output amplifier to cause snow, but it is very unlikely. One other possibility is weak rectifier tubes or low selenium rectifiers. A drop in the supply voltage could cause snow, but more likely the oscillator action would be affected first. This, of course, varies with different sets. To check this, measure the supply voltage, which should be fairly easily accessible, at the high-voltage fuse holder. In a transformer-operated set, this will run from 300-400 volts. In the series-filament sets with voltage-doubler selenium rectifiers it will be about 250 volts.

How to Fix Intermittent Receivers

Intermittent defects in either radio or TV sets are those that are not present all the time, but occur only from time to time. Actually, this type of trouble can be the serviceman's worst headache because of the difficulty of making an accurate diagnosis with symptoms that appear and disappear. An intermittent may cut out at intervals ranging from one minute to several hours, with the troubles showing up for only a short time. The situation is made even more annoying by the fact that the application of test instruments may shock the set back into operation.

This requires a somewhat different approach to the service problem, and a different use of our familiar test instruments. On the average, an intermittent defect takes longer to find than several ordinary troubles.

Except for the fact that they come and go at odd intervals, intermittent defects are identical to those you have been studying. Always remember this: the same general defects that cause permanent trouble can also cause intermittent troubles. Why? Because the only kinds of trouble that you can have in a radio or TV set are: shorts, opens, and changes in value. The difficulty in the case of an intermittent is that the symptoms often disappear before the defect can be localized.

However, with the proper use of test equipment, and a thorough knowledge of the set's circuits and of the characteristic effects of certain defects, you will be able to fix intermittent defects also.

Probably the most important single point in hunting intermittent troubles is this: IF YOU GET AN INTERMITTENT TROUBLE, LOOK FOR THE PARTS THAT WOULD CAUSE THAT SAME TROUBLE IF IT WERE PERMANENT. For instance, if you have intermittent oscillation, you would start looking for bypass capacitors. If the signal was simply cutting on and off, cleanly, with no signs of oscillation, your reasoning should be, "Something is interrupting the signal path; probably a coupling capacitor." If the complaint were intermittent hum, you would look for a filter capacitor, and so on through all of the whole list of permanent troubles. If a symptom appears intermittently, look for the parts that could cause it if it were permanent.

Some servicemen use a rather drastic cure for suspected intermittents. They replace *all* of the parts that could cause it. For instance, if the signal is cutting off and there are two coupling capacitors, they replace both, with no further checking. This is a pretty good way of avoiding useless time spent in trying to pin down an intermittent, but it sometimes fails because of the lack of sufficient information upon which to base an *accurate* diagnosis!

CAUSES OF INTERMITTENTS

Let us glance briefly at what causes intermittents. All intermittent defects are caused by *temporary* shorts, opens, or leakages. In many cases, thermal expansion is responsible. This is the expansion of the chassis and parts caused by heat. For instance, a metal part of one circuit may be almost touching the chassis or another part when the set is cold. Heat expands the chassis and the part, and the metal part touches the chassis, causing a short. If this were the metal wire on a coupling capacitor, it would stop the signal entirely, until the chassis cooled off enough for the parts to pull apart again.

A poorly soldered joint may be held together well enough until the expansion of the chassis places a strain on it that pulls it apart, opening the circuit. The fastening of the wire leads to the ends of a paper capacitor may be good when cold, but pull apart when warm. This is one of the most frequent intermittents, the intermittent coupling capacitor.

Tubes are also among the most frequent offenders, because they are the source of the heat. This heat can cause twisting or bending of the metal parts of the tube electrodes, possibly causing them to short. Some tube filaments may open up when heated, only to close and show continuity when cold.

Filter capacitors in the common ac-dc sets are also troublesome. The small metal tabs that make the actual connections to the aluminum roll of the capacitor plates can become oxidized, making a bad connection that can be healed by a sudden surge of current.

Professional servicemen classify intermittents roughly into two divisions: the mechanical intermittent and the electrical intermittent. Basically, these are exactly alike, but we will divide them into these two classes because of the difference in their treatment. The mechanical intermittent is the type that can be made to cut on or off by physically jarring the set. This type will act up when someone walks across the floor close to the set, when heavy trucks or streetcars go by, or when the cabinet is jarred. Most of these can be found without too much trouble.

The electrical intermittent will not ordinarily be affected by physical jarring of the chassis. The electrical intermittent is the most troublesome type, but we will give you the best methods for dealing with it. Let's take up the easiest first, the mechanical intermittent.

•

MECHANICAL INTERMITTENTS

Paper capacitors, connections, and tubes cause most of the mechanical intermittents, but other parts may also be responsible. Let us take up each in turn.

Capacitors. As you remember from your study of paper capacitors, the wire leads are rolled into a spiral and soldered to the ends of a roll of metal foil. This is the connection between the capacitor and the circuit. If this wire becomes loose in such a way that there is a slight separation or even a resistance path to the end of the roll of foil, any small jar can cause it to make or break contact. If this is a coupling capacitor, this intermittent make-and-break will cause interruptions in the flow of signals, causing the set to cut on and off, a very familiar complaint to the practicing serviceman. Similarly, if the capacitor is used as a bypass, when it opens up, the result will be intermittent

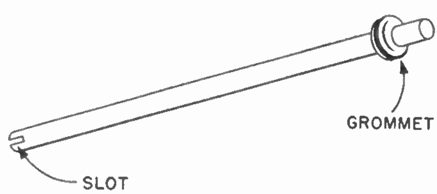


FIG. 5. You can make a tool for wiggling wires by sawing a slot in a fiber alignment tool.

oscillation that the capacitor was supposed to prevent.

Intermittent Capacitors. Intermittent capacitors can sometimes be found by the use of a "wiggling stick", illustrated in Fig. 5, and made out of an old fiber tuning tool with a small slot sawed across one end. The wire leads of suspected capacitors are wiggled back and forth with this tool in order to show up any possible loose connections between the leads and the foil roll. The same tool can be used to find intermittent connections, bad solder joints, loose tube-socket pins,

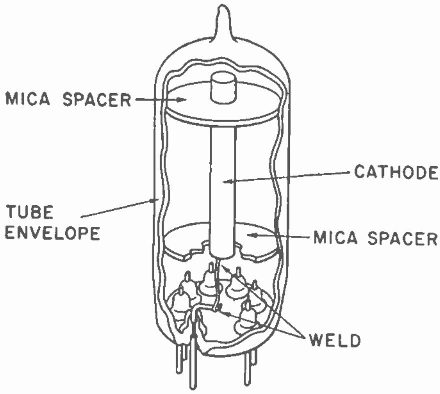


FIG. 6. Cut-away view of a tube, showing the connection to the cathode. The rest of the elements have been omitted in this sketch.

etc. If the trouble shows up when any particular part is moved, check carefully by wiggling all of the parts around that junction to see which one is giving the trouble. Noise when a connection is moved is a sure sign of trouble somewhere near there.

Tubes. Tubes cause a large percentage of the intermittents because of the heat they radiate. A broken weld in the tube structure that opens when hot and closes when cool, can cause a very puzzling intermittent. This is quite frequent in high-voltage filament tubes such as the 35Z5, 50L6, etc., which operate at very high temperatures. The cathode in these tubes, as shown in Fig. 6, is in the form of a round metal sleeve, coated with the active electron-emitting material. Connection to this element is made through a very thin metal ribbon, spot-welded to the bottom of the sleeve and to the base pin. The sleeve is held at the top and bottom by mica spacers. It is usually held firmly at the top, and loosely at the bottom, so that the cathode can slide up and down for heat expansion. Because of this tiny movement, the ribbon may come loose, breaking the small spot-weld. When the filament is heated, the sleeve will move downward, breaking the contact. If it is a rectifier tube, the cathode circuit of the tube opens, and there will be a complete loss of high voltage for the set, although the filaments will remain lighted. If the tube is the power amplifier, the cathode circuit will be opened, cutting off all dc plate and signal current through the output transformer primary, causing the set to be completely dead. There will still be high voltage on both the plate and the screen. High cathode voltage, however, is proof of an open in the circuit.

There is also the possibility of an intermittent open in the filaments. This is fairly easy to spot once it begins to show up, as all of the tubes, being in series, will go out. The problem then is only to find out which tube is open. This can be done by connecting an ac voltmeter across each of the filaments in turn. The entire line voltage will show up across the defective filament when it opens.

Coils. Coils and transformers are also affected by heat expansion. This will cause the coil forms to expand, and may cause one of the fine wires to break loose from its terminal lug if it was pulled too tight when manufactured. This can often be discovered by measuring the resistance of the coils while tapping the forms gently, or by carefully moving the leads with the wiggling stick while the set is playing.

Resistors. Resistors, like all other parts, can be intermittent. However, this trouble is confined mostly to wire-wound resistors and variable resistors, such as volume controls in radio or contrast, brightness, and linearity controls in TV sets. An intermittent contact in any variable resistor can usually be easily located by moving the shaft of the control. If the control is very noisy, producing scratching sounds in the speaker, or flashes and streaks of light on the TV screen, it will show up when moved. Cleaning it may help. If not, replace it.

The fixed wire-wound resistors used in high-current circuits in radios or TV sets, for voltage dividers, for instance, can develop intermittent contact between the resistance wire and the metal clip connections. Resistance wire cannot be soldered, so the connections are made by pressure alone. This leaves the possibility that oxidation will creep in and cause a bad contact. Such defects can be found by tapping the resistor heavily, jarring the chassis close by while listening for noise, or watching the screen for flashes or streaks.

Connections. Last but by no means least is the intermittent connections in the wiring itself. These can be caused by cold solder joints, corrosion, etc. Often, especially in the older sets, you will find ground connections for several bypass capacitors, resistors, or other parts, made to a "tie-point", several insulated lugs mounted on a strip of fiber. One of these lugs will extend past the strip, and form an eyelet, which is sometimes fastened to the chassis with a rivet. This forms a mechanical support and also the ground connection. If corrosion sets in between the lug and the chassis due to moisture, etc., you will find a very bad contact.

Poor chassis grounds can usually be located by wiggling the connections or parts, or by jarring the chassis. Once you find a poor connection of this sort, make sure of a good contact in the future by cleaning away the corrosion and soldering the lug firmly to the chassis. If the joint is so heavily corroded that you can't get the solder to stick, run a short piece of heavy wire from the lug to a close ground connection. On an aluminum chassis that cannot be soldered, a machine screw, lockwasher, lug, and nut will make a permanent low-resistance connection. If a screw connection rather than a rivet was originally used, loosening and then tightening the screw will clear up the high-resistance connection.

Finding the Intermittent. Now, for the actual methods used for locating intermittents. The mechanical type, as we said, is the easier. You can make the set cut out by jarring the chassis. Therefore, using the wiggling stick, tap the chassis at several places. You'll find several places that either cause the set to cut out or make a loud noise in the speaker. Any part that causes a popping noise in the speaker is probably defective. This is a sure sign of trouble. Never decide a set is repaired until you have found the sources of all of these noises, and eliminated them. This is one of the last steps used by professional servicemen after they finish a repair job. They always jar the set, heavily, to find any noisy parts, to avoid callbacks.

If you get a set that is noisy, start by tapping all the tubes. If one is noisy, replace it, and tap again. If this stops the noise, replace the old tube and recheck. You might have had a noisy socket connection, which was cleared up by removing and replacing the tube. Trouble of this sort is especially prevalent with "loctal" type tubes, so watch for it. However, if the noise is present with the old tube, and not with the new, but reappears when the old tube is installed, you are pretty safe in diagnosing the trouble as a noisy tube.

If the tubes do not seem to be causing the trouble, turn the set over, and tap all of the parts, one at a time, paying especial attention to capacitors, by wiggling their wire leads. Look the set over carefully for bad solder joints. Inspect each socket and terminal strip and check by wiggling the wires and parts. Usually, you'll find that one end or one part of the chassis will be noisier than others. You're getting close to the trouble so check each part in the suspected area carefully.

Now and then, you'll run into a set in which jarring will produce a comparatively small noise regardless of where you tap the chassis. No matter where or what you tap, you get the same noise. These are the most difficult of all, because of the lack of clues. Isolate the source of the noise as soon as you can by tracking it down to a certain stage. First, turn the volume control all the way down. If this has no effect on the noise, then it must be in the audio stage. If it cuts out or lowers the noise, then the defect is probably in the rf or i-f stages. Cases of this sort sometimes require drastic measures. You might replace *all* of the tubes at once, to see what effect this has, then put the old tubes back in, one at a time. Paper and electrolytic capacitors might well be given the same treatment.

Now and then, a very baffling case will turn out to have *two* causes, such as two intermittent tubes at the same time. Installing all new tubes and then putting back the originals, one at a time, will catch the bad ones. Although, in an ac-dc set, you can't pull tubes out because you would break the filament circuit, you can, if necessary, unsolder the B supply wire to the i-f transformer, for example, to kill that stage and the front end. Of course you can short out the grid circuit of any stage with a test lead or kill the set oscillator by shorting it out to disable any given stage thus eliminating it as a source of noise when the chassis is jarred.

There is another test you can make, using your signal generator. If the trouble seems to be in the audio stages, feed an audio signal, at 400 cycles, into the volume control. Turn the attenuator as high as it will go to give you the maximum signal. This will sometimes cause obscure intermittents to show up by putting a tremendous signal overload on the suspected stages. The same thing can be done in the rf or i-f stages. Feed the signal into the antenna, just as strong as you can make it. Sometimes, you will be able to get more information by turning the modulation off and using a pure rf signal. With a large unmodulated signal, tap the rf and i-f tubes gently. You will hear a ringing sound due to normal vibration of the tube electrodes, but you should not hear noise. If you do, the tube or part being tapped is defective.

ELECTRICAL INTERMITTENTS

The electrical intermittent is somewhat more difficult to find. With this type, often nothing you can do to the set in the way of jarring it will make it cut out. There are some methods of making this work easier, though. One of the best is questioning the customer as to the exact characteristics of the trouble. This will give you some valuable clues. For instance, if he says that the set plays for a definite period of time, then cuts off completely, you know that the defect is something that is heat-induced. Some part is failing when it gets hot. Look for a "hot short" in a tube, a coupling capacitor that opens when heat expands it, etc. You can make the set heat up fast by placing a box over it, on the bench, cutting off all ventilation. Holding a hot soldering iron on a part that will not be damaged (a resistor) or close to a capacitor or a coil is also a useful trick.

If the clue is the fact that the set plays normally until some other electrical appliance cuts on, such as a refrigerator, then you can suspect low voltage as a possible trouble, especially if the set is one of the little 3-way portables. If the power supply in the set is not quite as good as it should be, the lowered supply voltage caused by the extra load on the line is enough to cause the oscillator tube filament voltage to drop enough to make the set stop playing. The best way to test these is to lower the line voltage and check the performance. This is covered in your regular lessons.

Sudden surges in line voltage can cause physical movement in parts under stress such as tube electrodes and capacitor plates. This movement may open a connection. Generally jarring the parts and chassis will show up such troubles.

The intermittent tube filament may be another difficult trouble to isolate. These cut off and back on before you can find the bad one. Many servicemen have made up special testing rigs to catch intermittent filaments. As we have said before, if a tube opens up, in an ac-dc set, the full line voltage will appear across the open filament. Therefore, if we connect an indicator across each filament, when the trouble shows up, we can see immediately just which one it is. Some servicemen catch these tubes when they are acting up with automatic voltage indicating devices. Small neon lights, similar to the neon line testers are used. The lamps draw practically no current when they light up. They will not light on normal tube filament voltage, but will light on higher voltages. One neon lamp is used for each tube. They are connected across the filaments of the tubes, and the set is turned on. If one of the tubes opens up, only the neon light across it lights. A typical hookup is shown in Fig. 7.

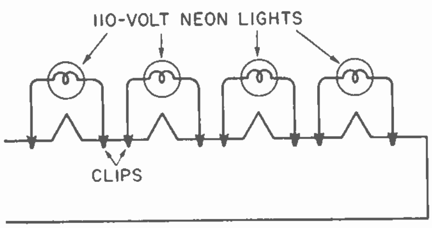


FIG. 7. How to connect a neon light across each tube filament to find which one is intermittent. If one opens, the neon light across it lights up.

The best way to find an intermittent defect is to isolate it as fast as possible to a certain stage. Then isolate the defective part by jarring, twisting, etc. If these methods fail, then take other steps, such as overheating the chassis by covering it with a box, or varying the line voltage. After that, the only thing to do is wait. The way most professional servicemen deal with electrical intermittents is simply to hook up the receiver, start it playing, push it to the back of the bench, and then go on with other jobs while keeping one ear cocked for signs of trouble.

The signal tracer is a great help when looking for intermittents. By connecting the tracer to the intermittent set, you can usually cut the volume off or down to where it will not be so annoying and can keep an eye on the indicator from time to time.

The worst problem is the large amount of time that is required to find the trouble. In really difficult cases, the customer would not be able to pay for the job if you actually charged him straight time for the amount used. Therefore, you must try

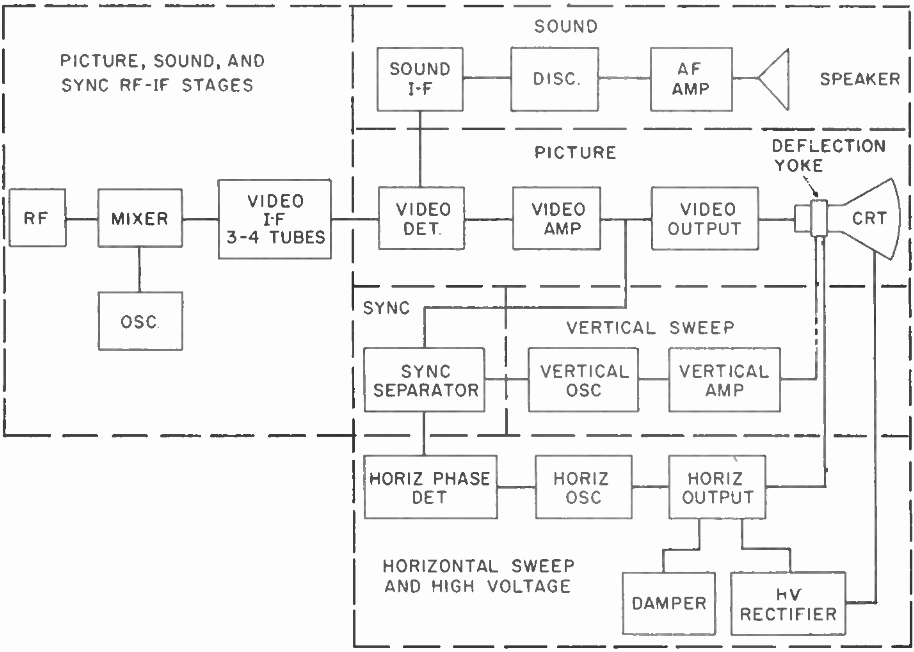


FIG. 8. Block diagram of a TV set.

to locate the trouble without spending too much actual service time. Use signal tracers, indicators, and every "short cut" you can develop in order to save as much time as possible on each intermittent job.

As a general rule, it is best to explain to the customer that you cannot accept an intermittent radio or TV set for service, if he insists on a certain time limit. Tell him that you can't take the job unless you can have enough time to be sure that you have found the trouble. Nothing is more disappointing than to think you have located the trouble in an intermittent, and deliver the set, only to have the customer call you back in a few hours, saying, "It's cutting out again!" Take enough time to be sure that you have definitely found the trouble. This means, in most cases, that the set must be operated on the bench for at least four hours before delivery, to be fairly sure that the trouble has been spotted. In some cases, even this will not be enough.

INTERMITTENTS IN TV SETS

All of the methods and practices mentioned so far apply equally to radio and TV sets. Intermittent troubles in TV sets can be found by using the same basic methods used in radio. Note the symptoms carefully to see what section of the set is affected. Make use of the block diagram, shown in Fig. 8, to identify the stages that may be at fault. For instance, if both picture and sound are lost, but the raster remains, you can suspect some stage associated with both picture and sound. Look for trouble in the front end, the video i-f, the video detector, and the video amplifiers. If the trouble lies in the high voltage circuits, the screen will go black, but the sound will not be affected. If there is a strong picture, but it is very un-

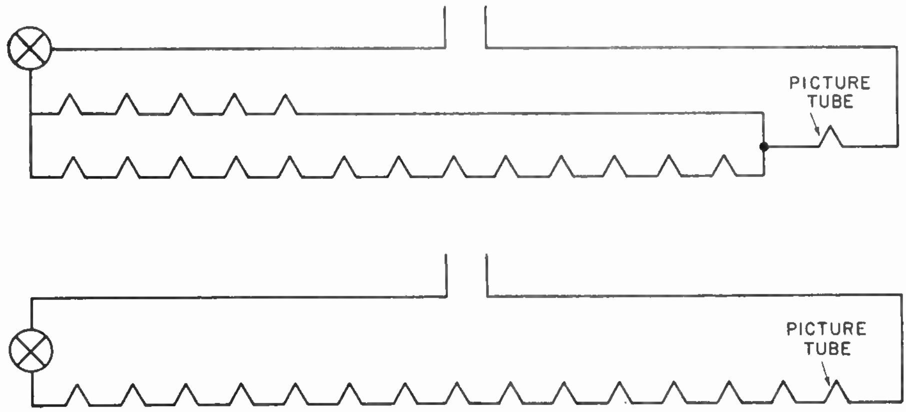


FIG. 9. Two types of series filament strings found in TV sets. In the circuit above, the heaters are connected in two strings. The tubes in each string are 300-ma tubes. The current from both strings flows through the picture tube filament, which requires 600 ma. In the circuit below, tubes designed for series-string operation and rated at 600 ma are used.

stable, rolling or falling out of sync horizontally, suspect some circuit associated with the sync alone. In this section, if only vertical sync is lost, the whole picture will move up or down, while remaining in one piece. If horizontal sync alone is lost, the screen will show diagonal stripes, but they will be stationary, vertically. If both horizontal and vertical sync are gone, suspect some section that handles both, such as the first sync clipper or the video amplifier. Sync circuits often differ widely in various sets, so that here, once again the best way to find a suspected trouble is to use the schematic diagram. In TV work, schematics are more important than in radio because of the increased complexity of the circuits. You will find for this reason that you are unable to trace circuits in TV with the same ease as in radios. Even professional servicemen always refer to the schematic diagram to avoid confusion.

An intermittent defect in a TV set that may be puzzling is a cathode-to-heater short in a tube in a series filament string. In some early models, the tubes were in two strings, but in many later sets, lower voltage tubes were used and only one circuit was required. These two types of filament strings are shown in Fig. 9.

A cathode-heater short in a tube in the middle of the string can cause the set to stop working by shorting out the filament voltage for all of the tubes between the short and B-minus. This is exactly the same problem we found in the ac-dc radio sets. The cathode is grounded, while the heater is normally insulated from ground (or B—). It is traced out in exactly the same way. First look to see which tubes are not lighted, and then replace the last tube in the string that *is* lighted. That will usually be the one with the short.

Sound Defects. Sound troubles, of course, can be traced just as in a radio set. Basically, the sound section of a TV set is just the same as the i-f and audio amplifier of an AM receiver. There will be one or more stages of sound i-f amplification, and possibly a limiter stage if a discriminator is used, but none if the ratio detector is used. The detector will be followed by one or two stages of standard audio amplification just as in a radio. Troubles in the sound section can be traced with the same methods used in checking a radio set's i-f stage, detector, and audio stage.

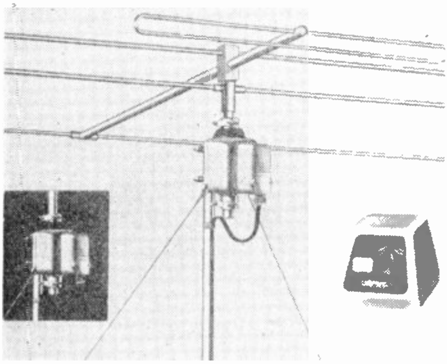
Picture Tube Defects. Among the intermittent defects found in TV sets, but not in radios, are intermittent picture tubes. If the screen goes dark (loses its raster) at odd intervals, there is trouble either in some of the high-voltage supply circuits or in the picture tube itself. If you can catch it as it goes dark, look at the neck of the tube near the base. If the filament goes out, it is intermittently opening and closing. This may be due to a bad solder joint inside one of the base pins (1 and 12) to which the filament is connected. Melt the solder and reheat. Do this with each of the filament pins, and recheck. Many times, an intermittent picture tube can be saved in this way and the customer will gladly pay the service charge when you explain to him that you have saved him the cost of a new picture tube. This same treatment also may be used on the other pins, if necessary. However, most of this trouble will show up in the filaments.

Another defect is a filament-to-cathode short in the picture tube. In a receiver in which the picture signal is fed into the cathode, the symptoms of this are a sudden loss of the picture while the screen remains lit up and the sound is usually not affected.

This trouble is best eliminated by installing a small isolation transformer. These are simply small iron-core transformers, with a picture tube socket on one end and a picture tube base on the other, usually on a short cable. The transformers have a 1-to-1 ratio, and isolate the filament of the tube from ground, preventing the cathode-to-heater short from removing the picture signal. A popular variation of this device is the combination isolation transformer-booster. This has a tapped transformer and may be used to step up the filament voltage so as to overheat the filament of an old picture tube which has lost so much emission that it will no longer give enough brightness. The excess filament voltage will raise the cathode temperature to the point where it will give off more electrons, restoring the emission of the tube, sometimes for quite a long while. Needless to say, the boost should not be used unless you are definitely sure that the emission of the tube is low. The transformer will eliminate the effect of a cathode-to-heater short.

Antenna Lead-In Defects. Another intermittent defect that can give you quite a bit of trouble unless you are watching for it is caused by a break in the antenna lead-in. It is a sudden cut-off or decided weakening of both picture and sound, with a sudden reappearance of both. If you get this complaint, the first thing that you should check is the antenna and lead-in wire, especially the lead-in! Because the line moves in the wind, the wires sometimes break on one side of the line, *inside the insulation.* Thus, the break is invisible, and the broken ends of the wires are so close together that the movement of the line causes them to make and break. There are several ways of checking for this. If it is practical, first check the resistance of the line with an ohmmeter to see if there is normal continuity. Leave the meter connected to the line while you shake the line vigorously inside the house. Then, have someone shake the line outside the house, while you watch the ohmmeter, inside.

Because of the very low resistance of the line, you might not be able to detect the change caused by a short circuit across the line. The only way to catch this would be to hook up a TV field strength meter and watch the meter reading while an assistant shakes the line outside. Of course, the set itself may be used instead of the meter, but this is not really conclusive because the trouble might still be in the set. If you're in a strong



Courtesy Alliance Mfg. Co.

FIG. 10. When a rotator is used, watch for breaks in the wires in the slack part of the lead-in because of the constant moving as the antenna is turned.

signal area, you might substitute another antenna, such as a rabbit-ears antenna, for the outside antenna. If with the substitute you get a constant though snowy picture, and with the original antenna the picture cuts on and off, you have found the trouble. Replace the whole line if you discover a break. The chances are that there are other weakened places in it, and you will save yourself and the customer trouble by replacing it with a whole new lead-in. This kind of trouble may also be caused by loose or defective connections in the antenna itself. This is quite common in cases where the antenna installation has been up for several years.

If the antenna installation uses a rotator, look for trouble where the lead-in makes the rotator loop. This is the slack shown in Fig. 10 which must be left in the lead-in to allow the antenna to turn. Because this part of the lead-in moves constantly as the antenna turns, one or both of the wires may break.

Other Defects. In some TV sets, you will find an unusual circuit in the audio power amplifier. This is shown in Fig. 11. The audio stage is connected in series with the video i-f. With a total B voltage of about 300 volts, there is 150 volts on the audio i-f tube and 150 volts on the video i-f tube. This can be confusing, especially in locating intermittents, unless the technician is thoroughly familiar with this circuit.

Now, let's look at some troubles in such a circuit. For instance, suppose both picture and sound suddenly

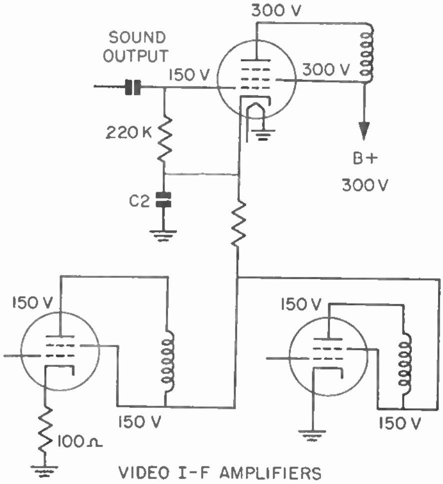


FIG. 11. A typical circuit where the audio output is connected in series with two i-f stages across the B supply.

disappear. By voltage measurements, the technician discovers that the plate and screen voltage on the video i-f stages vanish completely when the trouble shows up. There is the basic trouble, but is it the actual cause? No. The cause may be an intermittent short from cathode to heater in the audio power tube. In the series circuit, the cathode of this tube is 150 volts above ground and its heater, of course, is grounded. If the cathode-heater short occurs, the 150 volts which would normally furnish the plate supply for the video stages is grounded, and these stages have no plate voltage.

Other troubles can also occur in this circuit. If the coupling capacitor is leaky, for instance, the bias of the power tube will be upset. It will take considerably more current than normal. The voltage drop across the audio stage will be far higher than it should be. What is the result? The plate and screen voltage of the video i-f amplifier stage will be very low. On the other hand, suppose the primary winding of the output transformer were open. The stage would take much less than its normal current and the voltage on the video i-f stage would be too high. The best way to test a circuit such as this is to check the schematic diagram for the correct voltages, and then if there is over a 20% variation from any of them, check the entire circuit carefully. A 20% voltage variation can be expected in any set because of line voltage variations, tolerance of parts, etc.

A FINAL WORD ON INTERMITTENTS

Before we leave the subject of intermittents, let us give you one final word on them. Intermittents can be the most annoying problem you will encounter. Everything that we say here applies equally well to radio, TV, or any other kind of electronic apparatus.

Follow this four-step plan for locating intermittents: never "poke into" an intermittent, at random, in hopes of accidentally finding the trouble. Although you may find it in one set immediately, you won't be that lucky in the majority of cases. Sometimes you may clear up the intermittent condition without knowing what you did or what was causing the trouble, and worst of all, it is likely to reappear. The professional serviceman always uses a methodical, step-by-step series of tests, gradually eliminating sections or stages of the set, until he can pin down the trouble.

First, locate the intermittent section. For instance, in a TV set, find whether it is the picture, the sound, the sync, the high voltage, the low voltage, or a combination of these that is affected. The answer to this question will eliminate many circuits from the search. Again, referring to the block diagram in Fig. 8 will be of real help to you in localizing the trouble.

Second, locate the intermittent stage. For instance, if you had an intermittent high-voltage supply in a TV set, you would have these possibilities: the horizontal oscillator, the horizontal output, the high-voltage rectifier, and the damper tubes with their associated parts.

Third, locate the intermittent circuit. For instance, if the trouble has been found in the horizontal output stage, you might have trouble in the plate circuit, the screen circuit, or the cathode circuit. Check *all* circuits around a suspected stage, using the methods given previously, such as wiggling and jarring parts, measuring voltages, and checking waveforms.

Fourth, locate the defective part. With the preliminary steps finished, all that remains is the isolation of the defective part. Here is one thing that you can usually rely on; your trouble is apt to be in only one part. Because of the fact that the trouble is intermittent, with the circuit working all right part of the time, you can be fairly sure that the trouble lies in only one part. What you must do is locate this one intermittent part.

To do this, take plenty of time, and be as sure as you can that you have read the symptoms correctly. If your test results don't agree with your initial conclusions, don't hesitate to go back and reconsider. An open mind is the greatest help that you can have, especially in hunting intermittents. Check through the whole stage or circuit carefully, and repeat the measurements as many times as necessary.

The final test of an intermittent service job is, of course, operation. If it is at all possible, always operate an intermittent set for several hours on your bench before delivering it to the customer. If the trouble doesn't show up, you can be fairly sure that it is all right. However, professional servicemen usually leave themselves a loophole when they deliver an intermittent. They tell the customer frankly that because of the intermittent nature of the trouble, there is always a possibility that they did not find *all* of the bad parts because they did not show up under tests. They explain that the set played perfectly for four hours on the bench, but that they feel that there is just a small possibility that some of the trouble might happen again. Therefore, if the trouble does show up again, would the customer please call them right away and let them know just what happened? Although there is seldom any recurrence of the trouble, if it *does* show up under home conditions, this leaves a good impression with the customer and eliminates most of the unpleasantness of a callback. If the customer has paid for having an intermittent set repaired, he feels that it should work from then on; if it does cut out again, within a few days, he is quite apt to be very angry. Leaving him with this statement, and, in effect, asking his assistance, will help out in many cases. If the set should cut out again, he says, "Well, he said that it might," instead of flying into a rage because the technician didn't fix it, and charged him for it.

Recognizing Complaints Not Caused By Receiver Defects

Now that you've gotten into the technical aspects of radio and TV, you may find it a little hard to realize just how little the average person knows about the operation of even a simple radio set, let alone a device as complicated as a TV receiver. There will be times in your servicing career when you'll wish that the customer knew a bit more about how his set worked and what it could be expected to do as this would save you many an unnecessary service call. However, it is lucky in a way, that he doesn't. After all, you are planning to make a living by knowing all about it!

"Dry runs" are an experience of every serviceman; you go to a customer's house, only to find that the trouble is caused by something that cannot be helped—interference from outside sources, bad reception because the set is too small, bad wiring in the house, or many other things.

SET LIMITATIONS

If the complaint is not caused by a defect in the set, about the only thing you can do is to explain to the customer that the trouble is caused by something outside the set or installation that you cannot fix. For instance, if he is using one of the small transistor portables in New York, he can't expect to pick up stations in Florida and California with it, although on rare occasions such freak reception might occur. You'll have to explain to a customer just what his particular set will and, more important, *will not* do, and you'll have to be very diplomatic about doing it. It is not wise to say something like, "This cheap set just won't pick up stations because it's too little!" This might make any customer angry; after all, he bought the set, and to make a remark like that is a slur upon his judgment. It is better to say, "You see, these radios are built for operation in a big city, where there are several powerful local stations."

You are even more apt to have this kind of complaint about TV sets, especially in cases where the owner has been living in a large city, close to several powerful local stations, and using a low-gain outdoor antenna, rabbit-ears, or even a built-in antenna, and then moves to a fringe area. He is apt to expect the same snow-free performance that he used to get, and it may strain every diplomatic resource of the TV man to convince him that without a new set or an expensive antenna he can't get the same reception he had been enjoying.

Possibly the best attitude to take in such a case is this: tell the customer that he is in a weak signal area, and that his set must be in absolutely first-class shape if it is to give any performance at all. Because of the very strong signals they have been getting, they may not have noticed that many parts of their sets have deteriorated; tubes have become weak, rectifiers low. This is true of both radio and TV sets. Of course, you should use this approach only when you can obviously see that the trouble is due to weakness and not to design limitations of the set.

If the difficulty lies in the antenna, the best and most convincing answer is to set up a temporary antenna alongside the house for a demonstration. Show him the difference between his antenna and the type you have been using, and you can usually convince him quite easily. Once again, you must be quite diplomatic in doing this. The best course is to explain the difference in the area where he has been and the fringe area where he is now, and tell him how much difference there is in the signal strength received, and so on. If you do this right, the chances are that you'll wind up with a complete overhaul job on the TV set, and a profitable TV antenna installation job.

LOW LINE VOLTAGE

Check up on the symptoms, as described to you. If you get one of the more common complaints, such as "The radio won't play when I'm ironing!" you can suspect the line voltage of being low. Suggest changing the radio to another outlet. This is, of course, if you are sure that the radio is in good shape. By using some means of varying the line voltage in your shop, you should test all small radios, and especially portables, to see that they will keep on playing until the line voltage goes down to 100 volts. If they do this, they're all right, and you can feel pretty sure that the trouble lies in the home line voltage.

TV sets are also subject to these troubles. If the customer complains of the picture being too small, showing black edges, etc., you can almost always suspect low line voltage. This is also true if the trouble happens only at certain hours of the day. If the shrinking occurs only at suppertime, the housewife might be using an electric range or a high-wattage table appliance that is lowering the voltage on a circuit not designed for such heavy loads. These troubles should be referred either to the power company or to an electrician, although you can install a line-voltage adjusting transformer, a special transformer, with a tapped winding and switch, to raise the line voltage.

If you get a complaint such as this, you can suspect that the line voltage is low.

INTERFERENCE

Many times, you'll be called upon to check a radio receiver, especially just after you have repaired it, for complaints due to external interference, and not to a defect in the radio itself. If you suspect interference from the description of the trouble on the phone, take a portable test receiver along. When you arrive at the house, confirm the complaint; if it is obviously interference, plug in your portable and show the customer that it picks up the same noises. If you have a battery-operated portable set, you may even be able to track down the cause of the interference if it is in his own house. Look for an old refrigerator, a bad light switch, oil burner, etc., and then sell him an interference filter to install on it. If the interference is external, you will be able to prove it.

Many causes of radio interference originate in the horizontal output systems of the older TV sets. Because of the high voltages used, and the poor shielding and filtering of the high-voltage supply, they radiate interference over a surprisingly large area. Even though the fundamental frequency of this signal is only 15.75 kc, the high voltages used will give even the very high harmonics sufficient amplitude to cause interference in the broadcast band. For instance, the 30th harmonic is around 450 kc, which will cause squeals and whistles in a radio set because of coupling into the i-f stages. The only remedy for this is the complete shielding of the high-voltage stages of the offending TV set. There is no filter that will take it out of a radio.

TV sets can also cause interference to other TV sets by local oscillator signal radiation. A set on a given channel can have its oscillator on or near the frequency of another channel; if the oscillator is radiating a signal, the other set will pick it up in the form of an rf pattern on the screen, a series of thin wavy lines. Here again, the only cure is shielding the offending TV set to cut down the intensity of the radiation.

Interference can be caused by any electrical device that makes a spark or arc such as the older type electric motors with a commutator or any "make and break" contact such as a flasher, a dirty light switch, traffic lights, etc. Defective insulators or pole hardware on power lines can also cause interference. This usually shows up in the form of one or two bands of dots on the TV screen. These will be all the way from a thin line to a band one or two inches wide, and will usually float up and down the screen because of differences in the line frequency between the local power line and the power line in the city in which the TV program originates. The best course here is to report this to your local power company. They will send a crew out to locate and remove the cause of the interference.

Automobile ignition systems in some cars can cause a popping sound and horizontal bands on the screen. There is not much to do for this complaint. Moving the antenna or installing an antenna-booster is about the only remedy, and sometimes even this does not help very much. The use of a higher-gain antenna, with a coaxial lead-in cable, will often help.

Another trouble found in cities with strong local stations is interference with distant stations by the powerful local signal. In some cases, the local signal will cause beats to be heard all the way up and down the dial, by heterodyning with other station carriers. About the only method of dealing with this type of interference is to install a wave trap, tuned to the frequency of the local station, in the antenna circuit. A parallel-resonant wave trap, installed in series with the hot lead of the loop antenna, to the rf grid, will help out, by reducing the amount of local signal fed into the front end.

Similar interference may be found in TV receivers from the carrier of local FM stations. The cure is the same: install a wave trap in series with the antenna lead. Commercial traps are available for this purpose that can be tuned to the point of least interference. A quarter-wave stub may also be used, at less expense. Connect a short piece of 300-ohm lead-in wire across the antenna terminals, leaving the end open. Trim this off, a very small piece at a time, until it is of the correct length to act as a trap for the interference. An open-ended quarter wave of 300-ohm line will act as a short circuit across the antenna input at its resonant frequency. Clip the line a little at a time, while watching the screen. Leave it at the length that gives the best results. Start with a length of line about 36 inches long.

FADING

Another difficulty that is the cause of many complaints is fading. Although this is not too often found in sets with good tubes, perfect alignment, etc., either radio or TV, still there will be times when the signal simply fades out, for no apparent reason, and nothing can be done about it. Sometimes when the one signal fades out another may come in. This is due to atmospheric conditions and not a receiver defect. There is nothing you can do about it.

You may find so many stations coming in at one spot on the dial that you cannot separate the stations. This is caused by atmospheric conditions and the fact that there may be a large number of stations located in different parts of the country and operating on the same frequency. Under certain conditions, you may pick up several of these stations at once.

With more and more TV transmitters going on the air, the same problem is arising in distant TV reception. More powerful sets and antenna, together with more power at the transmitters, are combining to produce interference problems in areas previously thought to be far remote from such troubles. In some few cases, there is no practical solution other than the erection of very special, expensive, highly directional receiving antennas. For example, a viewer who had been watching a Channel 6 station, 75 miles distant, suddenly gets interference from another Channel 6 station which has gone on the air, directly "behind" his antenna. This station may be so far away that it is impossible to pick up a usable signal from it, but it may still be strong enough to cause severe co-channel interference, which is often called "windshield wiper" interference because that's what it looks like.

In cases such as this the only answer would be the erection of a screened antenna, to block out all signals from one direction. This would be quite expensive, yet possibly the only solution. Few commercial antennas have sufficient front-to-back ratios to cope with this type of problem.

In the fringe and far-fringe areas, fading is quite common in TV sets. In almost all cases, this is entirely due to signal fading, rather than to troubles in the set itself. The peculiarities of vhf signal transmission characteristics are not fully understood even yet; therefore, quite a few irregularities can be expected in reception far from the transmitting stations. High-gain very directional antennas with rotators are about the best solution to this problem. In some cases, the use of boosters to build up the signal strength to usable levels is necessary.

Fading and erratic performance may also be expected in auto radios, especially in the older sets. The signals received by an auto radio are constantly changing, as the car passes from a strong signal zone to a weak signal zone, under bridges, power lines, etc., and some changing in volume is inevitable. Some late model sets are equipped with a special, very fast-acting avc circuit, which minimizes the effect of the changes and keeps the output fairly constant. This type of fading is quite normal, so don't waste time trying to eliminate it.

TOO STRONG SIGNALS

In some localities, you may get complaints of poor reception on local TV stations, with unstable pictures, pulling, and buzz, while other more distant stations come in well. This trouble, especially in older or cheaper sets, may be caused by an actual overloading of the front end because of too much signal for the tubes to handle. This can cause sync clipping, buzz in the sound, and other troubles. If only local stations are used, the trouble may be cleared up by installing a "pad" across the antenna terminals to introduce a deliberate loss in signal strength. This will reduce the excessively strong signals to a point where the set can handle them. If other stations are being used, you will probably have to arrange this pad so that it can be switched into and out of the circuit, to restore the sensitivity of the set for distant reception.

If this complaint is on a late model set, check the setting of the agc control, if one is provided. It may be the cause. Actually, the basic trouble is lack of sufficient agc action in the set, due either to the design of the set or to defects in the agc circuit. Some of the cheaper sets do not have sufficient agc action, and a pad will probably have to be used.

EDUCATING THE CUSTOMER

With TV sets as complicated as they are, one of your major troubles will be that the customer does not understand how to run the set. This has happened many times. There is really only one cure. Be sure that the customer understands the operation of the various controls, what they do to the picture or sound, and is actually able to operate the set by himself.

The best time to do this is when the set is delivered. If you are making the initial installation, when you have finished the actual work and the set is running properly, take enough time to sit down with as many members of the family as you can get, and give them a short lecture on the controls of the set, and what they must do to keep it running properly. Many technicians have developed a stock lecture that they can give every time. Beware of rattling this off, though. Be sure that your customers understand what you're saying to them.

The best way to do this is to use the set itself; explain what each control is used for, and then actually operate the control, showing them what effect it has on the picture or sound. Go over all of the customer controls, brightness, contrast, tuner, volume, hold, etc., until you are as sure as you can be that he understands their operation. Don't rush this part of the process. Take enough time to be sure that you have him checked out on all of the "normal" troubles. This will save you many a service call, which would otherwise be necessary, just to turn a control a tiny bit. Calls of this kind are so difficult to collect for, that all technicians avoid them whenever possible.

A careful, thorough explanation of the operation of the set will often enable you to fix it over the phone, if the customer calls you later, saving you a dry run and him the cost of a service call. This builds up good will, which is an invaluable asset in the operation of any business. Incidentally, if you can make a diagnosis over the phone, this will raise the customer's opinion of your technical knowledge a great deal. He will tell his neighbors, and this is absolutely the best advertising that any technician can have: the word-of-mouth advertising given him by his satisfied customers. Get all you can, and keep it!

The NRI Practical Training Plan

The Practical Training Plan in this book is divided into two sections, one to give you experience in servicing a set for weak reception, and one to give you experience in working on intermittents.

WEAK RECEPTION

In servicing a weak receiver, the most important thing is to localize the trouble by its symptoms or through one of the localization techniques. Because of this, you should introduce defects in your receiver that will cause weak reception, note any of the identifying symptoms mentioned in this book, and practice the localization techniques that can be made with the test equipment at your disposal.

However, before you introduce defects, if you have a signal tracer and signal generator, connect them as we have described, and take the different measurements through the i-f stage. Write each reading down and notice how the indication increases each time you go through some stage. Make special note of the difference in signal levels at the plates and grids of the i-f amplifiers, at the mixer plate, the second detector, etc. Check the signal on the last i-f amplifier plate, and on the diode detector plate, to see the difference in a normally operating receiver. Remember these readings, and you can use them for comparison purposes when actually making this test on a set in for service.

Given below is a list of defects, and suggestions as to how they can be introduced in a receiver.

Open Cathode Bypass Capacitor. Look at your diagram, and note which rf or af amplifier tubes use an individual cathode resistor bypass capacitor. Unsolder one lead of this capacitor and tune in a station. Now touch the unsoldered lead back in place, and note how the volume increases. With the capacitor disconnected, try out localization tests. You will find that considerable patience is required to localize the trouble.

Open Antenna Coil Primary. This trouble can be demonstrated if your receiver uses an antenna. It is not necessary to unsolder the primary leads of the antenna coil. Simply remove and ground the antenna lead. Now connect about 5 feet of insulated hook-up wire to the antenna post of the receiver, and lay the wire on the floor. Tune for both weak and local stations. Notice the characteristic hissing when weak stations are tuned in.

Low Q in Resonant Circuit. This defect may be duplicated quite easily. Simply unsolder the lead from the coil to the capacitor in a resonant circuit, and insert a 100-ohm resistor in the circuit. If you find that the receiver is dead, use lower values of resistance until strong locals or the full output of your signal generator produces only weak signals. Now peak the trimmer of this modified tuned circuit. Note how broad the adjustment of the trimmer in the low Q circuit has become. Compare this broadness to its normal sharpness after you have removed the resistor from the circuit. Try this in several circuits, both in the preselector and in the i-f circuits. Before you restore the circuit to normal, tune in both weak and distant signals and try all localization procedures.

Weak Stage Localization. You can't simulate the effect of a low emission tube in an ac-dc set. Wait until you service an ac set to carry out this step. To lower the emission of a tube in an ac set, place a resistor in series with its filament. This will reduce the voltage across the filament, thus lowering the cathode emission. A 5- to 10-ohm, 2-watt resistor will be satisfactory. Tune in weak and distant stations, and note the results when the weak stage is located in different sections. Watch the action of the tuning eye if one is used. Practice the localization procedures.

Misalign the Set. You have had practice in alignment before, but try throwing the set out of alignment again, to notice particularly the symptoms of weak reception.

INTERMITTENTS

To demonstrate the effect of an intermittent on your Practical Training Plan receiver, feed the full output of an unmodulated signal generator into the receiver input and tap the chassis and various parts and tubes, and note the reaction. This is the reaction of a normal set.

Now, deliberately make a bad solder joint, somewhere in the signal path of the set: the i-f plate, for instance. Heat up the joint, and then shake the wire with your pliers while the solder sets, to make a loose joint. When the wire moves freely, tap the chassis, and note the effect. Make a poor connection somewhere in the audio section, too, to get an idea of what effects you get with an audio defect.

Now let's demonstrate the effect of an intermittent capacitor. Although it might be difficult to get a real intermittent capacitor, if you have an old radio on hand, look for one of the older bypass capacitors with a paper case. Take it out, and pull on the end leads, hard, then remove the last coupling capacitor from your set and solder this one temporarily in its place. See if wiggling the case of the capacitor causes intermittent reception. Note carefully just how the set acts, and you'll be ready for intermittent service jobs like this.

This completes your Practical Training Plan for servicing radios. You can gain additional experience by repeating the same plan on another receiver. Later in your course you will be given a Practical Training Plan for television.

ADVICE TO THE OBSTINATE

Lincoln, who frequently encountered acute differences of opinion in his cabinet, once said, "When you have an elephant by the hind foot and he wants to get away, it is best to let him go." It's good advice, still. If you can't have your own way, have the other fellow's—with as good grace as possible.

One of the most unpleasant persons we ever knew was a "come-hell-or-high-water" man who refused even to consider the possibility that he could be wrong, once he had made up his mind. He thought he had a strong character. All he really had was a closed mind.

It isn't always easy to tell whether you are right or are simply being stubborn, whether it is conviction or pride that is influencing you. At such times it helps to pick out someone you admire and respect and try to imagine what he would say and do in such a situation. Then behave accordingly.

J. E. Smith

TYPICAL RECEIVER DIAGRAMS AND HOW TO ANALYZE THEM

REFERENCE TEXT 35X

PIONEER HOME STUDY RADIO SCHOOL
NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

and the .000025-mfd. condenser. The antenna coil is tuned to resonance by trimmer T_6 and *V.C.*, the latter being connected to the coil through the .00004-mfd. condenser and contacts *11-5* of switch section S_1F. The .00004-mfd. series condenser is used to reduce the over-all capacity of the circuit so the ultra high-frequency f.m. band may be tuned with the regular gang tuning condenser.

Switch contacts *5-6* of S_1F connect the tuned circuit to the control grid of the 6SK7 r.f. amplifier tube through the .0003-mfd. coupling condenser, the cathode connection being through the chassis and the cathode by-pass condenser. Contacts *6-5* of switch section S_4R connect the plate circuit of the r.f. tube to its 10,000-ohm load resistor. Capacity coupling through the .0001-mfd. condenser transfers the amplified signal from the plate load resistor to r.f. transformer *7G1*. Only a small part of the possible gain of the r.f. tube is utilized due to the use of a 10,000-ohm plate load resistor, but a small value of resistance is necessary to shunt coil *7G1* and broaden the tuning.

The signal fed the r.f. coil is tuned to resonance by r.f. trimmer T_{10} and main tuning condenser *V.C.* which connects to the coil through the .00004-mfd. condenser and contacts *4-10* of switch section S_8F. Contacts *4-5* on this switch connect the resonant circuit to the 6SA7 mixer tube through the regular .0003-mfd. coupling condenser. The cathode connection is through contacts *5-6* of switch section S_6R, the oscillator coil and the chassis, so we have a duplication of the circuit used in previous band positions.

The oscillator uses coil *701* and trimmer *86-262*, with connections being the same as for previous bands. The variable condenser tunes the oscillator circuit through the .005-mfd. and .00005-mfd. condensers and contacts *11-5* of switch section S_5F. Contacts *5-6* on this switch connect the oscillator tank circuit to the oscillator grid of the 6SA7 through the .00005-mfd. coupling condenser.

Oscillations are maintained in the usual way, and the local oscillator and incoming signals are mixed within the tube. Since the oscillator and incoming signals differ by 4300 kc. (4.3 mc.), the i.f. carrier signal produced in the plate circuit of the tube has a frequency of 4.3 mc.

You will remember that in our previous discussion of the i.f. amplifier, the lower transformers were identified as being for the a.m. section. Now, of course, we are dealing with the upper or f.m. transformers. The primary of the first i.f. transformer, shunted by condenser C_8, is tuned to resonance by adjusting the iron core so that more or less of the core is inside the coil. The resonant circuit so formed offers a high impedance to the 4.3-mc. i.f. signal, and a large i.f. voltage is built up across the coil.

Resonant step-up results in a large circulatory current at the i.f. value, and the signal is induced into the secondary. The a.m. primary on the first i.f. transformer acts as a short as far as the f.m. signals are concerned, and this is also true in the case of the other a.m. circuits.

The f.m. secondary is connected to its trimmer C_9 through the low-reactance a.m. secondary when switch section S_7R is thrown to the *FM* position. Note the 50,000-ohm resistor shunted across C_9 and used to broaden the tuning of the first f.m. i.f. transformer. As was the case with the primary and all other i.f. transformers, resonance is obtained by core adjustment. The discriminator is an exception, being tuned by means of the two trimmers marked C_{14}.

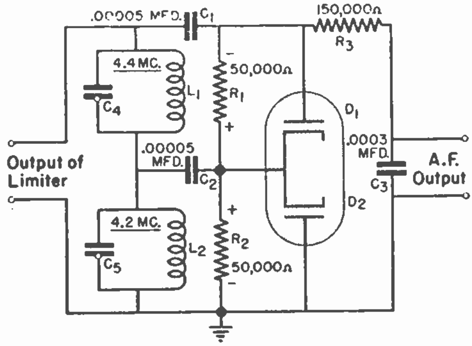


Fig. 15. Discriminator circuit. The i.f. value is 4.3 mc.

The signal applied to the input of the first i.f. tube is amplified, and appears across the broadly resonant plate load formed by coil *56-936*, C_6 and the 4000-ohm resistor. By capacity coupling through the .00005-mfd. coupling condenser and the .1-mfd. plate by-pass condenser, the signal is fed to the 500,000-ohm resistor and to the grid-cathode of the 6AC7 second i.f. tube. The cathode connection, of course, is through the cathode by-pass condenser.

The amplification contributed by the second 6AC7 tube results in a large i.f. signal across the broadly-resonant plate load formed by the transformer primary, condenser C_{10} and the 50,000-ohm shunt resistor. The signal induced into the secondary is applied directly to the grounded cathode of the 6SJ7 tube, and to its grid through the .000025-mfd. coupling condenser.

This 6SJ7, being a sharp cut-off pentode and being operated at low plate and screen grid voltages, acts as the limiter and delivers a signal of constant amplitude to the next stage, regardless of surges in signal strength that may result from static or other noise. Of course, the incoming f.m. signal must be strong enough to drive the 6SJ7 to the point where limiter action starts. The rectified voltage across the 100,000-ohm resistor in the control grid return of the 6SJ7 quency, we will find that practically all of the signal voltage appears across section *B* and is transferred to the lower 6SF5 tube.

The lower 6SF5 tube is thus a bass amplifier or bass-boosting tube. Since the amount of signal made available for the frequency-discriminating network is controlled by potentiometer *87-281*, this is the bass tone control.

The signals receiving bass-boosting action by the tube are developed across the 100,000-ohm plate load resistor. The .05-mfd. condenser across this resistor takes out signals above about 1000 cycles, so we have only the signal voltages of deep boomy bass notes across this resistor. These signal voltages are fed through control *48-281* with its 500,000-ohm shunt resistor, the .02-mfd. coupling condenser, and the 500,000-ohm resistor to the 100,000-ohm grid resistor for the 6J5 phase inverter tube. This control has no effect on bass notes because its .004-mfd. condenser is so small in comparison to the .05-mfd. plate by-pass condenser for the lower 6SF5 tube, but it does serve as a conventional type of tone control for the upper 6SF5 tube.

The upper 6SF5 tends to amplify all signals about the same amount but puts just a little more emphasis on the very high notes. It has a 500,000-ohm plate supply resistor across which the audio signals are developed. From here, the signals are fed through the 250,000-ohm resistor, the .02-mfd. coupling condenser and the 500,000-ohm resistor to the 100,000-ohm grid resistor for the 6J5 phase inverter. Thus, both 6SF5 tubes deliver signals to the phase inverter.

When the movable arm of tone control *48-281* is moved toward the .02-mfd. coupling condenser, the higher audio frequency signals (of which there are normally an over-abundance) passed by the upper 6SF5 tube are attenuated (cut down). When moved in the opposite direction, the effect is to give increased treble response, for the control then lets the over-amplified high audio frequencies come through.

The 250,000-ohm resistor between the upper 6SF5 amplifier plate and the .02-mfd. coupling condenser is used so the high audio notes will divide between them and the .004-mfd. tone control condenser when the tone control is set for minimum treble response. This arrangement also prevents interaction between the normal output circuit and the bass-boosting amplifier circuit.

The audio signals across the 100,000-ohm grid resistor are amplified by the 6J5 tube. The signals developed across its 50,000-ohm plate resistor are 180° out of phase with the grid signals, just as in any resistance-coupled stage. The signals across the 50,000-ohm plate load resistor are transferred to the input of the upper 6V6G output tube through the .02-mfd. coupling condenser and 10-mfd. filter condenser C_2.

The lower 6V6G grid is fed directly from the output of the 6SF5 tubes, and hence receives a signal 180° out of phase with that delivered to the upper 6V6G by the phase inverter tube. In this way, the 6V6G tubes are fed with signals 180° out of phase, as is necessary in any push-pull system.

The lower 6V6G receives far more signal than the 6J5, because of the 500,000-ohm and 100,000-ohm voltage divider system used to feed the latter tube. By choosing the right plate load for the 6J5, its gain is made just high enough so both 6V6G tubes receive the same amount of out-of-phase signal.

By using a push-pull arrangement, second harmonic distortion is avoided and we get the benefits afforded by the powerful 6V6G tubes. The odd harmonics, such as the third, fifth, seventh, etc., remain to be dealt with

The .002-mfd. condenser between the 6V6G plates tends to by-pass third and higher harmonics produced in the output tubes. Nevertheless, some of these harmonics will reach the voice coil and cause it to move, with consequent distortion of the clear tones which would otherwise be produced. The effect is not very bad because it is almost entirely eliminated by degeneration.

Note the 400-ohm and 25-ohm resistors shunted across the voice coil. These resistors act as a voltage divider, and the small signal voltage developed across the 25-ohm resistor acts on the grid input circuits of the 6SF5 tubes. The signals across the voice coil are 180° out of phase with the signals fed from the second detector to the volume controls and the 25-ohm resistor.

What is the effect of feeding a signal into an amplifier which is 180° out of phase with the regular signal? The effect is just the same as if we were to turn down the volume control a certain amount, for due to cancellation we are in reality feeding less signal into the amplifier input. Since all frequencies at the output transformer secondary receive exactly the same treatment, how do we discriminate against the distortion-producing harmonics? The harmonics are eliminated because they were not in the input to start with! They were produced somewhere in the a.f. amplifier, and by feeding them out of phase into the amplifier input, they are practically wiped out at their point of origin and only a trace appears across the voice coil.

After this discussion, you can now appreciate the care taken in the design of this amplifier, and can see that excellent tone quality should be expected either on a.m., f.m. or phonograph operation.

Tracing the F.M. Signals. Band switch position *5* is for f.m. reception, so we will trace the f.m. signals from the antenna to the volume control at the input of the a.f. amplifier, from which point the audio amplifier works in exactly the same manner as for a.m. reception. The three switch sections marked S_7R are all in the *FM* position now.

The f.m. signals flowing in the antenna are capacitively transferred to the antenna coil through contacts *6-5* of switch section S_2R

HOWARD Model 718FM-X Frequency Modulation Receiver

GENERAL Specifications. This Howard Model 718FM-X is a combination frequency modulation receiver with three amplitude modulation bands and six push buttons for automatic tuning on the broadcast band. The receiver is equipped with a loop for the broadcast band, has a built-in phono switch, bass and treble controls, and utilizes inverse feed-back to reduce audio distortion.

Signal Circuits. The wave-band switch presents no great difficulty in the circuit diagram of this set as shown in Fig. *12*, because all of the coils are plainly in view and their purposes evident. The switch has six sections, three facing the front of the set and three facing the rear of the set. The sections marked S_1F, S_3F and S_5F face the front of the set, and are shown as they appear when you look at the switch from the *front*. Sections marked S_2R, S_4R and S_6R face the rear of the set, and are shown as they appear when you look at the switch from the *rear*. The movable contact arms of the *F* sections rotate *counter-clockwise on the diagram* as the switch is advanced from position *1* (in which all switches are shown here) to position *5*, and the movable contact arms of the rear (*R*) sections rotate *clockwise on the diagram* as the switch is advanced.

The chart in Fig. *13* tells which switch terminals are connected together for each of the five positions. Position *1* is for push-button operation, covering the broadcast band. Position *2* is for manual tuning of the broadcast band. Position *3* gives coverage of the police and aviation bands, while position *4* covers short-wave programs, and position *5* covers the f.m. band.

Switch Position 1. We will study band switch position *1* first, and trace its circuits to the input of the i.f. amplifier. Since all switches are shown in position *1* in Fig. *12*, we can trace switch connections directly on the diagram.

When an outdoor antenna is used, signal currents flow through contacts *6-1* of switch section S_2R, and then to ground through the few turns of wire which are inductively coupled to the *LOOP* (drawn like a coil in this diagram). The loop is tuned to resonance, since it is connected through terminals *1-7* of switch section S_1F to r.f. trimmer *1*, whose button is shown as being depressed. Any signal at the resonant frequency of the loop undergoes resonant step-up when induced in the loop by antenna current through *L25*. The resulting signal is applied to the control grid of the 6SA7 first detector tube through contacts *6-5* of switch section S_3F and through the .0003-mfd. coupling condenser.

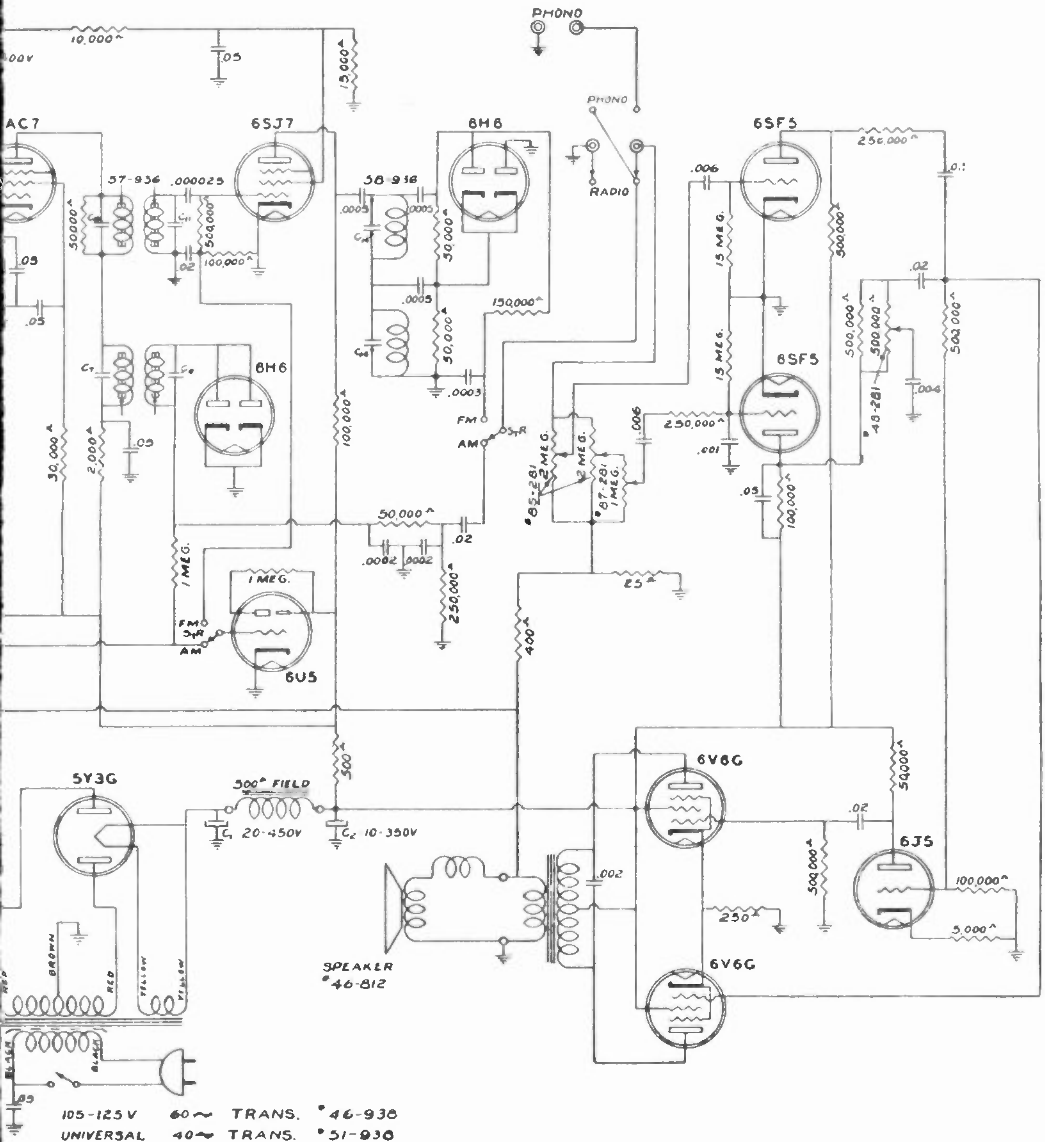
We have not mentioned the 6SK7 r.f. tube, but an examination shows that the signal is also applied to the input of this tube through contacts *7-6* of switch section S_1F and the .0003-mfd. coupling condenser for this stage. The r.f. tube will amplify this signal, but the plate of the tube connects through contacts *6-1* of switch section S_4R directly to B+. Thus, no load exists in the plate circuit and no amplified r.f. voltage is developed, even though the plate current is varying at an r.f. rate. The r.f. stage is therefore inactive when push-button tuning is used.

Now, we will investigate the oscillator. We see that the grid next to the cathode of the 6SA7 tube is the oscillator grid. It connects to the chassis through a 20,000-ohm resistor which is used for self-bias purposes. (Oscillator grid current flowing through this resistor produces the bias voltage.) The grid connects through the .00005-mfd. coupling condenser and switch contacts *6*, *1* and *7* of switch section S_5F to the oscillator tank circuit. The tuning condenser is oscillator trimmer *1*, whose push button is depressed, and the tank circuit coil is connected between switch contacts *1-2* and the padder marked *83-262*. Trimmer T_1 is the oscillator high-frequency trimmer for the broadcast band, but its capacity is negligible compared to that of the push-button trimmers.

The left-hand winding of oscillator coil *2035* is connected between the padder and ground, but has only a small effect on the inductance of the circuit. As you can see, it is in the cathode circuit of the 6SA7 tube and hence is the feed-back coil. The cathode current of the 6SA7 tube flows through this coil and induces a voltage into the tank coil. This variation in grid (tank) voltage causes

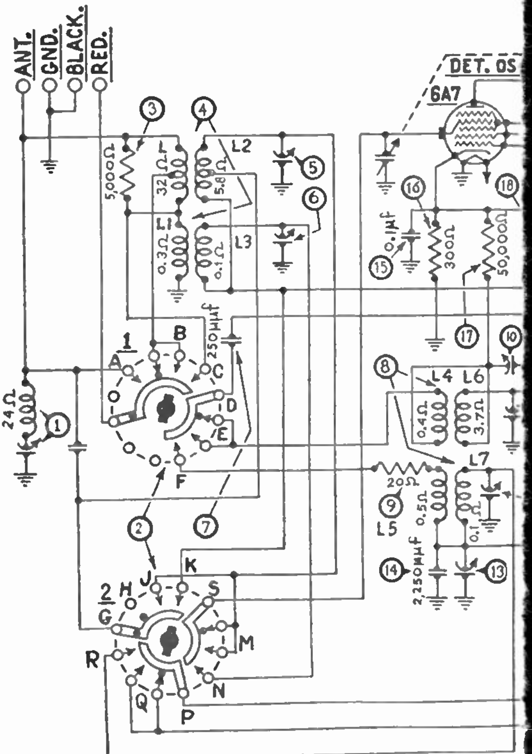
SWITCH POSITION	BAND	BAND-SWITCH SECTIONS						
		S_2R	S_1F	S_4R	S_3F	S_6R	S_5F	S_7R
1	BROADCAST, PUSH-BUTTON	6-1	6-1-7	6-1	5-6	6-1	1-6-7	AM
2	BROADCAST, MANUAL	6-2	6-2-8	6-2	1-5-7	6-2	2-6-8	AM
3	POLICE BAND	6-3	6-3-9	6-3	2-5-8	6-3	3-6-9	AM
4	SHORT-WAVE	6-4	6-4-10	6-4	3-5-9	6-4	4-6-10	AM
5	FREQUENCY MODULATION	6-5	6-5-11	6-5	4-5-10	6-5	5-6-11	FM

Fig. 13. Table showing band switch terminals which are connected together at each of the five switch positions.



AM I.F. 465 KC.
FM I.F. 4.3 MC.

four band fourteen tube f.m.-a.m. superheterodyne receiver.



NUMBERS INDICATE RELATIVE POSITIONS OF SWITCH SECTIONS FROM FRONT OF CHASSIS

tion corresponding to 1380 kc. to 1580 kc. on the broadcast band. When this set was built, the bands just below 2300 kc. and above 2500 kc. contained nothing of interest. Anything which was picked up at such frequencies was due to lack of preselection. On this band, only local police stations operating around 2400 kc. will ordinarily be heard.

Due to the tying together of the switch contacts at *Q* on switch section *2* and the tying together of the switch contacts at *E* on switch section *1*, the oscillator connections are the same as they were for the broadcast band. This means that the oscillator will produce a frequency 460 kc. higher than the dial setting for the broadcast band, or from 990 kc. to 2180 kc. However, the preselector only works from 2300 kc. to 2500 kc., corresponding to the 1380-kc. to 1580-kc. markings on the broadcast band dial. When the set is tuned to 2300 kc., the oscillator is working as it did for 1380 kc. on the broadcast band. In other words, it is producing 1380 kc. + 460 kc., or 1840 kc. Now, if a 2300-kc. signal is picked up, the difference between it and the oscillator working at 1840 kc. is 460 kc., which is the i.f. value of the receiver. At the 2500-kc. dial setting, the oscillator is at 2040 kc., the same as it was for 1580 kc. on the broadcast band. The difference between 2040 kc. and the top of band *2* (2500 kc.) is again 460 kc., the correct i.f. value.

From these figures we see that the oscillator works below the frequency of the preselector for band *2*, and this band does not cover the entire dial. The receiver can be tuned below 2300 kc. and above 2500 kc., but the oscillator and preselector won't track exactly and satisfactory reception isn't to be expected.

Now let's go to switch position *3* in Fig. *11*. Here the antenna current flows through the primary of *L1*. Note that *L* is shorted through switch contacts *A* and *C*. If the special two-wire Philco antenna is used, the *RED* lead makes contact through switch terminal *C* directly to the antenna lead and *L1*, while the *BLACK* lead connects to the grounded end of *L1*.

By keeping the short-wave antenna currents confined to *L1*, better results are obtained. The signal current flowing through *L1* causes a voltage to be induced in *L3*. One end of *L3* connects to the a.v.c. circuit, and the other end connects to the main preselector tuning condenser through switch contacts *N* and *S* of switch section *2*. Trimmer *6* shunts the gang tuning condenser section, and is the high-frequency preselector trimmer. It is adjusted at the high-frequency end of the short-wave band.

The resonant circuit composed of *L3*, the tuning condenser and trimmer *6* selects the desired station signal, which undergoes resonant step-up. This signal is applied to the mixer input of the 6A7 tube. At the same time, *L2* is completely shorted by switch contacts *J*, *K* and *G*, thus making this coil inactive when switches are at position *3*.

The oscillator tank circuit for band *3* starts from the oscillator grid, and traces through switch contacts *P* and *R* to coil *L7*. The position of trimmer *12* indicates that it is the oscillator high-frequency trimmer; it is to be adjusted at the high-frequency end of this band.

The other end of *L7* connects to ground and to the rotor of the oscillator tuning condenser through fixed condenser *14* and adjustable condenser *13*. These condensers are in series with the oscillator tank circuit, and comprise the low-frequency padder for the short-wave band. Padder *13* is to be adjusted at the low-frequency end of this band. Resistor *18* is the oscillator grid resistor for this band.

The connection of *L5* to the padder condenser means that additional feed-back is obtained in the short-wave oscillator circuit by capacity coupling. The other end of *L5* connects through resistor *9*, switch contacts *F-D* and condenser *7* to the grid serving as the oscillator plate.

ventional, but all oscillators of this type have a bias resistor somewhere between the oscillator grid and cathode. Resistor *17* must therefore be the oscillator self-bias resistor for band *1*.

Coil *L4* is the oscillator feed-back coil, and must receive energy from grid *2* (the oscillator anode grid) of the 6A7. The connection to padder *10* means that we have capacitive coupling as well as inductive coupling from the feed-back coil to the oscillator tank circuit.

Tracing the other lead of *L4*, we go to terminal *E* on switch section *1*, and through the black "ball" contact to pole *D*. Condenser 7 is the means of coupling the feed-back coil to the oscillator plate.

We have now traced all the oscillator and preselector circuits for the broadcast band.

A quick glance at the schematic as a whole reveals much the same maze of wires as in the preselector circuits, but now you know that if you go at the problem logically and follow through each circuit one at a time, you can get any information you need for test purposes. Don't expect circuits of this sort to look easier as you progress in radio. Wave-band circuits always *look* complicated, and you always have to trace them when you need any special information from them.

The work we have done so far has been fairly straightforward. Figuring the new contacts made through the wave-band switch when it is thrown to one of the other positions is a bit more difficult.

Experience and a knowledge of how the circuits should be arranged will help you. The little black balls on the switch sections represent the movable contacts. As there are two other positions on this switch, it's not so hard to visualize the balls moving clockwise one space for each new switch position. To make this easy, the switch settings for all three ranges are drawn in Fig. *11*. We have already covered position *1* for the broadcast band, so now will examine switch position *2*.

Let us assume that instead of using a Philco two-wire antenna system connected to the *RED* and *BLACK* terminals, we are using this time an ordinary aerial and ground connected to the *ANT.* and *GND.* posts. Remember that the switches are in position *2* as shown in Fig. *11*.

Antenna current now flows through the antenna primary coils *L* and *L1*, inducing voltages in *L2* and *L3*. The voltage set up in *L3* is very small and can be neglected, since *L3* is not connected to the tuning condenser.

The upper section of *L2* is short-circuited by switch contacts *G* and *J* of switch section *2*, so this portion doesn't play any part in the circuit either. Since switch contacts *G*, *J*, *M* and *S* are connected together, the tap on *L2* connects to the main tuning condenser and the 6A7 top cap. The lower section of *L2* goes to the a.v.c. circuit, then through a.v.c. condenser *25* to the grounded rotor of the tuning condenser.

The preselector section of the condenser gang therefore tunes the lower section of *L2* to resonance. The signal so chosen is applied to the mixer input of the 6A7 tube. The band coverage of this circuit is from 2300 kc. to 2500 kc.

Notice that this band is only 200 kc. wide, so only a portion of the dial is used—the por-

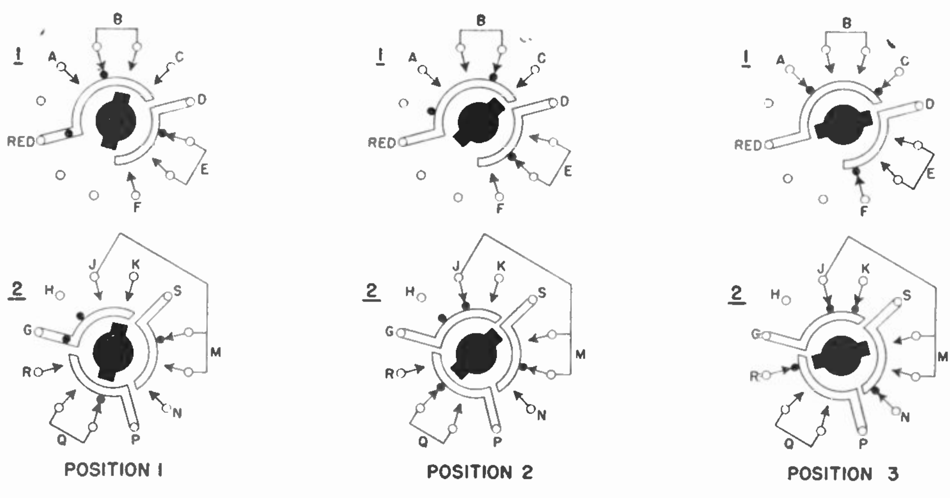


Fig. 11. Connections made for each of the three positions of the band-changing switch are clearly shown here. Note that the black balls all advance one step clockwise as the switch is advanced from Position 1 to Position 2 and from Position 2 to Position 3.

across the other three filaments will serve as its bias (the grid circuit of the 1A5G traces from the control grid through the 2-megohm grid resistor to the chassis, through the chassis to the grounded filament lead of the 1A7G, through the 1A7G, 1H5G and 1N5G filaments in turn to the filament of the 1A5G).

When the power cord is plugged into a 110-volt a.c. line and switches *SW* are closed, the set starts operating almost immediately from batteries. After about ¾ minute of battery operation, the filament of the rectifier has warmed up sufficiently so that the 25Z6 rectifier is conductive. Now both the 6-volt filament supply circuit and the 90-volt plate supply circuit are operating as conventional half-wave rectifiers with resistor-condenser filters.

The 6-volt section of the 25Z6 provides a d.c. voltage just enough higher than the A battery voltage so this half-wave rectifier circuit supplies filament current for the four tubes and at the same time sends a small charging current through the 6-volt A battery.

In an identical manner, the 90-volt section of the 25Z6 provides a voltage enough higher than the B battery voltage so this section furnishes all plate current requirements and also sends a small charging current through the 90-volt B battery. Under these conditions, the batteries act like condensers and improve the filtering.

For 110-volt d.c. operation, the plug must be inserted in such a way that the two plates of the 25Z6 go to the positive side of the line. The rectifier sections then conduct current continuously, and the filament and plate filter supply circuits merely act as voltage dividers which cut down the 110-volt d.c. line voltage to 90 and 6 volts respectively for the receiver circuits.

With this arrangement, no switching is necessary in changing from battery to electric current operation. If the power cord is not plugged in, the set operates from its batteries. When the power cord is plugged in, the set starts operating from batteries after being turned on, but automatically changes over to a.c. operation after the rectifier tube warms up.

Whenever the set operates from a power line, the pilot lamp glows. If the electric plug is removed while the set is playing, the set keeps right on playing from its batteries but the pilot lamp goes out, showing that the line is not supplying power. If desired, the receiver can be operated from a.c. or d.c. lines even with all batteries removed.

As with all other receivers that operate from 110-volt d.c. lines, there is a right and a wrong way to put the plug into the socket. If it is in the wrong way, connecting the rectifier plates to the negative side of the line, the set will operate entirely from batteries, and the pilot lamp will not glow. Rotating the plug half a turn in the wall outlet will then make the rectifier plates positive, and the set will operate entirely from the 110-volt d.c. line as soon as the rectifier tube warms up. The pilot lamp will glow.

When the set has been used a long time on battery power and the batteries have become weak, they can be recharged rapidly by operating the set from a 110-volt a.c. or d.c. line with the 1A5G tube removed. Twenty-four hours of this charging will give about 20 hours of service on the batteries. This quick rejuvenation should not be used until the batteries get low, and then for not more than 40 hours at a time. It can be repeated a great many times.

Removal of the 1A5G type tube interrupts the filament circuit, so that only the rectifier tube draws filament current. The supply voltage then rises much higher than 6 volts, and we secure rapid charging of the run-down A battery. Also, no plate current is being drawn through the 6000-ohm B supply filter, hence a higher voltage is applied to the B batteries for charging.

This is not strictly a recharging process, since dry batteries cannot be recharged. However, the negative battery electrodes become polarized during use, raising the internal resistance of the batteries and thereby lowering their output voltages under load. This rejuvenating process depolarizes the electrodes, lowering the internal resistance and permitting normal use of the battery until such time as all of the active ingredients in the cells have been used.

Biasing Methods. As we have previously pointed out, the control grid of the 1A7G type tube is biased by the voltage drop across the volume control and half of the 1A7G tube filament. In a filament-type tube, the effective control grid voltage is that existing between the control grid and the center of the filament. Voltage measurements, however, are made between the control grid and the negative side of the filament.

The grid return of the 1N5G i.f. tube is made directly to the negative side of its filament. Therefore, the effective d.c. grid voltage is half of the filament voltage.

The diode plate of the 1H5G tube likewise returns to the negative side of its filament (through the volume control), so the plate has an initial small negative bias. This has no effect on local reception, and does not seriously interfere with reception from weak distant stations.

The control grid of the 1H5G tube connects to the positive side of its filament through a 15-megohm resistor. Some of the electrons which start out for the plate hit this grid and flow through this resistor to the filament, producing a voltage drop which serves as the negative bias for the grid of the tube. Remember that when electrons flow through a resistor, the end at which they enter is always negative with respect to the end at which they leave.

The control grid of the 1A5G tube connects to ground through a 2-megohm resistor. Reference to the simplified wiring in motion and producing sound waves. The output transformer serves to match the impedance of the voice coil to the a.c. plate resistance of the output tube.

The .002-mfd. condenser connected from the plate of the output tube to the chassis makes the plate load of the tube essentially capacitive and thereby prevents any oscillation at ultra-high audio frequencies.

The A.V.C. System. The a.v.c. system for the receiver is entirely conventional. The d.c. component of the rectified i.f. carrier current developed across the 750,000-ohm volume control is applied to the control grid of the 1A7G, after the audio signal is removed by the 1-megohm resistor and .1-mfd. condenser. A.V.C. is not applied to the control grid of the i.f. tube.

You will note that the filament end of the volume control connects to the positive side of the 1A7G filament. Therefore, the detector portion of the 1A7G tube is supplied with a slight initial positive bias. As soon as a signal is received, however, this positive bias is overcome by the negative voltage produced across the volume control.

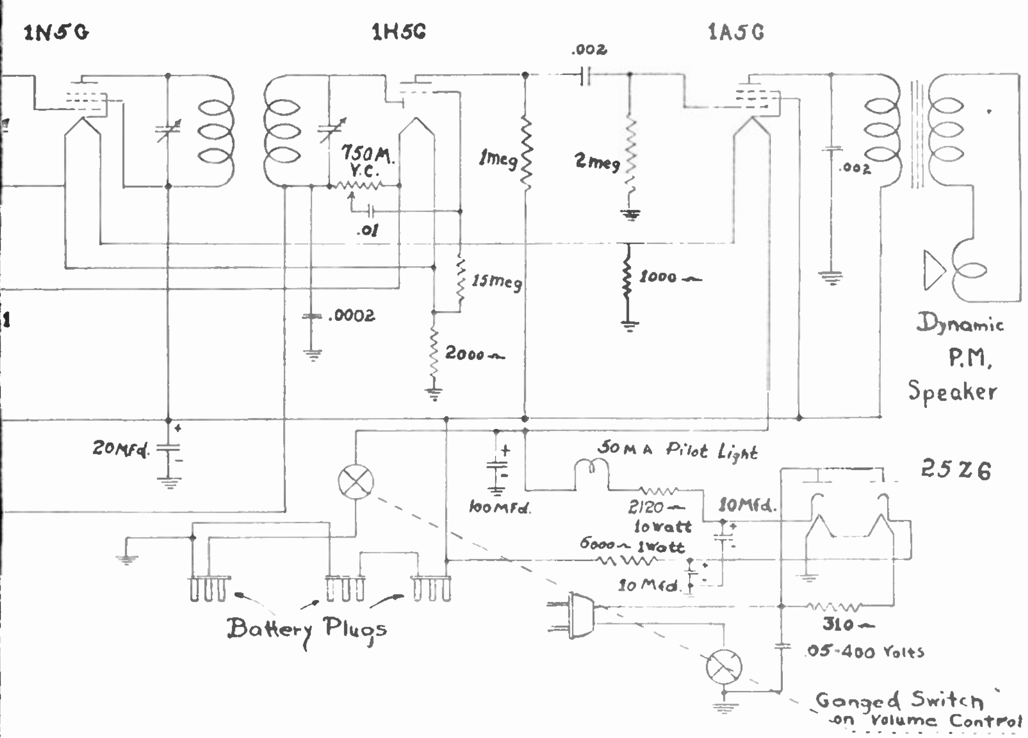
The Power Supply. At first glance, the filament and power pack connections in Fig. 8 appear somewhat unusual, but when the circuit is redrawn as in Fig. 9, we can see that there are really four independent circuits, each quite conventional in design. Let us consider each in turn.

When the two switches marked *SW* (operated simultaneously by the volume control shaft) are open, both the 6-volt battery and the power line are disconnected from the filament circuits so the set cannot operate. The 90-volt B battery cannot supply current under this condition because the tubes are not conductive when the filaments are cold.

When switches *SW* are turned on but the power cord is not plugged in, the rectifier tube filament is not heated and hence the two sections of the 25Z6 rectifier are not conductive. The 6-volt battery now furnishes current to the filament circuits of the tubes, however, and the 90-volt B battery furnishes plate current to the four signal circuit tubes.

Examining the filament circuits of the tubes more closely, we see that the filaments of the four 1.4-volt tubes are connected in series across the 6-volt battery, with the circuit being completed through the chassis. The 1000- and 2000-ohm resistors merely provide extra paths to ground for the plate currents of the 1N5G and 1A5G tubes, so as to reduce the amount of plate current which flows through the other two tube filaments to ground.

The 1H5G filament is next to the 1A7G filament in the line-up for a definite reason, to prevent the filament voltage drop of the 1N5G from serving as bias for the 1A7G. The 1A5G is at the + end of the line-up for the opposite reason, so the 4.5-volt drops



age between the center of the filament and the negative filament terminal is added to the voltage between the negative filament terminal and the control grid.

In these special low-voltage tubes which handle only small amounts of signal voltage, the bias is quite small. The a.v.c. voltage across *R12* is added to the voltage drop in one-half the tube filament to form the bias for the 1T4 i.f. tube and the 1R5 first detector tube. Since these tube filaments are supplied with approximately 1.4 volts, half of this or .7 volt is used as the initial bias. When signals are received, the a.v.c. bias voltage is added to this. The oscillator grid of the 1R5 receives half the filament voltage plus the voltage created across *R1* by grid current through this grid resistor.

The voltage drop across *R6* due to convection current through it, plus one-half of the filament voltage, biases the pentode section of the 1S5 first audio tube.

The 1S4 power output tube requires considerable bias, more than can be readily furnished by convection current through the grid resistor or by the filament voltage drop. Bleeder bias is employed by causing the plate currents of all tubes to flow through *R11*. The voltage drop across this resistor makes the 1S4 control grid (which connects to the negative end of the resistor) negative with respect to its filament, which connects to the grounded positive end of *R11*.

Battery Economizer. We have now considered the bias arrangement of all the tubes, but the discussion of the 1S4 bias brings up another related object. As you will note, the receiver is equipped with a two-position switch called an *economizer*. By throwing this switch to the "*OUT*" position, maximum power output is obtained from the 1S4 tube, so the total *B* current drain is 7.5 milliamperes. With the switch thrown "*IN*," the *B* drain is reduced to only 5 milliamperes, a considerable saving.

The economizer increases the bias on the 1S4 tube. When the switch is "*IN*" (when the switch bars are across the upper pairs of contacts), resistor *R10* is no longer in parallel with *R11*, and the total resistance between *B*— and the chassis is increased. Therefore the voltage drop across *R11* increases, and this increase in grid bias cuts down on the 1S4 plate current.

As in any battery set, the d.c. plate and screen voltages are applied between these electrodes and the tube filaments. The filaments are grounded to the chassis as shown. Therefore, since the voltage between *B*— and the chassis is increased when the economizer switch is "*IN*," the voltage between filaments and screens and between filaments and plates has decreased. This is unimportant save in the case of the 1R5 and 1T4 screen voltages. A decrease at this point results in a loss in sensitivity. To keep the sensitivity constant, the economizer switch in the "*IN*" position shorts out *R2* in the

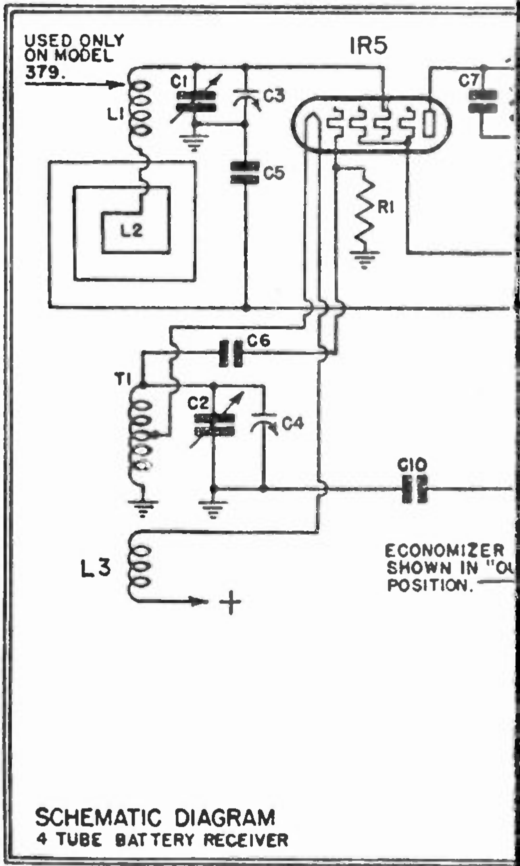


Fig. 7. Circuit diagram of Emerson Model DU-379 and DU-380 battery portable receivers.

screen supply circuit of these tubes, thus keeping the screen voltage constant and preventing a loss in sensitivity.

Voltage Measurements. The operating voltages for each tube are measured with a d.c. voltmeter. The negative probe of the voltmeter goes to the negative filament terminal (grounded terminal) in each measurement except for control grid voltage, where the positive meter probe goes to ground and the negative probe to the control grid.

A definite control grid voltage will be measured only on the 1S4 tube and, due to the high resistance of *R9*, the exact voltage will not be measured. However, this control grid voltage can be checked by placing the meter probes directly across *R11* (positive probe to chassis).

Miscellaneous. The alignment of the receiver follows standard superheterodyne procedure. There are only three i.f. adjustments, since the primary of *T3* cannot be tuned. There is no low-frequency oscillator padder condenser.

the circuit is tuned to 455 kc. by adjusting the coil inductance.

The i.f. signal across the secondary of *T2* is fed to the input of the 1T4 i.f. tube, the filament connection being through *C5* and the chassis.

The 1T4 causes a large i.f. signal current to flow through the primary of *T3*. A voltage is induced into the secondary, where it undergoes resonant step-up. The primary of *T3* is untuned, and hence the coupling in this transformer may be close enough to give high gain. This is typical of any i.f. transformer where only one winding is tuned.

The large i.f. voltage across *C11* is applied to the diode and filament of the 1S5, the filament connection being through *C12*. As a result, rectification occurs, and we have the audio modulation plus a d.c. component across volume control *R5*, which is also the diode load resistor. As previously stated, *C12* prevents any i.f. voltage from being dropped across the diode load, thereby insuring that all of the signal is applied between the diode plate and filament.

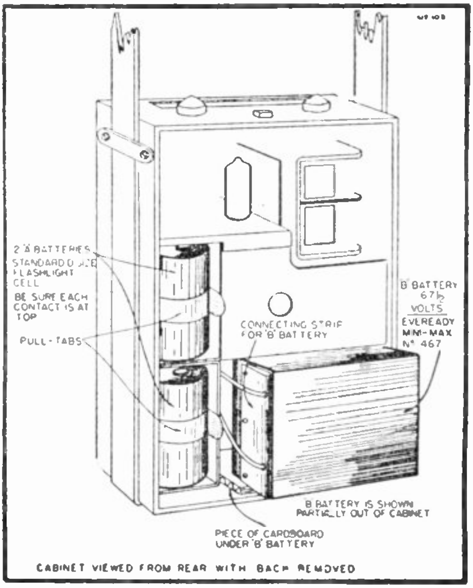
The d.c. voltage across *R5* is used for a.v.c. purposes, since it will vary directly with the strength of the carrier applied to the second detector. The ungrounded end of the resistor is negative with respect to the filament of the 1R5, which is at d.c. ground potential. Tracing the circuit from the negative side of *R5*, we see that part of this voltage is applied to the first detector control grid (third grid of the 1R5) through resistor *R4*. This resistor and condenser *C5* serve to remove the audio signal voltage, and only pure d.c. is available across *C5* for a.v.c. bias purposes.

The full d.c. voltage across *R5* is not used, for *R12* and *R4* are across *R5* and hence act as a voltage divider. The voltage across *R12*, which is in parallel with *C5*, is the a.v.c. voltage fed the 1R5 tube. Since *R4* and *R12* are both 5 megohms (the same size), both have equal voltage drops, and only half of the voltage across diode load *R5* is used for a.v.c. purposes. Thus, while a.v.c. action is reduced, the danger of cutting off the plate current of the 1R5 tube and causing blocking or motorboating on strong signals is eliminated.

The a.f. voltage across volume control *R5* is applied across resistor *R6* through coupling condenser *C13*. Since *C13* connects to the movable arm of the control, the setting of this arm will determine the amount of signal voltage fed to *R6*. As *R6* is directly in the grid input circuit of the pentode portion of the 1S5, the tube amplifies the audio signal fed it, and we have the amplified signal voltage across plate load resistor *R8*.

Condenser *C14* serves to by-pass any stray i.f. signal which may have been amplified by the tube.

The audio signal across *R8* is transferred across *R9* and *R11* through *C16*, *C10* and the chassis. The signal voltage across *R9* and *R11* is amplified by the 1S4 and delivered by impedance-matching output transformer *T4* to the loudspeaker voice coil, and is then converted into sound waves.



Rear view of Emerson Model DU-379 portable receiver, with back cover removed to show batteries. Note how the shoulder-strap antenna encircles the entire set. Control knobs and tuning dial are at top of set, between the loop straps.

Condenser *C17* prevents oscillation at high audio frequencies, and also tends to reduce harmonic distortion by acting as a by-pass for the higher audio frequencies which comprise the harmonics. In addition, inverse feed-back further reduces distortion.

As already pointed out, the input signal voltage is developed across *R9* and *R11*. No by-pass condenser is used across *R11*, and since the plate current of the 1S4 flows through this resistor, we have an audio signal produced here. This signal is 180° out of phase with the applied signal and cancels out the original signal produced across *R11*. In addition, distortion currents produced inside the 1S4 tube flow through *R11* and create voltages of the same distorted form across this resistor. These voltages were not there to start with, and they control the plate current of the tube in such a way as to reduce greatly the distortion inside the tube. The over-all loss in gain due to cancellation of desired signals across *R11* can easily be tolerated.

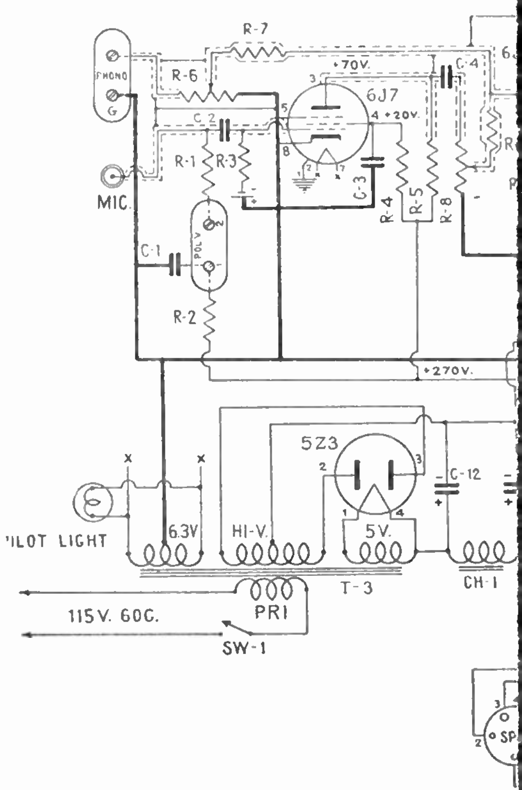
Biasing Methods. As you already know, the grid bias of a battery-operated filament-type tube is measured between the control grid and the negative side of the tube filament. The effective bias, however, is the difference in voltage between the center of the filament and the grid. Therefore, any volt

The output signal induced into the secondary of *T-2* thus has only a very small amount of third harmonic distortion. The secondary has a number of taps, so that it can be connected to match most any load. The grounded secondary terminal goes to one load (loudspeaker) terminal by way of terminals *4* or *5* and *A* or *D* on the *SPK.* sockets, and the tap selected by probe lead *C* of the output transformer goes to the other load terminal through *SPK.* socket terminals *3* and *C*.

When the amplifier is to feed a device over a considerable distance, either the 125-, 250- or 500-ohm taps are used, and a special matching transformer is placed at the other end of the line. The lower-impedance taps are used for voice coils, recorder cutting heads or other low-impedance devices.

Most voice coils have an impedance of 8 ohms, so for a single voice coil we would plug probe lead *C* into the jack marked *8*. If two speakers with 8-ohm voice coils were used, the coils could be connected in parallel; the combined resistance would then be 4 ohms, and the 4-ohm tap would be used. While voice coils are not ordinarily connected in series, we could do this and get a combined impedance of 16 ohms, which would be matched by using the 16-ohm tap.

If electrodynamic loudspeakers are employed, 10 watts of field excitation is available for one 5000-ohm or one or two 2500-ohm speaker fields. The following table indicates how speaker field connections are made to the *SPK* sockets. Note that in some cases a jumper wire is used between jacks on the terminal strip marked *FIELD*.



	Connect Jumper Between	Connect Field to Prongs
One 5000-ohm field..	Not used	1 and 5
One 2500-ohm field..	C and 2	2 and 5
Two 2500-ohm fields.	Not used	8 & E; 2 & 5
P.M. Loudspeaker (no field)	C and 1	....

For practice, see if you can figure out the field supply circuits and the reasons for the connections given in the table. When doing this, take into consideration the ohmic values of the fields and of resistors *R-16* and *R-19*.

The power supply circuit in this amplifier does not represent anything new, being very similar to those you have already studied in receiver diagrams. The rules for tracing circuit continuity apply to this amplifier just as to receiver circuits.

Most troubles which may be expected will take the form of distortion, hum and oscillation. The usual causes are to be suspected, but shielding is particularly important in the case of hum or oscillation. The reason for hum, if shielding is not employed, has already been pointed out. The thing to watch out for is poor ground contacts on the shielding.

The shields on the control grid and plate leads of the 6V6-G tubes prevent electromagnetic and electrostatic coupling between these points and others at a lower audio potential. Suppose, for example, the plate leads of the 6V6-G tubes were inductively coupled to the input of the 6J7 tube by being close to resistor *R-3*. Signal voltage would be induced into *R-3*, and being in phase with the input signal voltage, it would cause oscillation and a loud squeal.

The capacity existing between the 6V6-G plate leads and the grounded shields also tends to prevent oscillation. Beam-power output tubes have a tendency to oscillate and these tubes, when oscillating, have been known to draw sufficient current to damage power transformers. Oscillation will be indicated by serious distortion or a dead amplifier. The d.c. voltages will be very low due to the excess current drain.

In the schematic, you will see the operating voltages marked at the points at which the voltage measurements are generally made. The d.c. voltages are measured between the points shown and the chassis.

The output filter voltage is measured between the positive lead of C-13 and the chassis, and according to the schematic you cause a pentode tube fed with a strong signal will produce very strong harmonics, and these will cause severe distortion. Push-pull action and inverse feed-back permit the use of the 6V6 pentode-type output tubes, while the signal input of the first 6J7 is too low to produce much harmonic voltage. The signal fed to the second 6J7 is, for either microphone or phonograph operation, too large to permit pentode operation of the tube.

The second 6J7 is not replaced with a regular triode tube such as a 6C5, because even when connected as a triode the 6J7 can produce more gain than a 6C5. It is necessary to use a 6C5 in the next stage, for by now the signal is so strong that it would overload the 6J7 even when triode connections were used.

The a.f. signal voltage across *R-11* is applied to grid resistor *R-12* of the 6C5 tube through coupling condenser *C-6* and filter condenser *C-10*. The signal current flowing through grid resistor *R-12* produces a voltage drop which drives the grid of the tube. *R-12* is a potentiometer, and the movable arm connects to ground through *C-7*, a .03-mfd. condenser. As the arm is moved up, more and more of the high frequencies are shorted or by-passed around *R-12*, and hence are not applied to the grid of the 6C5. In this way we achieve tone control, which permits attenuation of high audio frequencies as desired.

The a.f. signal voltage across *R-12* alternately adds and subtracts from the d.c. bias developed across *C-8* and *R-13*, making the grid first more negative and then less negative. This variation in control grid voltage causes a corresponding variation in plate current. As a result, we have a pulsating d.c. plate current flowing through plate load resistor *R-14*. Condenser *C-9* and the primary of *T-1* comprise a short path for the a.f. component, hence the effective plate load for signals is *R-14* in parallel with *C-9* and the primary of *T-1*. Since the resistance of *R-14* is much greater than the impedance of the *C-9 T-1* path at audio frequencies, practically all of the signal current passes through *C-9* and the transformer.

This method of capacity coupling is a little out of the ordinary. If *R-14* and *C-9* were not used, the primary of *T-1* would be placed right in the plate supply circuit of the 6C5. The circuit would function but the d.c. portion of the plate current would tend to saturate the transformer primary, and the mutual inductance of the transformer would decrease. This would decrease the voltage induced into the secondary, and would cause distortion since the change in flux linkage would be greater for a decrease in plate current than for an increase. For distortionless transfer of signal, the flux must follow current changes exactly. The loss in gain would be more serious at the low audio frequencies, because the primary inductance, and hence the plate load impedance, naturally decreases with frequency.

By keeping the d.c. portion of the plate current out of the primary, we avoid transformer saturation and thereby secure good low-frequency response from this stage. Resistor *R-14* and condenser *C-9* do this; the resistor supplies d.c. plate voltage to the tube, and *C-9* blocks d.c. while allowing a.c. to pass. By choosing a value of *C-9* which will resonate with the primary of *T-1* at a low audio frequency, a definite boost in gain at low audio frequencies can be obtained.

A.F. signal current flowing through the primary of *T-1* sets up a flux linkage with the secondary, inducing an a.f. voltage in each half of the secondary. These secondary windings feed the two 6V6-G tubes in the push-pull output stage, with inverse feed-back being provided in the following manner by an extra center-tapped winding on output transformer *T-2*. Let us consider secondary *8-7* of *T-1* first. Terminal *8* goes to the control grid of the upper 6V6-G output tube, while *7* goes to terminal T_2 on the special winding having a center tap marked *CT*. Resistor *R-18* (a C bias resistor in the power pack) completes the path from *CT* to ground. The voltage between *8* and *7* thus acts in series with the a.f. voltage across the lower half of the "*CT*" winding and the d.c. voltage across resistor *R-18*. In a similar manner, the signal voltage between point *5* and point *6* acts in series with the a.f. voltage across the upper half of the "*CT*" winding and the d.c. voltage across *R-18*, all feeding the control grid of the other 6V6-G tube.

The 6V6-G tubes amplify the signals applied to their grids, and the resulting plate currents flow through primaries P_1-*B* and P_2-*B* of output transformer *T-2*. Due to the push-pull action, all even harmonics produced within the tubes are canceled out.

The odd harmonics, of which the third is the strongest and hence most troublesome, are not canceled out by the push-pull arrangement, but are taken care of by inverse feed-back (degeneration). The fundamentals and odd harmonics flowing through the primaries of output transformer *T-2* induce voltages in the "*CT*" winding as well as in the regular secondary. These voltages, as you just learned, act in series with the a.f. voltages applied to the grids of the output tubes but are 180° out of phase, due to the phase reversal provided by the output tubes.

The fundamental component which is fed back out of phase cancels out some of the fundamental at the grid input, thus reducing the gain. The designer took this into account, however, and there is gain to spare. The odd harmonics are also fed into the grid input of each 6V6-G, but since they were produced inside the 6V6-G tubes, they are not originally present in the input circuit. The fed-back odd harmonics thus enter the tubes, and cancel out some of the odd harmonics being produced by the tubes. Complete cancelation is impossible, for we must have some signal induced into the center-tapped secondary of *T-2* for feed-back purposes.

voltage because the two voltages are in parallel. The copper-oxide rectifiers prevent the battery from discharging through the charging circuit, because they do not allow current to pass in the reverse direction. For these reasons, the battery must be in the receiver even during a.c. operation. If the set were used on "*AC*" with the battery removed, the tubes would get excessive filament voltages and would burn out, and the vibrator and filter condensers might also be damaged.

Voltage Measurements. Figure *4* shows the socket voltage diagram for this set. The voltages given on it are measured between the points indicated and the chassis. The battery voltage is measured across the battery terminals, and the vibrator voltage is measured from *B+* to the chassis. Condenser *C21A* can easily be located in the chassis; since it is the input filter condenser, the *B+* voltage delivered by the power transformer may be measured across it. The resistance of *L5* is so low that the slight amount of voltage dropped across it will not affect the accuracy of this measurement.

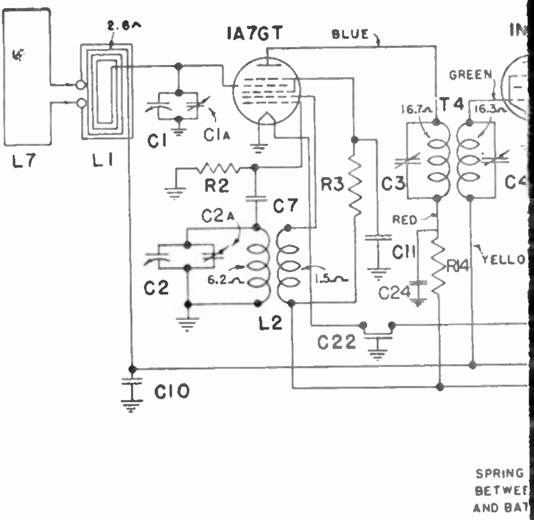
You will find that the value of *R14* is not given. Evidently the factory draftsman forgot this; such errors sometimes creep into diagrams.

If you had to replace *R14*, what would you do? First, you would consider the purpose of *R14* in the circuit. Obviously, it is not purposely used to reduce plate voltage, and neither is it a plate load. It must therefore act with *C24* as a filter to keep r.f. plate current of the 1A7GT out of the B supply. From past experience and from observing many similar circuits, we know that the resistor value is not critical and that manufacturers use values between 1000 and 10,000 ohms for this purpose. We feel sure that the choice of an average value of about 5000 ohms will work nicely.

We can get a confirmation by means of Ohm's Law if we wish. Since the plate of the 1A7GT receives 78 volts and the i.f. screen from which *R14* is fed receives 82 volts, 4 volts are dropped across *R14*. A tube chart tells us that the 1A7GT plate draws about .7 ma., and Ohm's Law says that resistance equals voltage divided by current, so by simple division we arrive at a value of about 5900 ohms for *R14*. Experience tells us that 5000 ohms is satisfactory, but if actual trial shows it to be too low, a larger resistor may easily be inserted.

Continuity Tests. Continuity tests are made in the usual way between points at a positive potential and the *B+* terminal, and between points at a negative potential and the *B—* terminal (the chassis here). *B+* is the red lead going from the junction of *R10* and *C21A* to the *B* supply.

The storage battery in this receiver must be disconnected for ohmmeter tests, just as in any other battery set. The bias cells need not be disconnected if you don't check from the grid of the 1Q5GT to chassis. However, a check directly across *R9* is perfectly all right.



POWER SELECTOR SWITCH OPERATION	
POSITION	CONTACTS CONNECTED
"OFF"	ALL CONTACTS OPEN
"BATTERY"	#1 to #2; #4 to #5; #7* to #8
"AC"	#1 to #2 to #3; #4 to #5; #8 to #9
"CHARGE"	#2 to #3; #8 to #9

* #7 terminal is not connected to circuit

Fig. 5. Schematic circuit diagram of General Electric Model LB-530 a.c. or battery-operated portable receiver.

To avoid possible short-circuit readings through the vibrator contacts, the plug-in type vibrator is pulled out of its socket during ohmmeter tests.

Expected Performance. With the two stages of i.f., excellent sensitivity and adjacent-channel selectivity may be expected. Some image interference may occur due to lack of preselection, but turning the loop to a different position by rotating the entire receiver will sharply reduce the pick-up of undesired signals.

The 1Q5GT can't deliver much output power, so you won't expect high volume. Both volume and tone quality will be less than that secured with a good table model receiver, but will be entirely satisfactory for a portable.

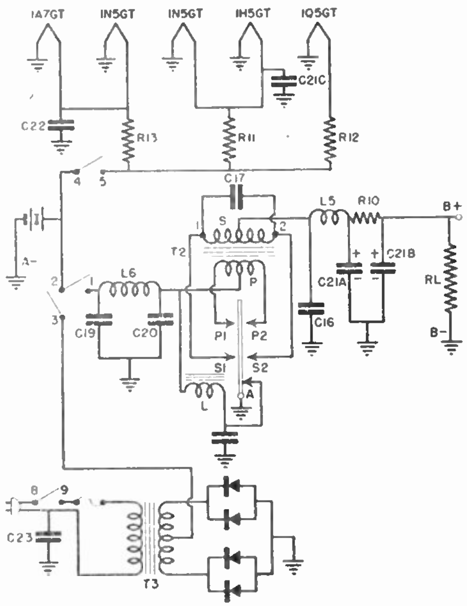


Fig. 3. Effective power pack circuit when power selector switch is set at "AC."

the electrons flow through *R10* and *L5* to get back to the center tap on winding *S*.

That portion of the induced voltage existing between the center tap and point *2* is not used now, and may be forgotten.

When the vibrator reed is pulled over to contacts *P1* and *S1* by the coil, it breaks the coil circuit at contact *A*. The natural springiness of the reed returns it to the neutral position, but the reed always overshoots the neutral position enough to make contact with *P2* and *S2*.

With contacts *P2* and *S2* grounded by the reed, we have electrons flowing from the minus battery terminal through the chassis to the reed and *P2*, then through the right-hand section of power transformer primary *P* and back through *L6* and contacts *2-1* to the battery. Since this electron flow is in the opposite direction from that which previously flowed through *P*, the induced voltage in the secondary has reversed polarity. Point *1* is now positive with respect to the center tap, which makes point *2* negative with respect to the center tap and gives electron flow through *RL* in the same direction as before.

From this, we see that the center tap on the secondary is positive with respect to whichever outer terminal (*1* or *2*) is being grounded by the vibrating reed. The vibrator thus provides full-wave rectifying action which gives a pulsating high d.c. voltage of the correct polarity between the center tap of *S* and the chassis. This pulsating voltage is filtered by *C21A*, *C21B* and *R10*, then applied to the plates and screen grids of the tubes in the receiver (connected between *B+* and *B—* like *RL*).

When the reed moves over to contacts *P2* and *S2*, it also touches contact *A*. This energizes the vibrator coil and pulls the reed over to *P1* and *S1* just as when the set was first turned on. The entire process then repeats itself.

Power Pack Circuit for "AC." When the power selector switch is set at "*AC*," contacts *1-2-3* are connected together, as also are contacts *4-5* and contacts *8-9*. The power pack circuit arrangement for this condition is represented by Fig. *3* if we close the four switches in the diagram.

The output voltage of the charging circuit is now applied directly across the battery just as in Fig. *1*. At the same time, the battery furnishes current for the tube filaments and the vibrator *B* supply. Since the charger furnishes the battery a little more current than is drawn from it by the receiver, the battery will be charged slowly while the set is playing.

The battery acts as a low-resistance bleeder across the charging circuit, and thereby keeps the charging voltage from getting too much higher than the rated filament voltages. The battery also acts like a condenser, removing the ripple from the charging voltage. When the charging voltage starts to decrease, the net voltage cannot become lower than the battery

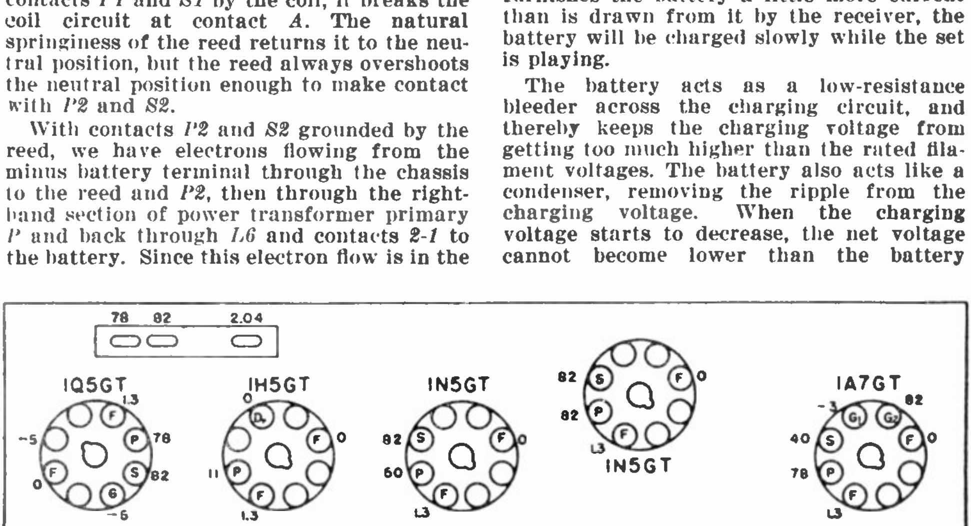


Fig. 4. Socket voltage diagram. The bias battery voltage should be measured only with a zero-current voltmeter, such as a vacuum tube voltmeter. The power switch should be set on "AC," with the charger operating. Tuning dial should be at 1000 kc., with zero volume and zero signal. Batter should measure 2.1 volts. Vibrator B+ voltage should be 95 volts d.c.

TYPICAL RECEIVER DIAGRAMS AND HOW TO ANALYZE THEM

General Electric LB-530 A.C.-BATTERY Portable

IDENTIFYING Tube Stages. When starting to identify tube stages on the circuit diagram of a receiver, we often work by a process of elimination. That is, we locate first the tubes which are easiest to identify. Knowing the stages generally used in a superheterodyne, we then concentrate on assigning the remaining tubes to the heretofore unidentified stages.

We will use this process to identify the tubes in the circuit diagram of this General Electric superheterodyne receiver (shown in Fig. 5). (Note: By folding page 2 under page 1 you can refer to this diagram while you study, without having to turn pages back and forth.)

We can start from either end of the receiver, so let us start with the 1Q5GT tube. Since this tube feeds the loudspeaker, we know that it is the output tube.

We know that this output tube should be fed by an a.f. voltage amplifier stage, and we find its input coupled to the triode section of the 1H5GT tube by R-C network *R8-C13-R9*. The control grid is fed by the diode section of the 1H5GT through *R1*, *R7* and *C12*, hence the diode section must be the second detector and the triode section must be the first a.f. stage.

The presence of volume control *R1* in the diode circuit confirms identification of the diode section as the second detector, because the volume control in a superhet is always an a.f. voltage control. A.V.C. voltage is taken from the diode detector load through filter *R4-C10*, for application to the a.v.c.-controlled tubes.

Surprisingly, the second detector is resistance-coupled to the output of a 1N5GT tube. This form of coupling might lead us to believe that the 1N5GT was the second detector if we hadn't already identified the 1H5GT as being in this stage. A glance to the left on the schematic shows two i.f. transformers, so sufficient selectivity is provided to allow the less-expensive and broad i.f. resistance coupling to be used here.

Our knowledge of superheterodyne stage sequence tells us that the 1N5GT is an i.f. amplifier, feeding the 1H5GT. It is transformer-coupled to another 1N5GT tube whose input is likewise fed from an i.f. transformer (identified by the tuned primary and tuned secondary). Thus we know that the left-hand 1N5GT in Fig. 5 is the first i.f. amplifier.

I.F. transformer *T4* is fed by a 1A7GT whose input connects to the antenna loop and whose first grid connects to a tank circuit through condenser *C7*. There are no more tubes in the set, so the 1A7GT must be the oscillator-mixer found in every superheterodyne receiver. In this simple manner we have identified the purpose of each tube in the receiver.

Signal Circuits. The parts list under Fig. 5 indicates that *L1* is the Beam-A-Scope Loop assembly, and it must therefore act as the antenna for the receiver. The expression "Beam-A-Scope" is a trade name used by General Electric to describe their shielded loop antenna. Additional pick-up may be obtained by means of an external loop *L7* which is furnished with the receiver and can be plugged into the terminals shown on the diagram. The two loops are inductively coupled together by the single turn of wire shown around *L1* in the diagram.

Loop *L1* is tuned to resonace by condenser *C1*, so signals picked up by *L1* undergo the usual resonant step-up. The use of *L7* will cause some detuning, but the resulting loss in signal is more than made up by the greater pick-up afforded by *L7*. The incoming carrier signal to which *L1-C1* is tuned acts directly on the control grid and filament of the 1A7GT, because *C10* provides a zero-reactance path to the grounded filament at r.f. and i.f. values.

The first and second grids of the 1A7GT (counting from the filament) serve as oscillator electrodes, the first being the oscillator control grid and the second being the oscillator anode.

The incoming signal and oscillator signal are mixed within the tube, and we have a strong i.f. beat signal developed across the primary of *T4*. The signal induced into the secondary of *T4* is applied to the input of the 1N5GT first i.f. tube, the filament connection being through *C10*. The amplified signal now appears across the tuned primary of *T5*, setting up a high circulatory current at the i.f. value, and this induces the i.f. signal voltage in the secondary of *T5*. Again we have resonant step-up, and the signal voltage across the secondary is applied directly to

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the input of the second 1N5GT i.f. tube.

The resulting variations in the plate current of the second 1N5GT tube produce a large i.f. voltage across plate load resistor *R5*. This i.f. voltage is applied across resistor *R6* through condensers *C8*, *C21B* and *C9*. The i.f. voltage across *R6* feeds the diode of the 1H5GT, the filament connection being through *C9*. The diode rectifies the signal and detection takes place. The a.f. signal divides between *R6* and *R1*, but since *R1* is many times greater in value than *R6*, the a.f. signal loss across *R6* is so small that it can be forgotten.

I.F. signals are shunted around *R1* by *C9*. The d.c. component of the rectified audio signal is fed through *R4* for use as the a.v.c. voltage for the control grids of the converter tube and the first i.f. tube. *C10* acts as the a.v.c. filter condenser. That portion of the audio signal which is between the movable contact of *R1* and ground is applied across *R7* in the grid input circuit of the 1H5GT triode section through *C12*.

The amplified audio signal across triode plate load resistor *R8* is applied across the grid input of the 1Q5GT through coupling condenser *C13* and through *C21B*. Plate by-pass condenser *C18* removes stray i.f. components from this signal. The plate current of the 1Q5GT, varying at an audio rate and flowing through the primary of output transformer *T1*, induces a voltage in the secondary. The resultant current through the loudspeaker voice coil sets the cone in motion, producing sound waves.

C14, connected between the plate and screen grid of the 1Q5GT, prevents audio oscillation by making the plate load capacitive at the higher frequencies where oscillation would otherwise take place. This condenser also by-passes the harmonics produced within the tube, and hence reduces distortion. The harmonics, being of a higher frequency than the fundamentals, are more easily by-passed by *C14*.

How the Tubes Are Biased. As in all filament-type battery tubes, the effective control grid voltage is the voltage between the control grid and the center of the filament. Naturally we cannot connect our voltmeter probe to the center of the tube filament, so the control grid voltage is measured between the control grid and the negative side of the filament. The tubes all have their negative filament leads grounded to the chassis, and the various grid voltage sources exist between the grids and chassis. The voltage between the center of the filament and ground (half of the filament voltage) serves as an additional bias.

The triode section of the 1H5GT is self-biased by convection currents through *R7*, which has a value of 4.7 megohms.

Bias cells (*B1*) are used to provide control grid voltage for the 1Q5GT power tube. Since *R9* has a value of 2.2 megohms, convection currents wouldn't produce much voltage across such a relatively low value of resistance in the grid circuit of a tube.

Bias cells are more expensive than a single resistor of high ohmic value, but there is a good reason for using them here. The 1Q5GT tube is subject to gas, as are so many power output tubes. If a high-value grid resistor is used with a gassy tube, the resulting gas current through the grid resistor will be opposite in direction to the convection current and much stronger. As a result, the gas current will drive the grid positive, increasing the plate current and releasing more gas, all of which causes serious distortion and shortens tube life.

Because of the low plate and screen voltages which are employed for the converter and the i.f. tubes, no external grid bias sources are necessary for these tubes. The voltages between the centers of the filaments and ground provide sufficient initial bias voltage in each case. When a signal is received, however, the a.v.c. voltage is applied to the converter and first i.f. tube control grids.

The Power Supply. The power supply of this receiver, shown inside the dotted lines in Fig. 5, is as complicated as any you will meet in ordinary receivers. This is due to the switching system and the manner in which the circuit is drawn.

The tube filaments are heated directly by the 2-volt battery, while the necessary high d.c. voltages for the tubes are furnished by a synchronous vibrator used in conjunction with a step-up power transformer and its associated filter circuit. The synchronous vibrator also operates from the 2-volt battery.

Provision has been made to charge the battery directly from the house current without removing the battery from the receiver circuit. Two charging positions are provided on the four-position power selector switch. The "*CHARGE*" position of this switch allows the battery to be charged at the rate of approximately 1.35 amperes from the house current during the period that the receiver is not being operated. The "*AC*" position of the switch allows the receiver to be operated at the same time that the battery is being trickle-charged at a low rate.

Charge Indicator. The degree of charge of the battery can be determined by removing the back cover of the radio and looking at the charge ball indicators which are visible through the hole in the metal battery case.

If the battery is fully charged, three indicator balls will be visible at the surface of the liquid in the battery. When the battery discharges, these ball indicators will sink and disappear in the following order:

1. The green ball sinks when approximately 10% of battery capacity has been discharged.

2. The white ball sinks when 50% of battery capacity has been discharged.

3. The red ball sinks when the battery is 90% discharged.

On charge, the balls rise or float in the reverse order. Charging is complete and may be stopped when all three balls appear in the opening.

To Charge Battery. The battery is charged merely by plugging the receiver power cord into an a.c. wall outlet and turning the selector switch to "*CHARGE*." The charge indicator balls should be checked frequently. Continued charging after all indicator balls are visible will not harm the battery, but will evaporate the water in it faster. A completely discharged battery will usually be restored in 20 to 30 hours.

Power Pack Circuit for "CHARGE." Setting the power selector switch to "*CHARGE*" (for charging the battery from the a.c. power line without operating the receiver) connects switch terminals *2* and *3* together, and also connects *8* and *9* together, as indicated in the box at the left of the diagram in Fig. *5*. When the power pack circuit is redrawn to show only these switch terminals and the associated parts which are effective, we secure the arrangement shown in Fig. *1*. Of course, switches *8-9* and *3-2* would be closed during charging. Charging currents can now be easily traced on this simplified circuit.

During charge, electrons must flow into the negative terminal of the battery and out of the positive terminal. The charging voltage need be only a small amount higher than the normal battery voltage of 2 volts. Transformer *T3* in Fig. *1* provides about 5½ volts a.c. between secondary terminals *x* and *y*. The four copper-oxide rectifiers, each pair in parallel, convert this to the required d.c. voltage.

When point *x* is negative, point *z* is positive. Then electrons flow from *x* through rectifier *Y2* and the chassis to the negative battery terminal, through the battery and back to *z*. Electrons only flow through the copper-oxide rectifiers in the direction from the flat plates to the triangles on the symbols, so there is no electron flow now through rectifier *Y2*.

On the next half-cycle, *y* is negative and *x* is positive, so *z* is now positive with respect to *y*. Electrons flow from *y* through *Y1* and the chassis, then through the battery in the same direction as on the previous half-cycle, adding to the charge of the battery. The electrons coming out of the positive battery terminal return to *z* through switch contacts *3-2*. We thus have a full-wave rectifier, with first one half of the transformer secondary and then the other half furnishing current to the battery.

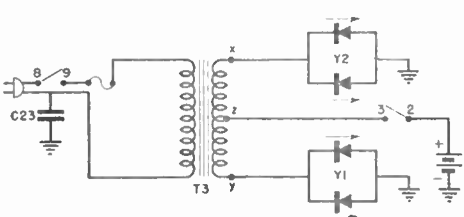


Fig. 1. Effective power pack circuit when power selector switch is set at "CHARGE." Arrows indicate direction of electron flow through rectifier units.

Power Pack Circuit for "BATTERY." When the switch is thrown to the "*BATTERY*" position for portable operation, contacts *4-5* and *2-1* are closed, giving the effective circuit arrangement shown in Fig. *2*. The filaments secure their voltage from the battery through contacts *4-5* and series resistors *R13*, *R11* and *R12*, with the circuits being completed through the chassis by means of grounds.

When the power selector switch is in its "*OFF*" position, all switch contacts are open, and the vibrator reed is in a neutral posit'on

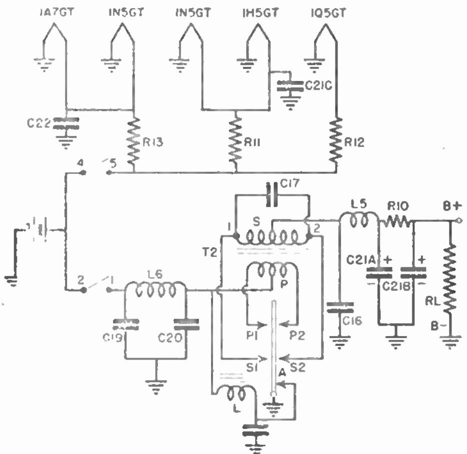
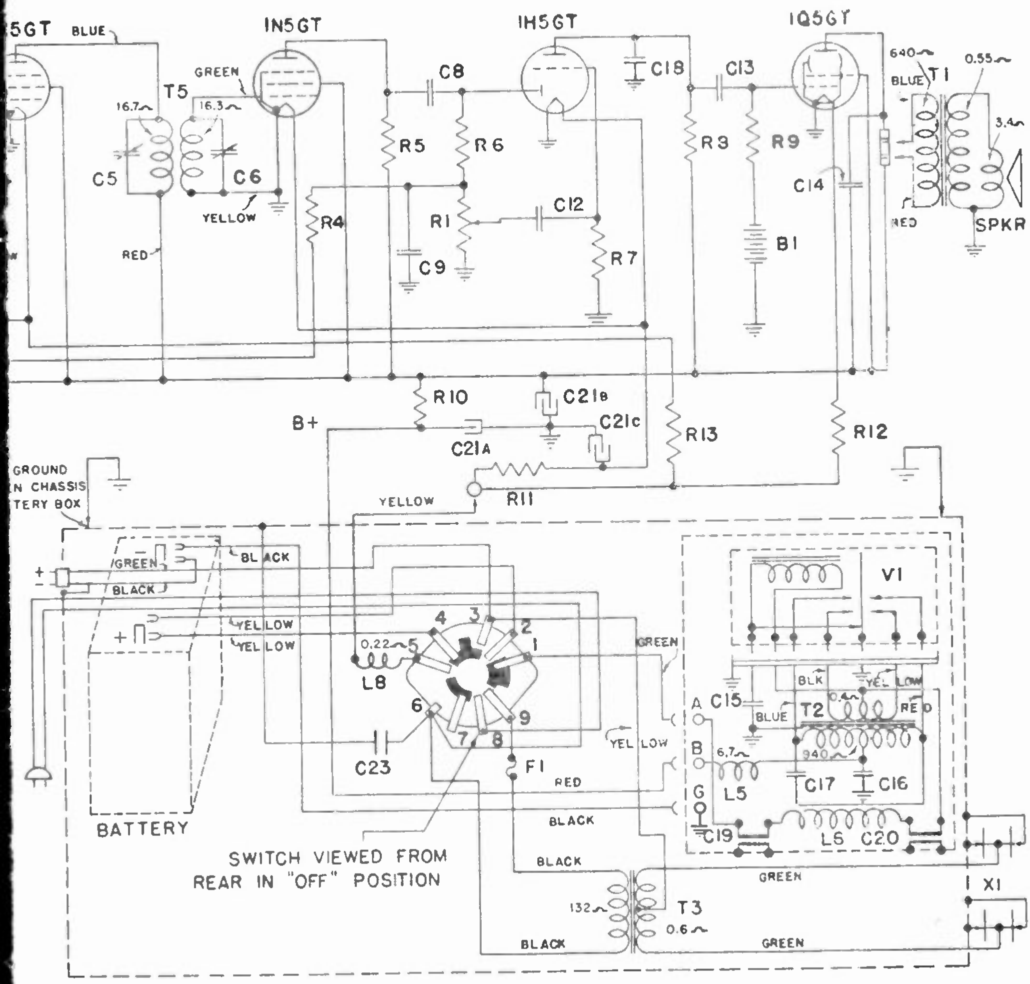


Fig. 2 Effective power pack circuit when power selector switch is set at "BATTERY."

half-way between contacts *P1-P2* and *S1-Sz*. Only contact *A* on the vibrator is closed.

Setting the switch to "*BATTERY*" closes switch contacts *2-1* and *4-5*, and the battery sends current through vibrator contact *A* and through the vibrator coil *L*. This energizes the coil, causing it to attract the vibrator reed. The reed is pulled toward the coil, thereby grounding contacts *P1* and *S1*. This results in electron flow from the grounded terminal of the storage battery through the reed and *P1*, through the left-hand side of the primary of power transformer *T2*, then through *L6* and switch contacts *2-1* to the positive battery terminal.

The sudden rush of current through primary winding *P* causes a high voltage to be induced into secondary *S*. Let us assume that it makes point *1* on the secondary negative with respect to the center tap. Electrons now flow from point *1* through contact *S1* to the chassis, then through all the tube loads in the receiver, represented in Fig *2* as resistive load *RL*. From the *B+* end of *RL*



C1, 2 ....CONDENSER—Tuning condenser and trimmers
C7 ....CAPACITOR—47-mmf. mica
C8, 9 ....CAPACITOR—100-mmf. mica
C10 ....CAPACITOR—.05-mfd., 200-V. paper
C11 ....CAPACITOR—0.1-mfd., 200-V. paper
C12, 13 ......CAPACITOR—.005-mfd., 600-V. paper
C14 ....CAPACITOR—.01-mfd., 600-V. paper
C15 ....CAPACITOR—0.1-mfd., 200-V. paper
C16 ....CAPACITOR—.05-mfd., 200-V. paper
C17 ....CAPACITOR—.006-mfd., 100-V. paper
C18 ....CAPACITOR—100-mmf., mica
C19, 20 ......CAPACITOR—0.5-mfd., 120-V.
C21A, 21B ....CAPACITOR—15-mfd., 150-V. dry electrolytic
C21C ....CAPACITOR—1200-mfd., 2-V. dry electrolytic
C22 ....CAPACITOR—0.5-mfd., 120-V. paper
C23 ....CAPACITOR—.05-mfd., 600-V. paper
R1 ....VOLUME CONTROL—0.5-megohm volume control
R2 ....RESISTOR—220,000-ohm, ½-W. carbon
R3 ....RESISTOR—47,000-ohm, ½-W. carbon
R4 ....RESISTOR—2.2-megohm, ½-W. carbon
R5 ....RESISTOR—27,000-ohm, ½-W. carbon
R6 ....RESISTOR—47,000-ohm, ½-W. carbon
R7 ....RESISTOR—4.7-megohm ½-W. carbon
R8 ....RESISTOR—1.0-megohm, ½-W. carbon
R9 ....RESISTOR—2.2-megohm, ½-W. carbon
R10 ....RESISTOR—1,000-ohm, ½-W. carbon
R11, 12, 13 ..RESISTOR—8.2-ohm, ½-W. carbon
B1 ....CELL—5.0-V. bias cell assembly
L1 ....BEAM-A-SCOPE—Loop antenna assembly (inside cover)
L2 ....COIL—Oscillator coil
L5 ....CHOKE—B choke
L6 ....CHOKE—Vibrator choke
L7 ....BEAM-A-SCOPE—External loop antenna
L8 ....CHOKE—Filament supply choke
SW1 ....SWITCH—Power selector switch
T1 ....TRANSFORMER—Output transformer
T2 ....VIBRATOR—Vibrator power transformer
T3 ....TRANSFORMER — 50-60-cycle rectifier step-down transformer
T4 ....TRANSFORMER—1st I.f. transformer
T5 ....TRANSFORMER—2nd I.f. transformer
V1 ....VIBRATOR—Power supply synchronous vibrator
X1 ....RECTIFIER—Copper-oxide rectifier
Spkr. ....SPEAKER—P.M. dynamic loudspeaker

THORDARSON 15-WATT AUDIO AMPLIFIER

THIS amplifier, whose circuit diagram is shown in Fig. 6, has sufficient power output to satisfy the requirements of many different public address installations. The versatility of the amplifier is evident when it is realized that it can be used for ordinary p.a. (public address) work, as a phonograph amplifier, for commercial or home recording, or to amplify the output of a photocell.

Starting with the output stage, we see that type 6V6-G beam power output tubes are used in a class *A* circuit. Distortion is kept below 5% even at full output by the use of inverse feed-back. This low level of distortion is quite good.

The high-impedance microphone and high-impedance phonograph channel, with independent gain controls, will allow use of any type of microphone and either a crystal or magnetic pick-up. The gain is sufficient to obtain full output either from the microphone or pick-up under normal operating conditions.

The circuit diagram shows two loudspeaker sockets, in which either electro-dynamic or p.m. dynamic loudspeakers can be plugged. The power pack is designed to serve as field supply for one or two electro-dynamic loudspeakers. More than two p.m. dynamic loudspeakers can be used, but normally there would be no reason to use more than two with a relatively small p.a. system like this.

When a phono pick-up is used, the leads are plugged into the jacks provided on the *PHONO* terminal strip, and microphone volume control *R-8* is set for zero volume (so its movable contact is grounded). The signal voltage from the pick-up is applied across phono volume control *R-6*, and the portion of this voltage between the movable contact and ground is applied to a voltage-dividing network consisting of resistors *R-7* and *R-9*. Only that portion of the signal across *R-9* is applied to the input of the second 6J7 tube, the a.f. signal across *R-7* being lost as far as the amplifier is concerned. This cuts the signal in half, but the gain built into the amplifier takes this into consideration.

The purpose of resistor *R-7* is to isolate phono volume control *R-6* from microphone volume control *R-8* when the microphone input is used. Under this condition, *R-6* is set to zero, and volume is controlled by *R-8*. If it were not for resistor *R-7*, control *R-6* in its off position would connect the control grid of the second 6J7 tube directly to ground, thus cutting off the microphone signals. Resistor *R-7* is 500,000 ohms, which is enough to isolate *R-6* from the microphone volume control.

Note the symbol for the microphone jack. The jack is of the telephone type, the outside shell going to ground and the hot (ungrounded) contact going to coupling condenser *C-2*. When a "mike" is plugged into this jack, one lead makes contact to the chassis through the jack shell, while the other connects to condenser *C-2*.

The mike signal is impressed through *C-2* across the single bias cell and resistor *R-3*. In this way it is fed into the input of the first 6J7 tube. This tube is connected as a high-gain voltage amplifier. The weak a.f. signal applied to its input is amplified many times, so a strong a.f. signal is developed across plate load resistor *R-5*. Capacity coupling through condensers *C-4* and *C-10* allows the signal to be applied across volume control *R-8*, whose setting governs the amount of signal fed into the second 6J7 tube.

At the microphone input, you will notice the terminal strip marked *POL-V*. This means polarizing voltage. When a condenser-type microphone is employed, a wire jumper is used to connect terminals *1* and *2* together, thus applying the necessary high d.c. voltage to the microphone plates. Here resistor *R-2* and condenser *C-1* serve as a decoupler filter, preventing any hum voltage from being applied to the condenser microphone and preventing the microphone signal from traveling through the power supply.

If a photoelectric cell of the gas-filled type is plugged into the mike jack, about 90 volts will be required to operate the cell. At terminal *1* we have about 270 volts, and when a photocell is used this is reduced to 90 volts across the mike jack by connecting a 5-meg-ohm, 1-watt resistor between terminals *1* and *2*.

If a condenser microphone or photoelectric cell is never to be used, *R-1*, *R-2* and *C-1* are eliminated during construction of the amplifier.

The shielding of wires and parts in the circuits of the two 6J7 tubes and the 6C5 tube is very important, if hum and noise are to be eliminated. Any hum or noise signals picked up at these points would receive great amplification. If they were as strong as the a.f. signals normally existing here, they would be just as loud at the loudspeakers, thus preventing use of the amplifier.

The microphone, photocell or phono signals applied to the input of the second 6J7 tube cause a large variation in the tube's plate current. The variation in current flowing through plate load resistor *R-11* produces a strong a.f. output voltage across *R-11*.

Before we follow the signal to the next stage, note the electrode connections employed in the second 6J7 tube. With the screen grid, suppressor grid and plate tied together in this manner, the tube acts as a triode instead of a pentode. The gain as a triode is considerable, but far less than that obtained with the pentode connection used for the first 6J7 tube.

The triode connection was employed be-

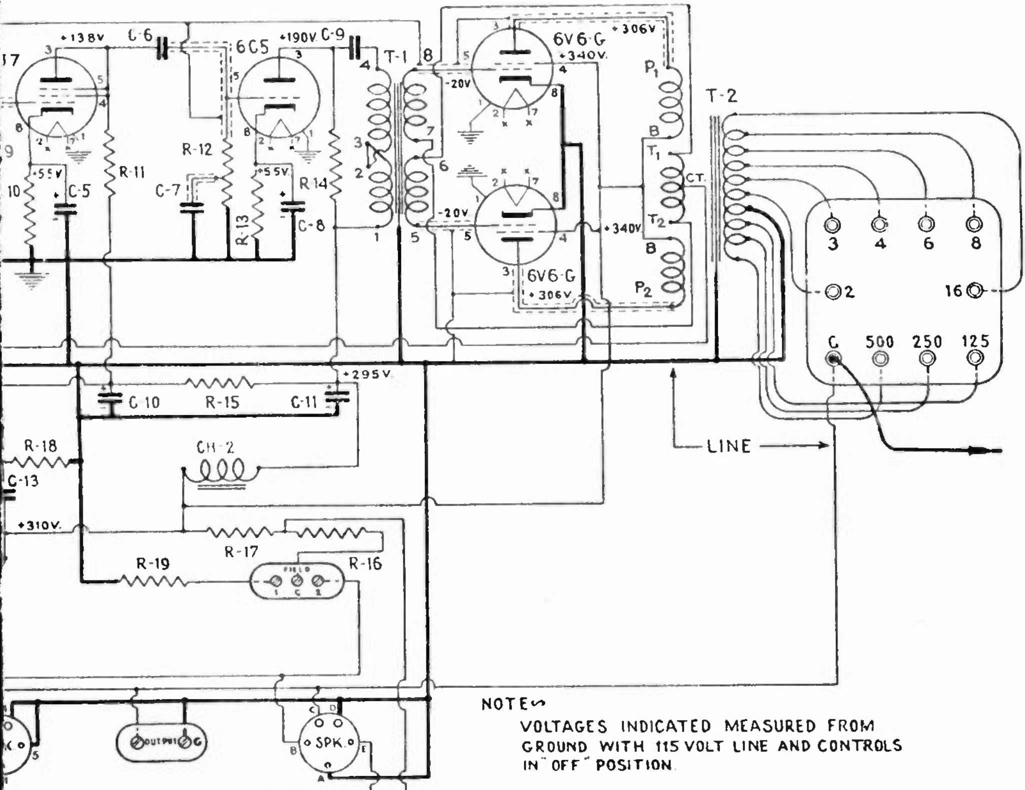


Fig. 6. Circuit diagram of Thordarson-designed 15-watt a.f. amplifier. The parts values are:

should read about 310 volts. Now notice that the screens of the output tubes are marked 340 volts. The screens connect directly to the positive lead of *C-13* and hence are at the same potential as *C-13* with respect to ground. The difference between the marked voltages shows that the draftsman who made up this schematic was careless. In a case like this, you must rely on your own knowledge and be able to make up your mind that an error exists. In all probability, 340 volts and not 310 volts is correct.

Note that the 6V6-G plates are marked 306 volts. If 310 volts is right and the plates are marked correctly, there is only a drop of 4 volts across the plate windings of output transformer *T-2*. This is not reasonable. Now if 340 volts is correct, the drop across the plate windings is 34 volts, which is about the amount you would expect.

The plate voltages of the 6J7 and 6C5 tubes were probably measured with a 1000-ohm-pervolt meter. If a more sensitive meter is used, a higher voltage will be measured, since the meter will draw less current through the plate load resistors and hence won't cause as much extra voltage drop to exist across them.

T-1	Input Transformer
T-2	Output Transformer
T-3	Power Transformer
CH-1	First Choke
CH-2	Second Choke
R-1	10-meg., ½-W.
R-2	10-meg., ½-W.
R-3	5-meg., ½-W.
R-4	3-meg., 1-W.
R-5	500,000-ohm, 1-W.
R-6	1-meg. Volume Control
R-7	500,000-ohm, 1-W.
R-8	1-meg. Volume Control
R-9	500,000-ohm, ½-W.
R-10	5000-ohm, 1-W.
R-11	100,000-ohm, 1-W.
R-12	500,000-ohm Tone Control
R-13	1000-ohm, 1-W.
R-14	20,000-ohm, 1-W.
R-15	20,000-ohm, 1-W.
R-16	2500-ohm, 25-W. wirewound
R-17	1500-ohm, 25-W. wirewound
R-18	125-ohm, 25-W. wirewound, Tolerance +10%, —0%
R-19	2500-ohm, 25-W. wirewound
C-1	.1-mfd., 400-V. paper
C-2	.1-mfd., 400-V. paper
C-3	.04-mfd., 400-V. paper
C-4	.1-mfd., 400-V. paper
C-5	10-mfd., 25-V. electrolytic
C-6	.1-mfd., 400-V. paper
C-7	.03-mfd., 400-V. paper
C-8	10-mfd., 25-V. electrolytic
C-9	.1-mfd., 400-V. paper
C-10, C-11	8-8 mfd., 450 W.V. electrolytic
C-12	8-mfd., 600-V. electrolytic
C-13	8-mfd. 600-V. electrolytic

EMERSON Model DU-379 and DU-380 Battery Portable

GENERAL Description. Although the diagram of this battery portable (Fig. 7) bears two model numbers, both models are essentially the same. The only difference lies in the degree of portability. The model DU-379 is an outdoor portable and may be carried by the special strap which fits over the user's shoulder. Since the loop is placed in this strap, there is a slight difference in the design of this loop and the one used in the model DU-380. Other than this, the two sets are identical and are both known as the DU chassis.

To achieve real portability, special small-size, low-current-drain tubes are used. Two flashlight cells connected in parallel serve as the *A* supply, and a special light-weight 67½-volt *B* battery is used.

The tubes and their functions, which you should be able by this time to identify without trouble, are: A 1R5 pentagrid converter tube as the oscillator-mixer-first detector; a 1T4 super control tube as the i.f. amplifier; a 1S5 diode-pentode as the second detector, a.v.c. and first a.f. amplifier; a 1S4 power output pentode to feed the loudspeaker.

Signal Circuits. There are a number of small but important variations from normal in the circuits of this receiver which make it of interest. Each item will be explained as we come to it.

Signals picked up by the loop may be tuned in by adjusting the tuning condenser dial, which controls ganged condensers *C1* and *C2*. Condenser *C1* tunes the loop, and the chosen signal receives a boost in strength due to resonant step-up.

In the shoulder-strap model DU-379, the inductance which is tuned by *C1* consists of loop *L2* and an extra inductance *L1*. In home-model DU-380, all of the inductance is concentrated in the loop, which is rigidly fastened in place, and *L1* is absent. In model DU-379, the loop shape will change as the wearer breathes and moves around. This results in some inductance change; to avoid serious detuning, most of the circuit inductance is concentrated in *L1*. Then even large changes in the loop inductance have only a small effect on the total circuit inductance and hence on tuning. The shoulder-strap loop is primarily a pick-up device rather than a tuning coil.

In both models, the resonant circuit is completed through *C5* which, as far as r.f. is concerned, acts like a short circuit.

The modulated carrier of the selected station appears across *C1*, and is applied to the input of the first detector. The filament connection is made through the chassis and the lower half of oscillator tank coil *T1*. At the same time, the oscillator signal is injected into the first detector. The two signals are mixed inside the tube. The resulting i.f. beat voltage, bearing the original carrier modulation, is applied to the primary of i.f. transformer *T2*.

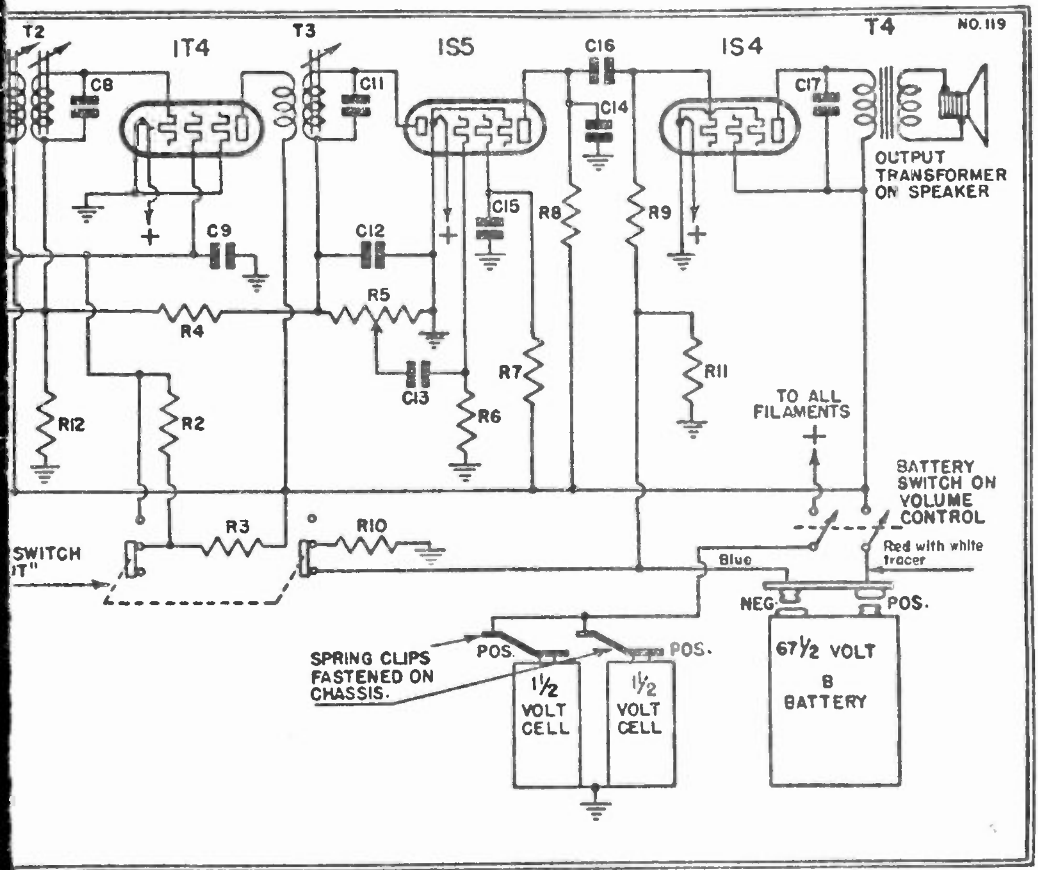
An examination shows the oscillator circuit to be different from that found with the usual pentagrid converter tube. First, you will note that we have been speaking of the 1R5 as a pentagrid converter, when only four grids are shown. The facts of the case are that the manufacturer's draftsman took a little poetic license and left out the suppressor grid, figuring perhaps that the tube drawing was going to be spread out enough as it was, and it didn't matter as far as service work was concerned. In this he was right, for the extra grid, placed between the screen and plate, connects inside the tube envelope to the negative side of the filament, and serves to prevent secondary emission from the plate to the screen. A serviceman can't get at this grid or do anything about it, so it doesn't enter as a service problem. If the grid shorts to the plate, a tube tester will show this up in the usual manner, and in the set the short, if it occurred, would appear to be between the plate and filament.

The oscillator is an ordinary Hartley with the plate grounded. Here the screen grid acts as the plate, and the screen is kept at r.f. ground potential by means of by-pass condenser *C9*. The screen also acts as the virtual cathode as far as the detector section is concerned. The third grid, which is the detector control grid, controls the stream of electrons coming through the screen grid. This electron stream is varying at the oscillator frequency, so the i.f. beat is produced in the detector (mixer) section of the tube.

Feed-back in the oscillator is obtained by causing the plate current to flow through the tapped portion of *T1*. The voltage induced into the rest of *T1* causes the circuit consisting of *T1-C2* to oscillate at its resonant frequency. The oscillator voltage is applied to the oscillator control grid through *C6*. *R1* is the oscillator grid resistor, and *L3* is used to prevent the 1R5 filament and the *A* battery from shorting the tapped section of *T1*. Such a short would prevent the oscillator from working.

Now that the oscillator has been investigated, let us return to the i.f. signal delivered by the 1R5 to resonant circuit *T2-C7* of the first i.f. transformer. This circuit is adjusted to resonance at the i.f. value (455 kc.), not by varying the capacity of *C7* but by adjusting the inductance of the primary. This winding has a pulverized iron core which can be screwed in or out of the coil to change the inductance. As more of the core is moved into the coil, the inductance is increased and the resonant frequency thereby lowered.

By mutual induction a voltage is induced into the secondary shunted by *C8*, and again



L1 ....Iron-core loading coil (Model DU-379 only)
L2 ....Shoulder-strap loop assembly (Model DU 379 only)
L2 ....Loop antenna (Model DU-380 only)
T1 ....Oscillator coil
T2 ....Iron-core double-tuned 455-kc. first I.f. transformer
T3 ....Iron-core single-tuned 455-kc. second I.f. transformer
R1 ....100,000-ohm ¼-W. carbon resistor
R2 ....5000-ohm, ¼-W. carbon resistor
R3 ....10,000-ohm, ¼-W. carbon resistor
R4, R12 ....5-megohm, ¼-W. carbon resistor (R12 is omitted on later models)
R5 ....Volume control, 1.5-megohm, with double pole battery switch
R6 ....10-megohm, ¼-W. carbon resistor
R7, R9 ....3-megohm, ¼-W. carbon resistor
R8 ....1-megohm, ¼-W. carbon resistor
R10 ....2200-ohm, ¼-W. carbon resistor
R11 ....1800-ohm, ¼-W. carbon resistor
C1, C2 ....Two-gang variable condenser
C3, C4 ....Trimmers, part of variable cond.
C5, C9, C15 ..0.02-mfd., 200-volt tubular cond.
C6, C12, C14 .0.00011-mfd. mica condenser
C7, C8, C11 ..Fixed trimming condensers, contained inside i.f can
C10 ....10-mfd., 100-volt dry electrolytic condenser
C13 ....0.002-mfd., 600-volt tubular cond.
C16, C17 ......0.001-mfd., 600-volt tubular cond.
4" permanent magnet dynamic loudspeaker
Double-pole, double-throw "Economizer" switch

Automatic Model P57 Three-Way Portable Receiver

GENERAL Description. The Automatic Model P57 can be powered from three different sources—self-contained batteries, a 110-volt a.c. power line, or a 110-volt d.c. power line. In other words, this is an a.c.-d.c.-battery receiver.

A study of the diagram in Fig. 8 shows that the receiver consists of a 1A7G pentragrid converter tube, a 1N5G i.f. amplifier tube, a 1H5G combination second detector—a.v.c.—first audio tube, a 1A5G power output tube and a 25Z6 rectifier.

Excellent reception can be had by using the self-contained loop aerial alone. Terminals *A* and *G* are provided, however, for connecting to an outside aerial and ground when more distant reception is required. When an aerial and ground are used, the antenna current flows through the wire placed around the outside of the loop, and induces a signal voltage into the loop.

Signal Circuits. The signal picked up by the loop is resonated by the tuning condenser, and the stepped-up signal voltage is applied to the input of the 1A7G type tube.

An r.f. oscillator signal is being produced at the same time in the 1A7G tube, due to feed-back from the oscillator coil plate winding to the tank circuit. You will note that the first two grids of the tube are used as the oscillator grid and anode electrodes. The tank circuit is coupled to the oscillator grid through the .0001-mfd. condenser. The 50,000-ohm resistor produces the oscillator grid bias due to the rectified grid current flowing through it.

The varying electron stream leaving the second grid passes through the screen grid to the plate. This electron stream is acted on by the signal voltage applied to the input of the tube, and the oscillator and incoming signals are thus mixed within the tube.

The screen surrounding the 1A7G control grid (the fourth grid from the filament) prevents any interaction between this grid and the oscillator electrodes, and also acts as a capacitive screen between the plate and the detector control grid.

The i.f. signal voltage developed across the primary of the first i.f. transformer causes a large i.f. current to flow through the transformer winding.

By mutual induction a signal appears in the secondary of the transformer and there undergoes resonant step-up. This signal is applied directly to the input of the 1N5G i.f. tube. Since this is a high-impedance pentode tube, a large i.f. voltage will be built up across the primary of the second i.f. transformer, much larger than the one which was applied to the input of the 1N5G tube.

The i.f. signal voltage induced into the secondary of the second i.f. transformer is now large enough for detection.

When the i.f. signal makes the diode plate of the 1H5G tube positive, electrons flow from the filament to this plate, through the secondary of the second i.f. transformer and through the volume control to the filament. The i.f. component is prevented from flowing through the volume control by means of the .0002-mfd. by-pass condenser connected from the hot side of the volume control to the chassis. The filament side of the volume control is grounded to the chassis by means of the .1-mfd. condenser.

The a.f. signal voltage appearing across the volume control is applied to the 15-megohm grid resistor and the grid of the 1H5G tube through the .01-mfd. coupling condenser.

The amplified a.f. signal appears across the 1-megohm plate load resistor of the 1H5G tube. This signal is also applied across the 2-megohm grid resistor for the 1A5G type tube through the .002-mfd. coupling condenser and the 20-mfd. output filter condenser, with the filament connection being through the 100-mfd. electrolytic condenser.

The application of the signal to the input of the 1A5G tube causes large changes in plate current flowing through the primary of the output transformer, and this a.f. plate current induces the signal voltage in the secondary. This causes a.f. current to flow through the voice coil, thus setting the cone

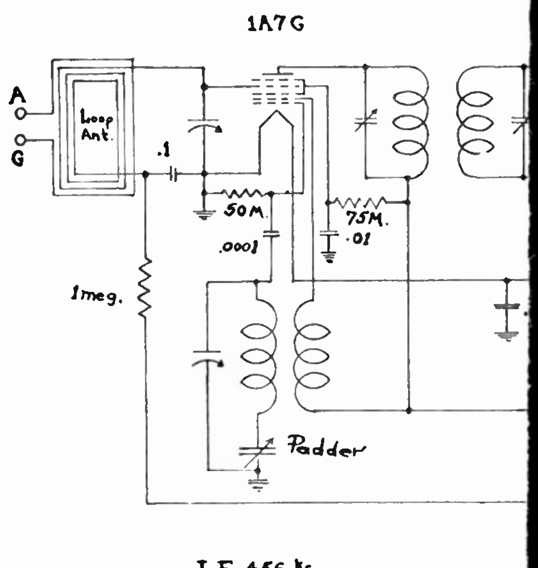


Fig. 8. Schematic circuit diagram of Automatic Model P57 combination a.c.-d.c.-battery portable 5-tube superheterodyne receiver.

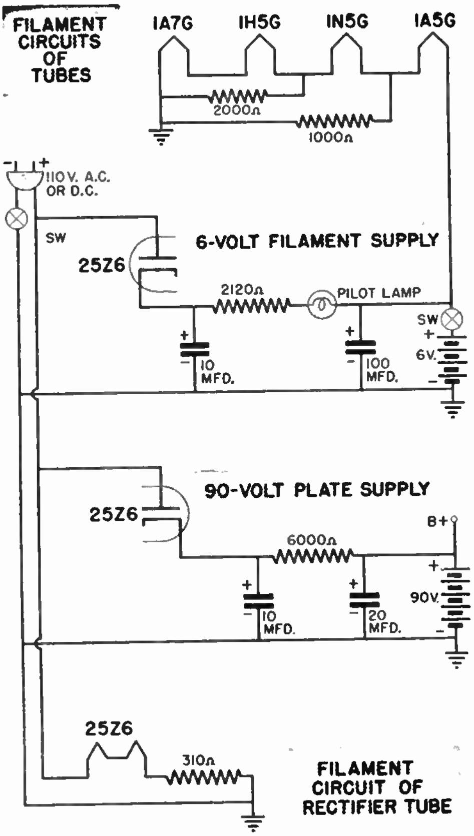


Fig. 9. The power pack and filament circuits of the Automatic Model P57 receiver have been redrawn here to show that the individual circuits are simple and quite conventional.

diagram in Fig. 9 will show that between the negative side of the 1A5G tube and the chassis we have the filaments of three tubes, each getting about 1.5 volts. This means that the grid of the 1A5G tube is about 4.5 volts negative with respect to the negative side of the 1A5G tube filament.

The 2000-ohm and 1000-ohm resistors in the filament supply circuits are used as shunts to take care of the plate currents of the tubes. Flowing through the 1A7G and 1H5G filaments are the .05-ampere filament currents and the plate currents of these tubes. The plate current of the 1N5G divides between the 2000-ohm shunt resistor and the filaments of the 1A7G and 1H5G tubes. The plate current of the 1A5G tube divides between the 1000-ohm resistor and the circuit consisting of the 1A7G, 1N5G and 1H5G filaments and the 2000-ohm shunt resistor. While the receiver would work without the shunts, the current through the filaments would be excessive and would tend to shorten tube life.

Servicing Hints. Receivers of this type are subject to the same defects as are encountered in a.c.-d.c. or battery receivers. Bear in mind, however, that when the receiver is operated from the power line, a defect in one power supply may be masked by proper operation of the other supply. For example, the rectifier tube may be worn out, but the receiver will play normally on the power line, for the batteries will furnish power. Bad batteries, on the other hand, will be masked by the power pack on power line operation.

We are most concerned here with straight battery operation, since you are familiar with a.c.-d.c. power supply troubles. About all that could occur to the power pack would be tube and filter condenser troubles, or burning out of the pilot lamp. If the pilot lamp must be replaced, use an exact duplicate as no other will work properly A burned-out pilot lamp should be replaced as soon as possible, because its failure forces the 6-volt battery to supply filament current during a.c or d.c. operation.

On battery operation, most trouble is due to worn-out batteries. If the battery voltages will not come up to normal and give satisfactory results even after prolonged operation of the receiver from the power line with the 1A5G tube removed, new batteries are necessary.

The battery voltage should be measured with the receiver operating only from batteries and all of the tubes in place. This places a normal load on the batteries, so high internal resistance which causes appreciable internal voltage drop in a bad cell will be revealed. Without normal load, a high-resistance serviceman's voltmeter won't draw enough current to produce an appreciable voltage drop in the batteries, and normal voltage will be measured even though the batteries are run-down.

Low battery voltages will usually affect the operation of the oscillator first, since this circuit is the most critical as to voltage. Since it is harder for oscillation to be maintained at the lower frequencies, the receiver will first go dead at the low-frequency end of the dial. As the batteries continue to deteriorate, the set will go dead over the entire dial, since the oscillator will refuse to operate at any point on its range.

When an oscillator goes dead in this manner, a very characteristic effect is sometimes observed; a powerful local station, usually one at the low-frequency end of the dial, will be heard regardless of how the receiver is tuned. Such an occurrence is definite proof of oscillator failure, and indicates that the set is acting as a broadly-tuned t.r.f. receiver.

About the only other trouble peculiar to battery receivers is intermittent reception and noise caused by poor or corroded connections inside of the batteries. A substitution of new batteries or a careful voltmeter check will show up such trouble.

Philco Model 610 Three-Band A.C. Superheterodyne

GENERAL Description. The Philco Model 610 is a three-band a.c.-operated superheterodyne using a type 6A7 mixer, a type 78 in the i.f. amplifier, a type 75 as a combination detector, a.v.c. and first a.f. tube, a type 42 in the power output stage and a type 80 rectifier in the power supply. All of these stages are clearly identified on the schematic circuit diagram in Fig. *10*. The wave-band coverage is: Band 1, 530-1720 kc.; band 2, 2300-2500 kc. (2.3-2.5 megacycles); band 3, 5700-18,000 kc. (5.7-18 megacycles). The design of this receiver is straightforward, the circuits being similar to those which you have already studied.

Wave-Band Switch and Circuits. A radio technician is only interested in that section or circuit in which trouble exists. He is guided to this point either by the symptoms exhibited by the receiver or by a stage isolation procedure as outlined in the Advanced Course in Radio Servicing. The rest of the receiver he ignores. With this method, he will probably escape the necessity of delving into the wave-band switching circuits.

However, if trouble is encountered in the preselector-mixer-oscillator system, he must be able to unravel the wave-band circuits and make tests on them. Furthermore, to align the set, he must be able to identify the trimmers appearing in the diagram and, from their electrical positions in the circuit, determine their purpose.

In such a case he sees the same thing you see here—a conglomeration of switch contacts, coils, condensers and wires. The expert ignores all this and sets about systematically to trace through the circuits. He knows that the 6A7 has a tuned input circuit, because no manufacturer would build a receiver without a preselector between the mixer and antenna. Furthermore, this tuned input circuit must connect between the 6A7 top cap and the a.v.c. bus. These two points are readily located in the diagram, the a.v.c. bus being the wire lead connecting to the junction of a.v.c. filter condenser *25* and filter resistor *29*.

Let us trace the tuned input circuit. We start with the 6A7 top cap, and follow the lead down to terminal *S* of switch section *2*. Looking at this section, we see that there are two other terminals like *S*, marked *G* and *P*, each feeding a different set of leads through contacts. We rightfully assume that this is a three-pole, three-position switch and that terminals *S*, *G* and *P* are input terminals for the three poles of the switch.

With the switch set to position *1* as shown in the diagram, terminal *S* makes contact only to terminal *M* through the round black "ball" which represents the movable contact element for this pole of the switch. This black ball always makes contact with *S*.

From *M* we go to the junction of trimmer *5* and tuning coil *L2*. We ignore the tap on *L2*, as a glance at terminal *G* of switch section *2* shows it isn't used. The other end of *L2* connects to the a.v.c. bus, which is the other end of the tuned input circuit we were tracing.

This gives us the general technique for tracing through the wave-band switch, and we can now trace the other circuits for switch position *1*. Coil *L3* and its primary *L1* are ignored, because coil *L2* is being used and we wouldn't expect another tuned circuit to be employed at the mixer input at the same time. Since *L2* is in use, its primary is in use, and we may be sure the primary is carrying energy delivered to it by the antenna system. The primary is checked by connecting an ohmmeter between the *ANT* lead and the chassis. We will expect a reading of about 32 ohms if everything is intact.

Switch position *1* is for the broadcast band (the lowest-frequency band on the set), because coil *L2* (connected to *S* for position *1*) has a higher resistance and hence a greater number of turns than coil *L3*. *L3* must be the short-wave coil for band *3*, since it has the lowest resistance and therefore the lowest inductance.

Since *L2* is the broadcast band antenna coil, its associated trimmer *5* is the broadcast band antenna trimmer, and is to be adjusted somewhere near the high-frequency end of its band (1400 kc. is a popular adjustment point).

Now that we have accounted for the preselector, let's take a look at the oscillator. We have two sets of coils, *L4-L6* and *L5-L7*. Coils *L6* and *L7*, being connected to trimmers, are the tank coils. Since *L6* has the greatest resistance, it is the broadcast band oscillator coil, in which we are now interested.

Again we have two reference points—the 6A7 oscillator grid, which is the first grid from the cathode, and the cathode of the 6A7. Since the cathode goes to chassis through resistor *16*, we will use the chassis for reference purposes.

Follow the lead from the oscillator grid, noting that it connects from oscillator tuning condenser *19* to pole *F* on switch section *2*.

The switch contact connects it to switch terminal *Q*, and from here we go to tank coil *L6*. This coil connects to tuning condenser *19* through condenser *10* which, being in series with the tank circuit, is the oscillator low-frequency padder. This padder, as its name implies, is to be adjusted at the low-frequency end of the broadcast band; 600 kc. is the most favored adjusting frequency.

Trimmer condenser *11*, which is in shunt with the oscillator tuning condenser, is the high-frequency oscillator trimmer. Like trimmer *5*, it is to be adjusted at 1400 kc. The position of resistor *17* is a little uncon-

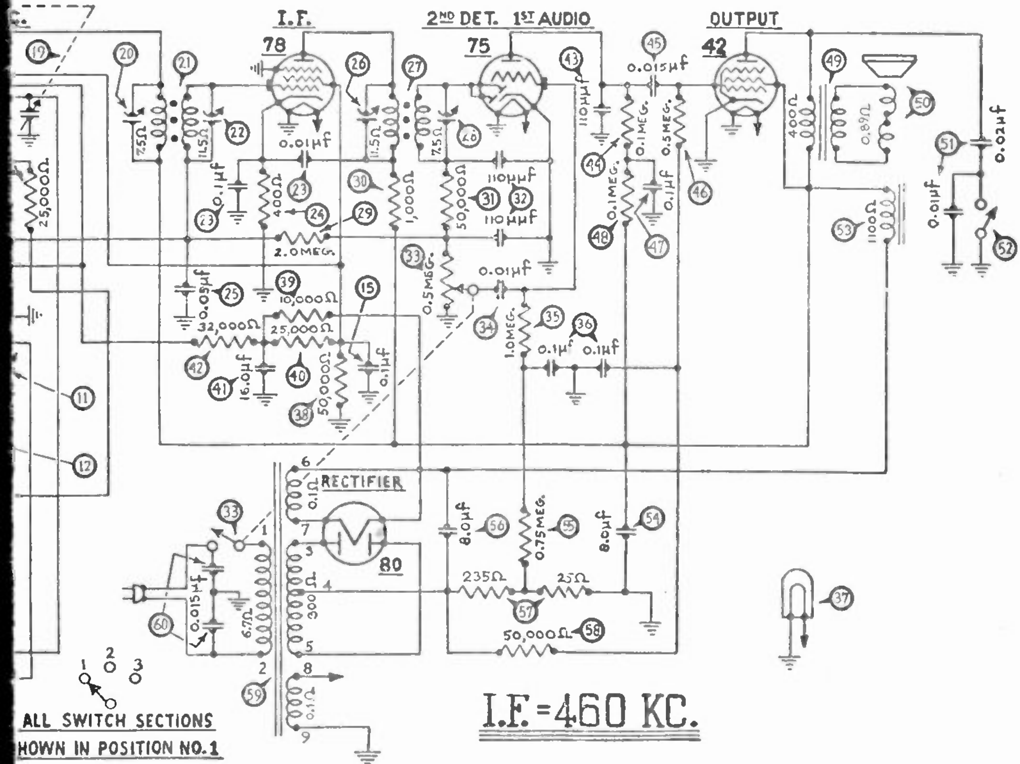


Fig. 10. Schematic circuit diagram of Philco Model 610 three-band superheterodyne receiver.

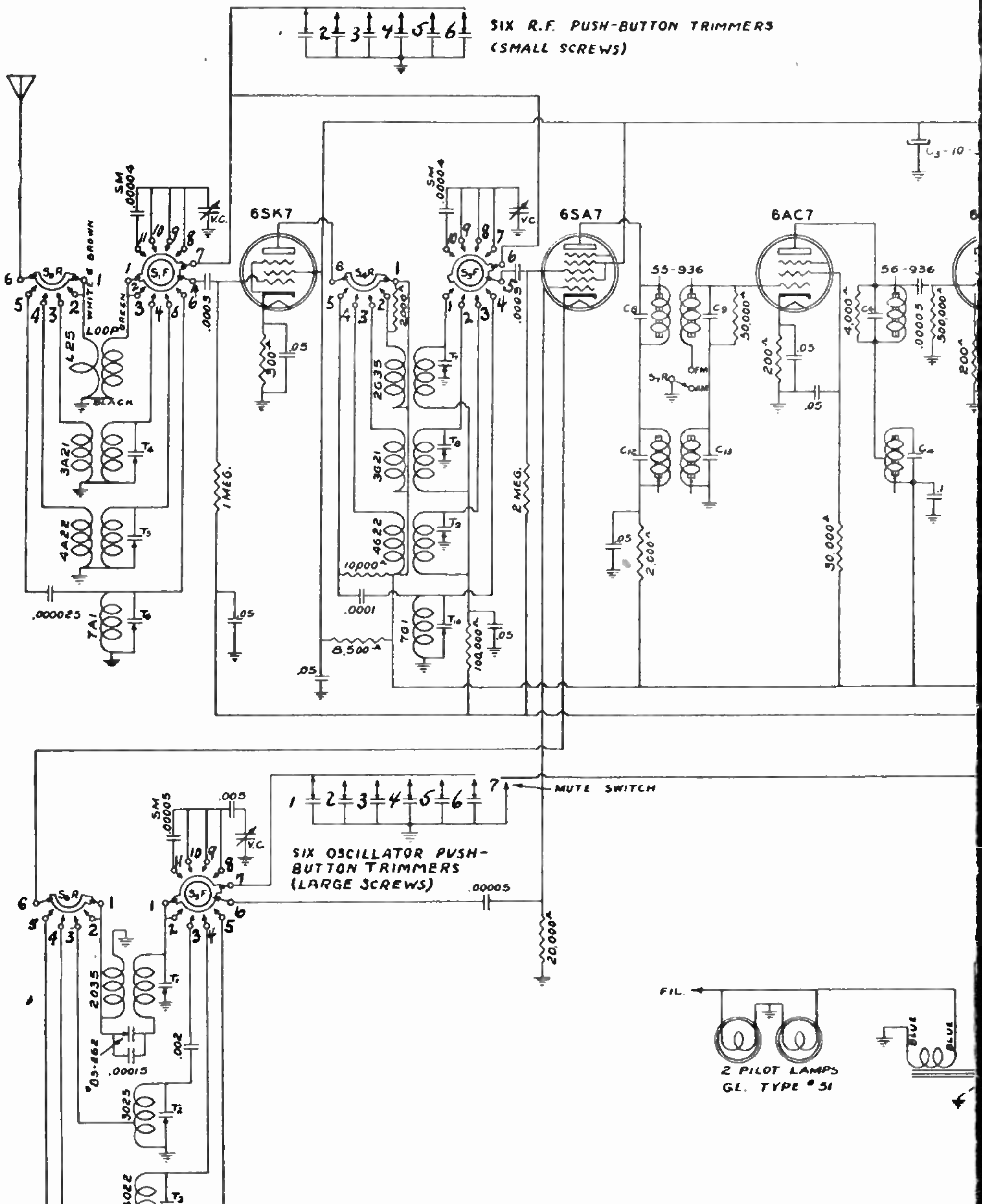
We have now investigated the important sections of the preselector and oscillator circuits for all bands. In each case, the oscillator signal and the preselector signal are mixed in the 6A7, and produce a 460-kc. beat. This is passed into the i.f. amplifier through the first i.f. transformer (*21*). After amplification by the type 78 i.f. tube, the i.f. signal is transferred to the diode detector circuit of the type 75 tube by the second i.f. transformer (*27*).

After detection, the rectified signal voltage appears across volume control *33*, which is also the diode load resistor. The signal amplified by the triode section of the 75 tube is passed by means of resistance coupling to the type 42 power output tube. The output of this tube feeds the loudspeaker voice coil through output transformer *49*.

Since this receiver was chosen to give you practice with wave-band switch circuits, we have omitted discussion of the rest of the receiver circuits. These circuits have previously been covered, and should hold no secrets from you. However, if you want a little practice you might explore their possibilities and explain them to yourself as we have done for similar diagrams.

Here is a little additional work of a practical nature. The following symptoms are often encountered in this receiver and are due to the causes listed. Try to figure out why these particular defects (causes) should result in these symptoms.

Symptom	Cause
Dead only when tone control *52* is on.	Short in .02-mfd. section of *51*.
Hum when cone is replaced.	Voice coil connections reversed.
Hum stops only when *42* tube is removed.	Open in right-hand section of condenser *36*.
Distorts; clears up when hand is held on 75 top cap and chassis.	Leakage in *45* or leakage in *47*.
Distorts and cuts off on strong signals when volume control is advanced.	Leakage in *34*.
Dead; circuit disturbance test shows all stages pass signal.	Open in resistor *42*.
Blasting when tuning from one station to another.	Short or leakage in condenser *25*.
Audio oscillation when tone control *52* is off.	Open in .01-mfd. section of condenser block *51*.



VC - VARIABLE COND. #59-270
C_1.C_2.C_3 - ELECT. COND. #51-266
S_8R. ETC. - SECTION TWO REAR - BAND SWITCH #57-814A
TRIMMER CONDS. #87-262 - T, T, T, T, T, T, T, T, T, T
SM - SILVER MICA COND.
C_4 C_8 - .0005 SM
C_6 C_7 - .0002 SM
C_8 C_9 C_{10} C_{11} - .000035 SM
C_{12} C_{13} - .001 SM
C_{14} - DUAL TRIMMER COND. #71-262

Fig. 12. Schematic circuit diagram of Howard Model 718FM-X

further variations in cathode current, and in this manner oscillation is maintained. The grid bias voltage produced across the 20,000-ohm self-bias resistor prevents the cathode current from exceeding the safe rating of the tube.

Due to the oscillator action, the electron flow from the cathode through the oscillator grid and the screen grid (oscillator plate) to the plate of the 6SA7 is a pulsating stream. As far as the mixer grid is concerned, however, the screen grid is the virtual cathode which is supplying a pulsating electron stream.

At the third grid from the cathode (mixer grid), the incoming signal is applied. It mixes with the local oscillator signal, and the resulting beat (the difference between the two signal frequencies) forms the intermediate frequency.

Switch Position 2. When the band switch is thrown to manual tuning, the switch connections are those shown for position *2* in Fig. *13*. Let us analyze the circuits which are in action now.

Antenna current flows through switch contacts *6-2* of section S_2R and through the primary of coil *L25* to ground. Section S_1F connects contacts *2*, *6* and *8* together so the secondary of *L25* is tuned by variable condenser *V.C.* The signal undergoes resonant step-up, after which it is applied to the 6SK7 r.f. amplifier tube in the usual manner. The amplified signal current flows through the primary of coil *2035*, which is shunted by a 2000-ohm resistor to broaden the tuning and thus prevent side-band cutting. A voltage is induced in the secondary, where it undergoes resonant step-up, and the resulting signal is applied to the 6SA7 input through the .0003-mfd. coupling condenser.

In the oscillator circuit, the connections and circuit action of coil *2035*, with its trimmers and padder, remain the same as for push-button operation. However, contact is made to *8* instead of *7* on switch section S_5F, to put main tuning condenser *V.C.* in the circuit in place of the push-button trimmers. Mixing occurs in the 6SA7 as before, and the i.f. signal is delivered to the i.f. amplifier.

Switch Positions 3 and 4. The circuits for these two short-wave band positions are identical to those for the broadcast band, and hence need not be traced in detail. The selector switches merely place different sets of coils in their respective circuits.

The A.M. I.F. Amplifier. From the schematic diagram, you see that there are two i.f. transformers between the mixer and the 6AC7 first i.f. tube, one for f.m. and the other for a.m. We identify the top transformer in the schematic as the f.m. transformer because its secondary connects to the *FM* terminal of S_7R. The primary of this transformer offers little opposition to the 465-kc. i.f. signal, so the a.m. signal passes through it to the primary of the a.m. transformer.

A large 465-kc. current flows in the tuned primary of the a.m. transformer, and a corresponding signal, which also undergoes resonant step-up, is induced into the secondary. This is applied to the control grid of the 6AC7 first i.f. tube through condenser C_9 and to its cathode through the chassis and the .05-mfd. cathode by-pass condenser.

The tube amplifies the signal and a large i.f. voltage is built up across the plate load. But what is the plate load? It is not the resonant circuit formed by coil *56-936* and condenser C_6, for these are shunted by a 4000-ohm resistor which is not used in a.m. loads. We can assume that condenser C_6 acts as a short across the coil and resistor at a.m. i.f. frequencies. The next device in the plate circuit is a tapped resonant circuit, and this is what serves as the a.m. plate load.

It is unusual to see a tapped resonant circuit of this sort, for only the lower coil section, between the tap and B+, acts as the load. The voltage across this section is large, due to the resonant step-up provided by tuning the circuit. This voltage is transferred through C_6, the .00005-mfd. coupling condenser and the .1-mfd. plate by-pass, and appears across the 500,000-ohm grid resistor for the next stage.

The 500,000-ohm grid resistor, therefore, shunts the lower section of the coil. The resistor is not across the entire resonant circuit, however, and because of this, a reasonable degree of selectivity is still secured. At the same time, since the entire voltage across the resonant circuit is not transferred to the grid resistor, the gain is reduced. With two stages of i.f. amplification, there is gain to spare, and the slightly broadened response curve of the i.f. amplifier results in good fidelity. The f.m. transformer is not tapped in this manner because both broad tuning and all available gain are desired.

The i.f. current flowing through the grid resistor builds up a large signal voltage across it. This voltage is applied to the grid-cathode circuit of the tube, the cathode connection being through the cathode by-pass condenser.

Amplification of the signal by the second i.f. tube results in a large signal voltage being developed across the resonant plate load formed by C_7 and the primary of the third i.f. transformer. The resonant frequency of the f.m. transformer is 4.3 mc., which is so far from 465 kc. that for all practical purposes, no a.m. signals are set up in the secondary of the f.m. transformer. However, a large i.f. signal is set up in the secondary of the last a.m. transformer, and this a.m. signal is applied to the plates and cathodes of the 6H6 second detector. The cathode connection is through the .0002-mfd. condenser and the chassis.

The A.M. Second Detector. When the i.f. signal makes the 6H6 plates positive, electrons leaving the cathodes are attracted to the plates. From there, the electron flow is through the i.f. secondary, the 50,000-ohm i.f. filter resistor and the 250,000-ohm diode load resistor to ground, then back to the 6H6 cathodes. Current flow is blocked when the signal makes the plates negative with respect to the cathodes. This is the action of a typical diode detector.

We have the rectified a.f. signal existing across the 250,000-ohm load resistor. Due to the smoothing action of the two .0002-mfd. condensers, we also have a rather large d.c. voltage across the diode load. The a.f. signal, being unaffected by the .0002-mfd. condensers, adds to this d.c. voltage and causes it to increase and decrease, forming a pulsating d.c. voltage across the load resistor.

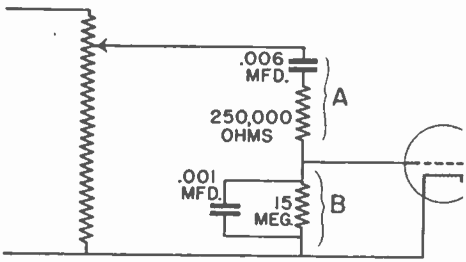


Fig. 14. Bass-boosting circuit.

No i.f. signal appears across it because the i.f. is shunted around the diode load by the i.f. filter composed of the 50,000-ohm resistor and the two .0002-mfd. condensers.

The d.c. voltage across the 250,000-ohm diode load is used for a.v.c. purposes and to operate the tuning eye. The a.v.c. filter network is made up of the 1-meg. resistor connected to the tuning eye grid through switch S_7R, and the .05-mfd. condenser in the control grid return circuit of the 6SK7 tube. Note that this a.v.c. voltage is used only for a.m. reception.

The Audio Amplifier. The audio signal component across the diode load is applied across the dual volume control through the .02-mfd. d.c. blocking condenser, contact *AM* of switch S_7R, the *RADIO* contact of the *PHONO* switch and the 25-ohm resistor between the volume control and the chassis.

Now we come to a unique method of tone control which is becoming more and more popular in high-fidelity audio amplifiers. Note that the dual volume control simultaneously feeds two 6SF5 tubes, and that the outputs of these tubes feed through .02-mfd. coupling condensers into a common load consisting of 500,000- and 100,000-ohm resistors connected in series between the control grid of the lower 6V6G output tube and the chassis.

The upper 6SF5 tube and its 15-megohm grid resistor are fed by the first section of the volume control through a .006-mfd. coupling condenser, with all audio frequencies being transferred about equally well.

Potentiometer *87-281* is connected to control the amount of signal which the right-hand volume control feeds through the .006-mfd. coupling condenser and a 250,000-ohm resistor to the 15-megohm grid resistor of the lower 6SF5 tube. A .001-mfd. by-pass condenser is in parallel with the 15-meg. resistor, so the impedance of the grid input circuit is a combination of these values. This is the special arrangement which provides tone control, so let us study its action in detail.

The tone control circuit has been redrawn in Fig. *14* to simplify our discussion of it. The signal dropped across section *B* is fed to the lower 6SF5 tube for amplification, while the signal dropped across *A* is not amplified. As in any voltage divider, the voltage distribution will depend upon the ratio of impedances of the two sections. If both are equal, each will receive the same amount of voltage. If one has ten times the impedance of the other, it will have ten times as much voltage. Let's investigate.

The .006-mfd. condenser in series-section *A* has a value of about 5000 ohms at 5000 cycles, which is negligibly small in comparison to the 250,000 ohms in series, so the combined impedance of section *A* is essentially 250,000 ohms.

At 5000 cycles, the .001-mfd. condenser across shunt-section *B* has a reactance of about 30,000 ohms, as compared to 15 megohms for the resistor. This makes the combined impedance of this section only about 30,000 ohms (the lowest reactance governs the impedance of parts in parallel). Therefore, at 5000 cycles almost all of the signal is dropped across *A*, with practically none across *B*, and the lower 6SF5 tube gets very little signal voltage at 5000 cycles and higher.

At 1000 cycles, the .006-mfd. condenser has a reactance of about 30,000 ohms, and this in series with 250,000 ohms of resistance gives a combined impedance of about 252,000 ohms for section *A*.

At 1000 cycles, the .001-mfd. condenser has a reactance of around 150,000 ohms. The 15-megohm resistor shunting this has negligible effect, so the combined impedance of section *B* is essentially 150,000 ohms. Now section *B* gets almost as much of the signal as section *A*, so the lower 6SF5 tube gets quite a bit of signal voltage at 1000 cycles.

Now let's drop down to the real low notes, say 100 cycles. The .006-mfd. condenser has a reactance of about 280,000 ohms now, and this in series with a resistance of 250,000 ohms gives a combined impedance of about 375,000 ohms for section *A*. The 2-megohm reactance of the .001-mfd. condenser at 100 cycles makes the impedance of section *B* essentially 2 megohms. Our voltage divider now consists of 375,000 ohms in *A*, and 2,000,000 ohms in *B*, so section *B* gets over five times as much signal voltage as section *A* at 100 cycles. As we go still lower in freis applied to the grid of the 6U5, so that the 6U5 may be used as a tuning indicator on f.m. reception.

Due to the rectification taking place in the limiter grid circuit, the negative signal peaks are almost cut off. The missing portion of the wave form is built up, however, by the flywheel action of the 6SJ7 resonant plate load. The i.f. limiter plate load consists of the two coils, tuned by trimmers C_{14}, in parallel with the 100,000-ohm plate supply resistor. The reactance of the .0005-mfd. coupling condenser is so low that it acts as a short at the i.f. value.

The discriminator, as the second detector of an f.m. receiver is called, differs somewhat from those you studied in the text on f.m. However, it's very easy to understand.

To simplify our study of the discriminator, its circuit has been redrawn by itself in Fig. *15*.

In an f.m. system, the strength of the carrier peaks has nothing to do with the audio signal, and carrier peaks may therefore be limited without distortion of the signal. In f.m., the carrier is caused to swing above and below its assigned or resting frequency. The greater the carrier frequency excursions away from the resting frequency, the greater the audio signal strength.

The rate or frequency of these frequency deviations is controlled by the frequency of the audio signal. Suppose we had a 5000-cycle audio signal and a 1000-cycle audio signal, both of the same strength. If they were used to modulate an f.m. system, both being the same strength would cause the f.m. carrier to swing the same distance in kilocycles above and below its resting frequency. However, the 5000-cycle audio note would make the carrier swing above and below the resting frequency 5000 times each second, while the 1000-cycle note would only cause the carrier to swing 1000 times each second. In this way, these two frequencies have indelibly stamped their characteristics on the f.m. carrier.

Because variations in audio signal strength cause the carrier frequency to change so much, an f.m. receiver must tune broadly. Sharp tuning would cut down the amount of carrier frequency variation, thereby reducing the range of audio volume.

If the limiter delivers an i.f. of 4.3 mc. (the resting frequency) to the discriminator, both diode plates will receive the same amount of signal voltage, because the reactance of C_4-L_1 is equal to that of C_5-L_2. When plate D_1 is positive, electrons flow from the cathode to the plate and through R_1, producing a voltage drop having the polarity shown. On the next half cycle, D_2 conducts while D_1 rests, and the resultant diode current produces a voltage drop across R_2 with the indicated polarity.

The a.f. output voltage of the discriminator circuit appears across the outside ends of R_1 and R_2. At the resting frequency, however, the two voltages are equal and opposite, and no voltage exists between the diode plates.

We must get a difference in the amount of voltage across R_1 and R_2 before we can obtain any output. This is done by tuning C_4-L_1 to 4.4 mc., which is 100 kc. above the resting frequency, and C_5-L_2 to 4.2 mc., which is 100 kc. below the resting frequency. Now when we tune in an f.m. program, the carrier will be swinging above and below the resting value of 4.3 mc. When it swings to a higher frequency, the voltage across C_4-L_1 increases, while the voltage across C_5-L_2 decreases. The resultant changes in diode currents D_1 and D_2 cause more voltage to exist across R_1 than across R_2, and the output is the difference between the two voltage drops. When the carrier decreases in frequency, the action reverses, and since C_5-L_2 now gets the greater part of the signal voltage, the drop across R_2 is greater than the drop across R_1.

The number of times per second the carrier swings back and forth across the resting frequency governs the frequency of the a.f. output voltage of the discriminator, and the amount of variation in the carrier frequency governs the strength of the a.f. output.

As you can see, R_3 and C_3 form an i.f. filter, used so that only the pure audio output of the discriminator will be available for application to the volume control through contact *FM* of switch section S_7R and the *PHONO-RADIO* switch in Fig. *12*.

We have now covered the important signal circuit features for the entire receiver. The power supply circuits are quite conventional, and you should be able to trace them yourself without difficulty.

THE ERROR OF HASTE

The fable of the hare and the tortoise is more than an interesting childhood story—it carries an important message we sometimes forget in this age of speed.

The hare, you will recall, started off in great haste. Soon he was so far ahead of the slow-plodding tortoise that he became over-confident and took a nap. The tortoise kept going steadily and won the race.

Haste does not always mean progress. Too often it leads instead to errors, to actual waste of time and energy, and even to complete failure as in the case of the hare.

We must learn to work and wait. Take time for all things, because time often achieves results which are obtainable in no other way. Shakespeare expresses it thusly: "*Wisely and slow; they stumble who run fast.*" More emphatic still was Benjamin Franklin, who said: "*Great haste makes great waste.*"

Don't risk the dangers of haste. Keep going steadily like the tortoise, and you'll approach your goal in radio steadily, inevitably.

J. E. Smith

RADIO FORMULAS AND HOW TO USE THEM

REFERENCE TEXT 39X

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

ENGINEERING DATA FOR TECHNICIANS

The primary purpose of this Course is to prepare you to install, operate, adjust and service radio, television and electronic control apparatus. Mathematical formulas are relatively unimportant in accomplishing this purpose, although some may find that a knowledge of formulas speeds up their work

Occasionally, however, a Technician finds it necessary to design a particular piece of equipment; he must then be able to predict beforehand how the unit will perform and must be able to compute the electrical sizes required to give the desired results. To those who want to design special apparatus with the least amount of experience, this book of formulas will be of great benefit. It is truly a valuable reference book, for in it has been combined the essential design data for many different devices.

For the present it will be sufficient if you simply go over the table of contents to find out exactly what is in the book, then spend an hour or so glancing at the material in it which interests you. After this, place the book in your reference library, where it can serve you long after you have graduated from this Course.

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RADIO FORMULAS AND HOW TO USE THEM

TABLE OF CONTENTS

How To Use Formulas

WHAT IS A FORMULA?

Before we get too involved in the use, manipulation and the type of formulas to be presented in this text let us make a few things clear. This text is only a reference book and contains simple, every day formulas as well as those of particular interest to the more advanced student. Keep it like a dictionary, referring to it only when the need for a formula presents itself. Only the formulas which are of use in the more practical phases of radio are given. Read the rest of the text so that you will know what this text contains and where to look for a specific formula when you need it.

The dictionary, which every student and radiotrician should learn to refer to, says that "any general fact, law or principle expressed in algebraic symbols" may be considered a formula. We have so far in our study of radio met many formulas which bear out the above definition. Let us consider how a fact, a rule or a principle may be expressed in terms of algebraic symbols.

Everyone knows that a train running at a uniform speed, for example constantly at the rate of 30 miles an hour, will travel a longer distance in 30 minutes than in 5 minutes. Knowing the relationship of these factors we can form a general statement as follows. The distance covered is equal to the uniform rate of travel times the time running. In fact this is so general that it applies to automobiles, runners, airplanes or anything that is in uniform motion. It may even apply to a sound or radio wave which is known to travel respectively at 1,089 feet per second and 186,000 miles per second. To set this up in algebraic form or notation, as it is called, let us say that the letter D will represent the distance traveled, that V will represent the uniform rate of travel (velocity) and t the time during which the motion we are concerned with takes place. Therefore the above statement regarding distance may be expressed in algebraic terms as

$$D = V \times t \qquad (1)$$

Observe that on the left-hand side of this formula we have D the factor we are to compute when we know the factors V and t, which are on the right-hand side. This algebraic statement of a fact is essentially an expression of equality, since what is on the left-hand side is equal to what is on the right-hand side—an equation. We say as much when the symbol (=) is used for *equals.*

Now there is a slight practical difference between an equation and a formula, which may be worth knowing. If the factor on the left-hand side is the unknown and all the factors on the right-hand side are known, we have a formula. If both the right and left-hand sides contain unknown factors, we have an equation. We shall shortly see how an equation may be transformed into a formula. We will now stress the fact that an equation is useless for purposes of calculation of the unknown unless all factors except the unknown are given or assumed to have some definite value.

Let us go back to our original idea about a moving train. We said that it travels 30 miles an hour. We may be interested in knowing how far that train will travel in 16 minutes. Note that in one case we have used the hour as the time unit and in the second case we have used minutes. In any formula where the factors of time, distance, area, etc., are employed we must be careful to use the same dimensions or units. Never mix hours, minutes and seconds; never mix miles, feet and inches unless the legend associated with the formula permits such an assumption. You would not say that 4 cows and 3 horses make 7 cows.

Thus, in order to carry out the principle of using proper units in the problem just given, we must either convert the rate of travel into miles per minute or the time into hours. Using the first scheme, we say that 30 miles an hour is the same as ½ mile per minute, simply because there are 60 minutes in an hour and 30 ÷ 60 is ½. You will get along much better in practical work if you express numbers in terms of decimals. So we would say .5 instead of ½. Everyone knows that if a train moves .5 mile per minute that in 16 minutes it will travel 8 miles. But if we use formula (1), we would go about it in this way. We would say that V equals .5, and t equals 16. Substituting in the formula we get

$$D = .5 \times 16$$
$$D = 8$$

Now let us consider other types of formulas.

There is a law or a principle in physics that stipulates that energy can neither be created nor destroyed. For example, if you send an electric current through a resistor, the electrical energy is transformed entirely into heat energy. We know from a study of electricity that the electrical energy is equal to the power multiplied by the time during which the power is supplied. In algebraic notation let us call W the energy, P the power and t the time, which with the above permits us to show that

$$W = Pt \qquad (2)$$

Note that the multiplication notation (×) is omitted in this formula. If P and t denote separate factors, it is customary when algebraic symbols are used to omit the sign of multiplication.

We also know that the power absorbed by a resistor is equal to the square of the current multiplied by the ohmic value of the resistance, and of course we are all familiar with the formula:

$$P = I^2R \qquad (3)$$

We may now say that the energy absorbed by the resistor is equal to the product of the square of the current, the ohmic value of the resistor and the time. As a formula we say:

$$W = I^2Rt \qquad (4)$$

Formula (4) means little to us until we know the dimensions of W, I, R and t, so as a useful formula we should say

The Formula→ $W = I^2Rt$ (4a)

The Legend→ Where W is in watt-seconds or joules
I is in amperes
R is in ohms
t is in seconds

Although the expert from long experience knows what to substitute in formula (4), the average man needs the information or legend given with the formula as in (4a). We must understand the dimension of the algebraic symbols if we want to make practical use of a formula.

RADIO USES FOR FORMULAS

Formulas are extremely helpful in service work. This does not mean that you cannot service without using formulas. For example, a C bias resistor burns out and it must be replaced. What replacement resistor should you use? If the service circuit diagram tells you the resistance value and the power rating, trying to figure out the proper resistor to use would be entirely unnecessary. In some cases, however, only the resistance value may be given. Shall you use a 1, 2, 5, 10, 25, or a 50 watt resistor? You know that the higher the rating the more costly will be the replacement resistor. Experience may tell you what power rating it should have. Substitution in a simple formula will remove all doubt. Again, maybe neither the value of the resistance nor the power rating is known. You may insert a variable resistor shunted with a voltmeter and adjust the resistor until you get the correct bias and then guess at the power rating. Simple calculation will eliminate this and even remove the errors of measurement.

Suppose you make a point to point resistance test. The chances are that you will not be told the net resistance between the two test points. If two or more devices are in series, you may simply add their respective ohmic values. Suppose some device is shunted by a resistor. What then? You must know how to compute the total resistance or the test value will be useless to you.

Should you decide to use a resistance-capacitance filter to buck out hum, you may juggle and change resistors and condensers until you get the right combination. If you compute the correct values from a formula, you will have accomplished a considerable saving in time.

If you want to extend the range of a milliammeter or a voltmeter, you will find that calculations will make the extension easy. Suppose you want to build an oscillator for service work, using a variable condenser that you have on hand. You may guess at a coil, then add or take off turns until by test you hit the right range. No doubt you may have to when you calculate the correct coil. The chances are good, though, that you will never need to add turns and probably will have to take off only a few turns if you start with calculations.

Example after example could be given to prove the helpfulness of computation with formulas. You may or may not find them useful or a time saver. People differ in this respect.

When we come to radio design, we find formulas an absolute need. Building a receiver or transmitter from blueprints or a kit is not design. It is merely assembly. What the value of a resistor, a coil or a condenser should be when starting from "scratch" is a problem of design in which formulas play an important part. You can't use formulas blindly, for the theory of the circuit and the effect desired has a lot to do with choosing the correct formula. That comes from your study and experience in radio.

NOT ALL TERMS ARE VARIABLES

Now let us look at a formula in more detail. We have by custom placed the unknown factor on the left-hand side of the formula, while on the right may be placed a simple or complex algebraic arrangement of known factors. These are called variables. To distinguish them, the known factors are referred to as independent variables because we may assign to them any desired value. The unknown factor is referred to as the dependent variable because it will vary as we vary the terms on the right-hand side, and its value will depend on what values are assigned to the independent variables. A simple example:

$$X_L = 6.28\, fL \qquad (1)$$

Where X_L is in ohms when
f is in cycles per second
and L is in henries

Here f and L are the independent variables for f the frequency may be 60, 120, 5,000, or 1,000,000 cycles per second. L may be 30, 2, or .002 henries. X_L will vary as we carry f and L, and its value in a particular case will depend on what values we assign to f and L. For example, if f is 60 c.p.s. and L is 10 henries, X_L according to the formula will be:

$$X_L = 6.28 \times 60 \times 10$$
$$= 3768 \text{ ohms.}$$

What about the number 6.28 in the formula? First of all we know it is a number that does not vary as we change f and L, under any condition. For that reason it is often called a constant. To be able to talk intelligently about these constants we must know how formulas are obtained.

Most of the formulas you will find in this reference text are the result of mathematical deduction. Mathematicians, fortified with such basic truths or laws as Ohm's Law, Kirchoff's Law, the law of conservation of energy, derive by mathematical manipulations, equations or formulas. As they try to establish practical facts from basic laws they obtain formulas that are extremely helpful to scientists, engineers and practical technicians.

We will not go into the derivation of formulas from basic facts. In fact, only a few men bent on research work and equipped with a knowledge of higher mathematics and practical physics can attempt such a procedure. Let us take what these capable men have provided and use their results as we see fit. In other words, let us stick to our specialty—for we live in a world of specialists.

Now what does all this have to do with the constant 6.28? The fact is that formula (1) could have been written as

$$X_L = 2\pi fL \qquad (2)$$

Apparently 6.28 must equal the expression 2π. The notation π (pronounced pie) is a geometric notation to express the ratio of the circumference to the diameter of a circle. It has a value of 3.14159 plus a string of numbers. Some one worked it out to about 600 decimal places. For radio purposes 3.14 is good enough. Therefore 2×3.14 equals 6.28. Now how did the number 2 and π get into the formula?

Without getting into deep mathematical discussion let us say that constants like these get into formulas as the result of expressing electrical ideas in geometric terms —circles, arcs and spheres. Thus 2π in formula (2) may be the result of expressing the ratio of the circumference to the radius of a circle. You will find a number of mathematical constants in radio formulas, particularly:

$\pi = 3.14$	$4\pi^2 = 39.5$
$1/\pi = 0.318$	$\sqrt{\pi} = 1.77$
$2\pi = 6.28$	$\epsilon = 2.72$*
$\pi^2 = 9.87$	

* ϵ is pronounced epsilon.

We have considered one way in which a constant may get into a formula. Let us consider another important way. We said that the electrical energy absorbed by a resistor of value R ohms when a current I amperes flows through it for t seconds will be given by the formula:

$$W = I^2Rt \text{ watt-seconds or joules}$$

But we know that this energy is transferred to heat and, if we have any knowledge of the branch of physics referred to as heat, we will know that heat energy is expressed in calories. One calorie is the energy required to raise the temperature of one cubic centimeter of water 1 degree Centigrade. Obviously, if we were a station operator where water cooled tubes were used, we would be interested in knowing the formula involving calories. By the law of conservation of energy we know that electrical energy is transformed into heat energy and there must be some number or constant that will express joules in calories. We show that in algebraic form thus:

$$W = KI^2Rt \text{ calories} \qquad (3)$$

We call the letter K the constant of proportionality; in fact formulas are full of them. By experimental evidence K in formula (3) is 0.24 and we rewrite the formula as:

$$W = 0.24\, I^2Rt \text{ calories} \qquad (4)$$

Here is another way of showing how the constant in a formula may apparently vary. You are all familiar with the resonance formula:

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad (5)$$

Where f is in cycles per second
when L is in henries
and C is in farads

But the farad is a very large condenser unit value never met with in practical problems. The microfarad is a more practical dimension. We may express formula (5) as follows: Where f is in cycles, L is in henries, and C is in microfarads, thus:

$$= \frac{159.2}{\sqrt{LC}} \text{ c.p.s.} \qquad (6)$$

For very high frequencies, even the henry is too large as a dimension, so formula (6) may be expressed thus

$$f = \frac{159{,}200}{\sqrt{LC}} \qquad (7)$$

Where f is in cycles
when L is in microhenries
and C is in microfarads

VISUALIZING FORMULAS

In your study of radio you must have noticed that a formula had other uses than for the purpose of computing the dependent variable. Formulas were introduced to give you some idea of the relationships involved in certain electrical phenomena. Take a simple case of heat dissipation in a resistor. The power loss is given by the formula:

$$P = I^2R \qquad (1)$$

Where P is in watts
I is in amperes
R is in ohms

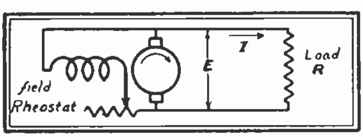


Fig. 1

Of course, in a simple circuit like Fig. 1, consisting of a resistor connected to a variable voltage generator, we may change R, or vary I by changing the voltage. Suppose we double the ohmic value of the load resistor R, keeping I constant by adjusting the generated voltage. Formula (1) tells us that the power loss doubles. On the other hand, suppose we double the current, keeping the load resistor constant, then formula (1) tells us that the power is increased four times, or, as the expert puts it, "as the square of the current." You can only get the full meaning of all this by substituting numbers for I and R in the formula. For example, let $R = 2$ ohms, let I at one time be 2 amperes, 4 amperes, 8 amperes, and etc. Figure out the power loss by means of the formula.

When $I = 2 : P = 2 \times 2 \times 2 = 8$ watts
$I = 4 : P = 4 \times 4 \times 2 = 32$ watts
$I = 8 : P = 8 \times 8 \times 2 = 128$ watts
$I = 16 : P = 16 \times 16 \times 2 = 512$ watts

Such a series of substitutions have the effect of portraying the formula. We learn that, when the current and resistance are increased, the effect of current on power loss is much more than the effect of resistance. This is what experts refer to as visualizing the formula.

So important is the visualizing of formulas that in the discussion of radio theory you will find that formulas or, to be exact, equations are presented with the sole purpose of showing how the dependent variable is affected by the independent variable. For example in the discussion of the force which moves the cone in a moving coil loudspeaker unit we may say that

$$F = KBNI \qquad (2)$$

Where F is the force
B the flux density
N the number of turns in the voice coil
I the current through the coil
K the proportionality constant.

As long as the value of K is unknown and the dimensions of B, N, I, and F are not given, formula (2) has only the power to help us visualize how F the force is affected by B, N, or I. We are told that increasing the flux density in the air gap (increasing the field current up to saturation) produces more force. Likewise, increasing the voice coil turns or current has the same effect. Even though the formula has no use in calculation, we may in design find that such a formula is valuable. After the speaker has been made, we may find that the force produced is too great. This formula tells us that if the flux or the coil turns are reduced the force will be proportionately reduced.

The constant K may be determined experimentally, if we set up a representative moving coil system and measure B, N, I and F. As we will see shortly, formula (2) may be rearranged as

$$K = \frac{F}{BNI} \qquad (3)$$

By substituting the values of B, N, I and F in this formula, we may compute K. As long as we do not alter the geometry of the system; that is, as long as we use in formula (2) the same dimensions that were used in formula (3) to compute K, we may assume that the value of K so computed will give us the correct result for F upon substituting specific values for B, N and I.

There is another way of getting K. We

have a more basic formula for force derived by mathematical physics namely:

$$F = BlI \qquad (4)$$

Where F is the force in dynes
B is flux per square centimeter
l is length in cm. of wire perpendicular to flux
I is the current in abamperes
(10 amperes = 1 abampere)

But note that l may be replaced by $l'N$, where l' is the average length of one turn of the voice coil in centimeters and N is the total number of turns. Comparing the formulas (2) and (4), it is obvious that l' and K are equal when the units given in formula (4) are used. However, if it is desired to express the force in more practical units, such as pound, K must be changed to include the factor of proportionality necessary for converting dynes to pounds.

But all we have said regarding K does not alter the use of formula (2) for purposes of visualizing, even if K is not known.

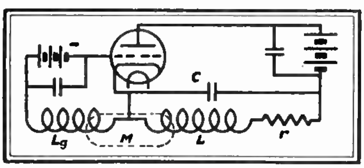


Fig. 2

Let us take one more example of the power of a formula to help visualize circuit conditions. Figure 2 is a simple tuned plate oscillator, using a tube having μ as the amplification factor and G_m as the mutual conductance at operating potentials. We say that oscillation will begin if the following relation is true:

$$M \geqq \frac{Cr}{G_m} + \frac{L}{\mu}$$

Where M is in henries
r is in ohms
C is in farads
G_m is in mhos
L is in henries
μ is a number

The notation $\geqq$ means "equal to or greater than," the value computed after the terms on the right side have been replaced by values and the total evaluated. This formula allows us to visualize the following facts: M, the mutual conductance between L_g and L, may be less for a tube having large values of G_m and μ. A large load r, which may be the resonant circuit resistance, with or without an applied load, calls for a larger coupling, M. It tells us that if L is large C may be small without altering the condition for oscillation. Of course this formula tells us nothing about the oscillator once it is in operation. It merely helps guide the design of an oscillator that will at least start to work.

EXPRESSING FORMULAS GRAPHICALLY

The previous section brings us face to face with the fact that we may go a step further in visualizing formulas. We may express the formula in picture form, generally called a curve or a graph. If drawn roughly from inspection of the formula, it is usually done so to convey generally the effects that the independent variables have on the dependent variable. Experts can look at a formula and roughly draw a curve showing the desired relation between known and unknown factors.

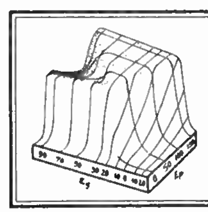


Fig. 3

Graphs and curves are not new to you, as you have constantly met them in your study of radio. But here let us investigate curves a little more critically.

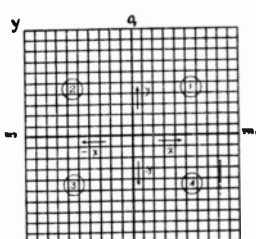


Fig. 4

As far as the practical man is concerned, a formula may be represented as lines on paper or, as we say, in two dimensions. To be sure, we may represent formulas as a solid or curved surface, often referred to as three dimensional representations. Perhaps you have seen clay models of formulas as in Fig. 3. The latter is particularly valuable when you wish to portray how the dependent variable depends on two independent variables. We will shortly see how all such formulas may be replaced by a representation on graph paper.

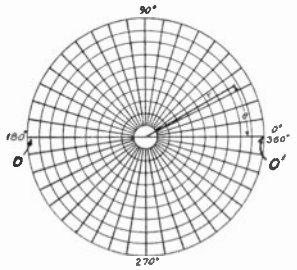


FIG. 5

In representing formulas we encounter several types of graph or plotting papers as represented by Figs. 4, 5, and 6. Figure 4 is referred to as rectangular coordinate paper, the vertical lines to the right and left of oO_1, representing * various values of the independent variable, or x, as it is often called in algebra. The horizontal line above and below the line mm_1 represents the value of the dependent variable, or y, as we often call it in algebra. In such a representation the vertical and horizontal lines are uniformly spaced and may represent any desired value of the factor: 2 feet, 2 henries, 2 microfarads, 2 micro-microfarads; or 4, 6, 10, 20 feet. Usually you will find, on rectangular coordinate graph paper, bold horizontal and vertical lines each separated by light lines dividing the bold lines in 5 or 10 equal spaces. For reason of simplicity in plotting and reading curves it is always well to have each major division represent some multiple or submultiple of 10—10, 20, 1, .01, etc. No doubt you have recognized all this

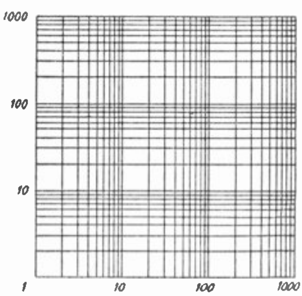


FIG. 6

* Lines oO_1 and mm_1 are drawn in if one wishes to plot in four quadrants, that is when there are + and − values of x and y. In most cases plotting in one quadrant is sufficient, as will be shown.

from the curves presented in the regular texts.

When you have a formula involving one independent and one dependent variable you can present it on a graph like Fig 7 by calculating the values of y (the dependent

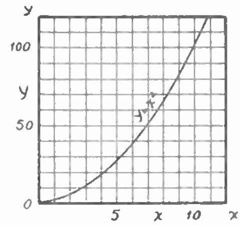


FIG. 7

variable) for various values of x (the independent variable). Spot the vertical line corresponding to x, and the horizontal line corresponding to y. At their intersection place a dot, a small circle or a cross. After locating several intersections, connect the markings with a smooth curve, using preferably a "french curve" (see Fig. 8) available at any drafting supply house. When

FIG. 8

drawing a curve with figures computed from a formula, you should be able to draw a smooth curve through all points. Although Fig. 4 shows four quadrants so as to represent + and − values of x and y, we rarely have to draw such curves, as negative values may be represented in a single quadrant, merely by noting the fact on the curve. As shown in Fig 7, ox then represents x and oy represents y.

Figure 5 shows another form of graph paper—polar coordinates. In rectangular coordinates any point on the surface of the paper can be referred to by means of two reference coordinates, the x dimension and the y dimension In polar coordinates, likewise, any point can be referred to or located with two reference coordinates, but one is an angle and the other a linear dimension or simply a length. Polar coordinate paper is generally used to represent formulas where an angle is involved and you want to retain the physical significance of the angle. For example: representing the shape of a straight line frequency condenser, or the special cut plate used in the oscillator of a superheterodyne receiver, or the field intensity around a transmitting antenna. In such cases the angle θ is the independent variable and the radius r, the dependent variable. Note that this graph paper is laid out so it is easy to spot any angle from 0 to 360 degrees and it is easy to assign any value to the various circles. A point at a distance r from the center O measured at an angle θ with respect to the horizontal reference line OO' establishes one of the points on the curve to be drawn.

Figure 6 illustrates the log-log plotting paper and is quite valuable in representing formulas involving logarithms of the independent and dependent variables. Log plotting papers are also made so only one of the rulings is spaced according to logarithms called semi-log paper. You will find a large number of formulas, which are best visualized by plotting on log-log or semi-log paper.

Now why is a picture of a formula so valuable? First you have a clearer insight to the formula. You can tell whether one factor changes faster or slower with respect to the other, observe if saturation is realized, whether there are maximum and minimum values, and how many. Graphs if carefully drawn may replace in practical work subsequent calculations using the formula. Approximate but valuable results are quickly obtained.

Going a step further, suppose we consider the formula for determining the impedance of the circuit shown in Fig. 9.

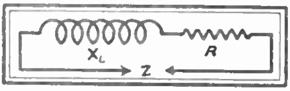


Fig. 9

The formula is:

$$Z = \sqrt{R^2 + X_L^2} \qquad (1)$$

Where Z is in ohms
R is in ohms
X_L is in ohms.

Here we have a formula with two independent variables R and X_L, and one dependent variable Z. Practical radio men want a simple picture of this formula, considering the fact that both R and X_L may vary. Suppose that R and X_L may each be any value from 0 to 100 ohms. We may start by saying that R is 0 and compute Z for various values of X_L from the simplified formula

$$Z = \sqrt{0^2 + X_L^2} = \sqrt{X_L^2} = X_L \qquad (2)$$

Obviously Z will equal X_L.

We may next assume R equal to 10, 20, 30, etc., ohms and compute from formula (1) the values of Z when X_L is 10, 20, 30, etc., ohms, from the formulas

$$Z = \sqrt{10^2 + X_L^2} = \sqrt{100 + X_L^2} \qquad (3)$$

$$Z = \sqrt{20^2 + X_L^2} = \sqrt{400 + X_L^2} \qquad (4)$$

$$Z = \sqrt{30^2 + X_L^2} = \sqrt{900 + X_L^2} \qquad (5)$$

....................etc.

Note that we have held one independent variable fixed while we substituted for the other variable. Thus we may have 11 curves to represent formula (1), by assuming R in one case to be 0 ohms, and in other cases to be 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 ohms. Plotted we get a group of curves as shown in Fig. 10 which are called a family of curves.

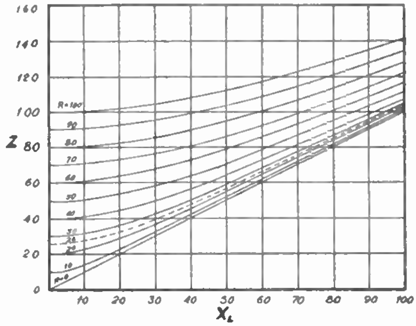


Fig. 10

Note that in such a representation each curve of the family is marked with the value that was assumed for the independent variable held fixed in computing that curve.

If desired, a second family of curves similar to Fig. 10 may be obtained to show how Z varies with R for a series of fixed values assigned to X_L. This is often done, particularly in the study of relationships somewhat more complex than that represented by formula (1).

In this simple case this is not necessary since we may use the family of curves of Fig. 10 to find Z for any of the value of R or X_L within the range of values specified. For example, if you wish to assume a value of 26 ohms for R, we can imagine a curve between $R = 20$ and $R = 30$ (as shown dotted) and thus find Z for any value of X_L between 0 and 100 ohms.

EMPIRICAL CURVES

Quite often we start with a curve or a family of curves and then derive the formula. It is then called an *empirical* formula, meaning a formula derived from observation or experience. Compare this with the formula derived by mathematical deduction. We should remember that a formula derived mathematically is checked by experiment by comparing the curve drawn from the formula, with the empirical curve.

There are many cases where the only solution to the problem is the result of experiment. If the phenomena is one where a formula would be valuable, one may be derived from a curve in which the results obtained experimentally are plotted with precision. Here is a typical case. In the manufacture of many of the basic products for radio equipment, high temperature furnaces are used. The temperature may be measured by inserting a platinum wire resistor and measuring its resistance. Each value of resistance in turn represents a definite temperature. Let us see how the corresponding values of temperature can be determined.

First of all, there is the simple fact that most metals change their resistance with temperature. By placing the resistor in a chamber in which the temperature, t, may be varied in known steps and then measuring the resistance at these representative temperatures enough figures are obtained to draw a curve, similar to Fig. 11. If you use the same resistor and the same curve, you have a temperature measuring device.

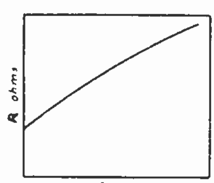


FIG. 11

Going a step further we find that the type of curve shown in Fig. 11, is typical of all metal resistors and may be expressed as an empirical formula:

$$R_t = R_o\,(1 + at + bt^2) \qquad (1)$$

Where R_t is the resistance in ohms at
t the temperature in centigrade
R_o is the resistance at 0 degrees Centigrade
and a and b are constants depending on the metal used.

By carefully analyzing the experimental curve we would find that for platinum wire, $a = +.00392$ and $b = -.000000588$, in which case formula (2) becomes

$$R_t = R_o\,(1 + .00392t - .000000588t^2) \qquad (2)$$

Here is another type of constant found in formulas. The values a and b are found mathematically from the experimental curve by a complicated process which we need not consider.

Formula (2) also tells us that in practical cases the term $(-.000000588t^2)$ is negligible in comparison with the first term $(.00392t)$ if the temperature t is not much higher than the reference temperature, 0 degrees Centigrade. We rarely expect parts in radio equipment to be over 50° C. If we use this as a limit, we may compare the two terms by substituting 50 for t. Thus:

$$+at = .00392 \times 50 = +.196$$
$$-bt^2 = .000000588 \times 50 \times 50 = -.00147$$

So if we neglect the second term we may have an error less than 1 per cent—which for practical purposes is quite all right. But, in the case of the furnace at 1000° C., b is a very important factor. Thus in low temperature work formula (1) reduces to:

$$R_t = R_o\,(1 + at) \qquad (3)$$

The idea of neglecting terms in a formula is very important and is used time and time again in radio work. Most solutions to radio problems can only be relied upon to about 5 per cent. So why complicate the work with useless computation? When terms in a formula have negligible effect on the answer, they should be neglected. Only experience or trial can guide you in this phase of formula simplification.

In practical radio the empirical curve is far more important than the resultant empirical equation or formula. The E_g-I_p, E_p-I_p, E_g-I_g, fidelity, sensitivity, selectivity, field radiation, and magnetic curves are only a few of the empirical curves that are used directly and never interpreted into a formula. Curves like formulas are essential for our purpose, in that they give practical information. If curves are simpler to get, are more direct and do the job, why try to make a formula out of them? Especially where the formula would not apply in all cases. Radio men do not try. They use the curves when it is to their advantage to do so.

FORMULAS INVOLVING CURVES

You will find a large number of radio formulas where the right hand terms include some factor whose value must be determined from a graph or perhaps a table. This table or curve may be the result of experiment or it may be the result of expressing complicated algebraic expressions in their simplest terms.

The most notable example of such a case is the computation of inductance from the geometry of the coil. The inductance of a round solenoid coil may be given by the formula

$$L = FdN^2 \qquad (1)$$

Where L is in microhenries
N is the number of turns
d is the diameter of the coil in centimeters or inches, depending on whether measurements are made in inches or centimeters
and F is a factor determined from a curve, see Fig. 12, depending on the ratio of the length of the coil to its diameter

In using formula (1) we may either have a coil with a definite number of turns and with a known coil length and diameter which permits us to compute L, or we would from trial and error try various N turns, l lengths and d diameters until we found a combination that would give the desired L.

From Fig. 12 we determine F for the ratio of l/d for each combination and substitute the value

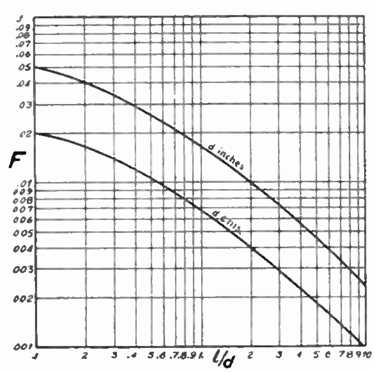


Fig. 12

in formula (1). In this case F is merely a constant that could be computed from l and d by a complex algebraic expression. The curve simplifies the problem of practical computation.

EVALUATING THE UNKNOWN

By now we know that a formula has on the left hand side the factor or variable that we want to compute. On the right hand side, expressed in algebraic manner, are the constants and independent variables that are known or quickly found from tables or curves. To evaluate the unknown we merely substitute on the right hand side the values for the algebraic notation and by mathematical operation derive the final single number or value. We may look on this as sort of a mill.

It is highly important that this reduction process be as systematic as possible, otherwise you will get into a tangle. There is only one way of developing the technique of manipulating algebraic reduction—by working at it. Take a simple formula, for example, the case of an inductive reactance, a capacitive reactance and a resistance all in series, as shown in Fig. 13.

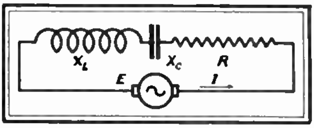


Fig. 13

If an A.C. voltage E is connected to this circuit, the current I flowing in the circuit will be given by the formula:

$$I = \frac{E}{\sqrt{R^2 + (X_L - X_c)^2}} \qquad (1)$$

Where E is in volts
R, X_L and X_c are in ohms
I is in amperes

We know that the right hand terms will reduce to a single valued number if we know the value of E, R, X_L and X_c and substitute them into the algebraic expression. Suppose $R = 2$; $X_L = 5$; $X_c = 2$; and $E = 10$. How would you go about reducing the right hand terms to a number? First of all, we substitute in formula (1) the number for the letters, thus:

$$I = \frac{10}{\sqrt{2^2 + (5-2)^2}} \qquad (2)$$

Our next problem is to get rid of the complex expression $\sqrt{2^2 + (5-2)^2}$. But let us do this in steps. First we know that $(5-2)$ equals 3; therefore $(5-2)^2$ must equal 3^2. So we obtain:

$$I = \frac{10}{\sqrt{2^2 + 3^2}} \qquad (3)$$

We know that 2^2 equals 4, and 3^2 equals 9, so as the next step in simplifying expression (3) we get

$$I = \frac{10}{\sqrt{4+9}} = \frac{10}{\sqrt{13}} \qquad (4)$$

Our next step is to evaluate $\sqrt{13}$. You may use the long method as taught in grammar school, or use the slide rule or logarithms as explained in a previous text. We will find that $\sqrt{13}$ equals approximately

3.60. Therefore, the next steps in evaluating the value of I when E is 10, R is 2, X_L is 5, and X_c is 3, follows:

$$I = \frac{10}{3.60} \qquad (5)$$

and by division:

$$I = 2.77 \text{ amperes.} \qquad (6)$$

You will find the evaluation of the unknown simple and quick if you follow a systematic method and realize the importance of certain algebraic notations. Thus:

ab means a multiplied by b
$a \div b$; a/b means a divided by b
$a + b$ means a added to b
$a - b$ means b subtracted from a
a^2 means a multiplied by itself (aa)
a^3 means a multiplied by itself twice (aaa)
$\sqrt{a}$; $a^{1/2}$ means the square root of a
$\sqrt[3]{a}$; $a^{1/3}$ means the cube root of a
$\sqrt[3]{a^2}$; $a^{2/3}$ means the cube root of the square of a
$2.72^{1.32}$ means the 1.32 power of 2.72

Furthermore, you may find expressions like $(4^2 + 2)\ 1.25$, the brackets ( ) indicating that you should first evaluate the terms within the bracket before multiplying by 1.25. Again you may find expressions like:

$$\sqrt{[(4^2 + 2)\ 1.25 + 29.3]\ 6.28}$$

which indicates that the term within the parenthesis ( ) is evaluated first; then the result is multiplied by 1.25, then this result added to 29.3, before multiplying by 6.28. Now you may find the square root of the resultant number.

In the case of fractions, always reduce the numerator and denominator to a single valued number before dividing.

SIGNIFICANT FIGURES

The number of significant figures to be used when substituting numerical values into a formula, and the number to retain in the final answer is important. Starting with more significant figures than are required is a waste of time and effort and does not yield a more precise solution. Don't overlook this fact. The subject, significant figures, is not new to you.

Precision of measurements is the important factor in determining how many significant figures you shall start with and retain in the answer. Let us take a simple example. Assume that we loaded a generator with a 3 ohm resistor and then measured the terminal voltage as 10 volts. Then by Ohms law, the current:

$$I = E/R = 10/3 \qquad (1)$$

Strictly speaking, $10 \div 3$ equals 3.33333333+ etc., indefinitely or until we get tired of writing the numeral 3. Suppose an 0 to 5 ampere meter was inserted in the circuit and for the sake of simplicity this meter had negligible resistance. What current value do you think you would read? If the meter is one of those used in ordinary radio work, the meter maker tells you beforehand not to rely on it to more than 2%. So with this as a start you may read 10/3 plus 2% or 10/3 minus 2%, which means that if everything else were perfect you may read any value between 3.26 and 3.39 amperes. The next question is in reading the meter scale as close as the latter values. The fact remains that you may read any value between 3.2 and 3.4 amperes. Common sense tells us that 3.3 amperes is a more reasonable answer than 3.33333 + etc.

In this simple problem there are other reasons why too many significant figures may be in error. In the first place, with what precision did we measure voltage, and measure the resistance? If you used an ordinary voltmeter calibrated to within 2%, you may have read 10 volts but could not rely on the value as being correct. The actual value may be between 9.8 and 10.2 volts. Likewise the resistance may be measured as 3.0 ohms, but may be larger or smaller than this value, depending on how precise is the measuring equipment. When you place a voltmeter in the circuit you disturb the circuit and 10 volts may be slightly low.

The upshot of the whole matter is, take a practical attitude towards significant figures. Use reliable measuring equipment and substitute in the formula the numbers that are obtained from measurements. Other figures —that is, constants—should not have any more significant figures. Here is an example:

$$X_L = 2\pi fL \text{ (ohms)} \qquad (2)$$

Where f is in c. p. . and
L is in henries

We may assume that the frequency of the supply is 291 c.p.s. and we measure L to be 6.2 henries. The value of π is 3.14159 to 6 significant figures. It will be perfectly safe to use the value 3.14. Thus:

$$X_L = 2 \times 3.14 \times 291 \times 6.2 = ?$$

If you follow the long multiplication method, you will get the absurd answer of $X_L = 11330.376$; if you follow the short method used by engineers, you will get $X_L = 11330$; if you use a 10 inch slide rule, you will get $X_L = 11330$.

Slide rule calculations are as close as you will need to compute on a sensible basis.

That is why every engineer and technician uses a slide rule.

COMPUTATION CHARTS AND TABLES

Magazines, texts and articles intended for the average technician often have special tables for finding squares and square roots, cubes and cube roots. Countless charts have been prepared to find the value of resistors in parallel, resonant frequencies of a coil and condenser combination, and other similar values. Of course they are time savers, and you may use them if you wish if they are available.

We feel that such schemes defeat the desired purpose of formulas. If you get into the habit of using charts and tables you develop mental laziness and fail to use formulas for the purpose they are intended. Get into the habit of using the formulas directly, computing by the engineers' short method, by using logarithms or a slide rule. It is good practice and you know at all times what you are doing.

Do not assume that graphical and mechanical means of solution are not desirable.* They are, but only where you are going to solve similar problems over and over again. This is usual where one specializes in designing similar devices.

REARRANGING FORMULAS

Quite often we remember or find a formula which is not set up for ready solution of the unknown, that is we find the unknown factor on the right-hand side with the known factors. We may use the formula as given or rearrange it into the usual form; unknown factor on the left, known factors on the right. A simple example will bring out what is meant. Take the important basic formula:

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad (1)$$

Where f is in c. p. s.
L is in henries
C is in farads

Suppose we have a problem where we know the frequency involved and have a condenser which we wish to use. We want to know what inductance together with the available capacitor will give resonance at the frequency f. If formula (1) was arranged so L was on the left and C and f on the right, we could solve our problem by direct solution. How can we go about arranging the formula into this form, assuming that we do not know the new formula? For such a procedure you must have a suitable knowledge of algebra.*

Algebra tells us that if we perform the same operation to both sides of an equation we have not destroyed its validity as a correct equation. So, in the above case, let us square both sides of the formula. We get:

$$f^2 = \frac{1}{4\pi^2 LC} \qquad (2)$$

Now let us multiply both sides by L, which gives us:

$$f^2 L = \frac{L}{4\pi^2 LC} \qquad (3)$$

We may now cancel the L in the numerator and the L in the denominator of the right-hand term, which then gives:

$$f^2 L = \frac{1}{4\pi^2 C} \qquad (4)$$

Now let us divide both sides of equation (4) by f^2, and get:

$$\frac{f^2 L}{f^2} = \frac{1}{4\pi^2 C f^2} \qquad (5)$$

Cancelling f^2 on the left-hand side, we get the desired formula:

$$L = \frac{1}{4\pi^2 C f^2} \qquad (6)$$

Most beginners, when they rearrange a formula, are doubtful of its correctness.

A simple check of the algebraic manipulations is easily made. We know that the original formula (1) is correct. Assume values for the unknown, in fact any value. Let us say that L is 2 henries, C is 2 farads. Of course, 2 farads is an absurd value, but it does not matter in a check. Substitute these values in formula (1) (the original), and we find that:

$$f = \frac{1}{2\pi\sqrt{2 \times 2}} = \frac{1}{6.28\sqrt{4}} = \frac{1}{6.28 \times 2}$$

$$= \frac{1}{12.56} = .0796 \text{ c.p.s.}$$

Assume that the value of .08 is close enough for our present needs. Now if the derived formula (6) is correct, we should get a value of 2 for L, when we substitute

* This subject is beyond the scope of the average N. R. I. student. For a man with an advanced knowledge of mathematics we suggest Lipka's book, "Graphical and Mechanical Computation," published by John Wiley and Sons, Inc., N. Y. C. Price, $4. Considers alignment charts in detail.

* We suggest that you study such texts as
Mathematics for Electricians and Radio Men, by Nelson M. Cooke. Published by McGraw-Hill Book Co., Inc., N. Y. C.
Algebra for the Practical Man, by J. E. Thompson. Published by D. Van Nostrand Co., Inc., N. Y. C.
Practical Mathematics, Part II, by C. I. Palmer. Published by McGraw-Hill Book Co., Inc., N. Y. C.

.08 (closest value to .0798) for f and 2 for C. Let us try this. Thus by substitution:

$$L = \frac{1}{4\pi^2 C f^2}$$

$$= \frac{1}{4\pi^2 \times 2 \times .08^2}$$

$$= \frac{1}{4 \times 3.14 \times 3.14 \times 2 \times .08 \times .08}$$

$$= \frac{1}{.505} = \text{approx. } 2$$

we have proved that the derived formula is correct.

Quite often it is not easy to rearrange a formula in the standard form. In fact, when a problem arises where the unknown is on the right with known factors, experienced technicians don't even try to derive a suitable formula. They make immediate substitutions and solve by algebra for the unknown. Let us consider a simple example.

A radio amateur desires to build a transposed feeder line between the antenna and his transmitter. The line is to have a surge impedance of 440 ohms and he wants to use standard transportation blocks that place the two feeder wires 2 inches apart. There is a formula for the surge impedance involving the factors

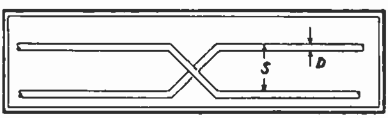


FIG. 14

given in Fig. 14. It is:

$$Z_o = 277 \log_{10} \frac{2S}{D}^{*} \qquad (7)$$

Where Z_o is the surge impedance in ohms
S and D are measured in the same dimensions, inches or centimeters.

From our problem we know that Z_o is 440 ohms and S is 2 inches. We want to know what the value of D should be. We may rearrange the formula, by algebra † or we may substitute the values and solve for S, as we shall in this case. Substituting the known values in formula (7), we get:

$$440 = 277 \log \frac{2 \times 2}{D} \qquad (8)$$

By arithmetic we reduce this to:

$$1.59 = \log 4/D \qquad (9)$$

What this equation says is that the logarithm of $4/D$ is equal to 1.59. Now what number would have the logarithm 1.59? From a log table we find that the number 38.9 would have that logarithm. Check this yourself. The characteristic of 38.9 is 1 and the mantissa is .5899, which is close enough to 0.59. Now we may say that:

$$4/D = 38.9 \qquad (10)$$

or

$$D = \frac{4}{38.9} = .103 \text{ inch} \qquad (11)$$

Referring to a wire table we find that a No. 10 B & S gauge wire would have a diameter of .102 inch. Therefore, the amateur would use this size wire.

COMBINING FORMULAS

We mentioned that radio experts who find formulas of particular use in their work memorize certain basic formulas and derive the ones they need. Two cases have been cited. This sort of formula manipulation may be greatly extended, and to cases where formulas are introduced into one another. Take the formula:

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \qquad (1)$$

which you will recognize as the impedance formula for a resistance, inductive reactance and capacitive reactance in series. This formula is always memorized.

Now consider the same circuit without capacitive reactance, that is in formula (1), $X_c = 0$. This gives us at once the formula:

$$Z = \sqrt{R^2 + X_L^2} \qquad (2)$$

If the inductive reactance is zero, that is $X_L = 0$, we get:

$$Z = \sqrt{R^2 + X_c^2} \qquad (3)$$

In the latter case we must realize that $-X_c^2$ equals $+X_c^2$, as taught in a course in algebra.

Suppose we do not know the inductive or capacity reactance, but know the line frequency and the inductance and capacity. There are two basic formulas that tell us that:

$$X_L = 2\pi f L \qquad (4)$$

$$X_c = \frac{1}{2\pi f C} \qquad (5)$$

If we substitute formulas (4) and (5) in formula (1), we get:

$$Z = \sqrt{R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2} \qquad (6)$$

which is a very important formula in A.C. circuit theory.

* There are two standard logarithms, base 10 and base ϵ (2.72+). It is customary practice to signify only the ϵ base by a subscript thus $\log_\epsilon 49$ Because the base 10 is so common the subscript $\log_{10}$ is omitted. In this text $\log x$ will mean to the base 10.

† By rearrangement we get:

$D = \frac{2S}{\log^{-1} Z_o/277}$ where $\log^{-1}$ means a number whose log is equal to the value of $Z_o/277$.

The ability to combine and interpret formulas is very valuable to the advanced radio technician. We will consider a very valuable case.

Suppose we have a resonant circuit consisting of a fixed coil shunted by a variable condenser. We know from experience that it will tune to a maximum and minimum frequency. Can we derive a formula that will tell us quickly what the ratio of the maximum to minimum frequency will be without tedious computation? We always start by setting down algebraically the statement that interests us, and then simplify. Suppose we consider the case where the inductance is L, the maximum capacity is C_1 and the minimum capacity is C_2. We must be sure that C_1 and C_2 include the distributed capacity of the coil.

We start with the basic formula:

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad (7)$$

For the maximum capacity of the condenser (100 dial position) we may say:

$$f_1 = \frac{1}{2\pi\sqrt{LC_1}} \qquad (8)$$

For the minimum capacity setting (0 dial setting) we may say:

$$f_2 = \frac{1}{2\pi\sqrt{LC_2}} \qquad (9)$$

We know that f_2 will be larger than f_1, so let us determine what the ratio of f_2 to f_1 is. Let us set this down algebraically thus:

$$\frac{f_2}{f_1} = \frac{\dfrac{1}{2\pi\sqrt{LC_2}}}{\dfrac{1}{2\pi\sqrt{LC_1}}} \qquad (10)$$

The next steps involve simplifying expression (10). Multiply the numerator and denominator of the right-hand side by 2π. This gives:

$$\frac{f_2}{f_1} = \frac{\dfrac{1}{\sqrt{LC_2}}}{\dfrac{1}{\sqrt{LC_1}}} \qquad (11)$$

Now multiply both numerator and denominator by $\sqrt{LC_2}$ and $\sqrt{LC_1}$. This simplifies the expression to:

$$\frac{f_2}{f_1} = \frac{\sqrt{LC_1}}{\sqrt{LC_2}} \qquad (12)$$

and finally:

$$\frac{f_2}{f_1} = \sqrt{\frac{C_1}{C_2}} \qquad (13)$$

With this formula it is simpler to tell through what range a given tuned circuit will respond. For example an R.F. broadcast tuned circuit may have a capacity variation of 9 to 1. In which case

$$\frac{f_2}{f_1} = \sqrt{\frac{9}{1}} = 3 \qquad (14)$$

This tells us that the f_2 will be 3 times f_1.

In a manner similar to the way formula (13) was derived, we can obtain the more complete formula where the inductance and capacity may vary. This is given by:

$$\frac{f_2}{f_1} = \sqrt{\frac{L_1C_1}{L_2C_2}} \qquad (15)$$

A PRACTICAL PROBLEM IN DESIGN

As a practical problem, let us consider the design of an oscillator and pretuner tuning stages of a superheterodyne so that they will track. We will assume, if two tie-down points are realized, that satisfactory tracking may be arranged by trimmer adjustments. The two tie-down points we will assume are 1400 and 600 kc. From the theory and practice of padding we know that, at 1400 kc., enough turns are taken off the oscillator coil so that a tie-down is obtained and so that the oscillator frequency is above the signal frequency by the I.F. value. At the lower frequency (600 kc.) the number of turns taken off are insufficient, so a so-called padding condenser is placed in series with the tuning condenser in the oscillator circuit so a second tie-down is obtained. The insertion of the padding condenser has little effect at the high frequency, and whatever upset is obtained may be corrected by a trimmer. Obviously the important problems in this design are the oscillator coil inductance and the value of the padding condenser.

Assume that the inductance of the coils in the preselector is 250 μh and the I.F. is 175 kc. From formula (13):

$$\frac{f_{p1}}{f_{o1}} = \sqrt{\frac{L_o}{L_p}}\,* \qquad (16)$$

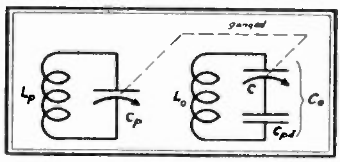


Fig. 15

we may now determine the value of the

* The notations are: p for pretuner, o for oscillator 1 for 1400 kc., and 2 for 600 kc. Thus f_{p1} is the resonant frequency of the pretuner at 1400 kc.

oscillator inductance L_o for this tie-down point.

Substituting in the formula we get:

$$\frac{1400}{1575} = \sqrt{\frac{L_o}{250}} = .89 \qquad (17)$$

Squaring the above equation, we get:

$$\frac{L_o}{250} = .792 \qquad (18)$$

Therefore $L_o = .792 \times 250 = 198\ \mu h$.

Now let us turn our attention to getting a suitable tie-down at 600 kc., knowing that $L_p = 250\ \mu h$ and $L_o = 198\ \mu h$. From formula:

$$\frac{f_{p2}}{f_{o2}} = \sqrt{\frac{L_o\, C_{o2}}{L_p\, C_{p2}}} \qquad (19)$$

we may determine the value of C_{o2}, that is the net value of C_{pd} the padding condenser in series with C for that position (see Fig. 15). We need to know the value of C_{p2}. First let us compute C_{p2} from the formula:

$$C_{p2} = \frac{25330}{f^2_{p2}\, L_p}\ \mu f. \qquad (20)$$

Where f_{p2} is in kc.
L_p is in μh.

Substituting into the expression we get:

$$C_{p2} = \frac{25330}{600 \times 600 \times 250} \qquad (21)$$

$$= \frac{25330}{90,000,000}$$

$$= .000282\ \mu f.$$

$$= 282\ \mu\mu f.$$

Now we may substitute into expression (19). If we express C_{p2} in micro-micro-farads, we obtain C_{o2} in the same units. Substituting we get:

$$\frac{600}{775} = \sqrt{\frac{198 \times C_{o2}}{250 \times 282}} \qquad (22)$$

simplifying:

$$.774 = \sqrt{\frac{C_{o2}}{356}} \qquad (23$$

Squaring both sides gives:

$$.600 = \frac{C_{o2}}{356} \qquad (24)$$

and:

$$C_{o2} = 214\mu\mu f. \qquad (25)$$

Obviously while the condenser C is set to have a capacity of 282 $\mu\mu f$., the net oscillator coil shunting capacity should be 214 $\mu\mu f$. As stated, the padding condenser is used for this purpose. For the two condensers in series the net capacity is determined from the formula:

$$C_{o2} = \frac{CC_{pd}}{C + C_{pd}} \qquad (26)$$

Substituting we get:

$$214 = \frac{282 \times C_{pd}}{282 + C_{pd}} \qquad (27)$$

Multiplying both sides by $(282 + C_{pd})$ we obtain:

$$60400 + 214C_{pd} = 282C_{pd} \qquad (28)$$

$$60400 = 68C_{pd} \qquad (29)$$

and $$C_{pd} = \frac{60400}{68} = 890\mu\mu f. \qquad (30)$$

In actual practice the padding condenser may be 850 $\mu\mu f$. shunted by a 100 $\mu\mu f$. trimmer. If the system is designed with the calculated values and the pretuner and oscillator aligned in the usual manner, very little trouble will be experienced.

CONCLUSIONS

In this short lesson on formulas and their use, we have shown how valuable a formula may be for explaining theory, how they may be used in design, and how they may help in servicing. We merely wish to add that if you have mastered your radio theory, and can select the appropriate formula, and learn how to juggle and compute with formulas, you can make formulas do "tricks" for you.

RADIO FORMULAS

A: FUNDAMENTAL RADIO—ELECTRIC CIRCUIT LAWS

Governing the entire theory of radio circuits are certain extremely important basic laws. With these laws, advanced radio engineers and scientists have developed many of the formulas given in this text. Experience has shown that a number of special problems are solved quicker by starting with the fundamental circuit laws. Many of these laws are valuable in visualizing what goes on in the circuit. Without regard to their relative importance, these laws are as follows:

Kirchoff's Laws

Law 1. The sum of all the currents flowing towards a junction (connection) in any network of conductors is equal to all the current flowing away from the junction. This law may also be stated as: The algebraic sum of all the currents toward a junction is zero. By the algebraic sum we mean that if the current toward the junction be considered + or positive; the current away from the junction shall be considered — or negative. Alternatively we may assume current "away" as +, and current "to" as —. As a formula, the law may be written:

$$\Sigma I = 0 \qquad (1A)$$

where the symbol Σ is read as "sum of." It is the Greek letter "sigma."

Law 2. In any complete circuit of any network the sum of all the voltages generated (e.m.f.'s) are equal to the algebraic sum of all the voltage drops (impedance or resistance drops). If we consider all the e.m.f.'s as voltage rises, we may state this law as: The sum of the voltage rises plus all the voltage drops in a complete circuit is equal to zero. Expressed as a formula, this is written as:

$$\Sigma E = 0 \qquad (2A)$$

Example of Kirchoff's Laws:

Given the supply and load circuit shown in Fig. 1A

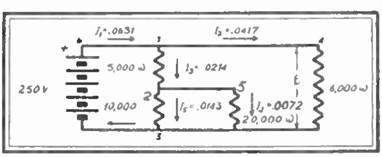


FIG. 1A

Observe that there are three junction points, namely: 1, 2, and 3. In all cases Law 1 ($\Sigma I = 0$) is true.

For

(1) .0631 — .0417 — .0214 = 0
(2) .0214 — .0072 — .0143 = 0 (close enough)
(3) .0072 + .0143 + .0417 — .0631 = 0

The only voltage rise in this circuit is the 250 volts, and it may be a battery, generator or the equivalent of the output of a rectifier. All other voltages of the circuit are considered voltage drops. In this case each voltage drop is equal to a resistance times the current flowing through the resistor. We have in this network three complete circuits in which e.m.f.'s and voltage drops are concerned. There are also other complete circuits if they are of value in finding a solution. Let us take the circuits each with an e.m.f. Considering the fact that $\Sigma E = 0$.

Circuit 6-1-2-3-6 according to this law gives:

$$250 - .0214 \times 5000 - .0143 \times 10{,}000 = ?$$
$$250 - 107 - 143 = 0$$

Circuit 6-1-4-3-6 gives:

$$250 - .0417 \times 6000 = ?$$
$$250 - 250 = 0$$

Circuit 6-1-2-5-3-6 gives:

$$250 - .0214 \times 5000 - .0072 \times 20{,}000 = ?$$
$$250 - 107 - 144 = 0 \text{ (close enough)}$$

Note that in this example we have given all the details of the circuit and proved by simple computations that Kirchoff's laws are true. Accordingly we have shown that the values are correct. This is of particular value to the practical technician, where circuit values are given and he wants to prove that they are correct. For the designer there is a greater use for Kirchoff's laws. Given certain facts about the circuit, he may want to find the remaining facts. For example, suppose the generated voltage and the resistance were known. He wants to know the currents. Using laws 1 and 2, he would set up as many equations as there were unknown currents to be determined and solve these simultaneous equations as they are called, by algebra. The equations for this circuit would be:

(1) $250 - 6000 I_2 = 0$ (circuit 6–1–4–3–6)

(2) $250 - 5000 I_3 - 10{,}000 I_5 = 0$ (circuit 6–1–2–3–6)

(3) $250 - 5000 I_3 - 20{,}000 I_4 = 0$ (circuit 6–1–2–5–3–6)

(4) $I_1 - I_2 - I = 0$ (Junction 1)

(5) $I_3 - I_4 - I_5 = 0$ (Junction 2)

For the solution of these equations we refer you to a text on algebra.

Ohm's Law.

Ohm's law may be stated in a number of ways. The most common statement is:

(a) The current through a resistance or a reactance is the voltage applied divided by the resistance or reactance. Stated as formulas we have:

$$I = E/R \qquad (3A)$$

$$I = E/X \qquad (4A)$$

Where I is in amperes
E is in volts
R and X are in ohms

We must recognize the fact that X may be inductive or capacitive reactance and that the inductive reactance X_L is equal to $2\pi fL$, while the capacitive reactance X_c is equal to $1/2\pi fC$.

Of course we may have a device that has resistance and reactance, the net being referred to as impedance Z. Ohm's law must then be written as:

$$I = E/Z \qquad (5A)$$

In the general case of a device having resistance, inductance and capacitance in series, Z in this formula is equal to:

$$\sqrt{R^2 + (2\pi fL - 1/2\pi fC)^2}$$

(b) Ohm's law is also stated as follows: The current through an inactive or passive device (a device which does not itself generate a voltage) is proportional to the voltage applied. Stated as a formula, we have:

$$I = GE \qquad (6A)$$

Where I is in amperes
E is in volts
G is in mhos

In this case G is referred to as the conductance.

For an inductance or capacitance this law is algebraicly expressed as:

$$I = BE \qquad (7A)$$

Where B is in mhos

The symbol B is referred to as the susceptance of the device and is the reciprocal of reactance, that is:

$$B = 1/X \qquad (8A)$$

Thus, for an inductance B_L is equal to $1/2\pi fL$ and for a capacitance B_c is equal to $2\pi fC$. Where the passive device or network includes susceptance and conductance, the sum effect is called the admittance, Y. Ohm's law therefore becomes.

$$I = YE \qquad (9A)$$

Where Y is in mhos

In the general case of a circuit having resistance, inductance and capacitance in parallel, Y in this formula is equal to:

$$\sqrt{G^2 + (2\pi fC - 1/2\pi fL)^2}$$

The importance of using resistance, reactance and impedance in one case and using conductance, susceptance and admittance in the other case arises from the fact that in series circuits, R, X, and Z may be added to get the resultant, while in parallel circuits G, B, and Y may be added to get the resultant.*

The Principle of Superposition.

In any network consisting of resistances, inductances and capacitances which do not change in value, the currents produced by the presence of many varied voltages (e.m.f.'s) may be considered to be the sum of the currents produced by the individual e.m.f.'s.

For example, if the voltage consists of a fundamental, a third and a fifth harmonic, the currents flowing may be considered first for the fundamental, then for the third harmonic and finally for the fifth harmonic. The total current at any point in the circuit then is the sum of the three. The absolute value of the current will be given by the formula:

$$I = \sqrt{I_1^2 + I_2^2 + I_3^2 + \text{etc.}} \qquad (10A)$$

If I_1, I_2, etc. is given in root mean square value, I will be in r.m.s.

In a number of circuits where the resistance, capacitance and inductance do vary, it is usual for initial purposes to assume that they are constant. Corrections or limitations are then necessary to qualify the actual and apparent conditions.

The Reciprocity Theorem.

If any type of e.m.f. located at one point in a circuit network produces a current at any other point in the network, then the same e.m.f. located at the second point would produce the same current at the first point.

This theorem does not apply to vacuum tubes, rectifiers or devices where the circuit acts only in one direction. The theorem is helpful in filter, transmission line and general circuit design. If E is the voltage acting at point 1, and I the current produced at the second point, then E/I is referred to as the transfer impedance. In short it reduces a complex device or network to a simple impedance.

Thevenin's or Pollard's Theorem.

A very important principle which states: If an impedance Z is connected between any two points in a network, the resultant current I through the added impedance will be given by dividing the voltage E existing across the two points prior to connecting the impedance, divided by Z plus the impedance Z_1 that would be measured across the two points prior to the connection of the impedance. In calculating the impedance Z_1 the e.m.f.'s are considered inactive. Thevenin's theorem in equation form is:

$$I = \frac{E}{Z + Z_1} \qquad (11A)$$

Obviously the new voltage across the two points will be IZ, and thus the new terminal conditions are determined.

This theorem is quite valuable when some load is to be added to an existing circuit

* It should be remembered that X, Z, B, and Y, must be considered as vectors and so treated when adding. We refer you to any standard text on the fundamentals of electrical engineering.

and the new terminal conditions are to be determined quickly.

Compensation Theorem

An impedance in any circuit may be replaced by a generator (with no internal impedance) which at every instant duplicates the voltage that appears across the replaced impedance.

This principle is extremely useful in representing such devices as microphones and vacuum tubes or networks as equivalent generators.

For purposes of substitution the theorem as it is now to be stated has a more practical value. If a network is modified by changing one portion of it by a *change in impedance*, the effect in any other portion of the circuit would be the same as if the change were made by an e.m.f. acting in series with the modified impedance and equal to the *change in impedance* times *the current* through that impedance before the change was made.

Points of Equal Potential

It is convenient at times when considering complicated networks to consider points of equal potential as electrically connected by a wire of zero impedance. An example of this is the balanced wheatstone bridge.

Short Circuit Current Solution of Circuits

All the principles outlined so far are used in solving circuit problems. Quite often the process is lengthy and tedious. The short circuit current solution given now is at times a superior method. This method is particularly suitable in solving circuits where several generators feed a load or a passive network. The principle is stated as follows:

The voltage across the real load is equal to an equivalent load considering the load and the generator impedances in parallel multiplied by the sum of the short circuited currents of each generator, derived by considering the terminals of each generator (including its series impedance) shorted.

Example: Consider the simple circuit shown in Fig. 2A.

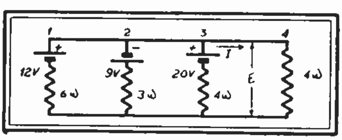


Fig. 2A

The equivalent resistance (we are dealing with pure resistances) is the sum of 6, 3, 4, and 4 ohms in parallel and equals:

$$\frac{1}{R} = \frac{1}{6} + \frac{1}{3} + \frac{1}{4} + \frac{1}{4} = \frac{2+4+3+3}{12}$$

Solving this by algebra, we get:

$$R = 1 \text{ ohm}$$

The short circuit currents of branches No 1, No. 2, and No. 3 are:

$$I_{s1} = \frac{+12}{6} = +2$$

$$I_{s2} = \frac{-9}{3} = -3$$

$$I_{s3} = \frac{+20}{4} = +5$$

The total short circuit current:

$$I_S = +2 -3 +5 = +4$$

Therefore according to the short circuit theory:

$$E = 4 \times 1 = 4 \text{ volts}$$

Current in the load:

$$I = 4/4 = 1 \text{ ampere}$$

With the information given so far we may compute the currents in each branch, knowing that the terminal voltage of each generator is 4 volts. For example, in branch No. 2.

$$I_2 = \frac{-9-4}{3} = -4\tfrac{1}{3} \text{ amp.}$$

(Current flowing down)

ADVANCED CONCEPTS

Note that examples were taken where resistors were the only circuit elements. The same principles hold true if impedances, Z were used. Also observe that in some of the theorems the impedance factor was used. The same principle will hold if resistances R are used.

In solving a problem where impedances are found, we should consider the impedance as made up of two components referred to as the real and imaginary components. To distinguish the imaginary from the real, it is prefixed by the letter j. Thus an impedance is always written:

$$Z = R + jX$$

Whereas an admittance is always written:

$$Y = G + jB$$

The absolute value of Z, always written $|Z|$, is given by the formula:

$$|Z| = \sqrt{R^2 + X^2}$$

Whereas the absolute value of Y is written:

$$|Y| = \sqrt{G^2 + B^2}$$

The manipulation of such values, called *vector* quantities require a knowledge of electrical engineering and advanced algebra. This is beyond the scope of this course. Students with a suitable training will find the subject treated in standard Electrical Engineering texts* and texts on Algebra.† Students interested in advanced radio engineering may consider this a subject for advanced study. In the following formulas only the absolute values, as read by a voltmeter or ammeter are to be considered.

* Communication Engineering by Everitt, published by McGraw-Hill Book Company, Chapters II and III

† Algebra for the Practical Man by Thompson, published by D. Van Nostrand Co., Chapter VIII.

B: RESISTORS

Resistance from Dimensions

$$R = \rho L/A \qquad (1B)$$

Where R is in ohms
L length
A the cross section area
ρ the resistance per unit length and cross section
If L is in feet, A in circular mils; ρ is the resistance in ohms for a wire one foot long and having a cross section of one circular mil. See special electrical tables: $\rho_{copper} = 10.4$; $\rho_{alum} = 17.1$; $\rho_{nichrome} = 600$; etc.

Conductance from Dimensions

$$G = \gamma A/L \qquad (2B)$$

Where A is the cross section area
L is the length
G is in mhos
γ is the conductivity

$$\gamma = 1/\rho \qquad (3B)$$

Resistance at a New Temperature (°C)

$$R_t = R_o (1 + \alpha t) \qquad (4B)$$

Where t is the new temperature degrees Centigrade
R_o is the resistance at 0° C
α is the temperature coefficient
R_t is the resistance (ohms at t° C)

Formula (4B) may be more conveniently used as:

$$R_{t2} = R_{t1} [1 + \alpha(t_2 - t_1)] \qquad (5B)$$

Where t_2 is the final temp.
t_1 is the initial temp.
R_{t2} the resistance at t_2
R_{t1} the resistance at t_1
α the temperature coefficient, for example: $\alpha_{copper} = .00393$; $\alpha_{alum} = .0039$; etc.

Temperature Rise in Electrical Conductors

$$\Delta t = \frac{1}{\alpha}\left(\frac{R_{t2}}{R_{t1}} - 1\right) \qquad (6B)$$

Wher Δt is the temperature rise

As copper wire is extensively used, the practical formula becomes:

$$\Delta t = 254 \left(\frac{R_{t2}}{R_{t1}} - 1\right) \qquad (7B)$$

Add Δt to t_1, the original temperature of the surroundings, to find temperature of the conductor.

Resistors in Series

$$R = R_1 + R_2 + R_3 + R_4 + \text{etc.} \qquad (8B)$$

Where R, R_1, etc., are in ohms
R_1, R_2, R_3, etc., are the series elements
R is the total resistance

When $R_1 = R_2 = R_3$, etc.:

$$R = nR_1 \qquad (9B)$$

Where R_1 is the resistance of one resistor
n is the number of resistors

Resistors in Parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \text{, etc.} \qquad (10B)$$

For three resistors in parallel:

$$R = \frac{R_1R_2R_3}{R_2R_3 + R_1R_3 + R_1R_2} \qquad (11B)$$

For two resistors in parallel:

$$R = \frac{R_1R_2}{R_1 + R_2} \qquad (12B)$$

For n resistors of equal value R_1 in parallel:

$$R = R_1/n \qquad (13B)$$

Conductance

$$G = \frac{1}{R} \qquad (14B)$$

Where R is in ohms
G is in mhos

Conductors in Parallel

$$G = G_1 + G_2 + G_3 + G_4 \text{, etc.} \qquad (15B)$$

Where G_1, G_2, etc., are the conductances of the devices

Equivalent Delta (π) of Star (T) or Vice-Versa

In reducing complex circuits to simple circuits, it is convenient in some cases to convert a delta (called in radio a π) circuit into a star (called in radio a *T*) circuit. The reverse may be the cases. See Fig. 1B for notation. If point *A* is grounded, point *B* with the ground is considered the input, while point *C* with the ground is considered the output, then the familiar π and *T* circuits in radio will be recognized.

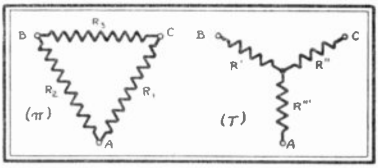


FIG. 1B

*To change a π to a T**

$$R' = \frac{R_2R_3}{R_1 + R_2 + R_3} \qquad (16B\text{-}1)$$

$$R'' = \frac{R_1R_3}{R_1 + R_2 + R_3} \qquad (16B\text{-}2)$$

$$R''' = \frac{R_1R_2}{R_1 + R_2 + R_3} \qquad (16B\text{-}3)$$

*To change a T to a π**

$$R_1 = \frac{R'R'' + R''R''' + R'R'''}{R'} \qquad (17B\text{-}1)$$

$$R_2 = \frac{R'R'' + R''R''' + R'R'''}{R''} \qquad (17B\text{-}2)$$

$$R_3 = \frac{R'R'' + R''R''' + R'R'''}{R'''} \qquad (17B\text{-}3)$$

Power Loss

$$P = I^2R \qquad (18B)$$

Where P is in watts
I is in amperes
R is in ohms

$$P = E^2/R \qquad (19B)$$

Where E is the voltage drop across R

$$P = EI \qquad (20B)$$

Where E is the voltage across
I the current through the load

* We may substitute Z for R if we deal with impedances.

C: CONDENSERS (STATIC)

Capacity from Dimensions

Two Plates

$$C = .225\,\frac{KA}{d} \qquad (1C)$$

Where C is in micro-microfarads, $\mu\mu f$
A is area in square inches of one plate meshing with the other
d is the plate separation in inches
K is the dielectric constant of the separating medium. $K_{air} = 1.0$; $K_{glass} = 8$ to 9; $K_{castor\ oil} = 13.0$

Several plates

$$C = .225\,\frac{KA}{d}\,(n - 1) \qquad (2C)$$

Where n is the number of plates
A is in square inches
d is in inches

$$C = .0885\,\frac{KA}{d}\,(n - 1) \qquad (3C)$$

Where A is in square centimeters
d is in centimeters

Plates to Remove for Desired Capacity

$$N_o = (N_1 - 1)\,\frac{C_o}{C_1} + 1 \qquad (4C)$$

Where N_o is the remaining number of plates
N_1 is the original number of plates
C_o is the desired capacity
C_1 is the original capacity

Capacity of Two Parallel Wires

$$C = \frac{3.68}{\log\left(\frac{2D}{d}\right)} \qquad (5C)$$

Where C is in micro-microfarads per foot
D is the separation of wires (center to center)
d is the diameter of the wire
d and D must be in the same units

Capacity of Round Wire Surrounded by a Round Tube

$$C = \frac{7.35K}{\log\left(\frac{r_o}{r_i}\right)} \qquad (6C)$$

Where C is micro-microfarads per foot
K is the dielectric constant of separating medium
$K_{air} = 1$. Assume $K = 1$ where beads are used only infrequently for spacers
r_i is the radius of the inner wire
r_o is the radius of the inner surface of the outer conductor
r_i and r_o are in the same units

Condensers in Parallel

General

$$C = C_1 + C_2 + C_3 + C_4 + \text{etc.} \qquad (7C)$$

Where C_1, C_2, C_3, etc. are in the same units, and represent the respective capacities of the condensers
C is the total capacity, same units as C_1, etc.

Equal Condensers in Parallel

$$C = nC_1 \qquad (8C)$$

Where C_1 is the capacity of one condenser
n is the number in parallel

Condensers in Series

General

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4} + \text{etc.} \qquad (9C)$$

Where C_1, C_2, etc. are the respective capacities of the condensers in series
C is the total capacity

Equal Condensers in Series

$$C = C_1/n \qquad (10C)$$

Where n is the number in series

Three Condensers in Series

$$C = \frac{C_1C_2C_3}{C_2C_3 + C_1C_3 + C_1C_2} \qquad (11C)$$

Where C_1, C_2, and C_3 are the capacities of the three condensers

Two Condensers in Series

$$C = \frac{C_1C_2}{C_1 + C_2} \qquad (12C)$$

Charge in a Condenser

$$Q = CE \qquad (13C)$$

Where C is in farads
E is in volts
Q is in coulombs

Energy Stored in a Condenser

$$W = 0.5\ CE^2 \qquad (14C)$$

Where C is in farads
E is in volts
W is in joules

Elastance of a Condenser

$$S = 1/C \qquad (15C)$$

Where C is in farads
S is in darafs

D: COILS (STATIC)

Inductance of Coils in Series.

$$L = L_1 + L_2 + L_3 + L_4 + \text{etc.} \qquad (1D)$$

Where L, L_1, etc. are in the same units; henries, millihenries, microhenries. No coupling between coils.

Inductance of Coils in Parallel (No Coupling)

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \text{etc.} \qquad (2D)$$

Inductance of Two Coils with Coupling

$$L = L_1 + L_2 \pm 2M \qquad (3D)$$

+ for aiding
− for opposing

Inductance of Single Layer Solenoids*

$$L = FdN^2 \qquad (4D\text{–}1)$$

Where L is in microhenries
N is the number of turns
d is the coil diameter in cms or inches
F the factor determined from curve Fig. 12, page 11

$$L = \frac{0.41\ a^2N^2}{9a + 10b} \qquad (4D\text{–}2)$$

Where a and b are as indicated in Fig 1D, and are in Centimeters, Multiply inches by 2.54 to get Centimeters.

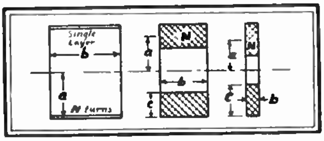


Fig. 1D

* All inductance formulas are approximations and in radio work should be checked by measurements and turn adjustments made.

Inductance of Multilayer Round Coils

See Fig. 1D. Applies to honeycomb, smooth layer and jumbled layer windings. When the width b is greater than the radius a:

$$L = \frac{.314a^2\ N^2}{6a + 9b + 10c} \qquad (5D)$$

Where L is in microhenries
a, b, c dimensions are in centimeters
When dimensions are in inches, multiply answer by 2.54 to get L in μh.

For a pancake coil where b is much less than c (applies strictly to a coil in which the b dimension is one layer wide):

$$L = \frac{.41a^2\ N^2}{8a + 11c} \qquad (6D)$$

Where L is in microhenries
dimensions in centimeters

For a square cross section coil $b = c$ and $a = 3/2\ c$ (diameter of core equals $2c$):

$$L = .064\ CN^2 \qquad (7D)$$

Where L is in μh
C is width and height in inches
N is the number of turns

Mutual Inductance of Coaxial Solenoids

The following formula is only approxi-

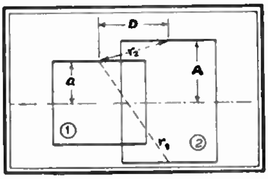


Fig. 2D

mate. Follow the given procedure. First find the value of r_1 and r_2 by the formulas:

$$r_2 = \sqrt{\left(1 - \frac{a}{A}\right)^2 + \frac{D^2}{A^2}} \qquad \text{(8D-1)}$$

$$r_1 = \sqrt{\left(1 + \frac{a}{A}\right)^2 + \frac{D^2}{A^2}} \qquad \text{(8D-2)}$$

Then find the ratio of $\frac{r_2}{r_1} = K$

Find N from the following graph, corresponding to K:

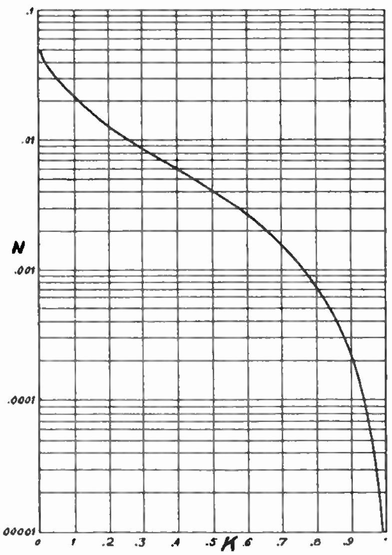


FIG. 3D

Compute the value of M_o from the formula:

$$M_o = N\sqrt{A \times a} \qquad \text{(8D-3)}$$

Where N is obtained from Fig. 3D
A and a from Fig. 2D (in cms.)

And finally by substituting M_o in:

$$M = n_1 n_2 M_o \qquad \text{(8D-4)}$$

Where M is in microhenries
n_1 is the turns in coil 1
n_2 is the turns in coil 2

The process holds true for single layer coils whose length is equal to the diameter. The method is close enough for other coils. r_1 and r_2 are measured to the centers of the wound layers.

Distributed Capacity Single Layer Coils

$$C_o = .6r \qquad \text{(9D-1)}$$

Where C_o is in $\mu\mu f$.
r is the coil radius in cms.

$$C_o = .76D \qquad \text{(9D-2)}$$

Where C_o is in $\mu\mu f$.
D is the coil diameter in inches

Chokes

C_o and the coil inductance L form an anti-resonant circuit at $\omega = 1/\sqrt{LC_o}$, where $\omega = 2\pi f_o$. Choke is inductive 0 to f_o, $2f_o$ to $3f_o$, $4f_o$ to $5f_o$, $6f_o$ to $7f_o$, etc. Choke is capacitive f_o to $2f_o$, $3f_o$ to $4f_o$, $5f_o$ to $6f_o$, etc. Maximum impedance at f_o, $3f_o$, $5f_o$, etc., and zero impedance at $2f_o$, $4f_o$, $6f_o$, etc.

Inductance of Two Parallel Wires

$$L = .281 \log \frac{2D}{d} + .030 \qquad \text{(10D)}$$

Where L is μh per foot of the transmission line formed by the 2 wires
D is center to center separation of wires
d is the diameter of the wire

Inductance of a Round Wire Surrounded By a Round Tube

$$L = .140 \log \frac{r_o}{r} + .015 \qquad \text{(11D)}$$

Where L is μh per foot of transmission line formed
r_o is radius of inner surface of outer tube
r_i is radius of inner wire

Suggestions in Coil Design

When dimensions of a coil are given, the inductance calculation requires simple substitutions in the proper formula. When a definite inductance or mutual inductance is desired and the dimensions are to be found, the following procedure may be used. Find the proper formula. If certain dimensions are fixed by practical needs, they should be substituted into the formula. Assume various values for the other dimensions and calculate the inductance. Remember that inductance roughly increases as the square of the turns, square of the diameter and inversely as the length. By these facts you may approximate a better value, and thus approach values that give the desired L.

To find the length of a coil assume a wire size and insulation covering and from a wire table find the number of turns per inch. For a single layer coil the number of turns divided by the turns per inch give the coil length. For a multilayer coil this should be divided by the number of layers.

Coils with Iron Cores

$$L = 1.26\, N^2 P \times 10^{-8} \qquad (12D)$$

Where L is in henries
N is the turns
P is the permeance of the iron circuit, and is defined by the expression $\mu \frac{A}{l}$; μ being the permeability, A the cross-section, and l the length of the core, all dimensions in centimeters 10^{-8} = .00000001

For radio and audio frequency chokes with a polarizing D.C. current, P should be the A.C. permeance, for the frequency employed.

Energy Stored in a Coil

$$W = 0.5 L\, I^2 \qquad (13D)$$

Where W is in joules
L is in henries
I is in amperes

E: CIRCUITS HAVING ONLY RESISTANCES*

Ohm's Law

$$E = IR \qquad (1E\text{–}1)$$

$$I = E/R \qquad (1E\text{–}2)$$

$$R = E/I \qquad (1E\text{–}3)$$

Where E is in volts
I is in amperes
R is in ohms

Generator with Resistance

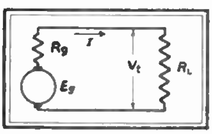


FIG. 1E

$$V_t = E_g - I\, R_g \qquad (2E\text{–}1)$$

$$E_g = I\,(R_g + R_L) \qquad (2E\text{–}2)$$

$$I = \frac{E_g}{R_g + R_L} \qquad (2E\text{–}3)$$

Where E_g is the no load or generated voltage
V_t the terminal voltage
I the line current
R_g the generator resistance in ohms
R_L the load resistance in ohms

E_g may be a generator; a battery or a vacuum tube, microphone or similar device which may by the compensation theorem be assumed as a generator.

Power Generated

$$P = E_g I \qquad (3E)$$

Where P is in watts
E is in volts
I is in amperes

* The formulas in this section apply to any A.C. or D.C. circuit with a resistance load. For A.C. circuits the r.m.s. values are considered.

Power Delivered

$$P = V_t I \qquad (4E)$$
$$P = I E_g - I^2 R_g$$

Efficiency of Circuit

$$Eff. = V_t / E_g \qquad (5E\text{–}1)$$

$$= \frac{R_L}{R_L + R_g} \qquad (5E\text{–}2)$$

To find $Eff.$ in percent multiply by 100.

Maximum Power

Obtained when:

$$R_g = R_L \qquad (6E)$$

Voltage Generated by a D.C. Motor with Shunt Field

$$E_g = K\, I_f\, S \qquad (7E)$$

Where E_g is the average generated voltage
I_f the field current
S the speed in revolutions per minute
K is a constant for a given motor determined by setting I_f, S and measuring E_g, the no load voltage $K = E_g / I_f S$. Formula holds good for values of I_f which do not produce magnetic core saturation.

Power Loss in a Resistance

$$P = I^2 R \qquad (8E\text{–}1)$$

$$P = VI \qquad (8E\text{–}2)$$

$$P = V^2/R \qquad (8E\text{–}3)$$

Where P is in watts
R is the resistor value in ohms
V is the voltage across the resistor
I is the current through the resistor

F: A.C. CIRCUITS WITH IMPEDANCE

Fundamental Concepts

Sine Waves

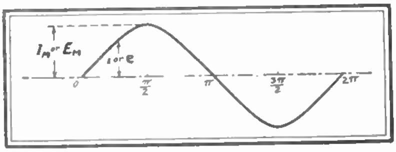


FIG. 1F

$$= I_M \sin \omega t \qquad (1F)$$

$$e = E_M \sin \omega t \qquad (2F)$$

Where i and e are the instantaneous values
I_M and E_M are the maximum or peak values
t is time in seconds
ω is the angular velocity and equals

$$\omega = 2\pi f \qquad (3F)$$

Where f is the frequency in cycles per second

Average Value

$$I_{AV} = .636\, I_M \qquad (4F\text{–}1)$$

$$E_{AV} = .636\, E_M \qquad (4F\text{–}2)$$

Root Mean Square Value

$$I_{R.M.S.} = .707 I_M \qquad (5F\text{–}1)$$

$$E_{R.M.S.} = .707 E_M \qquad (5F\text{–}2)$$

Phase Angle

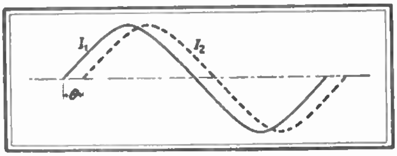


FIG. 2F

I_1 is the reference wave

I_2 lags I_1 by the angle θ.

Formulas indicating leading or lagging phase angles follow:

$i_2 = I_2 \sin(\omega t + \theta)$ for leading wave (6F–1)

$i_2 = I_2 \sin(\omega t - \theta)$ for lagging wave (6F–2)

To Change Degrees to Radian Angles

θ is usually expressed in degrees. When substituting in the sine formula it must be in radian angles.

$$\theta_r = \frac{\pi\, \theta_d}{180} \qquad (7F)$$

Where θ_r is the radian angles
θ_d is the angle in degrees

Representing Lagging and Leading Components

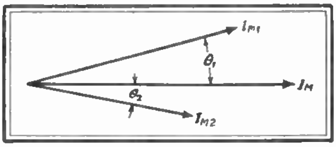


FIG. 3F

$$= I_M \sin \omega t \qquad (8F\text{–}1)$$

$$i_1 = I_{M1} \sin(\omega t + \theta_1) \qquad (8F\text{–}2)$$

$$i_2 = I_{M2} \sin(\omega t - \theta_2) \qquad (8F\text{–}3)$$

Power Factor

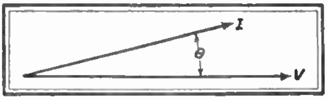


FIG. 4F

$$p.f. = \cos \theta \qquad (9F)$$

Power

$$P = VI \cos \theta \qquad (10F)$$

$$= VI \times p.f.$$

Where P is in watts
V voltage across device (rms value)
I current through device (rms value)

Reactance

$$X_L = 2\pi f L \qquad (11F\text{–}1)$$

Where X_L is reactance of coil in ohms
L is the inductance of coil in henries
f is the frequency of the current

$$X_c = 1/2\pi f C \qquad (11F\text{–}2)$$

Where C is the capacity of condenser in farads
X_c is the reactance in ohms

Condenser, Coil and Resistor in Series

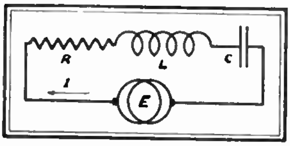


FIG. 5F

R, L and C in Series

$$Z = \sqrt{R^2 + (X_L - X_c)^2} \qquad (12F\text{-}1)$$

$$= \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$$

R and L in Series

$$Z = \sqrt{R^2 + X_L^2} \qquad (12F\text{-}2)$$

$$= \sqrt{R^2 + (2\pi fL)^2}$$

R and C in Series

$$Z = \sqrt{R^2 + X_c^2} \qquad (12F\text{-}3)$$

$$= \sqrt{R^2 + \left(\frac{1}{2\pi fC}\right)^2}$$

L and C in Series

$$Z = X_L - X_C \qquad (12F\text{-}4)$$

$$= 2\pi fL - \frac{1}{2\pi fC}$$

Current in Series Circuit

$$I = E/Z \qquad (13F\text{-}1)$$

Where Z is determined from (12F-1) to (12F-4)

Power Factor

$$p.f. = \frac{R}{Z} \qquad (13F\text{-}2)$$

Maximum Current I_o in Series Circuit

when $$2\pi fL = \frac{1}{2\pi fC} \qquad (14F\text{-}1)$$

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad (14F\text{-}2)$$

$$C = \frac{1}{4\pi^2 f^2 L} \qquad (14F\text{-}3)$$

$$L = \frac{1}{4\pi^2 f^2 C} \qquad (14F\text{-}4)$$

Where L is in henries
C is in farads
f is in c. p. s.

These are referred to as the necessary conditions for resonance and the current at resonance is given by the formula:

$$I_o = E/R \qquad (14F\text{-}5)$$

The current is in phase with the applied voltage. Theoretically with no resistance in the circuit the current is infinite.

Voltage Across Each Element of a Series Circuit

$$V_R = IR \qquad (15F\text{-}1)$$

$$V_L = 2\pi fLI \qquad (15F\text{-}2)$$

$$V_C = I/2\pi fC \qquad (15F\text{-}3)$$

Where I is computed from 13F-1

Coil and Condenser in Parallel Each with or without Resistance

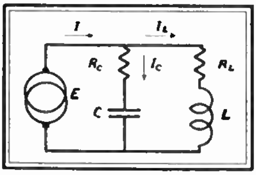


FIG. 6F

With R_c and R_L

$$I_c = E\Big/\sqrt{R_c^2 + \left(\frac{1}{\omega C}\right)^2} \qquad (16F\text{-}1)$$

$$I_L = E/\sqrt{R_L^2 + \omega^2 L^2} \qquad (16F\text{-}2)$$

If R_c can be neglected:

$$I = \frac{E}{\left(\dfrac{X_c\sqrt{R_L^2 + X_L^2}}{\sqrt{R_L^2 + (X_L - X_c)^2}}\right)} \qquad (16F\text{-}3)$$

If R_L is small compared to X_L:

$$I = \frac{E}{\dfrac{L}{C} \times \dfrac{1}{\sqrt{R_L^2 + (X_L - X_c)^2}}} \qquad (16F\text{-}4)$$

When $X_L = X_c$, resonance:

$$I = \frac{E}{L/R_L C} \qquad (16F\text{-}5)$$

The factor $L/R_L C$ is the apparent impedance of a parallel resonant circuit, and is purely resistive; i.e., the current I is in phase with the voltage E.

Practical Resonance Formulas

The general formula for the frequency at which resonance occurs in either series or parallel circuits is:

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad (17F\text{-}1)$$

This formula is based on negligible circuit resistance, a condition safely assumed in practical radio circuits, and:

Where in 17F-1 f is in c. p. s.
L is in henries
C is in farads
R is in ohms

$$f = \frac{159.2}{\sqrt{LC}} \qquad (17F\text{-}2)$$

$$L = \frac{25{,}330}{f^2C} \qquad (17F\text{-}3)$$

$$C = \frac{25{,}330}{f^2L} \qquad (17F\text{-}4)$$

Where in 17F-2 to 17F-4
f is in kilocycles
L is in microhenries
C is in microfarads

Q Factor or Circuit Q

Quite often in discussing a series or parallel *resonant circuit*, the term Q is found. Since in practical series and parallel resonance circuits the circuit resistance is inherent in the coil, the merit of a coil is expressed by its Q factor.

$$Q = \omega L/R \qquad (18F\text{-}1)$$

$$Q = 1/\omega CR \qquad (18F\text{-}2)$$

Where L is in henries
R is in ohms
Q is a figure of merit
C is in farads

When R includes all circuit losses and the load, the Q factor is better termed Circuit Q. The Q factor represents essentially the voltage amplification in a coil by virtue of its series resonance or the impedance amplification in a coil by virtue of its parallel resonance.

G: COUPLED CIRCUITS

Basic Formulas

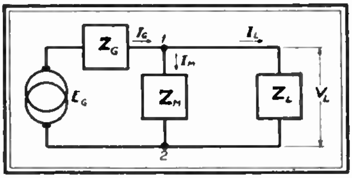


FIG. 1G

Given a general circuit with the coupling impedance Z_M, feeding a load whose impedance is Z_L. The generator has an impedance Z_G and generates a voltage E_G. In general coupled circuits and tube coupling, of primary importance, is the voltage across the load (V_L). For purposes of simple handling of the circuit, the equivalent impedance of Z_M and Z_L in parallel as viewed from the generator (terminals 1 and 2) is helpful This is termed the primary equivalent impedance of the coupling device.

Impedance Reflected Into the Primary

$$Z_{12} = \frac{Z_M Z_L}{Z_M + Z_L} \qquad (1G\text{-}1)$$

Where Z_{12} is the impedance of Z_M and Z_L between terminals 1 and 2

Primary Current

$$I_G = \frac{E_G\,(Z_M + Z_L)}{Z_G Z_M + Z_G Z_L + Z_M Z_L} \qquad (1G\text{-}2)$$

Coupling Current

$$I_M = \frac{E_G\,Z_L}{Z_G Z_M + Z_G Z_L + Z_M Z_L} \qquad (1G\text{-}3)$$

Secondary or Load Current

$$I_L = \frac{E_G\,Z_M}{Z_G Z_M + Z_G Z_L + Z_M Z_L} \qquad (1G\text{-}4)$$

Load Voltage

$$V_L = \frac{E_G Z_M Z_L}{Z_G Z_M + Z_G Z_L + Z_M Z_L} \qquad (1G\text{-}5)$$

It is to be remembered that any impedance Z may be a device having a real and imaginary component ($Z = R + jX$). Or it may be a resistor or a reactance. Transformer coupling or network coupling may be reduced to an equivalent Z_M. Experts with the above basic formulas have derived formulas for practical circuits.* We shall consider only those that are regarded as most important.

Transformer Coupled

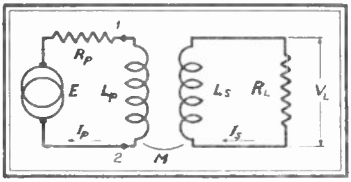


Fig. 2G

$$R_{12} = \frac{\omega^2 M^2}{R_L} \quad (2G\text{–}1)$$

$$I_P = \frac{E}{R_P + \dfrac{\omega^2 M^2}{R_L}} \quad (2G\text{–}2)$$

$$= \frac{E\,R_L}{R_P R_L + \omega^2 M^2}$$

Where, see Fig. 2G, L_P is small in comparison to L_S or unity coupling exists

Induced Secondary Voltage

$$E_S = \omega\, M\, I_P \quad (2G\text{–}3)$$

$$I_S = E_S / R_L \quad (2G\text{–}4)$$

$$= \frac{\omega\, M\, E}{R_P R_L + \omega^2 M^2}$$

$$V_L = I_S R_L \quad (2G\text{–}5)$$

$$= \frac{\omega\, M\, R_L E}{R_P R_L + \omega^2 M^2}$$

When the coefficient of coupling K is known:

$$M = K\sqrt{L_P L_S} \quad (2G\text{–}6)$$

When K is equal to 1 (unity)

$$M = \sqrt{L_P L_S} \quad (2G\text{–}7)$$

Ideal Transformer Coupled (K = 1)

ωL_P and ωL_S are very large in comparison to R_P or R_L. See Fig. 3G. Transformers may be considered on the basis of turn ratio.

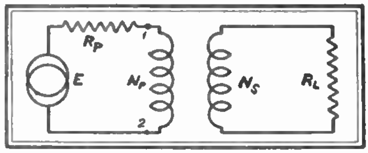


Fig. 3G

$$T_R = \frac{N_S}{N_P} = \frac{\text{Sec. Turns}}{\text{Pri. Turns}} \quad (3G\text{–}1)$$

Secondary Resistance R_L reflected into primary:

$$R_{12} = R_L / T_R^2 \quad (3G\text{–}2)$$

$$= R_L \left(\frac{N_P}{N_S}\right)^2 \quad (3G\text{–}3)$$

To match reflected R_L to R_P—condition for maximum power transfer when:

$$T_R = \sqrt{\frac{R_L}{R_P}} = \frac{N_S}{N_P} \quad (4G)$$

Reflected Impedance—Tuned Secondary

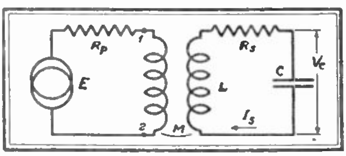


Fig. 4G

Case when C is tuned so I_S is a maximum.

Reflected Secondary Load into Primary is:

$$R_{12} = \frac{\omega^2 M^2}{R_S} \quad (5G\text{–}1)$$

Output Voltage

$$V_c = \frac{ME}{C} \times \frac{1}{R_P R_S + \omega^2 M^2} \quad (5G\text{–}2)$$

$$= \frac{\omega^2 M L E}{R_P R_S + \omega^2 M^2}$$

Maximum V_c when (optimum condition):

$$\omega M = \sqrt{R_P R_S} \quad (5G\text{–}3)$$

* For a more complete treatment of circuits containing L, C, R, and M refer to Henney's Radio Engineering Handbook, published by McGraw-Hill Book Co., New York City.

IT'S THE RUN THAT COUNTS

In baseball, the hero of the game is the man who scores. There are plenty of others who "almost" hit a home run—who "almost" scored—but these are forgotten men, as "almost" does not count.

First base—second base—third base—these are only stopping places on the road to a score. The world is full of stopping places, all guarded by other players equally bent upon winning. In the game of life, you must remember it is the run that counts—not the men "left on bases."

It's the fellow who knows *all* the rules—who is well trained and is prepared to take advantage of every opportunity who gets ahead. Don't be "left on base." Seize every opportunity to move forward—give the game everything that you have. Remember, no man can be stopped always—the fellow who keeps going is sure to win.

J. E. Smith

HOW TO MAKE EXTRA MONEY

FIXING RADIO AND TV SETS

NO. 12

HOW TO GO INTO FULL-TIME SERVICING

SPARE-TIME MONEY-MAKING AIDS

PIONEER HOME STUDY RADIO-TV SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

TABLE OF CONTENTS

FM5M658 1958 Edition Printed in U.S.A.

IN this series of "Spare-Time Money-Making Aids", you have learned how to test parts, how to check receivers for specific complaints, how to use tools and test equipment, and how to go into spare-time servicing. If you have studied those books carefully, used the hints given you, and followed the NRI Practical Training Plan faithfully, you are well on the way toward becoming a professional radio and TV serviceman.

Of course, you have not learned all there is to know about being a professional technician. In the field of electronics, so many new things are being developed every day that you will never be able to sit back and say, "I know it all". Always be on the alert to learn new things. As one professional serviceman said, "I learn something new every day, and I have been doing it for thirty years."

Your regular lessons from now on will give you more information on advanced servicing techniques that make the NRI-trained man stand out. You need this advanced training, and the sureness of action that comes only with experience before you can consider yourself a master of your profession. We want you to develop self-confidence, but never over-confidence. Always remember the little motto we gave you in an earlier book: Open Eyes, Open Ears, and an Open Mind!

You may not wish to go into full-time service work right now—indeed it would be best to finish your course before you take such a step. But by this time you should know enough about the profession to be able to devote some really constructive thought to this. This is the final book of this series. In this book we will discuss the problems of operating a full-time service shop. Of course, much of this information also applies to the spare-time service business.

Photo above, courtesy Howard W. Sams & Co., Inc.

THE SUCCESSFUL TECHNICIAN

The most successful technician is the kind of man who cannot bear to see a piece of machinery out of order. If you are the type who likes to fix things, who has curiosity about how any new piece of machinery works, and who is handy with tools, then you are well on the way. This type of man invariably makes good in any kind of repair work. It is his nature to make things work again. He likes the work, and that is one of the most important points. To be successful in any kind of work, you must enjoy doing it.

By progressing this far in your course, you have already shown yourself suited for work in electronics.

There are a great many NRI graduates who now operate their own full-time servicing business. Others have kept their servicing on a part-time basis. Some work at other jobs during the day and do service work at odd hours to supplement their regular income. Some look on servicing as a hobby, and use it mainly for relaxation. Some live in very small communities that will not support a full-time service business. There are many reasons why a man sufficiently competent to make a full-time career of servicing prefers not to do so.

Whether you should be a full-time or a part-time serviceman is something that you, and only you, can decide. We are not going to attempt to persuade you either way. Instead, we will give you practical advice, based on the long experience we have had in teaching many thousands of servicemen. This background will help you to make your decisions.

What factors should you consider before making up your mind? The most important are your own feelings. Another very important thing to consider is, "Do you have enough technical ability to be successful in full-time work?" Frankly, for most of you, we'd be compelled to say "No" at this time. Don't let this discourage you. When you graduate, you will have all the technical knowledge you need. Even so, electronics is a business in which you must constantly study to keep up with rapidly changing inventions and new developments. You will find that every successful full-time technician never stops studying; first, because he likes it, and second, to keep himself informed and up-to-date.

If you are attempting to do any service work now, you will find yourself stuck quite often. Every technician finds this, no matter how long he has been in the business. Of course, this is generally only momentary. With experience your "stuck" periods will get shorter and shorter.

FINANCIAL CONSIDERATIONS

Although interest and professional servicing ability are important, they alone are not sufficient reasons for choosing a full-time servicing career. You must also be sure that you can make an adequate living from servicing. Therefore, before going into it on a full-time basis, you will have to make a careful survey of the possibilities for financial success in your locality.

If you have been doing part-time service work, (and you should be, just for the sake of experience), you probably have a good idea of just how much servicing business there is. Do you now have all the business that you can handle on a part-time basis? If so, that is a pretty good indication that there is enough demand for your services to make full-time work profitable. Of course, this is true only if you are turning out sets right now with true professional speed. If you can handle almost any job in an hour or less, and still find work piling up on you, then you are probably getting enough work to justify full-time operation. If it takes you more than two or three hours to service a set, however, then you haven't too good an idea just how much work you can handle when you have greater experience.

If you don't have very much work, but haven't ever tried to get any, make a real effort for a few weeks to drum up business. By doing this now you can estimate future business pretty closely. Also, it will give you valuable experience in getting business.

Estimate your probable future volume of business just as closely as you can. If there is any doubt, be pessimistic. Take every possible factor into account. How large is the town? Is the general level of business activity brisk or slow? How many other shops are there, and how much business are they doing? Are they swamped with work at all times, or are they barely making a living? Incidentally, if some shops are doing good business, and others very little, find out why the latter are not getting the business, and make a careful note.

Talk with your local banker; he will be able to tell you about the chances for business expansion in your locality. Also, talk with the radio wholesaler in your area. He can give you an idea how the other shops are doing, and what your chances are.

Analyze your chances for financial success as realistically as possible. If it seems unlikely that you can make the income you want under existing conditions, it would be better to give up the idea of a full-time shop in that locality. You will be better off to continue with your part-time work or to open a shop in some other location where the chances for success are brighter.

Now suppose that you have the necessary interest in service work, you have completed your training, and there is enough potential business to give you the income you want. Is there anything else you should consider? Yes. Money!

You must be sure that you have sufficient capital to carry you *and your business* until the shop starts making its own way. It is sometimes possible to start a business on a shoestring but most of the time it is not advisable. This is especially true in electronics, because a comparatively large investment is necessary for test equipment, parts, tools, transportation, etc. More new businesses fail for lack of capital than for any other reason. For this reason, we recommend the conservative approach; try yourself out in part-time work until you are pretty sure you can make a success of full-time operation.

There is another reason too. By working part-time, you can make enough to buy the necessary test equipment and tools, thus relieving your budget of one of the biggest items when you start full-time work.

You must use a realistic approach to this problem. Take time enough to study the situation thoroughly. Find out as closely as possible just how much it will cost you to open the shop; how much test equipment you will need; how many parts and tubes you should have; what kind of transportation you will need; what rent and utilities will cost; and everything else necessary for operation of a full-time service shop.

Up to this point, what we have been saying can be summed up in four questions:

1. Do you really want to be a full-time serviceman?
2. Are you technically ready for full-time work?
3. Is there enough business in your locality?
4. Do you have enough capital to start?

When you can answer an unqualified "Yes" to all of these questions you are ready to start a full-time service shop of your own.

Establishing the Shop

Let us go over some of the problems involved in opening and operating your own shop. Some of these were taken up in an earlier SMA Book on running a spare-time service business. It would be a good idea to review that book, now.

LEGAL CONSIDERATIONS

One thing that you must check up on before you start a business is the legal aspects. There are many complications to this, and probably the best thing to do is to consult a local lawyer or your banker.

Many communities impose an "occupation tax" on each business, which is a fee charged the merchant for the privilege of doing business in the community. In other places, zoning restrictions limit the type of business that may be operated in certain areas. For instance, if you were planning to operate your shop in a garage or small shop-building at your home, as many servicemen do, you might run up against a law prohibiting such enterprises in a residential district. This is not common in smaller communities, only in cities, but it would be wise to check beforehand. Consult some of the city officials such as the city clerk, or the chief of police, regarding the laws and restrictions.

In many states there is a sales tax on all retail transactions. Find out before you start just what law your own state has on this subject, so that you will not be subject to a penalty for neglecting it. In those states that have a sales tax, you will be required to make a tax return, usually once a month, showing your total sales of parts and labor, and paying a tax of a certain percentage on the parts. This can be quite easy, if you set up your bookkeeping system correctly. When you make up your monthly totals, you can simply transfer them to the tax form. This is supposed to be paid entirely by the customer, although many servicemen forget to add it to their bills. This is not a wise financial practice, as the total of a few cents here and there can add up to a very sizeable figure over a month's time!

Other tax laws apply to you, too. You must pay Federal income tax, and Social Security, both on yourself and on any employees, even those who work part-time. Salary deductions are necessary, with regular payments to the government bureau involved. Talk with your local banker. He can give you information about the tax laws as they affect you, or tell you how to get the information. Another good source of information is your local income tax office.

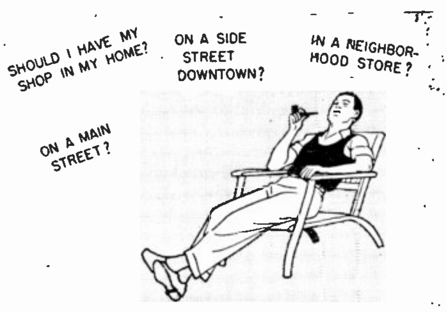
While we're discussing laws, taxes, etc., let us give you this one word of caution: Never take the advice of "coffee-shop experts" on any legal or tax matters. Unless the man who gives you the advice is a banker, a lawyer, or a tax man, his advice may not be worth much! There are always places where you can get help in these matters, especially on the tax laws, entirely free. If you have any doubt, go to the tax office concerned, and ask one of the experts there. They are there to answer your questions.

You might think that it's a little odd for us to be speaking of laws, taxes, etc., at the very beginning of this discussion of running what will be, for a while at least, a very small business, but we do so deliberately. Today, all businesses are regulated by laws, rules, and regulations as to taxes of various kinds, and there is no legitimate way of avoiding them. The beginning businessman must accustom himself to them, and take every precaution to see that he does not violate any of the laws. Remember, ignorance of the law is no excuse!

SELECTING THE LOCATION

Now, let's get on with establishing the shop. First comes the matter of selecting a location. This depends upon two things: the type of business to be done, and the expense.

By the type of business, we mean whether you are going to run a shop strictly for repair and service of electronic appliances, or whether you are going to attempt to sell radios, TV sets, and small appliances. If you plan to do only repair work, then the choice of a location is much simpler, and a lot less expensive. If you want to sell merchandise, you should consider getting a location as close to the business district as possible. There, you will have the "store traffic" needed so that potential customers will see your merchandise. This also means a higher rent.



Selecting the location for your shop is an important step. Give the matter careful consideration.

The straight repair shop, on the other hand, can be almost anywhere, as far as business is concerned, and the most economical location is the best. You are in the same class as a doctor, a garageman, or any other emergency service. The customer does not want you at all until some of his equipment breaks down, and then he will hunt you up. You don't have to be where he can see you all the time. Public attention is taken care of by your advertising, which should make your name and firm familiar enough to him so that he will think of you when he is in trouble.

Many servicemen have converted rooms in their homes into a shop, especially in the beginning; later on, they either build a small shop in the yard, or move to a separate shop-building, on the edge of the business district.

A separate garage or even a shed can be made into an ideal service shop. This offers some advantages over a room in the home itself. People might think that a serviceman operating from a room in a home is only a "tinkerer", and take their work to a man with a separate shop. This makes the separate building more advantageous, especially if it can be dressed up a little to give it a professional appearance.

Parking space is another factor that should be considered. In this respect a more remote location is better. You will be away from the congested traffic of the downtown areas, and the potential customer can always find a place to park his car. If you are going to do auto-radio work, this is essential.

SHOP DESIGN

The subject of work benches, storage space, and lighting has been discussed in the earlier book. Refer to that book in planning such items for your permanent full-time shop. Also, examine the pictures of shops you see in radio magazines; you may pick up some useful ideas.

If space permits, build a small counter to divide the "working area" of the shop from the "customer area". This will tend to discourage customers from hanging over you while you are working, which can be very annoying at times. The counter is also very handy for keeping books, small displays, etc., and for temporary storage of repaired small sets.

The front of the shop building is also important. It need not be elaborate, nor even have any display windows. If your building does have display windows, be sure to keep appealing display material in them at all times. Nothing detracts as much from the appearance of a shop as old, faded displays. Better to have nothing at all than to have obsolete, dirty displays. Tube manufacturers, and other manufacturers, will be glad to furnish you with all of the display material that you could possibly use, usually free. See your local parts distributors.

You should have a sign to identify the building as your shop. Tube manufacturers make these and sell them to servicemen at very low cost. See your distributor. The sign will have the tube manufacturer's name on it, too, but yours will be the most prominent. Decals are also available, and are probably the simplest, and by far the cheapest, form of identification. You can apply several of these, and put your own name on a small, neatly-lettered card, inside the window, and get by for practically nothing,

The business part of a service shop should be neat and clean, and conveniently arranged.

to begin with! These decals can also be used on your car, truck, or whatever vehicle you use for your service calls, and can save you quite a bit on signs there, too.

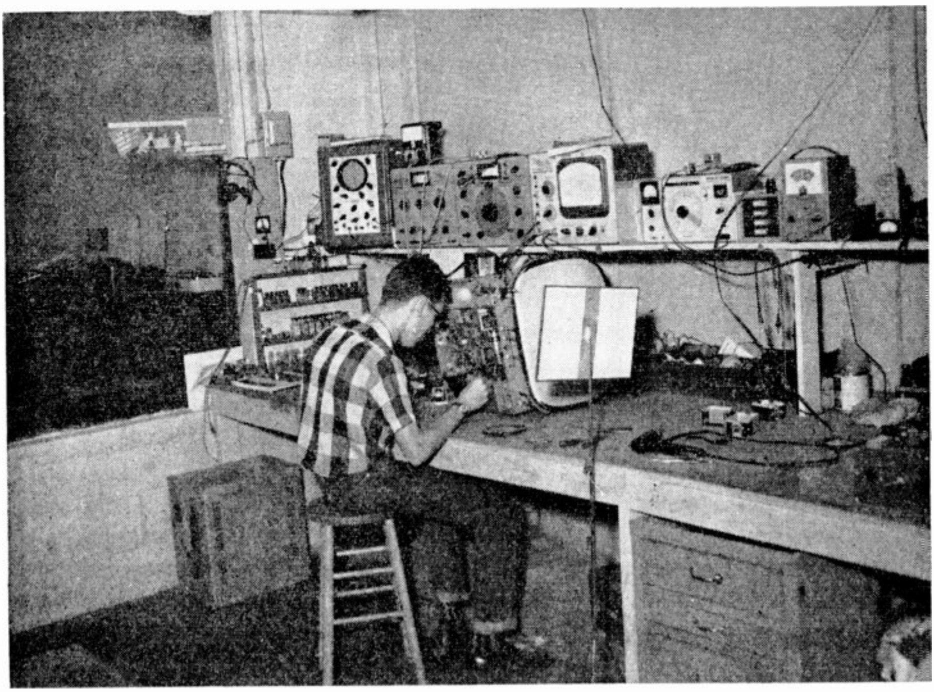
The last, and possibly the most important item about the shop building itself is *neatness.* No matter what kind of building you choose, be sure that it is neat and clean. This is a continuing requirement throughout your career as a serviceman. The favorable impression made on the customer is worth the small amount of time needed to keep the place tidy. Of course, some clutter is inevitable in a service shop. If you have tools scattered over the bench while working, that is one thing; if there is dust and dirt piled up in the corners, that is another! If you can, get some kind of floor covering—linoleum or tile—for the working area, and see that it is swept daily, and mopped when necessary.

There is a good reason for this. When the customer enters a clean shop, he will get the impression that it belongs to a careful workman, who can be trusted to take good care of his precious TV or radio set. If the shop is sloppy and dirty, he is apt to think that the technician's work will be, too. We stress this point, because of its importance, and because of the natural inclination of many electronics technicians to become so absorbed in the fascinating work they are doing that they neglect their housekeeping chores. One of the best ways to find out, by the way, is to ask your wife or mother what she thinks about the condition of your shop. You *may* even get her to drop in once or twice a week and help clean it up.

This principle also applies to your personal habits and dress. If the customer comes into a neat shop, and sees a man needing a haircut and shave, dressed in dirty, greasy khakis, the first impression will still be bad. Although radio-TV work, because of the dust and dirt which is inevitably found inside the cabinets of sets, is much dirtier than most people realize, still, the working technician can keep reasonably clean. Cleaning and dusting sets before beginning work on them will help a great deal, and keeping benches and stools clean will help still more. Even plain khakis, if they are neatly pressed and clean, will make a good impression on the prospective customer. Regular service uniforms are available from some tube and set manufacturers through their distributors. Often the cost is less than comparable garments in local stores. These are complete, even to peaked caps, and are very neat service uniforms.

Showmanship. There are several places in and around the service shop where you can make good use of the basic principles of showmanship. By this, we mean that any parts of the shop that are either visible or accessible to the public, your customers, should be set up in such a way as to impress them.

You have seen shops with large amounts of test equipment, scattered haphazardly here and there, piled on the floor, shoved back on the bench, etc., which made a very poor impres-



A typical workbench.

sion on you. On the other hand, you have seen shops with less equipment, but with that neatly arranged on a shelf, with hand tools kept in drawers, and everything neat and clean, that made a much better impression on you. That is the practical application of "showmanship".

Actually, the condition of the shop, as far as display of the equipment goes, has very little to do with its efficiency, but the appearance of the shop has a great deal to do with what the customers think of it! Test equipment neatly arranged, with test leads hanging up out of the way, tools in the proper places, etc., give the customer an impression that the man who runs *this* place must be a good workman.

Therefore, when setting up your own shop, take these factors into consideration; take the time necessary to work out an arrangement for your test equipment that will give both efficiency *and* a neat appearance. In almost all cases, this will go together, by the way; the neatest arrangement of a shelf will also be the handiest to work with.

PERMANENT EQUIPMENT

By "permanent" equipment we mean the equipment which might be considered part of the shop itself. This is different from the best equipment, which will grow obsolete in time and have to be replaced.

One of the first things you will have to have if you're going to do TV work is a good outside antenna to receive a good signal from the nearest TV station or stations.

It is generally considered wise to set up your shop antenna to receive all stations in your area, rather than just the strongest one. Some of your customers might be able to get only one certain station, and the set must be operated on that station to check oscillator alignment, etc.

Even if the TV signal is reasonably strong in your area, an outside TV antenna, mounted high and clear above your shop, is a good investment. Such an antenna, particularly if it has colored elements, is sure to attract attention.

You can mount a sign advertising your service on the mast supporting the antenna. A neat antenna installation is a good advertisement for another reason: You can show it to customers as a sample of your installation work.

The lead-in from this antenna can be brought into the shop room just as it would be into a home: through the walls or through a window. If you need an antenna for a radio receiver, the TV lead-in will do very nicely. Most radios use no outside antennas, but now and then you will run into a farm set, or a communications receiver that requires one.

In addition to the TV antenna, there are other items of "built-in" test equipment that will prove helpful. Chief among these is the test-speaker described in an earlier book of this series. We recommend you build one just as soon as possible.

If you plan to service auto radios, you must have a bench-type power supply capable of furnishing the voltages necessary to operate this equipment. Be sure to purchase the type of supply that will furnish both 6 volts and 12 volts. Also, you should have a bench-mounted auto radio antenna for use in testing the auto sets.

As you go on in the service business, you will undoubtedly find other built-ins that will help you do some job better or more quickly. When you do, build them and install them on **your bench; everything that helps** you do a job faster or easier increases your income!

PARTS STOCK

Stocking parts has been covered previously and we will only mention that your repair and replacement parts stock requirements will differ according to the location and the type of business you do. For instance, a man located in a city, with several parts distributors and wholesale houses within easy reach, has a different problem from that of a man who has a shop in a small town, and must depend upon mail-order service or weekly deliveries for his replacement parts. The small-town operator must maintain a somewhat larger stock of parts than the city dweller in order to give the quickest service to his customers.

The best advice we can give you on this point is to be quite conservative in buying parts until you see just what types of parts are needed in your locality. For instance, if you were in a town so far away from a TV station that no TV sets were in use, you would not stock any type of tube used exclusively in TV sets, such as picture tubes, special horizontal output types, etc. On the other hand, if you were in a large city, you wouldn't stock tubes used only in home battery sets such as are used on the farm.

Distributors. Your parts distributor can be a great help to you if you will take advantage of the many services he has to offer. It is to his interest to see you make a success of your business. The better your business, the better his business. Almost all reputable parts distributors will go to great lengths to help the new shop get started and operate successfully. In the smaller towns, the salesman will call on you at intervals of about a week; he is an invaluable contact with the outside world, as far as new test equipment, tools, merchandise, etc., are concerned. Many servicemen try to concentrate their parts business with one supply house, usually the one nearest to them. Choose the one that can give you the best service as far as mail delivery is concerned, to speed delivery of special orders. By concentrating your business, you will build up a large enough account so that you can get quantity discounts, first chance at special sale merchandise, "tie-in deals", etc. For instance, a TV serviceman's "tube caddy" would cost almost $30, if purchased outright, but almost all distributors have arrangements whereby a serviceman can get it free, if he will buy a certain amount of tubes. This may be spread over a period of time, if necessary, and the actual saving is quite worthwhile. This would not be possible if the serviceman bought ten tubes from one supply house, ten from another supply house, and fifteen from still another, and so on.

In many cases, especially in the smaller towns, where everyone must depend upon parts bought by mail order, the town's servicemen often set up a sort of informal working agreement, whereby they exchange parts between shops. If one man needs a certain part, but is out of it, he can get it from one of the other shops having one of the items needed in stock. The servicemen in some towns have even gone so far as to make up lists of seldom-used parts; each shop buys and keeps a few of them, so that they will be available for all. This kind of cooperation is very nice for all concerned, as it makes for much better relations between all men in the same line of business, and helps to avoid friction.

ADVERTISING

When you open a full-time shop, advertising is essential. You must tell the prospective customers of your business and the service you offer. Stress your business name, address, and telephone number.

Tube manufacturers make many useful advertising aids for servicemen. They include outdoor signs, letterheads, business cards, direct-mail advertising cards, and window display material. All of this is available at very reasonable prices. Talk with your local wholesaler; he can give you additional information.

A business listing in the classified section of your local telephone directory is very important. Persons looking for service will often check the classified listings first. A small ad here is a good investment. While we are on the subject of telephones, remember that the telephone will often be your first contact with a new customer. Be businesslike. Make it a rule to answer the telephone with your company name, or a phrase such as "Good morning. Radio and Television service."

Tube manufacturers publish booklets of business and advertising hints from time to time. These are excellent sources of advertising ideas. Your wholesaler will know about these, or you may see notices in radio magazines.

Direct mail advertising is very useful, particularly in getting new customers. From your local city directory, you can get the names of people living nearby. Send them postal cards mentioning your service. This is particularly good in a large city where you must limit your advertising to a relatively small area at first. Otherwise, you might get calls from areas so far from your location that it would be economically impractical to do the work.

In smaller communities, newspaper advertising is good. Incidentally, some of the tube manufacturers will furnish complete newspaper advertisements needing only the addition of your business name, address, and telephone number.

In any business, the best advertisement is a satisfied customer. When you get a new customer, remember that he is a potential advertisement. See to it that you make him a satisfied customer.

HELPERS

If you must be out of the shop, it would be a good idea to get yourself a helper, someone who could answer the telephone, and check sets in for repairs. There should be someone in the shop at all times, if possible. If your shop is in or near your home, you can solve this problem by installing an extension telephone. Then, someone in the house can answer it for you.

At first, the services of this assistant should cost as little as possible. Therefore, it will help if you can get some close relative to take over this job at little or no cost to you. If you must hire someone, by all means get someone who can help you with your bookkeeping as well as answer the telephone. Of course, it would also be very handy to have a helper who could assist you in doing small service jobs, but it is unlikely that you can afford someone with such technical ability, when you're beginning.

One possible source of such assistance is the school. Many schools have on-the-job vocational training programs, in which the students work part-time in the stores and shops of the community, in order to gain practical experience in the line of work they have chosen. Although this is part-time, it can be a valuable source of assistance to you. Girls can do your typing and bookkeeping, and boys can act as your assistants, in return for practical training in business methods and practices.

Local "hams" (amateur radio operators) can also be helpful, in this respect. Often you will find younger hams, who will give you a few hours of work each day, in return for help, used parts, and the like. This assistance can be invaluable in such jobs as erecting TV antennas.

How To Be A Businessman

It has been said of the American radio-TV serviceman that he is the world's best technician and the world's worst businessman. Although that statement is a little exaggerated, there is a certain amount of truth in it. What it refers to is the unfortunate tendency of technical men to become so fascinated with the technical details of their work that they neglect the equally important part of making a living out of it.

As you will find when you gain a little more experience in running a full-time business, this is undoubtedly true. The technical parts of the business are so much more interesting than dull bookkeeping, making out tax returns, etc., that you tend to neglect them. They *must not be neglected*. Probably the only way to avoid this is to force yourself, at the very beginning of your career, to form a set of good habits in this respect, and then stick to them.

By good habits, we mean taking care of the large amount of necessary paper work, making out monthly statements for your credit customers, checking up on your monthly volume of business to see if there isn't some place where you can make a small change and save some money, paying your bills on time so as to gain the advantage of the cash discount allowed by most wholesalers for payment before a certain date, checking up on your advertising seeing that there is just enough and not too much of it, checking the gross business to see if there is enough and if there is anything you can do to increase it, and so on. The best thing to do is to set aside a certain day each month, do all these things at once, and then forget them until the next month.

COLLECTING BILLS

Most important of all these tasks is the collection of your bills; the money owed to you by your customers. If you do not get this money, you cannot pay your own bills, and must soon go out of business. Unfortunately, you will always be troubled, as are all merchants, by the credit problem.

Your biggest trouble will be in the delinquent individual accounts; the customers who will "pay you Saturday". Unless you can manage to do a 100% cash business, you will always have a certain number of these accounts in your unpaid account file. Send them a statement on the first of the month following the delivery of the set. If they do not pay by the tenth, send them a reminder notice. If this fails to bring any action, send another statement on the first of the next month. If this does not get any action, turn the account over to a collection agency immediately. There will probably be someone or some firm in your town who specializes in collection of accounts like this, and they can get amazingly good results, in most cases. The older the account is, the higher commission these agencies charge for collection. Therefore, turn the accounts over to them at the earliest possible moment.

In many cases, when reputable customers see that they are going to encounter one of these large bills, such as picture tubes, they will confess, *beforehand,* that they are unable to pay such a large amount all at once. In such cases, he can always finance the transaction through a local bank. If the customer is known there, he will have no trouble getting the money.

In some of the larger cities, and in many smaller communities, the authorities have set up "Small Claims Courts", in which you can press claims for small amounts against your debtors. These take care of small claims, such as eight- or ten-dollar debts, too small to go through the whole process of law to reclaim, as court costs would take all the profit and more. If you have such a court in your home town, use it, whenever you are confronted with these problems.

There is no hard and fast solution to the credit problem for the small businessman. The only possible means by which he can avoid undue credit losses is to exercise great caution when granting credit. Quite often, with the good customers, you will gain a friend by allowing him an extension of time to pay off a bill. If he is a reliable person, your losses will be quite small from this source.

SHOP RECORDS

As we mentioned, there are quite a few taxes that the independent businessman is liable for. This means that he must maintain a detailed set of business records, so that he can prepare the necessary reports, without losing too much time from more productive activities. If you can pick up your books and make out a tax return in a few minutes, you can use the time saved for more profitable things. The records required for a service shop need not be elaborate, as long as they will give you an accurate picture of your business activities. This means that you must have three things: a record of all money received, and for what; a record of all money spent, and for what; and a record of what parts, materials, and store equipment is on hand, and its value.

To keep the business records, you can buy small ledgers at a stationery store, or you can subscribe to a bookkeeping service that will furnish the necessary books. There is at least one such bookkeeping service of this type that will furnish all the necessary books, tell you what records to keep, compute your taxes, and balance your books at the end of the year. Your banker or a local income tax office can tell you more about this service.

The job record card discussed in an earlier book is the basic business form. It is your record of the customer's name and address, the set repaired, the work done, and the date when done. It is also your record of the parts sold and the labor charges made. The customer's name and address will be helpful if you plan to do any direct-mail advertising in the future. When you start full-time servicing, get a supply of job record cards, and use them. Make one for each set that comes in. When the set is picked up or delivered, mark the shop part of the job record card "paid", and enter the information in a small ledger, or "Daybook", under the date. The customer's name is written in the center, and the amounts received for parts and service in the appropriate columns. The card is then filed under the customer's name. There, it serves as a permanent record of the job. If you must make sales tax returns in your state, you will have the necessary figures. Many states charge sales tax on parts (merchandise), but not on labor or service charges. Therefore, you must be able to divide your income into these two categories.

Another small book is needed for recording money paid out. This can be another small ledger. Set up one page for each type of expense. You might use the following categories: Automobile expenses, parts, miscellaneous items, utilities, postage and freight, wages, advertising, test equipment.

Be sure to put down *everything* you spend even for ten cents worth of bolts. In a year even small items add up.

As far as the income tax is concerned, this record need not be very detailed. Your tax is figured only on your net profit. The detailed breakdown of the different expenses is for your benefit. In this way, you can tell almost at a glance just how much you are spending for each item, and make adjustments, if necessary. For instance, if your freight bills seem to be unusually large, you can make savings by ordering larger amounts at one time. Individual shipments of small parts use up large amounts of postage. Concentrate your orders, to take advantage of the bulk rates. If your advertising bill is running over the percentage of income you allotted it, cut it down. This kind of record is not difficult to keep and will tell you quickly and accurately just where you stand financially, at any time.

with only the need of adding one or two columns of figures. This is very important, especially to the beginning serviceman; he should be able to tell whether or not he is making any money!

Depreciation. When you make out your income tax return, you can save quite a bit of money by deducting the depreciation on your test equipment, or on any piece of permanent equipment such as your truck, etc. This means that you are allowed to charge-off a certain percentage of the initial cost of an item each year, until it has all been taken off. For instance, if you had a signal generator that cost $100, you could estimate its useful life at five years. It makes no difference what the *actual* service life of the instrument is; you can use any reasonable figure as its estimated life. In this case, you would be entitled to deduct $20 each year as depreciation for this one item. At the end of five years, the total cost would have been depreciated. If you then sold or traded in this instrument, paying $100 for a new one, its cost could be depreciated at the same rate. Cars and trucks can also be depreciated; if you buy a used truck, for $1000, and estimate that it will last for three years, you can deduct 1/3 of its cost each year. The only requirement for this is that you keep a separate record of the cost of each item in these categories; don't enter them along with your other expenses. The income tax collector may examine your books some day, and he will want to see these records. If there is any question, you may have to show him the original invoices for him to verify the ledger entries.

For this reason, it is a good idea to save all invoices you receive. This, again, is not difficult, if properly done. Get a letter file box, about 12 x 20 inches, and a few file folders from your stationer. Mark the tabs on each of these with the appropriate name. "Parts from John Smith & Co.", "Automobile Expenses", "Test Equipment", or whatever is necessary. Place them in the box, and then file all invoices under the appropriate names. At the end of the year, take them all out, empty the folders, tie the invoices in a bundle with string, and put them in another cardboard box. Tie this up, mark the year on the outside with a heavy pencil, and store it somewhere in the back room. After three years, you may dispose of it, as far as the income tax people are concerned.

Make up another set of file folders, to keep your tax returns—one for income tax, one for sales tax, etc. These can be kept in your regular file, and be available when needed.

At the end of each year, you must make up a report of the operations of the business. This should be done for your own information, and must be done for income tax purposes. To get this data, you must know three things: how much you took in, how much you paid out, and how much of this is deductible. Also, you must have a profit and loss statement on the operations of your business. This means you must have an inventory of your stock, as well as records of money paid out and received.

Inventory. To take inventory, you must make a thorough count of all parts and merchandise in your shop, and figure out the cost price on each item. The total of this is your "ending inventory" for the year just concluded. At the end of your second year in business, you put down the inventory taken at the first of the year, your "beginning inventory", add to this the cost of parts purchased during the year, and you have the total of the parts used during the year and left in stock at the end of the year. By subtracting the amount of your ending inventory from this you find out how much the parts you sold during the year cost you. This is your largest item of expense, usually, and is very important, in your tax report. For instance, if you had $500 worth of parts on hand at the beginning of the year and bought $5000 worth during the year, your total figure would be $5500. If your ending inventory showed $1000 worth of parts on hand, you would know the parts you had sold during the year cost you $4500. This, plus your other expenses of doing business such as lights, heat, transportation, tools, rent, depreciation on test equipment, etc., is deducted from your gross income, which is the total money you take in, and the result is your net income for the year—what you have left after all expenses are taken out. We recommend that you have a talk with your local income tax man to get any points straightened out that you have any doubts about. He will be glad to help you with any details.

Organizing Your Service Work

When you get quite a bit of work, you will find that it goes much more smoothly if you work on a regular schedule. For instance, take the morning hours to work on sets in the shop; the small radios, etc., that came in late yesterday afternoon. Get these all cleared away, with the job tickets made out, and then check up on the service calls that have come in. From one o'clock in the afternoon on until about four-thirty or five is a good time to run these. Make out your list so as to cover the most calls with the least mileage.

When you finish a shop job, set it on the counter, or on the shelf reserved for finished work, and make out the job ticket in full, right then! If you put this off, you'll wind up in such confusion that you'll never get it straightened out. Notice that we didn't allow any time for "catching up with back paper work". This is deliberate; you should not accumulate any back paper work. Never let it pile up. Get it done and get it over with, and then you can get on with your more interesting work.

If a shipment of parts comes in during the morning, let it sit there until you get through with the job you're doing. Then, open it, check the contents against the packing slip, mark the right list prices on all items, and put them up on the shelves. Incidentally, if you're busy, the noon hour is a good time to do this kind of work.

Notice that we mentioned marking

the list prices on each part as it was unpacked. This, in many a service shop, is neglected; consequently, the serviceman spends many a useless minute poring through catalogs looking for the correct list price on a given part. You can avoid this waste of time by marking the price on each item as it is unpacked. At that time you have the packing slip right there, with the price you have paid for each item plainly marked on it, and usually the list price. Many components come in cardboard boxes, which will provide space for marking the price. Other items, such as capacitors, can be priced from a list, and a note posted alongside your capacitor storage bin.

Tubes are an exception to this. You will always have the latest list prices for tubes, as all of the major tube companies issue new price lists at intervals. Have one posted in the shop.

Almost all standard replacement parts are marked up by the same amount: the retail price is twice the cost. Tube prices are determined from the list supplied by the wholesaler.

SERVICE INFORMATION

Except for the simplest service jobs, the technician must have accurate service information, to avoid wasting valuable time. Even for such jobs as restringing a dial cord on a small radio, the service information will save time, and time is always money in a service shop.

There are several publishers specializing in service information; the two best known are John F. Rider and Howard W. Sams & Co., Inc. These firms publish service data, both in bound volumes covering one year of production, and in separate sheet or folder form covering only a few sets. In addition to these, you can get service data from the set makers, either in the single-set folders or in bound volumes covering a full year's production. Many manufacturers have service organizations to which you can belong by paying a small yearly fee. The company then sends you, at monthly intervals, the latest schematics on their current sets, both radio and TV. All of these are worthwhile. Through them you can get the very latest schematic diagrams and other service information on the new sets, often quite a while before the sets themselves even appear in your locality. It is not possible to have too much service information. Get all you can, and have some place to keep it, with some sort of filing system, so that it is accessible.

This data file need not be elaborate; it can even be just a few pasteboard boxes, at first. In some cases, you may be able to buy several bound volumes of service data from supply houses, or from ads in the magazines. Often full sets of these are available from some shop that is closing. These, if in good condition, can be a bargain. Later on, you can get hold of a used file cabinet to store your loose-leaf data sheets. If you can find a four-drawer style, get it, as you will need it in the future. The number of diagrams you will accumulate will be amazing, and you'll need every one of them at one time or another!

If you get the bound volumes of service data, they will have indexes already. If you have any loose-leaf

Courtesy Howard W. Sams & Co., Inc.

A convenient file of service information can be a great time-saver for you.

data, you will have to have some way to keep it filed, so that you can locate any given schematic without losing too much time. If you have the filing cabinet, get a set of tall cardboard dividers, with a tab on top, showing a letter of the alphabet. File your diagrams under the first letter of the maker's name.

Later on, as you accumulate more and more schematics, it would be a very good idea to separate the TV diagrams from the radio diagrams: this will save you quite a lot of time in hunting up the schematic needed. You can further subdivide your file into auto radios, amplifiers and PA systems, etc. The standard by which anything like this must be judged is quite simple. Will it help you find any given diagram quicker? If it will, do it.

All of the loose-leaf diagrams you will get will be punched for standard notebook binders; you might pick up a few of these and keep your most frequently used diagrams in them, for greater convenience. Larger binders are available at book and stationery stores, or from the manufacturers themselves, for binding a full year or more of their diagrams.

Many technicians have built shelves above their benches, so that they can keep their service information at their fingertips. Others place the filing cabinet at one end of the bench. Wherever you keep it, make every effort to keep it neat and orderly, as a disordered or sloppy filing system, especially for service information, can take up more time than it saves, and that is its major purpose: to save you time. Without it, you could doubtless puzzle out even the most complicated set in time; with it, you can go swiftly to the source of the trouble.

SERVICE CALLS

If a large part of your business is in TV, you will have to make several outside service calls every day. TV owners almost always call the serviceman to the home, rather than bringing the set into the shop. If you can arrange for someone, such as a relative, to watch the shop while you are out, by all means do so, to keep from missing any jobs during your absence. If you must leave the shop unattended, get one of the little signs with a clock face on it, saying "Will be back at —" and hang it on the front door.

If you have several service calls, try to route them so that you will cover the most territory with the least travel. For instance, you might take the one farthest from the shop first, then work your way gradually back toward it. This saves traveling time, gas, etc.

You must make it a point to be prompt. This is more noticeable to the customer than anything else. If you tell her that you'll be at her house at 2:00 PM, make every effort to be there at that time. When making estimates on your time, it is always wise to leave yourself a little margin. If you expect to arrive at about 2:00, you might say, "I'll be there before 2:30", leaving yourself some room for error. A previous service job may take longer than you anticipate, making you a little late.

Customers will appreciate your promptness, both in arriving at their houses, and in making deliveries of repaired sets. If you make a delivery estimate on a set, therefore, be very sure that you can meet it. Always overestimate the time required to make a service call. If you can get there with the set an hour early, you'll make a better impression than if you are an hour late. Whenever possible, avoid being pinned down as to the time you will complete the job. There are too many uncertain factors in any electronic job for even the most experienced technician to be *absolutely* sure how much time he

Courtesy Howard W. Sams & Co., Inc.

When making service calls, make it a habit to be prompt.

will take on even the simplest job.

If the job is an intermittent set, don't make any promises at all as to the time of completion. Simply tell the customer the truth: because of the intermittent nature of the defect, that you will have to have an unlimited amount of time to make a perfect repair job on it. It may show up within a few minutes, or it may take several days. The truth is the best policy, in this as in all other cases.

DEALER SERVICE WORK

In almost every town or city, there are TV and radio dealers who farm out their service and TV installation work to independent service shops, rather than go to the expense of purchasing the expensive equipment and hiring the technicians to run their own service departments. This can be a good field, especially if you can get several dealers to give you their exclusive business. In return for this, you can afford to do their service work at a small discount from the regular prices. This gives them an opportunity to make a small profit with no investment, and also an incentive to send customers to your shop.

Hardware stores, electrical appliance dealers, department stores, and even drug stores often sell radios and TV sets; many garages sell auto radios. Check up on these merchants in your town, and talk to them about doing their service work. If they sell TV sets, they will often give you the entire antenna installation, in return for the installation of the set itself, which merely means that you pick up the set, take it to the home, and set it up, instructing the customer in the proper operation of the controls when the job is finished. If you give the dealer a small discount on the jobs, he may even act as a salesman for you, in selling TV antenna installations and similar jobs.

Often this dealer business will include doing "warranty service" work on both radio and TV sets. This is service free to the customer during the initial warranty period, which is customarily 90 days after purchase, for all tubes and parts. During the first 90 days, the dealer pays the labor charges for replacing any defective parts.

In doing this warranty service work for a dealer, you will have to work out some sort of arrangement with him about tubes and parts replaced. In most cases, this is a straight exchange. Any defective parts from new sets are shipped to the state distributor at regular intervals; he replaces them with good ones, shipped back to you or to the dealer. Most servicemen doing this kind of work maintain a small stock of the parts that give the most trouble, in the make on which the work is done. In this way warranty replacements in sets can be made with tubes and parts of the same make. You may be able to get the dealer to stock these parts himself or you may have to. The amount of these parts you should keep in stock will depend on the volume of work you do for this particular dealer. In any case, when making an arrangement of this kind with a dealer, be very sure that all points are clear to both parties, as to the procedure to be followed in exchanging defective parts. Also, be sure to read a copy of the manufacturer's warranty.

When you are the one who handles this exchange, be sure that you do not leave the old parts lying around the shop until they run out of warranty. In that case, they will be a dead loss, and must be discarded. If you have several different makes to handle, it is a good idea to set up cardboard boxes for defective parts, each labeled with the name of the manufacturer. See to it that these are shipped in to the distributor on a certain date, once a month, at least. It would be better still to make shipments every two weeks.

The dealer should agree to give you *all* of his service business in your line for you to give him a discount. This discount cannot be too big; in no case should it be over 10%, and in most cases, around 5%, of the total bill. If you have a dealer who will send his own delivery men out to pick up and deliver the sets, bringing them right to your shop, so that you do not have to take the time to pick up and deliver them, you can afford to extend him a larger discount than the dealer who makes you do all pickup and delivery work.

Many garages and auto parts supply stores also sell auto radios, and only a few of them have enough volume to justify maintaining a service department for installing and repairing the sets.

There is one final point about this type of service work. You must assure each of your dealers, if you have more than one, that his business will be kept strictly confidential between the two of you. Never tell one dealer anything about the other dealer's business. If you do, he will suspect that you are also talking about his business to others. Keep each dealer's account strictly confidential to avoid trouble. In fact, it would be a good idea to mention this when beginning negotiations. Tell him that his business will always be strictly confidential.

There is another advantage to doing this kind of work. It is the affiliation with nationally known manufacturers. Many of these people make available to the serviceman free schematic diagrams, emblems, advertising, uniforms, etc., or make a reduced price on such material. The advertising tie-in will often be of value to you, and the information available certainly will.

SELLING

Another thing you will have to decide when going into business for yourself is whether you want to sell radio and TV sets or stick just to servicing.

Even though you may not want to set yourself up as a dealer who sells a full line of radio or TV sets, there are many items you can stock in small quantities, at small cost, and sell to increase your income.

You will have your stock of regular replacement parts, of course, tubes, transformers, etc., but these are the parts used in repair work. In addition to these, you can also keep a small stock of auto-radio antennas, phonograph needles of the many types used in both standard and high-fidelity record players, phonograph cartridges, rear-seat speakers for auto radios, and quite a few other items.

Your distributor's salesman will have many new items, from time to time, for this kind of selling, and he will be glad to show them to you. It would be advisable to keep only a small stock until you can see how rapidly they are going to sell.

If your shop does a good bit of dealer service work, you may be able to pick up a few extra dollars by reconditioning trade-in radios or TV sets for them, then setting them up in your shop, for sale. In this way, the dealer is relieved of the trouble of having the sets fixed up, and given the opportunity of disposing of them at a profit.

Items such as a rear-seat speaker for a car are available in kit form which can be displayed on your counter. The speaker, switch, grille, and all wire needed are included. Most of these are packaged in a display carton, which can be folded back so as to display the unit. When you deliver a car radio to the customer, you can suggest the installation of a rear-seat speaker; you'll be surprised how many you can sell in this way. This is given only as an example. There are many different items suitable for this kind of merchandising, and they can make a small profit for you, with a little investment, if handled properly.

Similarly, new record changers may be sold, for installation in older-type console radio-phonographs. There are still many single-speed changers in use, and the alert serviceman can often make a sale by telling the customer about the advantages of a modern multi-speed changer, which will play records at several different speeds. Because of the comparatively high net cost of these changers, it would probably be better to sell from the catalog at first. Show the customer a picture of the changer, and get the order before ordering the new changer yourself. Later on, you may want to stock one of these units, if they sell very often.

TV antennas and accessories, such as new lead-in wire, lightning arresters, masts, etc., would be considered more as a part of your regular parts stock than as customer goods, but you can still sell some of this material to the "do-it-yourself" type of customer, who wants to put up his own antenna. In many areas near the TV stations, the serviceman can stock a few of the ornamental types of "rabbit-ears" TV antennas. Some of these include lamps or clocks, in their design, and can be sold over the counter as the customer can easily install them himself.

Don't go overboard in buying some item, merely because it appeals to you. Get one or two of them, and see if they appeal to your customers. You can later stock any fast-selling item in larger quantities.

Intercommunication systems in particular can provide the technician with a good source of income, both in installation and servicing. Basically, these are no more than small audio amplifiers, and the circuitry is quite simple. Almost any business establishment with more than two employees is a good prospect for an intercom installation. Check up on the businesses near your shop, make a survey of their stores, and then approach the owner. There are also available small intercom units, using only two stations, one master and one remote or slave station, which are ideal for doctors' offices, lawyers' offices, etc., and can actually be installed in a few minutes. They require only one very fine pair of wires, which can be run around doors, over windows, etc., held in place by pins or tacks. If your shop has separate sections for the "business office" and the shop, install an intercom. Customers are sure to notice it and ask questions.

Check up, also, on the larger industrial establishments: garages, lumber yards, factories, etc. Any business which has several buildings, separated by more than a few feet, is always a prospect for one of the larger intercom systems. An installation of this type can be very profitable, as you get not only the profit on the sale of the equipment, but also on the installation. Your distributor's salesman will help you to plan the installation from his catalogs.

You and Your Customers

Customer relations are one of the most important parts of your business, and unless you pay sufficient attention to them, you may well find yourself without customers, no matter how skilled a technician you are. Large businesses employ highly-trained men to manage their customer relations, and you'll find it wise to do the same, in your own way. In this case, you're your own customer relations man, and you must take full advantage of every opportunity to make yourself popular with them! In almost all cases, this means only one thing; do the best job you can on their sets, and be willing to stand firmly behind your work! Try to make a friend out of every customer, and your business will prosper accordingly.

GUARANTEEING YOUR WORK

One of the things which seems to make the best impression on the average customer is a positive guarantee on all the work you do, and the parts or tubes you replace. Actually, this is not hard to do. If you use the proper kind of replacement parts, their life should be far beyond the period of the guarantee, which is usually 90 days from the date of installation. Just as an example, a good electrolytic capacitor should last for around five years; coils, transformers, etc., for similar or longer periods. Although the service life of a tube is impossible to predict, good tubes will last for a surprisingly long time, and the few which do fail during the guarantee period will be replaced by your distributor.

Of course, you must be very careful not to go overboard in making guarantees to your customers. Most servicemen guarantee *only* the parts and services which they have done. It would be foolish to attempt to guarantee the entire set. Be sure to explain to the customer that your guarantee covers only the parts you have installed. Show him the job card, listing these parts, with the date, and explain that this is for *his* protection. Incidentally, here's a good point in your public relations department. Be sure to remark that you want to be certain that the customer gets his money's worth, and therefore, you are keeping a record of the job. If any part that you put in goes bad during the guarantee period, he is to be very sure to bring the set back, and you will cheerfully replace the bad part, at no extra charge.

This is one of the best practices that you can follow in building up your reputation. If the customer gets the impression that you have confidence in your own work, and that you are primarily interested in making his set work well, he will be more apt to come back the next time. Better still, he will recommend you to all his friends. This, by the way, is by far the best and cheapest advertising you can get: word-of-mouth. The potential customer is far more impressed by a casual recommendation from a neighbor than by the most elaborate advertising campaign that could be put on. Therefore, make every effort to get and keep the goodwill of every customer, from now on. This is a never-ending process, but it will pay off richly, in a continuous flow of customers.

There is one thing which may give you some difficulty, the actual dating of the guarantee. The job card is one way to avoid arguments on this. You will find that the average customer has a very vague idea of the actual date on which his set was repaired, and his estimate of the elapsed time is invariably short, sometimes by an amazing amount. When making out the job card, or when delivering the set, always casually point out the date on the card. If they see this, they will be more apt to accept it, where they would naturally be tempted to argue with you if it were a question of your unsupported word against theirs!

Avoid arguments whenever possible; even if you win an argument, you are likely to lose a customer, thus losing money in the long run.

Most people are fair-minded about these things; there is only a small minority who will try to take advantage of you on guarantees. In time, you will learn to recognize the type when they come in, and take precautions to cope with them by very obviously marking dates on the job, and so on. Most of these people will be discouraged by this type of proof, and will not even attempt to argue. The honest customer is usually very easily convinced by your written records, and will readily admit that his memory is at fault.

In justice to the customer, you must always remember that to him the symptoms may all be the same. No matter whether a picture tube has burned out, the horizontal output tube shorted, the horizontal oscillator quit, or whether a fuse has just blown, he has a dark screen! His precious radio or TV set will not work; therefore, he is in quite a bad humor. Remember this when beginning your first dealings with him. Most successful servicemen have adopted a sympathetic attitude, when discussing the repair job, at first; a "That's too bad; your set won't work. Let's see what we can do to help you" attitude. If the serviceman gives the impression that he is not interested in the customer's troubles, but that it is only another job to him; that all he wants is the money, the customer won't like it. Therefore, take the sympathetic approach; let the customer know that you *are* actually interested in him and his problems, and that you will do your very best to get his set working again, at the least cost to him. Then you've taken the first big step toward making yourself into a successful professional serviceman.

Actually, for the best results, you *should* have this attitude. The lifeblood of your business is customers; unless you have plenty of them, you're not in business for long. The best impression you can make on them is the sympathetic attitude, and they will come back again and again, and bring their friends with them.

What if one of your jobs actually does fail before the warranty expires? Then, you must make good on it, if you are to retain the customer's confidence and his patronage. The simplest case, of course, is the one in which your part is actually at fault. There is a small percentage of failures, even in the best parts. In this case, if the tube is shorted, and your date shows that it was replaced only 30 days ago, your only possible procedure is to replace it with a new one, apologize to the customer, and return the bad tube to the distributor for credit. Incidentally, you will usually have a much longer warranty period on tubes from your distributor than you give to the customer; sometimes this is six or nine months. This is to cover the period of time that the tube may be on your shelf before it is sold.

Now and then, you will find the customer who will attempt to pay you for either the tube or for your service, on making replacements under guarantee. It is a better policy not to accept payment. The impression made on the customer is worth far more than the small amount you would make on the service charge. In almost all cases, he will go back home and make it a point to spread the word all over the neighborhood, about what a fine, honest serviceman you are. Once again, this is the most effective type of advertising you could possibly get.

On the other hand, you will find yourself faced with the problem of explaining to the customer that the part that failed was *not* one you replaced the last time the set was serviced. Remember, as we just said, the symptoms may look the same to him; it has quit working, and he will almost invariably suspect the brand-new part you just installed, rather than the hundreds of old parts still remaining. It will be your job to show him as diplomatically as possible just what the trouble is, and then show him, by reference to the job card, just exactly what work you did, and which parts you replaced, on the last job. In some cases, it is best to let the customer watch you test the set, so that he can see just what you are doing. While making these tests, you might casually point to a part and and remark, "There's the piece we put in last time. It's still good!"

We have taken up a good deal of time talking about customer relations, but this is because we feel that it is important.

THE QUALITY OF YOUR WORK

There is one more point on which you will have to be *very* careful, especially for the first year or so you're in business as a full-time technician. This is the *quality of your work*. We have made informal surveys among customers, as to what point made the most lasting impression on them: price, workmanship, speed, etc., and the answer most often received was the quality of the work. The price charged was decidedly secondary, and in many cases was not even mentioned at all.

So, when you first set up your own shop, and begin repairing radios and TV sets for the public, take plenty of time on each job, no matter how small it is, to assure yourself that the set is in just as good shape as it can possibly be, before you return it to the customer. In the beginning, this is doubly important: if you should acquire a reputation as a slipshod, careless workman, it will take you a lot longer to live it down than it did to acquire it!

KEEP UP WITH THE WORLD

Even though you live in one of the larger cities with facilities for attending service meetings and thus keeping posted on all of the latest developments, there will be many new items that you will miss unless you're careful to check up on things. The technician living in the smaller towns does not have the opportunity to attend such meetings unless they are within a reasonable distance of his home. Even so, many country servicemen will drive 75 to 100 miles to attend these meetings, and consider the time well spent.

When color TV service clinics were held by the manufacturers, one serviceman used this system. Two weeks before the service clinic was to be held, he put some magazines with articles about color TV in his window with a note saying that the shop would be closed during the time of the clinic, and explaining the purpose of the clinic. Arrangements were made to switch all calls to his home during the time he was closed. He attended

Keeping up your technical knowledge is an important part of a successful career.

the clinic and got a lot of good advertising at the same time.

When you enter a field as fast-growing as electronics, you must make a definite effort to keep up with the latest developments, or you will soon find yourself behind. Every day sees some new development or a new application of an old one, in this fast-moving field. In almost all cases, the alert serviceman will make a positive effort to keep himself posted on these new developments as they occur.

This is not as difficult as it might seem, even for the man in a small town. In the general field of electronics there are quite a few trade magazines. Some of these are aimed specifically at servicemen; some are for amateur radio operators only; several others cover the whole field, with articles and discussions on items of interest in all fields of electronics. We recommend that you pick out several of these magazines, and subscribe to them. Read them through carefully, and see just how much helpful information you can get from them. Each month there will be short technical discussions of new tube types that have been brought out by manufacturers with characteristics and specifications; articles on new circuits used in commercial TV receivers, the latest developments in color television, the latest in new test equipment, etc. Many magazines have departments devoted to the serviceman, with letters sent in by servicemen from all over the country about unusual problems. An expert diagnoses these and answers their questions. A companion to this is the department where the servicemen themselves send in case histories on peculiar problems that they have run into. In many cases, these will be helpful to you, as you may have the same problems.

Some magazines publish complete schematic diagrams of TV receivers and radios that you can clip out and file with your other service data. They can be very valuable. Most of them are for very late sets, and it may be some time before the schematics are available elsewhere.

Another source of much helpful information is the advertisements in these magazines. It is through them that you can keep up with the latest types of test equipment, and above all, special tools. Many servicemen watch these ads with interest, and if they see a special tool that they know will make their work easier, they clip the ad and send it to their regular parts supplier, who will order the tool for them.

Incidentally, all money spent for subscriptions to magazines and trade papers used in your job, is fully deductible from your income tax as a legitimate business expense, so don't forget to put it down. So is the money spent for going to service meetings. You can deduct traveling expenses both ways, and living expenses while there, if the trip is for the purpose of attending a service meeting or trade convention connected with your business.

Keep yourself abreast of all the new developments in electronics. In this way, if you do run into a new type of set or circuit, the chances are you'll be at least familiar with it from reading about it in the trade magazines, and servicing it will be much easier. Some of the magazines even have regular series of articles on color TV, industrial TV, and other new developments, giving the basic principles of the new circuits. A few years ago, many servicemen who had been doing nothing but radio work, prepared themselves for TV work by taking a short refresher course, and then reading the many articles published in the magazines on TV. These same men are now keeping up with the latest circuits, ideas, etc., such as color TV, by reading the articles in the same magazines.

Of course, by the time you have finished this course, you will be up to date on all of the basic theory and applications in electronics. However, never make the mistake of thinking that you know it all. When you have finished this course, you have just begun to study. From now on, you will have to keep on studying; get all the latest material, from magazines, manufacturers' releases, and everything else you can get your hands on, and study it thoroughly. Many professional men who have spent 20 or 25 years working in electronics, are still keeping themselves up with the times. This is not going to be as difficult as it sounds, however. The typical serviceman is so fascinated by his profession that he eagerly reads everything he can find on it. If you will make only a very small effort, you'll find that you can keep yourself and your shop abreast of the times, and that the world will not run off and leave you.

LOOKING AHEAD

You are about to enter one of the most fascinating fields today, electronics. There is an opportunity there for you to make a very good living, and enjoy yourself while doing it. Your upward progress in electronics is limited by only one thing, your ability to work. Make no mistake about it, you'll have to work, study, and improve yourself in all ways, both in your knowledge of electronics and in your ability, or skill, in the mechanical aspects of your job. The fact that you have gotten this far through your course proves that you have the will to work to improve yourself.

When you finish the whole NRI course, you will have a good basic foundation upon which to build your career in electronics, whether you go into fulltime servicing, or into one of the other allied fields. The basic theory that you are learning from your lessons and from these SMA Books will give you just as good a background as you can get anywhere! If you work hard on your studies—if you make sure you understand everything the course has to teach you, and if you put real thought and energy and a lot of good hard work into creating a servicing career for yourself, then you have a wonderful chance for success. What you are doing now is merely putting in the foundation upon which you can build your future. Just as a house cannot stand firm and solid if the foundation is unsteady and crooked, your future in this business depends upon how well you build the foundation of the basic theories of electronics. If you build this foundation square and solid, you have a very good start toward building a future you can be proud of. We know that you'll make a success in it.

Good luck!

IMPORTANT

This is the LAST of the "Spare-Time Money-Making Aids" Books. Your servicing training will continue in your regular study lessons. There you will learn professional servicing techniques in more detail.

INITIATIVE

The man who does only the routine tasks, the ordinary jobs in his profession, always waiting for the other fellow to take the lead, can expect only moderate returns for his labors. He who is continually on the alert to grasp each new opportunity gets the greatest profits. The immediate financial returns from work in a new and specialized branch of your profession may not be great, but the reputation you gain for progressiveness will soon result in more profitable routine jobs. It all boils down to these simple facts —you must do out-of-the-ordinary things, stand above the crowd in some way, to attract favorable attention. People remember you first for the unusual, then for your ability to do ordinary work well.

J. E. Smith

PROFESSIONAL SERVICING TECHNIQUES

36B

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO SCHOOL

NATIONAL RADIO INSTITUTE

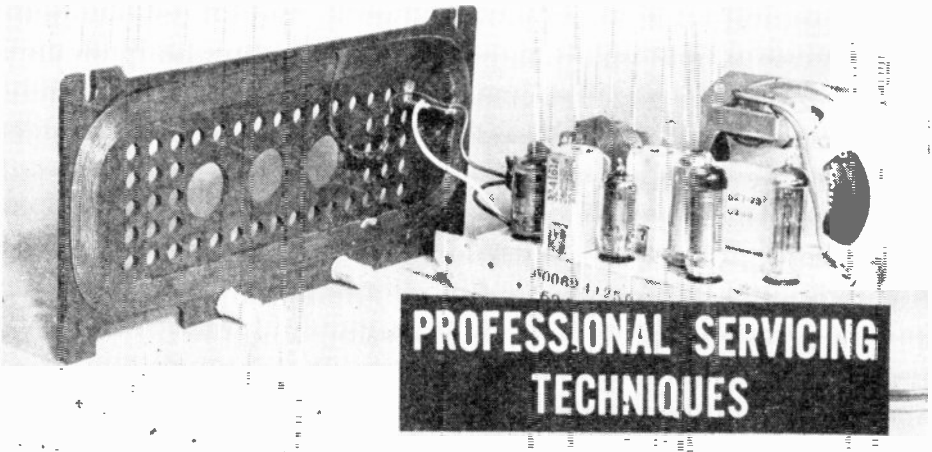
WASHINGTON, D. C.

ESTABLISHED 1914

Study Schedule No. 36

For each study step, read the assigned pages first at your usual speed. Reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

FM4M1258 **1959 Edition** Printed in U.S.A.



PROFESSIONAL SERVICING TECHNIQUES

WHEN you as a serviceman are called to service a radio or television receiver that has been in use for several months, it is reasonable to assume that some defects have developed in that receiver. The customer's complaint will be based upon a definite change in the performance of the receiver, and his description of this change can be an important clue to the actual cause of the trouble.

In rare cases, you may be called to service a receiver that has been in use only a few days. Here it is entirely possible that the customer is expecting too much from that particular set. Your job then is to explain the limitations of various types of receivers.

One thing a serviceman must recognize right from the start is that no receiver is perfect. Modern receivers are the result of an engineering compromise between desirable technical characteristics, cost, and sales-getting features. Good selectivity and exceptionally high fidelity cannot both be obtained at the same time. A communications receiver has excellent selectivity at a sacrifice of fidelity; a high-fidelity broadcast-band receiver has less selectivity; the average home radio has a compromise between the two.

A radio engineer or a well-trained musician might object to the sound from a receiver with more than 5% harmonic distortion, yet the average customer would not ordinarily notice a gradual rise in harmonic distortion up to 10%. It is only when a circuit defect garbles speech and music or makes reproduction raspy or unintelligible that the average customer calls a serviceman to eliminate distortion.

Poor sensitivity is a typical example of a complaint that is sometimes unjustified. A particular receiver may be entirely satisfactory to a person who is interested only in nearby powerful stations, yet this same set might be inadequate for a rural listener who must depend upon distant stations for his programs.

Your job as a serviceman is to restore the original performance of the receiver, not to change or improve the factory design. If the receiver itself is inadequate for the customer's requirements, recommend that he get a more suitable set for his purpose.

By checking the performance of each receiver you work on, you will quickly acquire the ability to predict the performance each type of receiver can give, and to tell whether or not a customer's complaint is justified and the set should be worked on.

The Customer's Complaint

Ordinarily, about all you will know after a customer phones is that his receiver is not working satisfactorily and that he would like you to fix it. You can often get more helpful information from the customer, however, over the phone, at his home, or at your shop if he brings in the set.

First of all, let the customer describe in detail exactly what he is complaining about in the performance of the receiver. He may have several complaints, so be sure to let him tell you about all of them. You must remember that people's tastes differ greatly as to what is and is not good in radio and television reception, and you cannot do a satisfactory repair job unless you know exactly what the customer expects.

Don't ask the customer outright, "What's wrong with the set?" Use questions like these: "How is the set acting now? When did the trouble first start? Did it come suddenly or gradually? Did you notice any other trouble before this started?"

After getting this information from the customer, turn on the set and check its performance yourself to verify the customer's complaint and to see if there are other clues to the location of the trouble.

If the receiver is dead when you first try it, always check for missing tubes, a disconnected power cord plug, a disconnected antenna, or other disconnected leads. Oftentimes people will disconnect wires or remove tubes as soon as trouble develops, in the hope of preventing further damage to the receiver.

Defects like howling, noise, hum or severe distortion are easy to recognize, but they may mask other troubles. Furthermore, defects like occasional noise, inability to pick up certain stations, fading, blasting or intermittent troubles are not so obvious and sometimes would not even be noticed during an initial check of performance. Considerable time can be saved by allowing the customer to tell how his receiver is misbehaving. Listening to the customer is an important part of professional servicing. You'll find that most people are willing and anxious to talk, if only you give them a chance and listen respectfully to what they say.

No matter how a customer describes the complaints, you can usually recognize them instantly and place them in one or more of the following groups:

1. *Dead receiver.*
2. *Noisy reception.*
3. *Excessive hum.*
4. *Squealing or howling.*
5. *Distortion.*
6. *Low volume.*
7. *Poor sensitivity.*
8. *Poor selectivity.*
9. *Station interference.*
10. *Intermittent reception.*

We will now discuss each of these major complaints, and learn what clues to look for in each case in order to recognize and verify the customer's complaint while checking receiver performance. In many cases, we will also take up effect-to-cause reasoning for localizing the trouble in a general way. However, this lesson is just a preview of the entire field of professional servicing. Later lessons will give you more detailed instructions.

In this lesson, we will be concerned primarily with AM and FM radio receiver servicing techniques. Television receiver servicing techniques will be taken up later after you have studied TV receiver circuits. However, we will not ignore TV complaints entirely, because many of the servicing techniques used in repairing radios can also be used in TV sets.

DEAD RECEIVER

The customer may simply say that the set does not play, but even in a dead receiver there may be clues indicating the nature of the trouble. If the pilot lamp lights up, you know that the set is receiving power from its source. See if all the tubes light up or get warm. Listen for the low-level hum and weak rushing sounds that are heard on almost any receiver when no stations are tuned in. If you hear these, you know that the power supply and loudspeaker are probably good. Also listen for the normal rushing sound usually heard when the volume is turned up with no station tuned in (proof that the stages between the volume control and loudspeaker are good). A popping or clicking sound should be heard from the loudspeaker when the ON-OFF switch is turned on and off quickly after the receiver has been operating for a few minutes; failure to get it can mean a loudspeaker defect, a power supply defect, or an af output stage defect.

In an AM-FM receiver, try to tune in stations on both bands. If you can get reception on only one band, then the trouble is in the preselector, mixer, i-f, or second detector section for the dead band.

Even simple listening tests like this on a dead receiver can give valuable information. For example, a low-level hum heard all the time the set is on associated with a popping sound when the power switch is turned on and off, means that the main power supply is functioning. Absence of all of these symptoms indicates that the power supply or the last af stage is dead, the filament circuit is open, or the loudspeaker is defective.

Other combinations of symptoms will give other clues as to the source of trouble, once you have learned to analyze the customer's complaint and verify it by checking the performance of the receiver yourself.

NOISY RECEPTION

A certain amount of noise is always present in both amplitude and frequency-modulated receivers, in phonograph amplifiers, and in public address amplifiers, even when the units are operating properly. In television receivers, it appears as white spots on the screen.

If it were not for noise, distant broadcast-band reception would be limited only by the gain of the receiver, and it would be unnecessary to have high-powered transmitters.

Noise is a problem only when it becomes greater than normal for the particular system in question. Here again, considerable judgment is required to determine whether or not the amount of noise is normal. By checking the performance of good receivers whenever you have an opportunity, you will quickly learn how much noise to expect from various types of sets with various types of antenna systems.

Noise due to something entirely outside of the receiver is called *external noise*, to distinguish it from *internal noise*, which is due to a receiver defect or to limitations in receiver design.

External Noise. Spark-producing devices like motors, generators, vibrators, diathermy apparatus, household electrical appliances with moving contacts, electro-medical devices, ignition systems in automobiles, and oil burner electrical system all produce a type of interfering noise, which is often called *man-made* static. Manufacturers of electrical equipment are today turning out units that produce a minimum of noise interference. Special noise filters are available for apparatus that does produce excessive noise; they are covered elsewhere in the course.

In addition to man-made interference, we also have nature's source of noise, consisting of electrical disturbances produced by local or distant electrical storms and by lightning discharges. Natural noise is known as atmospheric disturbance or static. If you are near powerful broadcast stations, it will take a local thunderstorm to produce static that will be able to override the carrier of the station. In an AM broadcasting system, little can be done to reduce the effects of atmospheric disturbances. With a good frequency-modulation receiver, however, radio reception can usually be enjoyed right through the strongest local electrical storms. Atmospheric disturbance of this type does not interfere with TV reception because of the high frequencies of the VHF and UHF bands.

Internal Noise. Noise originating inside a receiver can be due to either an actual circuit defect or certain unavoidable and natural characteristics of tubes and circuits.

A poor connection in a receiver can produce a crackling noise that interferes with reception and is, hence, a justifiable customer complaint. If you jar the receiver or tap on certain parts, the intensity of the noise will usually increase. Your job is to locate and correct the faulty connections or locate the faulty part that is causing the internal noise.

Circuit noise exists because of the erratic motions of free electrons in the conductors and resistors. Since these movements increase with temperature, the effect is called *thermal agitation*. The electron movements produce small voltages, and when these voltages are in the input stage of a receiver, they are amplified thousands of times by the high-gain tubes in modern receivers. The result is a characteristic rushing noise.

In addition, there is another type of noise produced in every radio tube known as the "shot effect." It is due to the irregular movement of electrons from the cathode to the plate inside a vacuum tube. The sound produced from the loudspeaker as a result of this electron movement sounds like sand or raindrops falling on a tin roof.

Tubes and circuit noises together produce a noise signal that is only a few microvolts at the most, except in the frequency converter tube where it is much higher. This internal noise is a sort of hissing sound. It is most evident when the set is tuned off a station and the volume control is advanced for maximum loudness. The avc system is then set for maximum rf gain, and the af system is getting the entire output of preceding stages.

To make sure that signals will override noise originating in the frequency converter tube, receiver design engineers place an rf amplifier stage ahead of the converter whenever cost and design considerations permit. This extra stage makes distant reception more enjoyable. Without an rf stage in a superheterodyne receiver, the noise in the frequency converter would be the chief factor limiting distant reception.

When confronted with a customer's complaint of noisy reception, find out first whether it is an internal or an external noise. The simple procedure for doing this quickly is given elsewhere in the course.

EXCESSIVE HUM

If you listen intently, you will ordinarily be able to hear hum from the loudspeaker of any receiver operating from an ac power line, or from a vibrator-type of power supply. Keeping this normal hum below the level at which it becomes objectionable is an important design problem.

In high-fidelity receivers, which produce sounds as low as 30 cycles, considerably more hum reduction is required than in midget or table model receivers, which do not reproduce much below 150 cycles. In any receiver, the hum should be only barely audible, and listeners in the same room should not be conscious of its presence during a program.

There are a number of receiver defects that can cause the amount of hum to increase considerably. The hum level may increase gradually as the electrolytic filter capacitors dry out. On the other hand, the hum level may rise suddenly through failure of a filter or bypass capacitor, or development of cathode leakage in a tube. Hum may become so intense that it overrides broadcast programs or may be annoying only when tuning between stations.

Hum is one trouble that definitely irritates the listener. The longer he listens, the more offensive the hum becomes, and the more critical he becomes of hum.

SQUEALING OR HOWLING

In the days of regenerative receivers, it was normal for a set to squeal and to cause squeals in nearby receivers during tuning. This type of set as fortunately almost extinct now, but modern receivers may still squeal or howl when certain defects occur in circuits or parts.

Radiation from the horizontal sweep circuits of a nearby TV receiver will result in squeals equally spaced across the entire broadcast band. Moving the radio to another part of the room to a different wall outlet, or turning it to take advantage of the directional characteristics of its loop antenna may reduce the interference to an acceptable level. Shielding the circuits of the offending TV receiver (explained elsewhere in the course) will eliminate most of the interference.

Image interference at low-frequency dial settings, caused by signals from high-frequency stations entering the preselector, will also cause squeals. This trouble is quite bad in some localities and is never found in others.

Occasionally, an experimental regenerative receiver or the oscillator circuit of a superheterodyne will radiate a signal and produce an audible squeal in nearby receivers. You can recognize this external squeal source because it will be intermittent and its frequency will vary as the offending set is tuned.

Internal sources of squealing are more numerous, and are covered in detail elsewhere in the course. You may find squeals due to troubles inherent in the process of frequency conversion in a superheterodyne receiver. As a general rule, the number of tuned circuits in a receiver, its basic design, and its i-f value determine just how much of this trouble will occur. Also, squealing may be due to oscillation caused by an open bypass capacitor or misplaced connecting lead. The defect may be in the rf, i-f, or af system of the receiver, or can even be due to an open output filter capacitor in the power supply.

Defects in the supply circuit filters of an af amplifier, or defective bypass capacitors that are common to two or more screen grids of rf or i-f tubes, can cause a putt-putt noise, commonly called *motorboating*.

Loose or flexible elements in tubes or other radio parts, or even a thin, flexible chassis itself can give rise to a variable-pitched howl under the influence of powerful sound waves from the loudspeaker, giving an effect called *microphonics*.

The ability to recognize, localize, and remove the cause of squeals, howls, motorboating and microphonics is an important part of servicing work.

DISTORTION

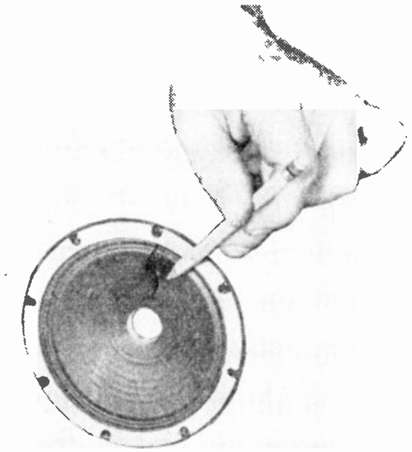
When a customer complains that voice or music is muffled, harsh, raspy, or unintelligible, you have a definite and justifiable complaint of distortion due to an internal receiver defect.

Equally important cases of distortion, however, are those situations where the customer's complaint is rather indefinite. He may say, *"It just doesn't sound right."* Careful questioning in cases like this will probably reveal that the customer quickly gets tired of listening to the receiver, or reveals that listening for an hour or so gives him a headache or makes him so irritable that he gets up and turns off the set in disgust. Certain amounts of distortion are not noticeable as such by the average person, but an hour or more of listening to distorted reproduction produces a definite reaction.

In a case of distortion, it is important to find out whether it is on local or distant stations or both, and whether it occurs only at high or low settings of the volume control or at all settings. Combining a thorough check of receiver performance with

Distortion may be due to low emission or gas in tubes, leakage in coupling capacitors, defects in supply circuits that change operating voltages, or opens or shorts in some parts or in wiring.

Distortion can be due to improper alignment, and this in turn may be either the result of normal aging of parts or of a breakdown in some part.



A damaged loudspeaker cone like this will cause distortion.

this additional analysis of the customer's complaint is an important feature of radio service work, because it helps to isolate the probable location of the defect. For example, if the sound is distorted on all settings and all stations, you would suspect a defect in the audio output section of the receiver.

There will be cases of distortion in which there is nothing you can correct. For example, selective attenuation of the sidebands from sky-wave signals, or phase cancellation of signals at a location near the skip distance limits, can give distortion.

Distortion may exist in the loudspeaker due to a rubbing voice coil, to a damaged or old cone or, if the speaker is an electrodynamic unit, to a complete absence of field excitation. It is your job as a radio serviceman to recognize and correct abnormal distortion. In fact, it would be rare indeed, that you would be called at all for distortion which was not definitely abnormal.

LOW VOLUME

The average radio receiver is designed so that reception of a fairly powerful local station with the volume control fully advanced and with an antenna of average effectiveness will overload the loudspeaker and perhaps produce rattling. Fortunately, however, the avc system in a receiver levels out variations in signal strength sufficiently to prevent excessive overloading of the loudspeaker or other stages at normal volume control settings. The average listener rarely advances his volume control fully; he is satisfied to know that the set has sufficient reserve power to blast out if he does advance the control.

With the possible exception of some three-way portable sets, modern receivers will give more than sufficient volume for the average room in a home, even for weak local stations and for not-too-distant stations. It takes a little experience to be able to tell whether or not a receiver is delivering a normal amount of volume, but you probably know already what the acceptable volume is for ordinary sets.

When the volume is definitely lower than normal for both local and distant stations, but you can still tune in the distant stations, you can be sure that a defect exists in the audio system. It may be a low-emission tube, or low electrode voltages on an af tube. When low volume is associated with poor sensitivity (the next complaint to be discussed), so that distant stations cannot be tuned in, look for a defect in the rf system.

When local stations come in with adequate volume but both volume and sensitivity are poor for distant stations, you can suspect a poor pick-up system (loop or antenna). It is easy enough to recognize the defect of low volume, but in applying professional servicing techniques, you must go further and investigate every symptom that may help you to isolate the probable causes of the trouble.

POOR SENSITIVITY

A customer would probably describe the condition of poor sensitivity as inability to pick up his favorite distant station. Your first step is to determine whether the trouble is actually poor sensitivity, or whether it is a natural condition. Some small ac-dc sets do not have enough gain to pick up distant stations, and the customer may be expecting too much from a set of this type.

Ask if the customer has picked up that distant station regularly before both in summer and in winter, with that *same receiver* in exactly that *same location.* For example, a New Yorker moving to Washington, D. C. might complain of inability to get New York stations, yet his set was never capable of giving good distant-station reception.

If questioning indicates the possibility that the receiver is defective, check its pickup performance by trying to tune in one or more distant stations. Judge the sensitivity according to the manner in which the stations come in, making due allowance for the time of day and season of the year. Memorize the frequencies of several near-distant stations that can be picked up regularly in your locality with a good receiver, so you can tune them in quickly when checking the sensitivity of a receiver.

If a receiver fails to give adequate volume on distant stations when used with an antenna known to be in good condition, then poor sensitivity is definitely the complaint, and is probably due to a circuit defect. It should be noted that the customer will generally complain of low volume rather than poor sensitivity, although both troubles are present when the defect is in the rf system.

Complaints of poor sensitivity may also be due to normal variations in radio reception with changes in season. Reception is generally far better in winter than in summer, and better at night than during the day for broadcast band stations. This is a situation most people recognize, but you will still find customers who will welcome an explanation of these peculiarities of radio.

As you can see, a serviceman is more than a trouble-shooter and repairman. He must have a broad general knowledge of radio, covering the broadcasting system as a whole and basic design features. He should know, for instance, that a receiver with limited rf gain but high audio gain produces extremely loud signals on local and semi-local stations.

POOR SELECTIVITY

When the customer complains that a powerful local station prevents him from receiving a distant station on a nearby frequency, you have the condition of poor selectivity. It may be a condition inherent in receiver design, or it may be due to a circuit defect.

A leaky tuning capacitor, a damp coil, conductive dirt on tube sockets, or dirt elsewhere in rf circuits can definitely produce poor selectivity. These defects lower the Q factors of resonant circuits, thereby lowering the sensitivity and selectivity of the receiver. In extreme cases the symptom of low volume may also be present.

On the other hand, poor selectivity may be due to the natural characteristics of the superheterodyne circuit, along with some local receiving condition. It may be the result of several stations operating on nearly the same frequency, with atmospheric conditions particularly favorable for reception of the more distant of the two stations, so that both came in at the same time.

Whenever a customer's complaint of poor selectivity is found to be due to atmospheric conditions, an explanation in non-technical language will satisfy and please the customer in most cases.

It is obvious that in this brief presentation of the complaints of low volume, low sensitivity, and poor selectivity, we can merely mention only a few of the causes. Remember that all these troubles are taken up in greater detail elsewhere in your course. They are mentioned here only to stress the need for more than casual recognition of the customer's complaint. The value of a thorough check of receiver performance cannot be stressed too much in this study of professional servicing techniques.

STATION INTERFERENCE

There may be as many as 40 or 50 low-power stations operating on some frequencies. Under certain atmospheric conditions, some are bound to interfere with each other, so that two stations having the same frequency are heard at the same time. This type of interference usually occurs at the high-frequency end of the broadcast band, because most of the low-power stations are crowded together here. You can recognize troubles of this kind by the fact that they occur only for a few stations, not for all signals received. The interference usually occurs during the hours of darkness and shortly after daybreak on the east coast (the rest of the country is still dark). It is much more noticeable during the winter months. There is nothing you can do to eliminate this interference.

When interference is due to a code station operating at or near the i-f of the receiver, or is due to image interference or to harmonics of the oscillator beating with a high-frequency station, you can use a wave trap tuned to the frequency of the interfering station to eliminate the interference. Many sets have a built-in wave-trap circuit.

INTERMITTENT RECEPTION

When a complaint exists for a short period of time and then corrects itself, you have the trouble known as *intermittent reception.* As one example, a tube filament can break in such a way that it opens after being heated for a short period of time, causing a dead receiver, but makes contact after the filament has cooled off. Reception is thus alternately good and bad, with the cycle repeating itself at regular intervals.

This condition occurs on *all* signals, local as well as distant. If *only* the signals from distant stations fade in and out, but local stations are received normally, then you do NOT have a receiver defect. Fading only on distant signals is due to natural atmospheric conditions, and there is no way of controlling it. You may have to explain this to your customer.

A break in a connecting wire inside or outside a part can cause intermittent reception. For example, the internal connection between the pigtail leads and the metal foil of a paper capacitor may break due to a strain during assembly of the capacitor or during the wiring of the receiver. The break may be such that any vibration or heat in the chassis will cause a temporary open circuit. A loud portion of a program from the loudspeaker may break the connection; then if you jar the cabinet, you may cause it to make contact again. Heat may likewise intermittently make and break such a defective contact.

In addition to being intermittently dead, the set may intermittently have any of the other receiver complaints, depending upon the location of the defect. Thus, if the capacitor in question happens to be a screen-grid bypass capacitor, the break will normally cause intermittent *oscillation.* If the capacitor is a plate-grid coupling capacitor in an audio amplifier, the complaint could be intermittent *weak reception* or *dead reception* during those intervals when the capacitor is open.

In the customer's home, all you should do is confirm the customer's complaint that an intermittent exists, and get as detailed a description as possible of the exact nature of the trouble during the defective operation. It is well to do this, because the intermittent defect may not appear immediately when you turn on the receiver and check its performance. Find out whether the trouble is intermittent dead reception, intermittent hum, intermittent oscillation, etc. Knowing which one it is, you can localize your search to the defects that will produce the type of complaint observed.

Another valuable clue to an intermittent defect is the rate at which the set becomes defective and the regularity of the trouble, so be sure to ask the customer how often the trouble occurs. Intermittent troubles that occur at a more or less regular rate are due to heat, whereas troubles that occur at irregular intervals are due to vibration of poor connections.

In general, if an intermittent trouble does not reveal itself in ten or fifteen minutes while you are in the customer's home, it is best to check over the antenna, ground, and power cord systems to clear them of suspicion; then remove the chassis and take it to your shop for further observation.

Basic Defects in Radio Receivers

A radio receiver is essentially an electrical assembly of tubes, resistors, capacitors, coils, transformers, a loudspeaker, switches, and connecting wires.

To emphasize the large number of parts which make up an average radio receiver, we counted the connections in a typical modern ac-dc superheterodyne. (We used the Motorola Model 52X13U.) We found a total of 100 connections.

A defect in any one of the parts or connections can produce one or more of the receiver complaints you have just studied. Furthermore, this total is by no means a complete indication of the number of defects we can have in an average receiver. In a typical pentode tube, for example, there is a possibility of over two dozen defects. Resistors and capacitors can also cause a wide variety of troubles.

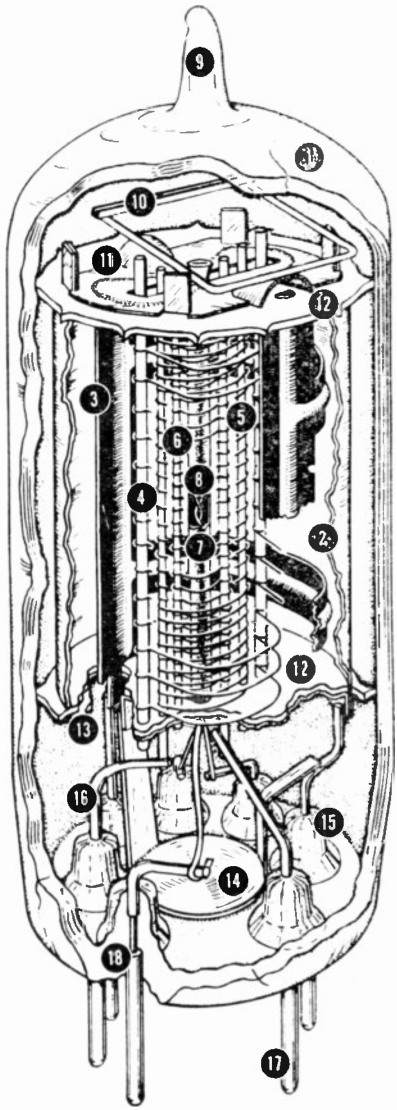
In order to get a better over-all picture of the problems in radio servicing, let us now consider in detail the various kinds of defects that can happen to each type of radio part. We need not consider mechanical defects like broken or crushed parts, since they can be spotted readily during the initial surface inspection of the receiver for obvious defects.

TUBE DEFECTS

A tube tester is an indispensable instrument for any service shop where a customer may bring tubes in to be tested. The serviceman uses the tube tester as a merchandising aid to help sell tubes. The bulk of a radio serviceman's profits, however, come from his labor charges and not from his discount on the new parts he may install. For this reason, a serviceman with a small business, who does not have a store, often will not get a tube tester until his business has increased. He will carry enough tubes on each service call so that he can substitute new ones in the set for those he suspects are bad.

Substitution is the best way to test a tube. A tube may test "good" in a tube tester, and yet not perform satisfactorily in every circuit in which it may be used. Mutual conductance tube testers are better in this respect than the more widely used emission testers, but there are troubles in tubes that will escape even the mutual conductance tube tester. In TV work, tubes are tested almost entirely by the substitution method instead of in a tube tester. Let us take up common tube defects.

Low Emission. If the emitting coating on the cathode of a tube has been used up, the cathode will not emit a normal number of electrons, even when it is heated properly. An emission tube tester or a mutual conductance tester will readily show this defect. There are defects, however, that may be mistaken for the low emission just described. For example, if the tube has a filament defect, such as a partial short in the filament or excessive cathode-to-heater leakage, and the tube is in a circuit with a constant filament current (an ac-dc filament string), the cathode temperature will not reach the normal operating value. Because of the short, the voltage drop will be less than normal, but the current will be near normal. The filament power will be less, so there will be less heating, and emission will be low. When the tube is tested in a tube tester, the voltage will be normal, and the current will be high. Since the filament power will be above normal, the heating and emission will be above normal if the tube does not fail because of



Courtesy RCA

The structure of a miniature tube. 1—glass envelope; 2—internal shield; 3—plate; 4—suppressor grid; 5—screen grid; 6—control grid; 7—cathode; 8—heater; 9—exhaust tip; 10—getter; 11—spacer shield header; 12—insulating spacer; 13—spacer shield; 14—inter-pin shield; 15—glass button-stem seal; 16—lead wire; 17—base pin; 18—glass-to-metal seal.

excess current. Therefore, the meter on the tester will probably read well up into the "good" section. As you will learn later, a tube with this defect can be spotted in an ac-dc receiver by measuring the voltage drops across each tube filament.

Open Elements. Some types of tube testers will reveal open elements, but this defect can also be identified readily by the action of the circuit.

An open filament is readily detected because the tube will feel cold when touched, and there will be no filament glow. It is always wise, however, to check the tube in a tube tester, too, because an open in the socket or in a filament lead can cause the same symptoms.

Shorted Electrodes. These are readily detected with a tube tester, by circuit action, by continuity tests with an ohmmeter, or by voltmeter tests.

Leakage Between Electrodes. Cathode-to-heater leakage often occurs in heater-type tubes. Most tube testers will indicate this trouble, but leakage of this type is not in itself sufficient cause to discard a tube. Cathode-to-heater leakage may do no harm when the cathode and filament are both grounded or at the same potential with respect to ground. Leakage is important only in series-string sets or when the cathode is ungrounded.

Excessive Gas. All tubes contain a certain amount of gas. The gas causes grid current to flow, but it is objectionable only in high-resistance grid circuits. You can check for excessive gas in a tube by measuring the voltage across the grid resistor. This test is valid, however, only if the preceding grid-plate coupling capacitor is not leaky; a leaky coupling capacitor will give the same type of voltage indication. You will learn how to make these tests in various types of radio receivers later. Gas is one defect not ordinarily revealed by tube testers.

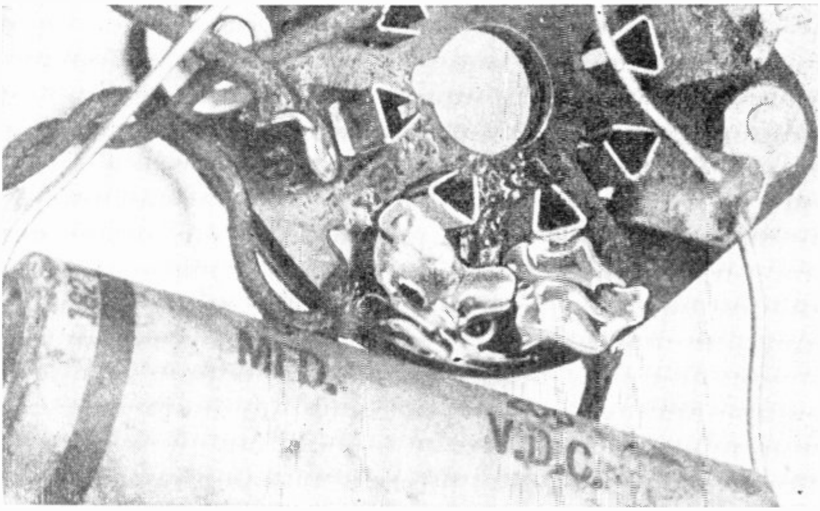
SOCKET DEFECTS

Defects in tube sockets are sometimes visible on inspection, but more often you will have to use professional servicing techniques to isolate the defect. It is important to realize that professional techniques are required to locate even simple socket defects. Let us go into some of these.

Open Prong Contacts. If a tube is repeatedly removed and reinserted into its socket, the prong contacts may spread apart so much that they no longer grip the tube prongs. Faulty material used in the construction of a socket will cause the same trouble. When the defect cannot be detected visually, make a continuity check between the bottom end of the suspected tube prong and its socket terminal.

Shorted Prong Contacts. Shorts can occur between adjacent contacts on a tube socket, particularly if a number of wires are grouped together on the contact prongs, or if there is excessive solder on the lugs. You should suspect this trouble if noise occurs when the tube is wiggled in its socket. Bend the socket terminals and rearrange the leads so that they cannot short. Also, remove all excess solder from the lugs.

Leakage. Dust, a conductive greasy film, or rosin on the surface of a tube socket will provide a leakage path between socket terminals. Leakage between any of the socket terminals



Dirt and rosin between tube socket terminals as shown here can cause leakage between the terminals. Note also that too much solder has been used.

can cause trouble, but it is most serious if leakage occurs between the grid and plate terminals. Usually you can clear up this trouble by brushing the socket with a small brush dipped in a suitable solvent. The leakage path between the high voltage plate terminal and other terminals may become so serious that the insulating material on the socket will become charred. The only remedy for charred sockets is to replace them.

Courtesy Raytheon

Transistors compared in size to an ordinary match book.

TRANSISTOR DEFECTS

Although transistors are much more rugged and last longer than tubes, they do not last indefinitely. There are transistor testers available that can be used to test transistors. These testers will detect most of the defects you are likely to find. However, an even better test is to try a new transistor in the circuit. If you have isolated a defect to a circuit using a transistor, and all the parts in the circuit besides the transistor check good, try a new transistor. If the new transistor clears up the trouble, the old one is defective and should be discarded.

Some transistors fit into sockets somewhat like small tube sockets. Defects in these sockets, similar to the defects described in the section on tube sockets, do occur, and often may lead you to suspect that the transistor is defective. Do not overlook the possibility that a socket defect could be causing the trouble.

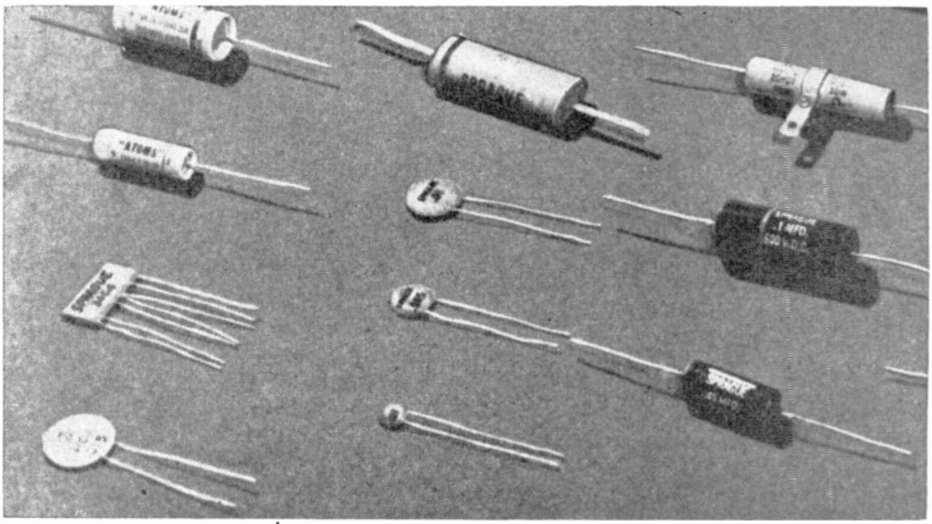
Many transistors are soldered directly into the circuit. When replacing one of these transistors, avoid heating the transistor excessively; you may damage it. Use a small pencil-type soldering iron when replacing transistors. Also, hold the transistor lead you are soldering with your long-nose pliers, between the transistor and the point where you are soldering the lead into the circuit. The long-nose pliers will carry away most of the heat that might otherwise reach the transistor and damage it.

DEFECTS IN PAPER, MICA, AND CERAMIC CAPACITORS

The method used to test a capacitor depends on the nature of its defect and on its capacity value.

Shorts. A short can occur in a capacitor if a surge voltage punctures the dielectric, allowing the metal foil on each side of the dielectric to make contact. An ohmmeter will always reveal shorts in capacitors. It is usually best to unsolder one capacitor lead when making an ohmmeter test to prevent resistance paths in the circuit from causing misleading meter readings. Voltage measurements also can reveal short circuits and leakage in capacitors.

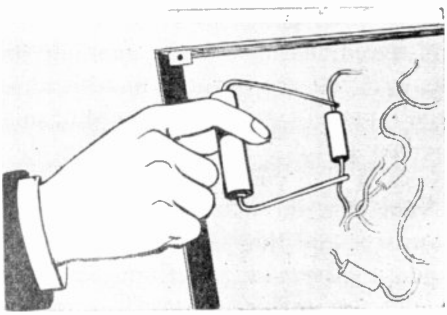
Leakage. If the resistance between the terminals of a capacitor is greatly lowered, current can "leak" through the capacitor. This lowered resistance may be the result of internal deterioration of the dielectric, or of an ac-



Courtesy Sprague Elec. Co.

Several typical capacitor types are shown above.

cumulation of conductive dirt on the surface of the capacitor between the terminal leads. As with the shorts test just described, one capacitor lead must usually be disconnected in order to make the leakage-resistance test with an ohmmeter. The leakage-resistance value may be hidden by the resistance value of parts usually shunted across the capacitors.



The best way to test a capacitor for an open is to bridge another known to be good across it, as shown here.

A small amount of capacitor leakage is unimportant in many radio and television receiver circuits. An alert serviceman will recognize these, and will not waste time making leakage tests. For example, leakage in a capacitor shunted across a cathode resistor is relatively unimportant. A small amount of leakage in a grid-plate coupling capacitor, on the other hand, can cause distortion and other troubles. A properly trained radio serviceman never makes unnecessary tests.

Opens. Both paper and mica capacitors are apt to open, particularly at the point where the pigtail leads are bonded to the metal foil inside the housing. Fortunately, opens are rare in ceramic capacitors. The most practical test for open bypass capacitors is simply to shunt each suspected capacitor in turn with a good one of approximately the same capacity while the set is in operation.

An ohmmeter test for open capacitors is not very satisfactory, especially for a small capacitor, which will not hold a charge even when it is good, although an ohmmeter could be used to check a large capacitor for an open. If an ohmmeter is used, the capacitor should be disconnected from the circuit. If it is not open, you will notice a momentary deflection of the meter pointer. The amount of deflection depends on the ohmmeter range you use, the size of the battery in the ohmmeter, and the value of the capacitor. Only capacitors above .05 mfd give a noticeable deflection; smaller capacitors cannot be checked in this way at all. Shunting a suspected capacitor with one known to be in good condition is the best test for open capacitors.

An open can often be detected by wiggling each capacitor in turn while the receiver is operating; noise will occur when the defective capacitor is touched. A capacity test in a capacitor tester will reveal an open in the part.

DEFECTS IN ELECTROLYTICS

You will have to replace electrolytic capacitors more often than any other type of capacitor in radio and TV equipment. Wet electrolytic capacitors become ineffective when not used for a long period of time. Modern dry electrolytics are much better in this respect. They ordinarily give long life if they are not overloaded by excessive voltage and not dried out by excessive heat. Nevertheless, voltage surges and unusual climatic conditions can cause dry electrolytics to become defective.

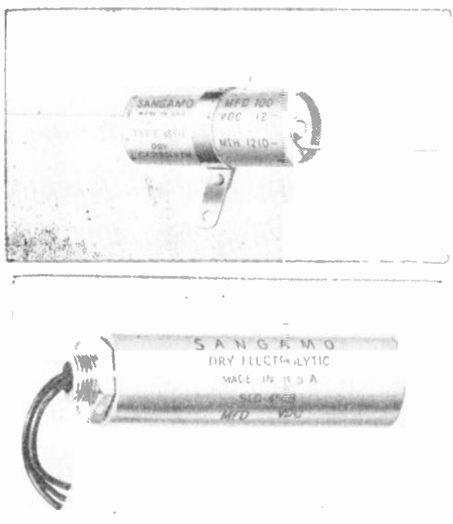
Opens. Opens are rare in electrolytics, but corrosion can cause high resistance joints to occur internally at the junction between the foil strips and the contact lugs or terminal leads. The most practical way to check this is to shunt a good capacitor across the suspected one.

Shorts. A short will occur in an electrolytic capacitor if an excessive voltage is applied, or if voltage of the incorrect polarity is applied for any length of time. In a wet electrolytic, the short will probably heal, but in dry electrolytics, the part will have to be replaced. An ohmmeter will reveal shorts.

Leakage. All electrolytic capacitors have a certain amount of leakage, which is equivalent to a resistance shunted across the capacitor terminals. The leakage resistance can be measured with an ohmmeter and its value will depend upon the polarity of the ohmmeter connection. The leakage resistance will be larger when the positive terminal of the capacitor is connected to the positive terminal of the voltage source in the ohmmeter. This is the correct connection to make when checking the leakage in an electrolytic. However, be sure to discharge the capacitor by shorting its terminals before reversing the ohmmeter leads.

An ohmmeter test gives only a general check-up on the condition of an electrolytic capacitor. You can get more complete information with a capacitor tester, or by a simple substitution test. If connecting a good electrolytic in place of the suspected one clears up the trouble, you can be sure you have found the defect.

Poor Power Factor. A perfect ca-



Courtesy Sangamo

Two types of dry electrolytic capacitors. The one shown above is a single-section unit; the one shown below has two sections.

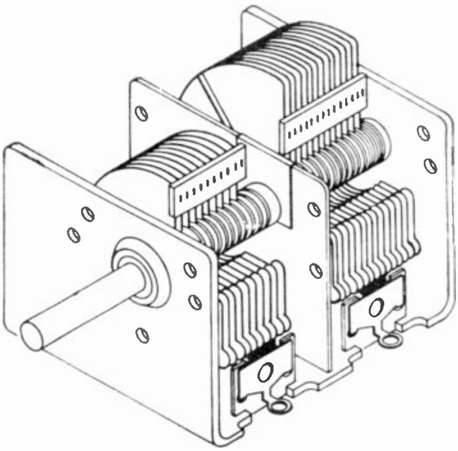
pacitor would theoretically have a power factor rating of zero. When a capacitor develops a high power factor, it is the same as if a resistor were installed in parallel with it. Thus, a capacitor with a high power factor (approaching the characteristics of a resistor) dissipates energy just as a resistor does, and this produces heat in the capacitor. The heat causes evaporation of the solution or chemical paste in the electrolytic capacitor, raising the power factor still more, and eventually drying out the unit entirely.

A capacitor that feels hot is definitely drying out and has a high power factor. It should be replaced, because it will break down in a short time.

If you have no further trouble when you substitute a good electrolytic capacitor, you have identified the original capacitor as defective.

TUNING CAPACITOR DEFECTS

Gang tuning capacitors are particularly susceptible to mechanical damage, because they are usually entirely exposed and have moving parts. The following are some of the defects that can occur in them.



Courtesy Insuline Corp. of America
A tuning capacitor. They are particularly susceptible to mechanical damage.

Opens. The mechanical construction of a tuning capacitor is such that an open in its circuit is extremely unlikely. If an open does occur, it will be at the terminals, and you can easily repair it by resoldering the connection. Continuity tests between the connecting leads and the rotor and stator sections will reveal the trouble.

Shorts. Shorts can occur between the rotor and stator sections of a tuning capacitor if mechanical strain is applied to the chassis, if the frame or plates of the capacitor become warped, if the mounting screws become loose, if the chassis is accidentally dropped, or if the tuning capacitor is tampered with. You can usually identify such a condition by a scraping sound heard when the tuning knob is rotated. When testing for shorts or leakage with an ohmmeter, temporarily disconnect the coil associated with the gang tuning capacitor if it is connected between the rotor and stator sections. Shorts usually occur over the middle of the movable range. Be particularly on the lookout for bent plates in the outside rotor section, especially if the plates have split segments that can be individually bent for alignment.

Leakage. You can use the high-resistance range of an ohmmeter to detect leakage in gang tuning capacitors. One common cause of leakage is dust between the rotor and stator plates and on the insulating sections of the unit. The dust can be blown out or wiped out with a pipe cleaner of the type obtainable at any tobacco store.

Poor Contacts. Any resistance at the wiping contacts in the gang tuning capacitor or in the stator mounting screws is rather difficult to measure with ordinary test equipment. A resistance of only one ohm can cause trouble here. Poor wiping contacts in the rotor section is a frequent cause of low sensitivity and poor selectivity, and it can also cause rf oscillation, if the set uses a stage of radio frequency amplification. These symptoms are a direct clue to poor rotor contacts in many cases.

TRIMMER DEFECTS

Both the air-dielectric and mica-dielectric types of trimmer capacitors are reasonably free of trouble. They very rarely become open, shorted, or leaky. If defects do occur, they can be tested like any other variable capacitor.

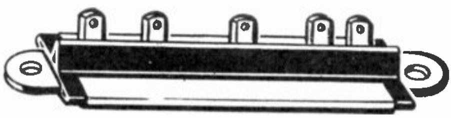
The mica type is subject to capacity changes as a result of changes in temperature or normal aging, but this is usually easy to recognize because it affects the alignment of the receiver. The mica dielectric can crack or flake, causing changes in the capacity and eventual shorting between the plates. A change in capacity is one defect that cannot be located by simple meter tests; you must be able to recognize the effects of capacity changes on receiver performance.

FIXED RESISTOR DEFECTS

As a general rule, low-wattage resistors (ranging from .1 watt to 2 watts) are of the carbon or metallized type. Higher wattage resistors are wire-wound, and often covered with a ceramic cement. You will occasionally find small 1-watt and 2-watt wire-wound resistors molded in a Bakelite housing, which resembles that used on some carbon resistors. These wire-wound units, however, will rarely have more than about 5000 ohms resistance.

Resistors that crack or break in any way can usually be spotted visually. Therefore, we will concentrate here on defects that can be located only by tests.

Opens. When a resistor is overloaded due to excess current flow



A "Candohm" resistor. In this type of resistor, you may find shorts to the metal case.

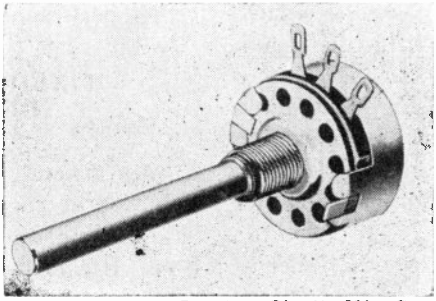
through it, the resistance material may burn out or the resistor may open at the point where the wire lead makes contact with the resistance material. You can check for opens in resistors with an ohmmeter.

Shorts. A direct short between the two terminals of a resistor is not common. However, it is entirely possible for resistor leads to touch each other, the chassis, or other parts, and give the same shorting effect. Also, resistors encased in metal can short to the metal case. A short in a resistor can be located with an ohmmeter.

Changes in Resistance. Carbon resistors are particularly susceptible to changes in resistance; wire-wound resistors rarely change. If a carbon resistor is overloaded or operated at its normal temperature for a long time, its resistance will decrease, which increases the current flow through the resistor, and overloads it still more. You can check the resistance value with an ohmmeter. Remember, however, that carbon resistors are generally used at points where a wide variation in resistance value is acceptable, or where the resistor is operated well under its rated wattage. In many receiver circuits, variations as great as 20% in resistance value are permissible.

VARIABLE RESISTOR DEFECTS

Variable resistors and potentiometers are far more subject to trouble than are fixed resistors. Since they are mechanical in operation, the moving parts will wear. You can easily locate the defect because noise or intermittent reception will occur when you rotate the control knob. An open volume control will not permit proper control of the receiver volume even though it may permit partial transfer of the signal.



Courtesy Ohmite Mfg. Co.

A typical volume control potentiometer.

Opens. In both carbon and wire-wound controls, the movement of the contact arm over the resistance element may eventually wear away the metallic or carbon deposit, or wear down the nichrome resistance wire, and create an open. Loss of spring tension in the movable arm may also cause an intermittent or a complete open.

When the resistance element wears away, the control may not be able to dissipate enough heat. In fact, a current-carrying control unit may be overloaded by normal current or momentary excessive current after it has worn down. This can cause the resistance element to burn out and cause the control to open. When the defect is not visible, an ohmmeter check will isolate the trouble.

Shorts. As with fixed resistors, shorts are not common in variable resistors and potentiometers. However, if the metal case of the variable resistor or potentiometer is "hot" and an insulating bushing is used between the chassis and the mounting bushing of the control, a defective insulating washer or bushing will often create a short to the chassis. To locate a defect of this type, you usually have to unsolder all the leads, and test between each terminal of the control and chassis with an ohmmeter.

Change in Resistance. When the carbon or metallized material in a variable resistor or potentiometer wears off, the total resistance of the control increases. In most circuits where potentiometers are used, the resistance value of the control can vary over a wide range without affecting the circuit operation. A worn resistance element will produce noise when the control is rotated. Therefore, if noise is produced in the loudspeaker when you manipulate the control, or if you are not able to control the volume or tone with the control, you know that the potentiometer is defective.

AIR-CORE COIL DEFECTS

Here we are concerned with air-core rf transformers, i-f transformers, and rf chokes. The coils on these devices consist merely of copper wire and insulation, but several types of defects can develop in them.

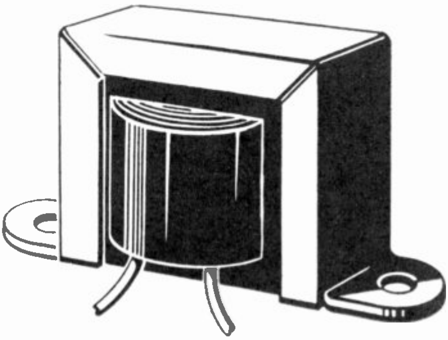
Lowered Q Factor. A coil that becomes damp or coated with conductive dirt will develop high rf resistance, which has the effect of lowering the Q factor. This, in turn, affects the operating characteristics of the stage in which the coil is used. For example, a lowered Q factor in an rf coil can cause poor sensitivity or poor selectivity even in a properly aligned stage and can cause low output in an oscillator stage. The Q factor of a coil can be measured with a Q meter, but this information will be of no value unless you know what the normal Q factor and the permissible tolerance in Q factor should be.

You can isolate the trouble to a coil having lowered Q factor by inspecting the coil and by adjusting the resonant circuit trimmers. The trimmer adjustments will be sharp for a high Q coil, but quite broad for a low Q coil. Experience in evaluating receiver performance and adjusting tuned circuits will help you to decide when a coil should be replaced because of lowered Q factor.

Shorted Turns. These may develop in all coils, particularly those with special diamond, basket, or bank weaves to form the windings. If a great many turns are shorted out, these may be enough change in coil resistance so that an ohmmeter reading compared with the original resistance given on the schematic will indicate the short. Otherwise, the action of the circuit is the only clue to the trouble. For example, if an rf coil used in a resonant circuit has several shorted turns, more capacity will be needed to align the receiver, and both the sensitivity and the selectivity will be poor even after alignment.

Adjacent coils may also touch each other, particularly when wound close together or one over the other. Here an ohmmeter test from one coil to the other will verify the trouble.

Opens. The windings in a tightly wound coil may break from expansion due to increased temperature, especially at points where the wire passes through the coil form or connects to a terminal. More often, however, corrosion at a terminal will create a high-resistance joint. In a primary coil that carries the plate current of a tube, the direct current flow may start electrolysis, which will cause a joint to corrode and eventually open. Noise will be the first symptom of this condition. An ohmmeter test will indicate above-normal coil resistance and high resistance due to corrosion at joints.



An iron-core filter choke.

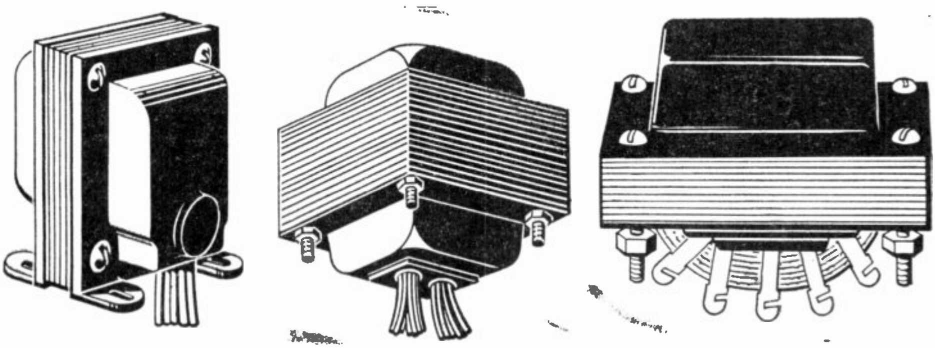
IRON-CORE COIL DEFECTS

Since iron-core coils are used chiefly in audio frequency and power frequency circuits, you will not be concerned with changes in Q factor. Actual mechanical defects in the coil windings or failure of the insulation between the windings are the two chief problems here.

Opens. Opens in iron-core coils can be readily detected with an ohmmeter. They can be caused by electrolysis at the terminals of a filter choke if fairly high currents are flowing through joints formed by dissimilar metals. Of course, a sudden voltage surge or continued overloading of a coil by excessive current may melt the wire and cause an open.

Shorts. Shorts between turns due to failure of the insulation are not readily detected with an ohmmeter. However, you can usually detect shorts between layers of windings because there will be a greater change in the coil resistance.

You can easily locate shorts in iron-core coils by their effect on receiver operation. For example, if there is a short in a choke coil, normal current flow through the coil will cause a lower ac voltage drop across the coil, and hum will also be heard in the receiver output. If a short occurs in a power transformer (found in TV sets,



Power transformers with three different types of mountings.

high fidelity equipment, and in many older radios) the transformer will overheat, the insulation will become charred, smoke will be produced from the transformer, and the output voltage will be lower than normal. These same effects will appear when turns are shorted to a grounded iron core and the transformer circuit is grounded at some other point. You can find a short between the transformer winding and the core with an ohmmeter.

In an iron-core transformer an odor of burned insulation and a charred appearance is always an indication of a defect. It is normal for a transformer that is handling power to become hot when in operation. Therefore, if the transformer in a receiver is hot to the touch, it does not mean that it is defective. The exact amount of heat produced by the transformer varies with different manufacturers and with different transformer uses. Some transformers will operate quite cool, while others are designed to operate at the heat limits set by the Board of Fire Underwriters.

To check a power transformer for shorts, remove all the tubes from their sockets. If the smoking and overheating stops when all tubes are removed, there is a shorted filter capacitor drawing excessive current, or there is a shorted tube or some other short to ground in the plate or screen supply circuit. If smoking continues even with the tubes removed, the transformer is probably defective, or there is a short in the rectifier tube socket or the transformer leads.

LOUDSPEAKER DEFECTS

Loudspeakers are subject to normal wear and aging because the voice coil-cone assembly is continually moving during operation. Once you isolate a defect to the loudspeaker, you have the following possibilities to contend with:

Weak Flux. An open can occur in the field coil of an electrodynamic loudspeaker due to corrosion, electrolysis, or overloading. If the field coil is also serving as the filter choke, as is often the case, the receiver will be dead. If there is a separate filter choke, there may be enough residual magnetism in the iron core of the loudspeaker to permit operation, but the sounds will be weak and generally distorted. A simple ohmmeter check will reveal an open field coil. Although the electrodynamic speaker was widely used for years, its use in new equipment is almost totally confined to auto radios. In these sets, the field is never used as a choke coil in the B supply.

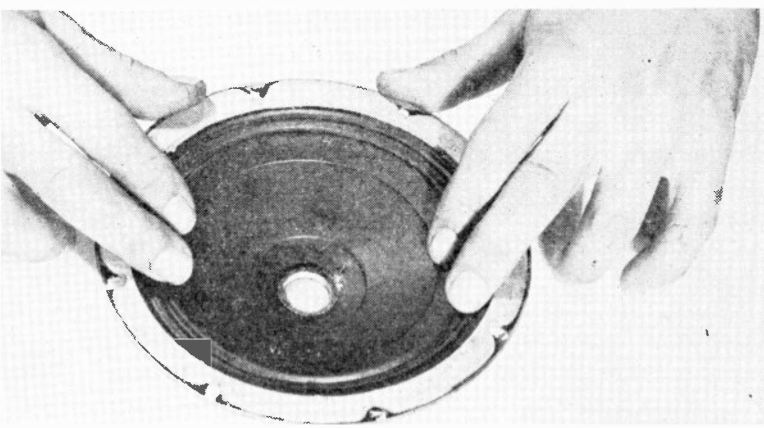
Weak and distorted reception will also occur in the permanent magnet of a PM dynamic loudspeaker when it loses its magnetism. You must remember, however, that there are many other possible defects in a receiver that can produce these same symptoms. The defect should be definitely isolated to the loudspeaker before you make extensive tests on the loudspeaker.

Open Voice Coil. The voice coil of a loudspeaker may open at one of its joints or in the flexible leads that connect it to the output transformer secondary. Although these leads are extremely flexible, they sometimes break because they are connected between the fixed terminals on the loudspeaker frame and the rapidly moving terminals on the voice coil. An ohmmeter will detect an open in the voice coil if you first disconnect one voice coil lead from the output transformer.

Grounds. A ground can occur in the field coil, the voice coil, or in the hum-bucking coil of a loudspeaker. You can find this defect easily by measuring with an ohmmeter between the suspected coil and the frame of the loudspeaker.

Defective Spider. The flexible material of the spider may become brittle and crack, or may lose its elasticity. When the condition is serious, the symptoms will be a peculiar type of distortion. You can usually look at the spider and see the defect.

Sometimes the spider will become loose at the point where it is glued to the cone, causing raspy sounds. You may be able to reglue the spider with cone cement. Loose dust caps in the center of the cone will also cause the same trouble. If the spider becomes unglued from the speaker frame, you will hear a popping sound on loud bass



You can test for a rubbing voice coil by pushing the speaker cone in and out with your fingers as shown here, and listening for a grating sound.

notes, because the cone must move a considerable distance to reproduce the loud tones. This will also occur as you tune past stations.

Off-Center Voice Coil. As a loudspeaker ages, the parts will usually warp and shift a certain amount from their normal positions. Rough handling can also cause warping and shifting of the parts. The condition becomes serious, however, only when the voice coil rubs against the pole pieces.

Iron filings, bits of metal, or hard particles of dirt lodged between the voice coil and the center pole piece can cause the same trouble as a shifted voice coil or other shifted parts. You can detect a rubbing voice coil by pushing the cone in and out with your fingers when the receiver is turned off. The vibration due to rubbing will be transmitted to your fingers and you can hear the grating and scraping sound of the voice coil rubbing against the pole piece. The sound produced by an off-center voice coil will be distorted when the loudspeaker is reproducing low notes. There is much more voice coil movement at low frequencies than at high frequencies. Therefore, a rubbing voice coil may distort men's voices without affecting women's voices.

Cone Defects. A cone may become hard and inflexible due to aging and drying out. The fidelity of the sound produced by a loudspeaker having this defect will not be normal. Also, the outer edge of the cone, which is glued to the frame, may become loose and cause raspy, buzzing sounds and distortion at low audio frequencies. A cone may become softer than normal due to absorption of moisture, causing distortion. In a few cases, the cone may actually crack or tear. You can easily see the crack or tear in the speaker cone.

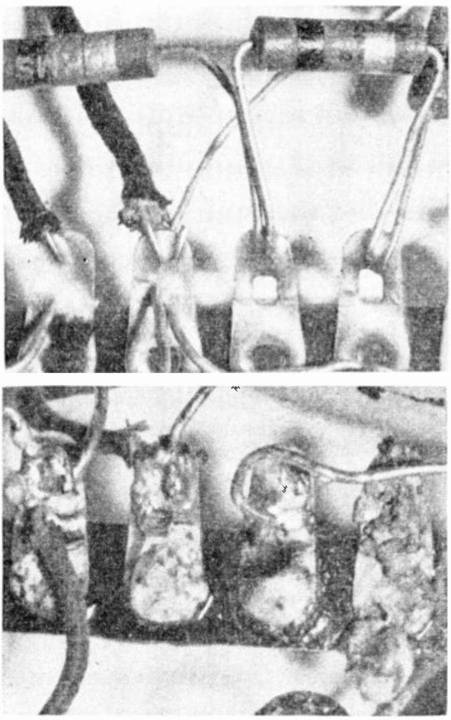
DEFECTIVE CONNECTIONS

Under this classification, we can list the hookup wire used to connect the various parts and tube sockets, the terminals on the various parts, and the tie points used for supporting small parts by their leads. A defective connection is an excellent example of a trouble that may require many minutes to locate, even with professional servicing techniques, but which ordinarily can be repaired in a few seconds.

Opens. An open at a soldered joint may be due to poor soldering at the factory. As a rule, however, soldering in factories is done by people with considerably more training in soldering techniques than the average serviceman has. Opens at soldered joints are more probable in equipment that has previously been serviced. Oftentimes a soldered joint looks good but is held together by rosin. Rosin, of course, is an insulator. Corrosion and electrolysis at joints may cause opens, partial opens, or even intermittent opens. Poor soldering occurs less often in new work in which printed circuits and dip soldering techniques are used.

To find opens in receiver wiring, you would generally check the continuity from each tube electrode to the chassis, the rectifier plate, or the rectifier cathode. You can then compare the ohmmeter readings with the resistance values indicated on the circuit diagram for that particular receiver.

When you have isolated the defective circuit, you can check the parts and connecting wires that make up the circuit by following a step-by-step ohmmeter procedure. However, the most common method that servicemen follow is to push or pull on each joint in the suspected circuit while the receiver is in operation. You can use a special tool, called a soldering aid, or a pair of insulated pliers for this purpose. When you move or jar the defective joint, there will be a noise in the receiver output. Another procedure is to heat each soldered connection with a hot soldering iron to make the solder flow freely over the entire joint. If the joint smokes excessively when you apply the hot soldering iron, you know that the joint contained an excessive amount of rosin.



An example of good soldering is shown above, and of poor soldering below. Notice the lumpy cracked appearance of the poor joints, and the smooth neat appearance of the good joints.

Shorts. Connections and bare leads sometimes short to the chassis or to an adjacent connection, particularly when the terminal lugs are close together as on tube sockets and terminal strips. When wires go through holes in the chassis, frayed insulation may allow the wires to touch the chassis and cause a short. If it is a high-voltage lead, such as the plate supply leads, you may be able to see sparks at the point of contact when you wiggle the lead.

Sometimes terminal lugs become loose or bent, or excessive solder is used in making connections at the lugs. This can result in a short circuit. Consult the circuit diagram of the receiver. If the diagram indicates that a complete circuit should be isolated from the chassis, use an ohmmeter to test between that circuit and the chassis to see whether or not a chassis short exists.

Leakage between connections is common and may cause trouble in rf circuits. This defect can usually be cleared up by drying out the moist or damp chassis. Use a fan and an electric heater to blow warm air on the parts and leads. If this procedure does not clear up the trouble, you may have to install new leads or parts.

SWITCH DEFECTS

The contacts of the various switches used in radio and television sets may corrode, causing opens or noisy partial opens. Loss of springiness in the movable contact arm can cause the same symptoms and troubles. In addition, connections to the switch terminals may be open, shorted, or partially open.

Circuit continuity tests will usually reveal switch defects quickly. It is not uncommon for a movable contact arm or a terminal lug of a switch to break off and cause an open. You can use an ohmmeter continuity test to reveal the defect.

LOCATING DEFECTS

Once the defective part in a receiver is located, anyone with a little mechanical ability and a knowledge of soldering can make the necessary replacement or repair in a few minutes. The real work of a trained radio serviceman is in locating the defective part or connection, or the cause of the trouble.

When the trouble in a receiver is simply a defective part or connection, and an unlimited time is available, a person with a little training in the use of a tube tester, an ohmmeter, or perhaps a capacitor tester can test each part and connection in the receiver until he locates the defective one. Of course, the chances are good that he will locate the defective part long before he has tested all the parts. However, even if he were able to find the part in an average of fifty tests per chassis, you can readily imagine what an enormous amount of time he would spend.

As a matter of fact, there are many servicemen without the type of professional training you are now acquiring, who actually do test various parts one after another until they find the defect. With experience, they learn that certain parts or connections should be checked first for each type of complaint. They become good at guessing defects without knowing the reasons for them. With professional servicing techniques, you can locate troubles faster than these men right from the start of your servicing career. Your techniques will work on all sets, whereas testing of individual parts will tell nothing at all about many kinds of receiver troubles.

Complete Professional Servicing Procedure

The preceding analysis of the many possible troubles that can occur in a radio receiver shows that a great many defects can be detected by checking voltages with a voltmeter or by checking continuity with an ohmmeter. Nevertheless, such random tests are highly inefficient and waste a lot of time.

The man who relies on a guess-and-try method of testing each part in turn will frequently find himself confronted with troubles that defy detection. After wasting a great deal of time in testing parts, he will be forced to resort to such simple versions of

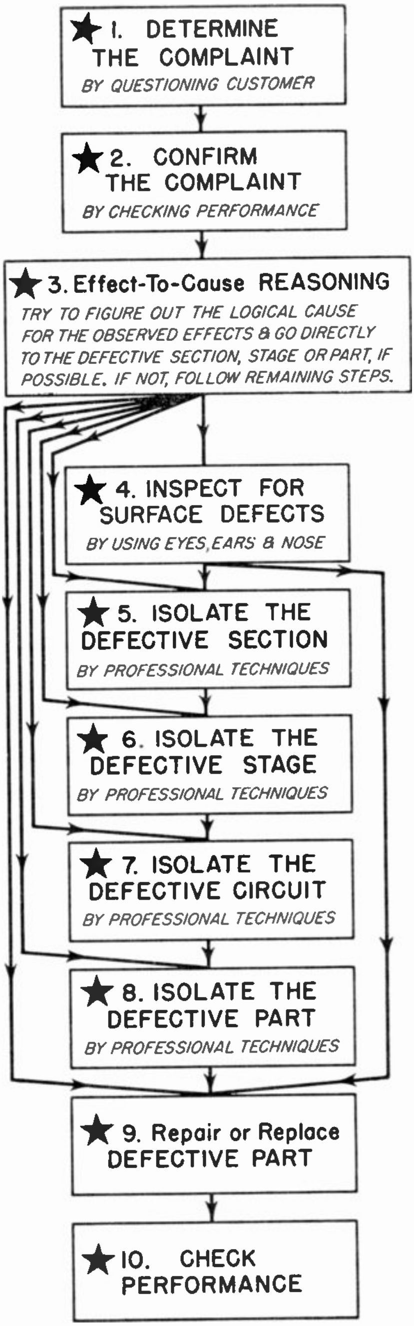


FIG. 1. The 10-step professional servicing plan.

professional servicing techniques as he is able to carry out. If given sufficient time, he may eventually be able to localize the defect, for as a last resort he can begin putting in new parts one by one until he eventually does find the trouble.

The professional servicing procedure that you will learn in this course is designed to teach you to repair receivers in the least possible time. This eliminates immediately the guess-and-try test methods, which are the chief technique of the untrained mechanic. To become a professional radio serviceman, you must master a carefully planned series of professional servicing techniques. These make use of your training, ability, and experience to find the cause of the trouble quickly.

THE TEN-STEP PLAN

A *complete* professional servicing procedure for repairing radio receivers involves a maximum of ten distinct steps, as indicated in Fig. 1. If you are successful in carrying out Step 3, however, you may be able to omit up to five of these steps. If you locate the trouble in Step 4, you will be able to omit the next four steps.

These steps are so planned that you will be led directly to the trouble in a logical, step-by-step manner. As your training continues, however, and as you gain more practical experience, you will soon find Step 3 assuming more and more importance. Thus, you will get a logical, direct approach to the trouble with a minimum of wasted time and effort. As you become more like the thoroughly trained professional, you will learn the short cuts that can be used.

Since the professional technique you want to develop involves all of these steps, let us now look into these steps in detail, to see just how they are related to each other.

1. Determine the Complaint. This has already been discussed in detail, and can be summed up here in just one sentence: *Find out exactly what the customer thinks is wrong.*

2. Confirm the Complaint. Try out the set and check its performance. The things to watch for while checking performance vary with the nature of the complaint, as you learned earlier in this lesson. In general, however, this step involves turning on the receiver, tuning to the dial settings of a few local stations and noting how they come in, then trying out the volume control, tone control, and any other controls there are.

3. Effect-to-Cause Reasoning. When a receiver becomes dead, hums, distorts, howls, oscillates, has inadequate volume, poor selectivity, poor sensitivity, or has some other symptom that you have verified by checking receiver performance, there is definitely a *cause* for the observed condition. If you can figure out what that cause is by means of reasoning, it is only logical to check the likely cause first.

Usually, however, there are several possible causes for each complaint. To use effect-to-cause reasoning efficiently, you must know when to give up checking probable causes and start the next step in the procedure. Once you begin checking every possible cause for an observed symptom, you are really resorting to the guess-and-try methods of the untrained man.

Proper use of effect-to-cause reasoning can be best explained by means of a few examples. Let us take first the case of a dead receiver. You know that a burned-out filament in a tube will ordinarily cause a dead receiver, so isn't it logical to suspect tubes when the symptom is no reception? Since you are eventually going to test the tubes in the receiver anyway, it is quite logical and permissible to test the tubes after you have made sure that the receiver is getting power and its antenna-ground system is normal. When the tubes are cleared of suspicion, however, you have before you dozens of possibilities, because a break anywhere in a signal circuit can cause a dead receiver. This is where you should give up effect-to-cause reasoning and proceed to the next step of inspecting for surface defects.

How about oscillation or howling? You know that an open plate bypass capacitor for the power output tube or an output filter capacitor with greater than normal power factor can result in oscillation. So it is entirely logical to suspect and check the various capacitors when oscillation is the symptom. This can be done quickly by the substitution method in the case of an open bypass capacitor, by placing a good capacitor of approximately the correct value across each suspected capacitor in turn while the receiver is in operation. You will have to install a good electrolytic capacitor in place of the suspected one in the case of high power factor in the output filter. If none of these tests restore normal performance, however, and there are no associated symptoms to limit the trouble to a particular section, your next move should be an inspection for surface defects.

A leaky input filter capacitor will cause weak reception, possible hum, overloading and perhaps damage to the rectifier. Therefore, if you observe all these symptoms, you would correctly question the input filter capacitor. If it is leaking sufficiently to draw excessive current, it may burn out the filament tap on the rectifier as well as the pilot lamp, depending of course on the particular circuit used. If a power transformer is used, the rectifier plates may run red hot and the transformer may be damaged.

A thorough knowledge of circuit actions thus makes it possible at times to analyze a number of observed symptoms and reason out the exact location of the defect. It is unnecessary to memorize long lists of symptoms and possible defects when you are able to figure things out for yourself like this.

In general, when there is only a single symptom, it is good practice to check first for common causes of that particular trouble. For example, if the symptom is hum, it would be wise to check the electrolytic filter capacitors and to check for cathode-to-heater leakage in the signal circuit tubes. If a selenium rectifier is used in the receiver, make a mental note to try a new one if the capacitors and tubes prove to be in good condition.

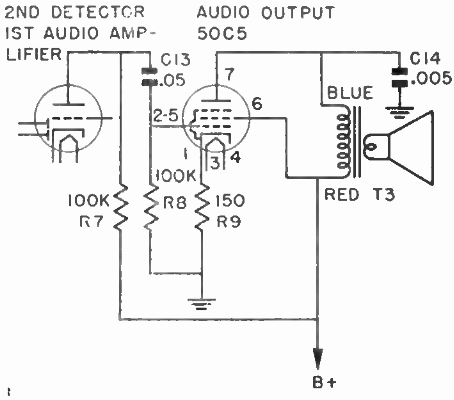
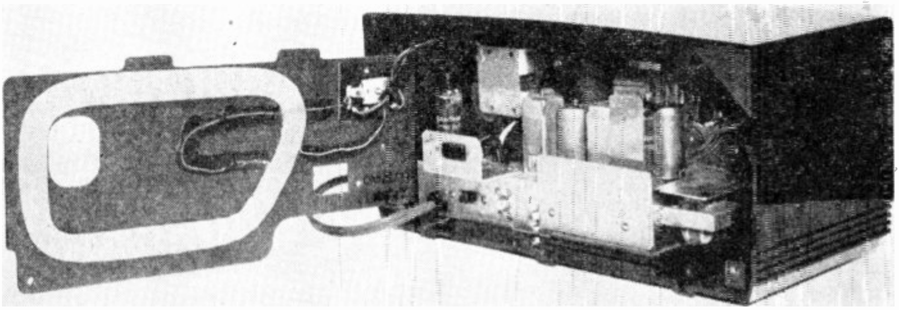


FIG. 2. The audio output stage of a typical ac-dc receiver.

If distortion is the only complaint, and you are convinced that it is not due to a loudspeaker defect, check for leakage in the grid-plate coupling capacitor in the audio stage before proceeding to the isolation tests. The audio output stage of a typical ac-dc receiver is shown in Fig. 2. If the .05-mfd coupling capacitor, C13, is leaky, it will produce a positive bias on the grid of the audio amplifier stage, thereby causing distortion. Excessive gas in the output tube will also cause the same type of distortion and the same voltmeter indication across the grid resistor R8.

4. Inspect for Surface Defects. Before going into the chassis, you



A typical ac-dc radio with the back removed to inspect for surface defects.

should inspect the top of the chassis for surface defects, such as tube burned out or out of its socket, the line cord plug out of the wall outlet, the loop antenna disconnected or unplugged, etc. This inspection may precede effect-to-cause reasoning, become a part of this step, or follow it, depending on the complaint. It may even become a part of the second step, because you may confirm the complaint by seeing if the tubes light or get warm, sniff for odors indicating overloaded parts, and listen for noises as you rotate controls while trying the set.

The nature of the trouble, together with effect-to-cause reasoning, will suggest possible surface troubles to look for. If the set plays but is noisy and the tubes are not dead, there is probably a loose connection or intermittent shorts somewhere in the wiring. Thus, this step may be a part of the effect-to-cause reasoning process.

Finally, if effect-to-cause reasoning does not suggest anything, it is still desirable to spend a minute or two looking over the surface of the set. However, don't waste time; learn to go over the surface of the set with a quick glance. If you don't see anything wrong, go on to the isolating steps immediately.

5. Isolate the Defective Section. A single test, often without instruments, will in many cases enable you to localize the trouble to a defective section.

If the receiver is dead, but all the tubes light up, the next logical step is to use an isolating technique to determine which section of the receiver (power supply, af amplifier, rf amplifier, i-f amplifier, or local oscillator) is defective. In later lessons, you'll learn exactly how to do this.

6. Isolate the Defective Stage. By using appropriate techniques given later, you localize the trouble to a defective stage in the defective section.

7. Isolate the Defective Circuit. Once the defective stage is isolated, you can usually make a few simple circuit-continuity tests for dc electrode voltage measurements to localize the trouble to a particular tube circuit in the defective stage (to the grid circuit, plate circuit, screen-grid circuit, or suppressor grid circuit). This eliminates quite a few parts from your list of suspects for the next step.

8. Isolate the Defective Part. Using either an ohmmeter or a dc voltmeter, you make tests in the suspected defective circuit (or the suspected stage if circuit-isolating techniques cannot be applied) until you have tracked down the defective part. This should not be a haphazard task, however, for a rational step-by-step procedure will save time.

A logical, general procedure for locating the defective part in the defective stage or circuit involves first checking the tube, if it has not already been checked. Next comes the check of the tube electrode supply circuits, either with a dc voltmeter or with an ohmmeter used with all power turned off.

Check the electrode voltages with respect to B- or chassis, after making sure that the main plate supply voltage to the stage is correct. If there is no voltage at a tube electrode, connect one probe to the chassis or B- and move the other probe along the supply circuit, part by part, until you reach a point where you measure the normal voltage. By proper interpretation of the voltage readings, you can easily detect shorts or grounds. By watching the meter pointer, you can also localize noisy connections and noisy parts.

It is not always possible to locate a defect by means of dc voltage measurements. For instance, a defect in a signal circuit that is not carrying direct current would not be revealed by a dc voltage measurement. Coil defects, tuning capacitor defects, and certain grid circuit defects are examples. Grid bias voltages in high-resistance grid circuits can be measured accurately only with extremely high-resistance vacuum tube voltmeters, and these are not always available. For these reasons, some servicemen prefer to use continuity tests for locating the defect in a stage. Continuity tests with an ohmmeter can be used to supplement dc voltmeter tests or can be used exclusively. It is a matter of personal preference in some cases, and a necessity forced by instrument limitations in others.

Continuity tests with a multi-stage ohmmeter are made with the receiver turned off and with the power plug removed from the wall outlet. Continuity is checked first from each tube electrode (at the tube socket terminals) to some reference point, such as the rectifier cathode or to the chassis or B- as the case may be, to establish existence of continuity in complete supply circuits.

An infinitely high ohmmeter reading for any particular step indicates an open circuit. To find which part in the circuit is actually open, you can move the ohmmeter probes along and check each part, or you can check small groups of the parts, or you can leave one ohmmeter probe at one end of the circuit and move the other one back along the circuit, including fewer and fewer parts between the probes until you find the open.

This procedure will also detect shorts when there is a large change in resistance due to the short, as compared to the total resistance being measured. If you had a 20-ohm coil in series with a 100,000-ohm resistor, and checked across both together, you could not tell whether the coil was shorted or not. The reading would be so little different from 100,000 ohms that you would be unable to detect the presence of the coil. A low resistance part must be checked for shorts directly across the part itself.

Of course, we are just giving the barest description of the methods used—we'll go into them in detail later.

9. Repair or Replace the Defective Part. If the defect is traced to a poor connection, the repair is a simple mechanical procedure. If the trouble is traced to misalignment, the correction of the trouble is likewise a mechanical procedure, but one requiring considerable technical knowledge and involving the use of test instruments.

When the trouble is traced to a defective part, it might seem that the simplest procedure would be to get an exact duplicate replacement from the manufacturer of the receiver or one of his distributors. But remember that thousands of different receivers and amplifiers have been built by hundreds of different manufacturers, many of whom are no longer in business. Each of these sets contains a minimum of perhaps fifty different parts. If you insisted on making exact duplicate replacements and wanted to keep on hand a stock of all parts you might need, your stock would be tremendous. On the other hand, if you carried no parts at all in your own stock, you would be ordering parts every day for service work.

Fortunately, radio and TV parts are standardized to a great extent, thus making exact duplicate replacements unnecessary in the majority of cases. Parts, such as tubes, pilot lamps, single fixed resistors, fixed capacitors of all types, and batteries, are replaceable with products of any make, provided size and electrical characteristics are suitable. When space permits, even size can be ignored. Furthermore, electrical ratings can be overlooked in many cases. For example, an rf bypass capacitor originally specified as .01 mfd can be replaced with a .1-mfd capacitor without a noticeable change in performance. Also, if the original capacitor is rated at 400 volts, you can replace it with one having a higher voltage rating, such as 600 volts.

By stocking only basic parts and by making wise substitutions instead of exact replacements, you can conduct your business with a minimum of overhead expense and a minimum of wasted time. It is a matter of good business to keep the stock of parts on hand as small as possible, because parts require a capital investment, and there is always the risk that purchased parts may never be used.

The ability to tell whether or not an exact duplicate replacement is necessary for a particular part can be acquired by experience, or can be figured out from your knowledge of how the part works in its circuit. A combination of experience and knowledge is ideal and you will soon have this combination.

Only in a few cases will it be necessary to order an exact duplicate replacement, and in these few cases the replacement part will usually be available from your local parts distributor or from a mail order supply house.

With such items as variable tuning capacitors, tuning-dial mechanisms, and rf, i-f and oscillator coils, the need for exact duplicate replacements becomes considerably more important. In some cases the mechanical construction and styling make it impossible to use universal replacement parts. In the case of air-core coils, the entire receiver design is usually based on these coils; few receivers have identical circuit design.

When exact duplicate replacement parts are not available from distributors, you can usually get parts that will work as well as the original parts from local or mail order distributors. Power transformers, loops, iron-core choke coils, and audio transformers can be replaced with universal parts having necessary adjustments to fit in most receivers. On the other hand, a missing or broken knob of an unobtainable type presents a problem that can be solved by replacing all of the knobs with a new design.

If necessary, rf coils can be replaced with standard types. The only coil that may give real trouble is the oscillator coil, because it controls the receiver dial readings. Naturally, greater care and more thought is necessary when selecting equivalent replacement parts; thorough mastery of radio fundamentals is invaluable when you must decide between universal and exact replacement parts in a particular circuit.

10. Check Performance. Try the receiver out, to make sure that all of the customer's complaints have been cleared up. It is often a good idea to let the set run for several hours (volume can be turned down for this) before making this final checkup, to see if any new troubles develop after the set is thoroughly warmed up. This is particularly desirable for sets that have not been in operation for a month or more, or when dealing with a customer who may be unreasonable regarding future troubles that are not your fault.

DISCUSSION

In a sense, locating trouble in radio receivers is similar to expert detective work. The technique to use in each case depends upon the nature of the job, your analysis of it, and the test equipment you have on hand. Each complaint calls for its own careful selection of service steps.

Noise, for instance, is a complaint for which only a limited use of effect-to-cause reasoning is justified. It is usually best to start right away on the isolating techniques that reveal the section, stage, and circuit containing the defect.

You can isolate a noisy stage without any test equipment simply by silencing each stage in turn while working from the loudspeaker towards the antenna. You can silence a stage by shunting a .25-mfd capacitor from the control grid to cathode, or in an ac set by removing its tube. If the noise stops when this is done, you know that the defect is either in that tube or in the stages ahead of the tube (towards the antenna). If the noise continues with the stage silenced, you know that the trouble is between that tube stage and the loudspeaker, or is in the power supply.

Of course, a simple isolation procedure such as this has its limitations, and requires further tests for final verification. If you have an expensive signal-tracing instrument, you can listen to the signal at each stage while working from the antenna to the loudspeaker. The first stage at which noise is heard is the one that is likely to contain the defect.

In this course you will learn still other methods of isolating the defect when the complaint is noise; some will be better for shop work where full equipment is available; others will be more suitable for work that has to be done in the customer's home with minimum equipment.

SUGGESTIONS FOR MASTERING PROFESSIONAL SERVICING TECHNIQUES

Servicing does not follow an absolutely fixed pattern. You cannot say that hum is caused only by an open filter capacitor or that distortion is caused only by a leaky coupling capacitor. These are common causes for the particular complaints. However, there are always exceptions to the general rule. To be a successful radio-TV serviceman, you must have a general approach that will localize the trouble regardless of the cause. Then, by effect-to-cause reasoning and from practical experience you can use short cuts where they are possible. You should never have to resort to the guess-and-try procedure of the inefficient, untrained serviceman.

Unlike many other skilled occupations, that of a radio-TV serviceman is a one-man job. Once a serviceman starts a job, he is in the best position

Reviewing your early lessons will help you as you go along in your course.

for completing the work. No one sitting on the sidelines can give definite advice unless the serviceman can state clearly the exact trouble, all the symptoms, and all the results of his measurements. Even then, an adviser can only suggest more likely sources of trouble, and more efficient isolating techniques.

In order to become an expert professional serviceman, you must know the various professional servicing techniques, you must acquire experience, and you must be able to figure out technical problems. As you proceed to master the various techniques, as given in the following lessons, you will appreciate more and more the importance of knowing the fundamentals of radio circuits.

Value of Reviewing Early Lessons. A review of previous lessons on radio-TV fundamentals at the rate of two or three lessons a month will prove highly beneficial during your study of these advanced lessons. Early lessons will have an entirely new meaning, and the fundamentals of circuits will seem far more practical now that you really recognize their value in radio servicing work.

Following the NRI Plan. Elsewhere in the course, we have given a plan for acquiring practical radio servicing experience in your own home. If you have not already carried out this plan, we strongly recommend that you give this phase of your training immediate attention, if you want to get the most out of these advanced lessons on radio servicing. Get a suitable radio receiver chassis as soon as you can, and begin to carry out on it the NRI plan for gaining the experience so necessary for efficient radio servicing.

You can also use this chassis in connection with your advanced servicing lessons; whenever you study a particular professional technique or learn about locating a particular defect, try it out on the chassis and demonstrate for yourself the relative effectiveness of the recommended procedures. Your studies will take on a new meaning when you do this, and you will have little trouble in remembering what you studied. You may not be able to test everything you study, but those tests that you do carry out will definitely prove worth while. Later on in your course you will be given a similar plan for getting practical experience in television servicing.

Lesson Questions

Be sure to number your Answer Sheet 36B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. What value is there in letting the customer describe the way in which his receiver is operating?
2. Which *section* of a radio receiver would you suspect first if the customer complained that the sound from his set was distorted at all settings of the volume control and on all stations?
3. What test procedure would you use to find a partially shorted filament in an ac-dc receiver?
4. What is the easiest way to test a bypass capacitor that you suspect is open?
5. Suppose you find that an electrolytic filter capacitor in a radio receiver is hot to the touch and that the B+ voltage is lower than normal. What would you suspect is the matter with the capacitor, and what step or steps would you take to repair the receiver?
6. Referring to the circuit diagram in Fig. 2, what is the most probable circuit defect if you can measure dc voltage between B- and the screen grid of the output tube but no voltage between B- and the plate?
7. If a radio receiver operates intermittently when the chassis is jarred, what is the probable cause of the trouble?
8. Using effect-to-cause reasoning, what defect is indicated when the sensitivity and selectivity of a receiver is poorer than normal and realigning the set does not improve its operation?
9. What part in the receiver would you suspect if low-frequency sounds, such as male voices and drums, are distorted, but high-frequency sounds, such as female voices, are reproduced faithfully?
10. Suppose you find a defective 90,000-ohm, 20% resistor in a radio receiver. Will a 100,000-ohm, 10% resistor work in its place?

Be Business-Like

No matter how much you know about the technical side of servicing, you will attain success much faster once you acquire a business-like attitude.

The first essential of a success-getting attitude is nothing more or less than *self-confidence.* You must know what to do and when to do it, and must be able to go ahead and do it.

Confidence in your own technical knowledge will come automatically soon after you complete the Course and engage in radio-TV work, because your NRI training ranks among the finest in the world.

Equally important, however, is confidence in your ability to deal with people. This type of self assurance is developed by planning your moves carefully *before* tackling a job, and by being methodical, accurate and careful. Before each interview with a customer, spend a few minutes figuring out what questions or problems might arise, and figure out your answer for each one. You will then be able to answer questions promptly *and confidently,* in a business-like manner which commands respect and inspires confidence in others. Be business-like—it pays!

HOW TO LOCATE DEFECTIVE PARTS

37B

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

Study Schedule No. 37

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. Introduction . . . . Pages 1-2

☐ 2. Effect-To-Cause Reasoning and Surface Inspection Pages 2-11

In this section you study common receiver complaints and learn what might cause them.

☐ 3. Isolating Trouble to a Section, Stage, and Part . . . . Pages 12-24

First the operation of a superheterodyne receiver is discussed, then isolation procedures of circuit disturbance, signal injection, signal tracing, and stage blocking are described.

☐ 4. Defects in the RF Section . . . . Pages 24-28

The effects of defects in the various parts in the rf section are given here.

☐ 5. Defects in the Audio Section . . . . Pages 29-32

The effects of defects in the various parts in the audio section are given here.

☐ 6. Defects in the Power Supply Section . . . . Pages 33-36

The effects of defects in the various parts in the power supply section are given here.

☐ 7. Answer Lesson Questions.

☐ 8. Start Studying the Next Lesson.

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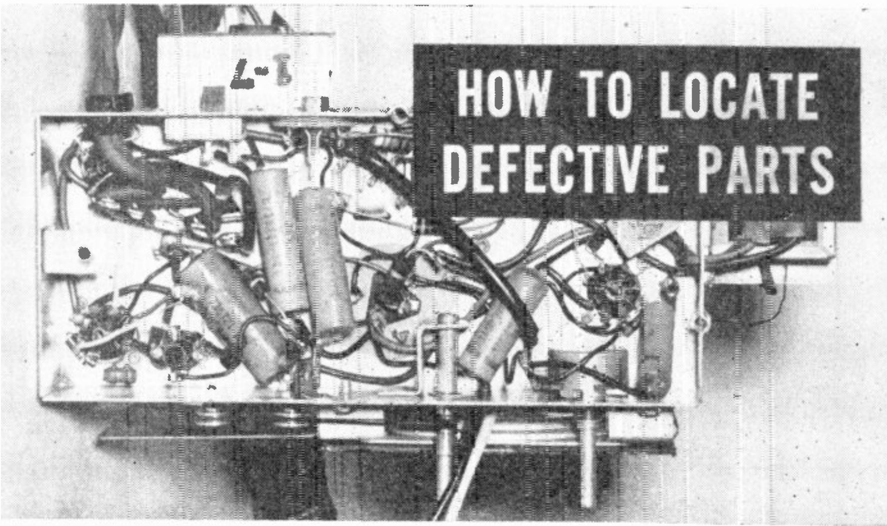
HOW TO LOCATE DEFECTIVE PARTS



A PROFESSIONAL serviceman is concerned with two vital points: first, to find what is wrong with a set he is servicing, and second, to do so as quickly as possible. There are many ways of finding a defect, but only a carefully planned procedure will lead you to it quickly and directly.

Never lose sight of the fact that a serviceman is selling time. If you can shorten the time consumed on any repair job, you can handle more jobs and have more time to plan your business and to advance yourself. It is important, therefore, that you learn the basic procedure for localizing trouble. A straightforward procedure of isolating the defective section, stage, circuit, and part, which is much faster than a guess-and-try procedure, can be followed even by a serviceman with little experience.

Before going into the procedure for isolating the defective section, stage, and part, we should complete the four preliminary steps shown in Fig. 1. These preliminary steps may lead you directly to the trouble. If they fail to do so, they will at least indicate the correct isolation procedure to follow for the particular complaint, thus making other tests unnecessary.

When you have isolated the trouble to a certain section or stage, you can usually tell by the way the set acts which part is probably causing the trouble. Even when you cannot tell which part in a section or stage is bad, you can usually make a few tests in the defective stage and quickly find the part. In making these tests, you are in effect isolating the trouble to a defective circuit in a defective stage. You are measuring the tube

Once you have found the defective part, it is a simple matter to replace it.

electrode voltages or making continuity measurements in one or more electrode circuits. The test procedures are essentially the same in each circuit, so we will not give a detailed explanation of how to carry them out. If you know how to connect the meter probes to take the measurements in one stage, you will have no trouble making the same sort of tests in other stages.

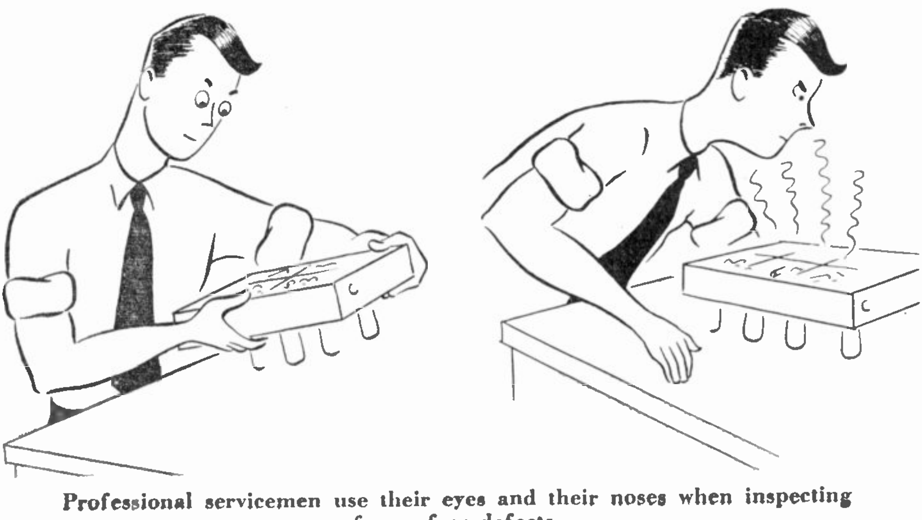
We have already covered the first two steps in another lesson, so we can now concentrate on Steps 3 and 4. In this lesson we are going to study Steps 3 and 4 together, because the inspection for surface defects often is part of the effect-to-cause reasoning process, as you will learn shortly.

Effect-to-Cause Reasoning And Surface Inspection

The first thing you should do when servicing any set is to go over the external connections and as much of the top of the chassis as possible before removing the chassis from the cabinet. However, with most receivers, you will have to remove the chassis from the cabinet before you can make a complete inspection.

Remember that you are trying to save time. Therefore, concentrate on the surface defects that could be causing the complaint, instead of making a minute examination of everything. If you do not find the trouble in a few moments, when checking for surface defects, go on to the next step in the servicing procedure.

Examining a receiver and its installation will often reveal an external defect and save the time you would otherwise spend in removing the chas-



Professional servicemen use their eyes and their noses when inspecting for surface defects.

sis from the cabinet. If the preliminary examination indicates internal trouble, however, you must proceed to localize the trouble.

Effect-to-cause reasoning is the process of reasoning from the observed effect back to its possible cause. It can save you more time than any of the other steps, if you use it properly. If you omitted this step, you could go on to the isolation procedures and would eventually find the trouble. However, a minute or two spent in diagnosing the trouble will frequently provide short-cuts around one or more of the servicing steps shown in Fig. 1. Furthermore, a little reasoning will help you choose the proper technique or test methods for each complaint.

When you start your servicing career, you will probably find that effect-to-cause reasoning does not work for you every time. Keep trying to use this step, however, because the ability to use it will come to you with experience. Also, experience will add to your store of clues; you will soon learn that there are different kinds of hum, noise, etc., each indicating a particular source of trouble.

Now, let's take up common receiver complaints, and see what might cause them.

DEAD RECEIVERS

There are so many defects that can make a receiver dead, that it is usually wiser to start right away on an isolation technique. Nevertheless, there are certain symptoms associated with a dead receiver that are worth watching for, because reasoning can often lead directly from them to the cause of the trouble.

Tubes Do Not Light. If the pilot lamp does not glow, and none of the tubes heat up, first make sure that

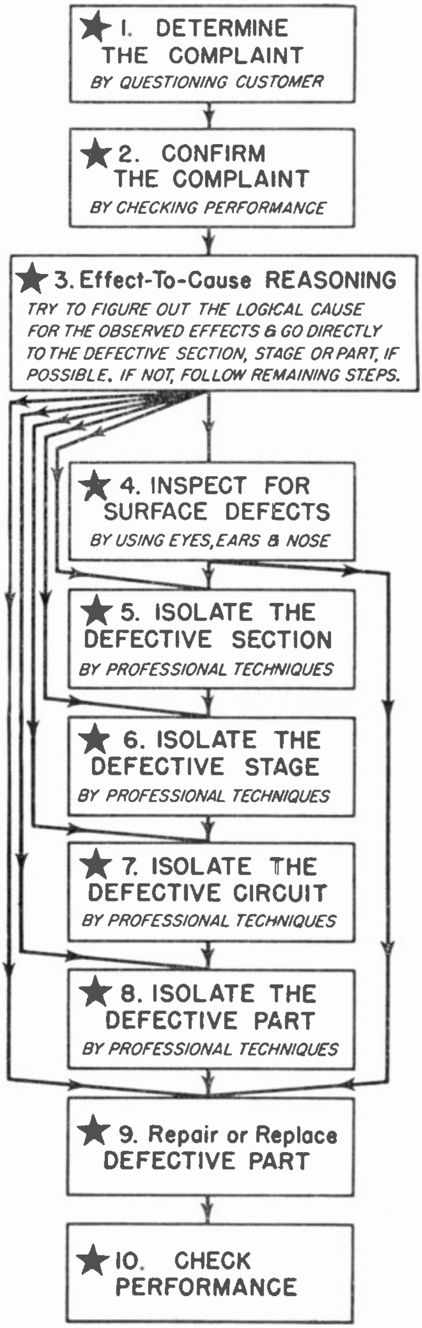
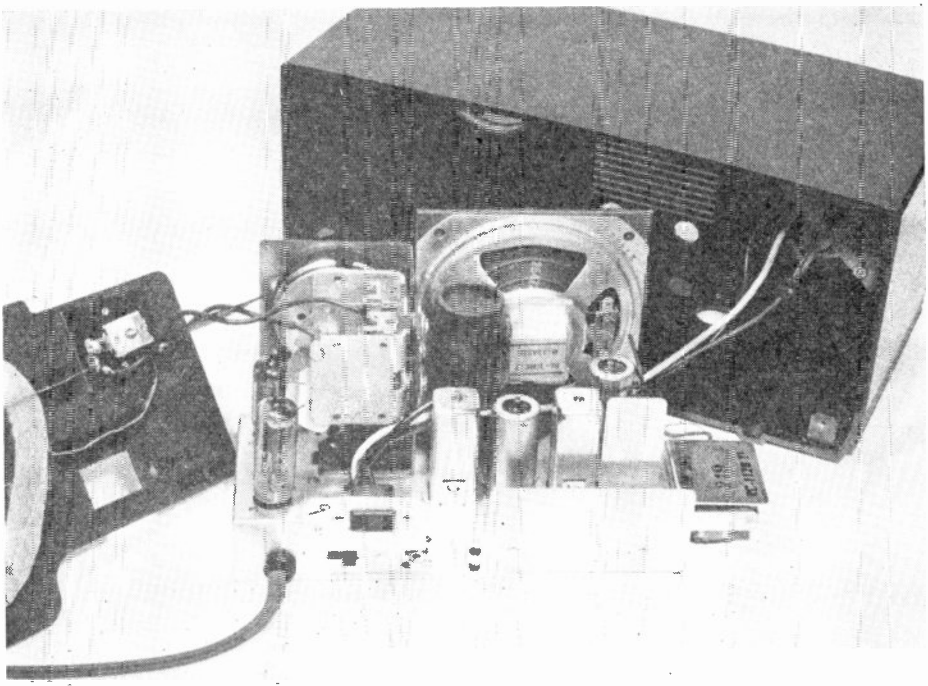


FIG. 1. The complete professional servicing procedure.



A chassis removed from the cabinet for surface inspection.

the receiver is getting power. See if the power cord plug is in the wall outlet, and inspect the plug. Hold the plug in one hand and pull on each wire. If the insulation on one lead stretches, the wire is broken. In the case of molded plugs, repairs in the plug are so difficult that it is best to install a new plug.

Be sure the power source is of the correct type for the receiver. There are still a few 110-volt dc homes in large cities, and ac receivers will not work in these; in fact, the power transformer will burn out if an ac receiver is plugged into a dc outlet. Furthermore, with universal ac-dc receivers and dc receivers, the power cord plug must be inserted with the correct polarity for satisfactory dc operation; try reversing the plug.

With battery receivers, check the condition of all batteries with the set turned on, and check all battery connections. Failure of any battery or any battery connection can definitely cause a dead receiver.

The wall outlet may be defective or it may not be getting power. If you suspect this, check the voltage at the outlet with a meter, or plug a floor lamp into the outlet. Wiggle the plug in the outlet, because it may not be making contact.

When the tubes in an ac-dc receiver do not light, and the power cord is not open, the trouble is almost always due to a defective tube. Check individual tube filament continuity by removing each tube and touching your ohmmeter probes to the filament pins. If the rectifier tube uses a tapped filament and it is open, look for causes of excess rectifier plate current before installing a new tube. The points to check are covered in detail later in this lesson.

Some Tubes Light. In an ac receiver you may find that all tubes except one heat up normally, yet the one tube may test good. Since other tubes heat, there must be a break in the wiring to this one socket or the socket itself must be defective. A break in any circuit will remove an operating voltage; but if the filament voltage is still applied to a tube, the tube will become slightly warm. Thus, a completely cold tube indicates a filament circuit break.

If one or more tubes do not light in an ac-dc set, look for a cathode-to-heater short in another tube which is shorting the filament of each tube that does not light. In an ac set, one using a power transformer, failure of one tube filament will affect that tube only.

Tubes Light. If the tubes in a dead receiver light or heat up, inspect the loudspeaker leads, the loudspeaker plug or terminal connections if used, and the loop leads or antenna and ground connections, depending on which are used in the set. Look particularly for an open voice coil lead if the set is completely dead (no hissing, hum, or other sound from the loudspeaker). If there are any special switches at the back of the chassis or any front-operated push buttons, see if they are set correctly.

NOISY RECEPTION

When you are called to service a set with a complaint of noisy reception, the first thing to do is to find out whether the noise is originating inside the receiver chassis, outside the chassis but in some part of the receiver installation, or entirely apart from the receiver installation.

If the noise becomes worse when a control, switch, or tuning knob is adjusted, you would reason that the part itself is defective and would check it immediately.

If you do not have such a clue, short together the leads from the loop or the antenna and ground terminals if used (you will find these in most old receivers). If the noise now stops or is greatly reduced, there is an external noise source, or the loop or the antenna-ground system is at fault. If the noise does not change appreciably, the trouble is in the receiver itself, or the noise is coming in through the power line.

Rotate the loop or rotate the entire cabinet, and listen to the sound produced. If rotating the set causes a change in the amount of noise, the trouble is external.

Noise may originate in the power line system and enter the receiver through the power cord. If a line noise filter is available, the filter can be plugged into the wall outlet, and the receiver plugged into it to block any noise signals coming in over this path. Sometimes reversing the power plug reduces noise coming in over the power line.

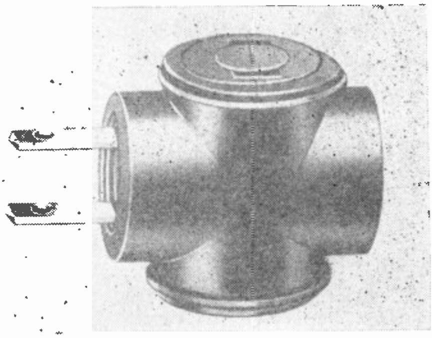
If the noise starts or stops when you turn a light or other appliance in the house on or off, you have localized the noise to the lamp, switch, or appliance. If the noise occurs when someone walks across a room in the house, pipes in the plumbing system may be rubbing together, or the receiver power plug may be making a poor contact in the wall outlet. Check by wiggling the power cord and plug. If the noise increases, examine the plug for broken wires, bend the prongs to make better contact, or replace the plug. Be particularly suspicious of any cube tap (three-outlet, plug-in device). Try plugging the radio into another outlet, using an extension cord if necessary.

If the noise source is outside the set, and the set uses an outside antenna, check the antenna and ground leads. Turn the set on, and shake these leads vigorously. If this increases the noise, look for a poor connection or break.

If you have localized the noise to the receiver, tap each tube while the receiver is in operation. Again, an increase in the noise level indicates that you have found the trouble. Don't be misled by this test, however. Sometimes tapping a tube may jar the actual defective part or terminal and thus lead you to believe the tube is defective. If a new tube acts the same way, you have an under-the-chassis defect.

Variable capacitor plates just barely shorting together may cause noise. This trouble can be identified quickly, however, because the noise will increase when you move the rotor plates as you tune the receiver.

A loose cone or loose turns on the voice coil of the loudspeaker may produce a combination of noise and distortion, which can be recognized after being heard a few times. Remember to notice such combination symptoms, because they frequently lead you right to the trouble.



This cube tap is a common source of noise. Poor contacts develop in these devices.

EXCESSIVE HUM

There are quite a few causes of hum that are external to the chassis. The polarity of the power plug may permit the receiver chassis to pick up stray ripple fields. The resulting hum current in the chassis can enter a grid circuit and cause hum. The hum will usually decrease if you reverse the power cord plug in the wall outlet.

Tubes in the af stages with cathode-to-heater leakage can cause hum. Check the tubes in a tube tester for leakage, or better still try new tubes.

Defective filter capacitors are the most common cause of hum, because their chief job is suppression of hum. An electrolytic capacitor which is open, or has a high internal resistance (high power factor) due to drying out, will be less effective in reducing ripple voltage than a good one. Shunting each suspect with a good capacitor is a quick check for an open capacitor or one that has lost capacity. If the capacitor has leakage, high power factor, or is short-circuited, you will have to disconnect the suspected one from the circuit and substitute a good one in its place.

The output filter capacitor has more to do with hum than the input capacitor, so it should be checked first. As additional clues, an open output filter capacitor may result in motorboating (oscillation or squealing), and there may be a loss in the low-frequency response (a form of distortion). Also, a *leaky* output filter capacitor will draw excessive current through the choke, which results in excessive hum and a decrease in the dc voltage. Hence, hum coupled with low dc voltage is a double clue to filter capacitor trouble.

A defective electrolytic should be completely disconnected from the circuit when you repair the receiver. Never connect a good capacitor permanently across a bad one, even though this clears up the trouble at the time, because the bad unit may eventually break down and short the power supply.

Continuing with our reasoning, an open by-pass capacitor in an R-C filter for a tube may allow ripple currents to enter the tube stage and produce hum. If a control grid circuit is open, the high input resistance allows small hum currents to set up large hum voltages which the tube will amplify. An isolation procedure will save time in locating these troubles.

SQUEALING OR HOWLING

In general, squealing or howling is due to electrical or mechanical coupling between circuits. A missing tube shield can cause this. Excessively long speaker leads and ground leads are sometimes jammed into the cabinet and cause coupling between stages, resulting in squealing. Shortening or repositioning the leads is the remedy.

Howling can occur when some part vibrates under the influence of sound waves from the loudspeaker. The electrodes in some of the tubes made some time ago were not well braced. The electrodes would vibrate when the tube or chassis was jarred. Hence, these tubes were particularly subject to microphonic trouble. You can usually identify a microphonic tube because the howling will stop when you touch it. The best way to clear up the trouble is to replace the tube.

If the rubber supports under the chassis becomes hard, mechanical feed-back from the speaker, through the cabinet, will cause howling.

Front-panel control shafts should not touch the sides of the cabinet holes, and control knobs should be a short distance away from the panel. Felt washers are often used between the knobs and the panel to minimize chances for mechanical feedback that might cause howling.

Mechanical vibration of the rotor plates on gang tuning capacitors will cause a howl, as this changes the capacity at an audio rate. Rubber mountings are usually used under the capacitors to prevent this; be sure they have not hardened.

Oscillation in any section of a receiver can also cause howling. A simple test will determine whether the trouble is in the af or the rf section. If tuning the receiver has no effect on the squeal, you can definitely say that it is originating in the second detector or the af amplifier.

With the trouble isolated to the af amplifier, a putt-putt sound (motorboating) indicates a low-frequency oscillation and leads you to suspect an open capacitor, either in the power supply or in an af stage.

In the case of a high-pitched squeal

originating in the af amplifier, suspect an open plate bypass capacitor in the output stage. This capacitor is put in the circuit to make the plate load capacitive, thus preventing oscillation.

A squeal in the rf or i-f sections can be produced only by two signals that differ in value by an audio frequency. Thus, a single stage may go into self-oscillation, producing a signal that combines with the incoming signal to produce audio frequency squeals or a motorboating sound. Also, two stages may be oscillating at the same time, at frequencies which differ by an audio value. This produces a squeal that will be heard even when no stations are tuned in.

Therefore, when a squeal is isolated to the rf system, reasoning would lead you to try to isolate the defective stage by bringing your hand near each rf tube in turn. When the pitch of the squeal changes or the frequency of the putt-putt sound varies as you approach a particular tube, you have probably found the defective stage. Remember, however, that bringing your hand near the oscillator stage in a superheterodyne receiver will shift its frequency, thus detuning the set and causing a change in the pitch of the squeal. Disregard this indication.

The first thing you would suspect if an i-f stage is oscillating is a defective output filter capacitor or an open in a paper capacitor shunting the output capacitor. An open plate bypass capacitor destroys the shielding action of the screen grid. In older ac receivers, check the screen bypass capacitor and look for excess screen voltage caused by an open bleeder resistor.

DISTORTION

Distortion is most commonly caused by a defect in the af system, so you would first check all the af tubes. As a general rule, it is a good idea to check all tubes in a tube tester when the complaint is distortion. A low-emission af tube is a possible cause of distortion, because it changes the shape of the Eg-Ip characteristic curve. Strong signals then swing over a non-linear portion of the curve. Gas in the output tube, as you learned earlier, can also produce distortion. All tube testers do not have a provision to test the gas content in a tube. Therefore, if your tester does not have a "gas" test, substitute a new tube in place of the suspected one. The substitution method also can be used to check for low-emission tubes.

Defective loudspeakers are another common cause of distortion. Once you have learned to recognize the effects of loose turns on the voice coil, off-center voice coils, excessively hard or excessively soft cones, broken spiders, etc., you will be able to recognize these troubles when checking performance.

Leaky af coupling capacitors are so often encountered when distortion is the complaint that they should come to mind immediately. To check the possibility quickly in either an ac-dc receiver or one using a power transformer, measure the dc voltage drop across the grid resistor. If the grid end of this resistor is positive with respect to the B- end, leave the receiver turned on, and disconnect the capacitor lead from the grid terminal. If the voltage drops to zero, you know the capacitor is leaky; if the voltage is still present with the capacitor disconnected, the tube is gassy.

Since the tube filaments in an ac receiver are usually connected in parallel with the filament winding of the transformer, you can quickly tell whether the coupling capacitor is leaky or the tube is gassy by removing the output tube from its socket. If the positive voltage on the grid remains, the capacitor is leaky. On the other hand, if the voltage disappears, the tube is gassy. The tube filaments in an ac-dc set are connected in series; so if you remove the output tube in this type of receiver, the filament voltage will be removed from all the tubes.

If these preliminary tests fail to reveal the defect, it is time to begin the defective stage isolation procedure.

LOW VOLUME

When the complaint is low volume, be on the lookout for a phono-radio switch set in the phono position, particularly when the switch is on the rear of the set or on the phonograph mounting board. The set owner will usually turn the knobs on the front of a set but will frequently overlook others.

Suppose you find that volume is low for both local and distant stations. If the receiver will pick up distant stations at all, it must have normal rf sensitivity. Therefore, you would suspect a defect somewhere in the audio system. If you find on checking the avc voltage the expected variations when a station is tuned in, this should increase your suspicion that the defect is in the audio system. Low-emission tubes are a likely source of trouble, so you would check them.

Combination defects give you clues that guide you more definitely. For example, if low volume is associated with a high-pitched tone (little or no bass), you can reason that an open in an af coupling capacitor is lowering the coupling capacity so much that only the higher audio frequency can get through. You would then check the coupling capacitors before starting isolation procedures. As a rule, however, when looking for the cause of low volume it is best to try to isolate the defective stage immediately.

POOR SENSITIVITY

There are certain conditions you can do nothing about, such as seasonal changes in reception, differences between day and night-time reception, or inability of the particular receiver to deliver the expected results, because of its basic design. If you don't recognize these, you may let yourself in for an impossible service job.

When the receiver is designed for distant reception, but distant stations cannot be picked up, the symptom is poor sensitivity. Even local stations may not come in with normal volume if the sensitivity has dropped greatly. If there is a tuning indicator on the set, it can be quite helpful. In case of low sensitivity there will be little or no indication from a tuning indicator when stations are tuned in. Tuning indicators will be found only on older receivers. Unsatisfactory reception of distant stations can be due to a defective pickup system. Therefore, you should check the loop continuity thoroughly.

An rf or i-f tube with low emission can cause poor sensitivity, so again it is wise to check the tubes. Poor sensitivity, accompanied by considerable hissing noise, indicates that the rf gain is all right, but that little signal is reaching the input of the set. This should suggest that you check the primary of the antenna transformer with an ohmmeter to see if the primary is open, which would prevent the signal from entering the receiver. Lightning discharges often open the primary winding and cause this trouble. In more modern receivers, check the loop and the avc filter capacitor.

Improper alignment will cause poor sensitivity; all stages will not be properly adjusted to give maximum response to the incoming signal. If stations come in at the proper dial settings, you know that the oscillator trimmer is all right. Effect-to-cause reasoning here would lead you to check only the preselector and i-f trimmer settings. If you find that the trimmers are badly out of adjustment or that stations do not come in at the correct dial settings, you must realign the entire receiver.

When poor sensitivity is accompanied by hum, check each filter capacitor for an open by shunting it with a good capacitor. An open input filter capacitor lowers the operating voltages; an open output capacitor can cause degeneration. Both cause poor sensitivity.

POOR SELECTIVITY

First, determine whether the trouble is poor selectivity or station interference. If the interfering station is on the *same* frequency as the desired station, you have station interference. Also, if the interfering station is more than 40 kc away from the desired station, the trouble is station interference, because the tuned circuits would remove any such interfering signals under ordinary conditions. It is only when the interference is from a station or stations on *adjacent* channels that the selectivity of the set can be questioned. Generally such stations are geographically located so as to make such interference very unlikely. For this reason poor selectivity can hardly be considered a complaint of a broadcast-type superheterodyne.

Next, some judgment is necessary in deciding whether the complaint is actually due to a receiver defect or is caused by local conditions. If the set uses an excessively long antenna, or the assigned frequencies of local stations are too close together for the particular receiver design, the selectivity may appear to be worse than it actually is.

If the local oscilator stops, the receiver is usually dead, but sometimes one station may spread out over most of the dial, giving the effect of poor selectivity.

In actual cases of poor selectivity, something is wrong with the tuned circuits. Here the first thing to do is to check the alignment. This will either correct the trouble or will suggest further tests.

If one particular trimmer will not peak, or peaks very broadly, you know that there is trouble in that tuned circuit. If the trimmer peaks broadly, you know that the Q of the circuit is low, and you should look for high-resistance leakage paths across the tuned circuit. Also, look for resistance in the circuit itself, caused by poorly soldered connections.

In the alignment procedure, adjust the trimmer capacitors one at a time and observe the receiver reaction to each adjustment. In this way, you may be able to isolate the defective stage. Of course, if the trimmer adjustment clears up the trouble, the circuit was out of alignment and no other defect exists.

STATION INTERFERENCE

Here, effect-to-cause reasoning plays a very important part in determining the correct cure. Reception of more than one station at the same dial setting need not be due to poor selectivity. For example, in the early morning when part of the country is still dark, if you are in a lighted region, you may pick up a distant station from the darkened region, and find that it interferes with a weak local station operating at the same frequency. Turning the receiver cabinet to take advantage of the directional characteristics of the loop may help. This is natural and is not a set defect. Be on the lookout for such complaints during the winter months and explain the nature of the trouble to your customer. Don't try to fix it.

If you hear a code station all over the dial, you are safe in assuming that it is operating at the same frequency as the intermediate frequency of the set, or is at one-half this frequency so the second harmonic of the code station produced by the frequency converter will travel through the i-f amplifier. Shifting the frequency of the i-f amplifier 5 or 10 kc will usually clear this up, but will prevent perfect tracking of the oscillator and preselector circuits in receivers not using a low-frequency padder capacitor. In addition, you can use a wave trap tuned to the frequency of the interfering station to prevent the undesired signal from entering the set.

In some cases you may hear a squeal at the dial setting for a low-frequency station, but not on other local stations. This is usually due to image interference produced by a station operating at the high-frequency end of the dial, and is due to the design of the receiver and the location of the particular set. It is not a defect that can be repaired.

INTERMITTENT RECEPTION

If a radio receiver becomes weak or simply goes dead at intervals, effect-to-cause reasoning tells us that practically any part may have failed. You will save time if you use an isolation procedure first to localize the trouble as much as possible instead of trying to test each part and connection.

In some instances, the intermittent condition does not take the form of weak reception or a dead set; instead, there may be hum, distortion, or perhaps squealing at irregular intervals. Here, effect-to-cause reasoning is a powerful tool. You may be able to determine what part could cause the particular symptom to occur. Use the same method of reasoning already described for these symptoms, but bear in mind, of course, that the defect must be such that it can occur intermittently. Because of its construction, an electrolytic capacitor would not be likely to open and close intermittently, and thus cause intermittent hum. However, cathode-to-heater leakage in a tube can be intermittent, because the heater expands when it heats and may touch the cathode occasionally.

In some localities, the power line voltage drops considerably during certain intervals of the day. In industrial localities this happens during working hours, and in residential districts, it happens in the early evening. Such variations in line voltage generally result in complaints only on three-way portables. The lowered voltage stops the local oscillator. Sometimes a larger oscillator grid resistor will help.

Isolating Trouble to a Section, Stage, and Part

There will be many jobs where an inspection for service defects and effect-to-cause reasoning will not lead you directly to the defective part. Then you must use procedures which will pin-point the trouble to a section, to a stage, and then to the defective part.

When we speak of isolating trouble to a section and to a stage, we mean to find the defective section of the receiver and the defective stage in that section. There are several different isolation procedures or tests that you can carry out to find the defective section and stage. Which particular test method will be the most effective depends on the nature of the complaint. In this section of the lesson, we will describe each isolation procedure and indicate when each should be used. Sometimes you will find that several methods will work satisfactorily in isolating the same complaint. With practice and experience, you will be able to tell which one will lead you to the defective stage in the least time.

After you have isolated the trouble to a stage by one or more of the isolation procedures, you may have to take voltage or continuity measurements (sometimes both) in the defective stage to locate the part that is causing the trouble. By now, you know how to use a voltmeter and an ohmmeter; so we will give only a brief description of how to use these instruments.

OPERATION OF A SUPERHETERODYNE RECEIVER

To make use of the section and stage localization procedures, you must thoroughly understand the basic actions that take place in a complete receiver. This is covered elsewhere in your course, but we will briefly describe the operation of a superheterodyne receiver again here. If you feel you need a more thorough understanding of the actions that take place, a review of your earlier lessons will be well worth your while.

A receiver may be broadly divided into three sections:

1. The rf section (which includes all the stages between the receiver input and the second detector).
2. The af section.
3. The power-supply section.

A schematic diagram of a typical ac-dc receiver is shown in Fig. 2. The various stages are identified as well as the parts in them. This is an arbitrary division since some parts, the volume control, for example, are actually common to two stages. However, the division shown will satisfactorily serve our purpose.

In Fig. 2 the rf section includes the antenna and the preselector, the mixer, the i-f amplifier and the second detector—avc stages. The af section includes the first af amplifier, the second af amplifier, and the loudspeaker. The power supply section includes the rectifier, the pilot lamp, the power cord, all of the tube filaments, the filter choke and the filter capacitors.

Passing radio signals induce voltages in the loop antenna. When a station is selected, the loop is tuned so the voltage induced by the desired station signal is higher than that in-

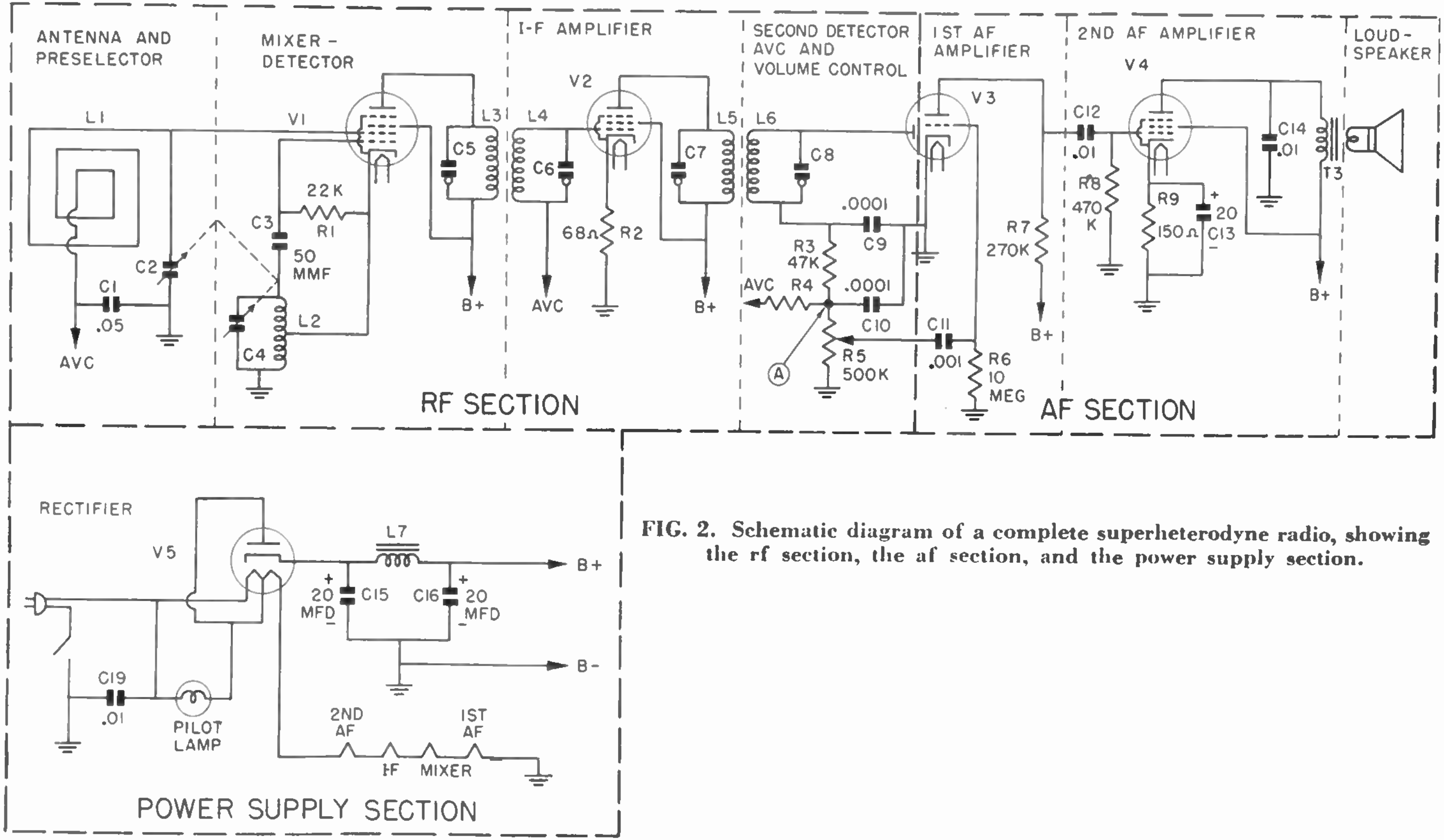


FIG. 2. Schematic diagram of a complete superheterodyne radio, showing the rf section, the af section, and the power supply section.

duced by undesired stations. The signals across the loop are applied to the mixer input. The oscillator in the mixer stage produces a signal higher in frequency than that of the desired station by the i-f value of the receiver.

Beat frequencies are produced between the local oscillator signal and all of the signal voltages applied to the input of the mixer, but only the beat between the oscillator and the desired station will have a frequency equal to the i-f of the receiver. The i-f transformer selects this beat frequency, rejecting others, and applies it to the input of the i-f amplifier. The signal is amplified in the i-f amplifier and is delivered to the second detector through the second i-f transformer, which rejects any small undesired signals that may still be present. Here the amplitude modulation is removed from the i-f carrier, and the modulation appears across the volume control.

A dc voltage whose strength is proportional to the rf carrier is also developed across the volume control. After filtering, this dc voltage is applied to the control grids of the mixer and i-f stages as an avc voltage.

Any part of the available signal between the slider arm of the control and ground can be applied to the control grid of the first af stage. It depends upon the setting of the volume control. The amplified signal produced by this stage is applied to the input of the second af stage, and the signal produced by this stage is fed to the loudspeaker where the electrical variations are converted back into sound waves.

There is one important point you should keep in mind. It is common practice to speak of the signal "flowing" through a receiver from the input to the loudspeaker. Actually, the signal voltages do not flow from one stage to another. Each stage makes an entirely new signal, using the signal fed to it as a pattern. Thus each stage will reproduce what is fed into it and the effect is the same as a smooth and uninterrupted flow of a single signal through the receiver, which is increased in strength as it passes through each stage.

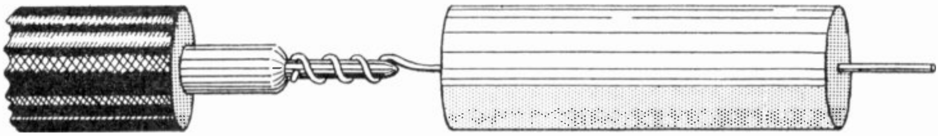
Now, we will describe each of the following isolation procedures, and learn how they can be used in the receiver circuits in Fig. 2:

1. Circuit disturbance.
2. Signal injection.
3. Signal tracing.
4. Stage blocking or interruption.

Neither the circuit-disturbance nor the stage-blocking tests require a signal to be tuned in. If the trouble is distortion or intermittent reception, on the other hand, you must have a signal before you can localize the trouble. Here is where signal tracing and signal injection are useful. You can tell not only whether the signals are coming through, but also the condition of the signal.

CIRCUIT DISTURBANCE

The circuit-disturbance test is the simplest to use in locating the defective stage in a dead receiver. Let us suppose the receiver in Fig. 2 is dead, and you want to use this test. To do so, you touch the control grid of each of the stages with your finger, or if it is hard to get at, with the end of a thin-bladed screwdriver at the same time touching the screwdriver blade with your hand. This puts your body into direct electrical contact with the control grid. Your body is at ac potential with respect to ground because of the ac present in the room from the house wiring; so you will be introduc-



If your signal generator does not have a built-in isolating capacitor, when you are using signal injection, make your connections to the receiver through a .01-mfd, 600-volt capacitor in series within the ungrounded signal generator lead, as shown here.

ing a 60-cycle ac signal into the grid circuit of the tube.

If the defect is in the first af stage, you will hear nothing from the speaker when you touch the control grid of that tube, but you will get a loud 60-cycle buzz when you touch the control grid of the second af tube, showing that it and the speaker are good.

If the defect is in the rf section, you can tell it, because you will get a signal from the speaker as far back as point A in Fig. 2, which shows that the entire audio section and also the power-supply section are working. Point A is the hot terminal of the volume control. It is easy to find, and you can touch it with your finger without the danger of getting a shock from touching other parts at the same time.

You can check the individual stages in the rf section by touching the control grids with your finger, even though the rf stages cannot amplify a 60-cycle signal. Touching the grid will introduce a voltage surge in the rf or i-f stages, which will shock-excite the resonant circuit and cause it to oscillate for a few cycles at its resonant frequency. The momentary signal created will produce a thud or click in the loudspeaker instead of the continuous buzz produced when you touch point A.

If you hear the disturbance in the loudspeaker when you touch the i-f control grid, but not when you touch the mixer control grid, then you know that the mixer or the coupling between it and the i-f tube is defective.

Touching the oscillator control grid will result in a loudspeaker disturbance whether or not the oscillator is working. The test is useful in locating a shorted oscillator tuning capacitor, but as far as the condition of the oscillator is concerned, such a check has no meaning.

If you get a disturbance at the mixer grid but the set is dead, you know that the oscillator is probably at fault and you should concentrate on it.

At times the click heard when a control grid in the rf section is touched is so weak as to be inconclusive. Then, better results can be obtained by momentarily shorting the control grid to B- or to the cathode of the tube.

SIGNAL INJECTION

When you are not satisfied with the results of a circuit-disturbance test in isolating the defective stage in a dead receiver, you can get a more conclusive test by injecting a signal from a test oscillator into the various stages. The same signal generator used for receiver alignment is ideal for this purpose.

Furthermore, you can feed the signal not only into the control grid circuit but also into the plate circuit, thus testing the coupling between the stages. The lead of the signal generator must have an isolating capacitor to avoid a short through the cable. Most commercial signal generators have such a built-in capacitor. You can check to see if yours has one by measuring for continuity between the signal generator leads with your ohmmeter. If you do not find continuity, there is a built-in isolating capacitor. If there is no capacitor, make your connections to the receiver through a .01-mfd, 600-volt capacitor in series with the hot (ungrounded) signal-generator lead.

The audio output of the signal generator is used for tests in the af section, and the rf output of the signal generator is used for all tests ahead of the second detector.

When checking in rf stages, tune the signal generator to the frequency normally present at the point of injection. In an i-f amplifier, the signal generator should be tuned to the i-f of the receiver. You can get this frequency value from the manufacturer's service information. The signal generator should be tuned to the receiver dial setting when injecting a signal into the mixer grid. When substituting the signal generator signal for the oscillator signal (fed into the oscillator grid) set the signal generator to the receiver dial setting plus the i-f value of the receiver. Then the signal generator will produce a signal having the same frequency as would be produced by the receiver oscillator if it were present.

SIGNAL TRACING

You can check the amount and quality of the signal at any stage in an improperly operating set. This method of checking section and stage operation is known as signal tracing.

The most fundamental test to locate the defective stage in a dead receiver using this method is to measure the dc diode load voltage with a vacuum tube voltmeter or a high-resistance voltmeter. If you measure normal diode load voltage as you tune from station to station, the gain in the rf section is normal, and all stages in the rf section are operating. No voltage at this point, or voltage which your experience tells you is low for your location and for a receiver of the type under test, could mean that the trouble is in the rf section. If you check the rf section and find that it is all right, the trouble must be in the af section. Normal operation of either the rf section or the af section automatically clears the power supply section as a source of trouble. None of the receiver stages would operate if their operating voltages were not applied.

The voltage at the diode load, when measured with a meter, is dependent on rf stage gain only. Such a measurement is not a check of the quality of the signal. To check quality you must listen to the signal, using an amplifier and a loudspeaker separate from the receiver. Special test equipment is available for this purpose. An instrument for doing this is called a signal tracer. It may be very simple or quite elaborate. In its simplest form the signal tracer consists of a high-gain audio amplifier, a loudspeaker, and a slip-on detector probe so the signals in the rf section can be sampled. Most signal tracers use a tuning eye with a calibrated control so the difference between the signal at the input of the stage and at the output of the stage can be seen. The better signal tracers use very accurate methods of measuring the stage gain; this is useful when servicing weak receivers.

The very best signal tracers use a preselector ahead of the built-in detector. This preselector stage can be tuned to the i-f of the receiver, to any broadcast receiver preselector setting, or to any frequency produced by the receiver local oscillator. The tuned signal tracer will pick up only signals of the frequency to which it is tuned. An untuned signal tracer, on the other hand, will pick up signals of all frequencies both desired and undesired.

The greatest disadvantage of the untuned signal tracer is in making tests in the preselector and at the mixer output. There are signals of many different frequencies at these points, and the untuned signal tracer cannot distinguish between them. As an example, you might be able to hear a signal at the mixer output. With a tuned signal tracer you can determine if there is an i-f signal present, which would indicate the oscillator is working. With an untuned signal tracer you cannot distinguish between an i-f and rf signal. Further on in the receiver towards the loudspeaker only the desired signals are present.

The problem, however, is not too serious, and the untuned signal tracer is perfectly all right once the operator understands his instrument and how to use it.

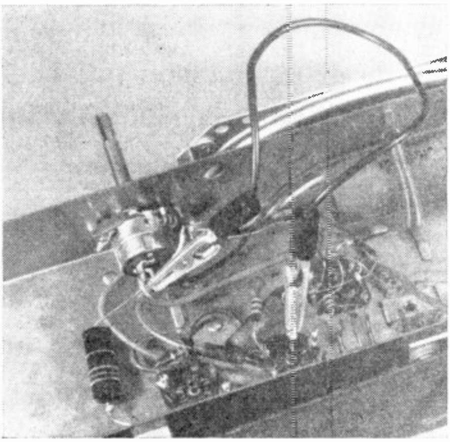
All types of signal tracers can sample signals in the af system, roughly measuring stage gain, giving a preview of signal quality, and showing whether there is hum or noise at various points.

To the beginner the signal tracer may sound like the ultimate test instrument, and it is good; it helps make the beginner circuit wise, but the experienced man can generally do just as satisfactory work using the circuit disturbance test and other procedures you will learn about. A beginner should look on the signal tracer as one of the most valuable training tools he can buy.

STAGE BLOCKING

When you are confronted with a noisy receiver or one that hums or oscillates, signal injection, circuit disturbance, or signal tracing tests will be of little use in isolating the defect. What you want to find out is where the undesired signal (noise or hum) is getting into the set. When you know this, you concentrate on that stage or on the section of the power supply feeding it.

The stage-blocking procedure is basically similar to the circuit-disturbance test. However, here you are interested in blocking the circuit and preventing it from amplifying a signal, not in introducing a surge voltage. Therefore, you can move in either direction in a receiver, although it is customary to start at the output and work back toward the antenna. By killing each stage, you can find where the trouble is originating.



To kill a stage in an ac-dc receiver, you can short across the plate load resistor or from grid to B— with a piece of wire with clips attached.

To kill a stage, you can use a wire with clips at each end to short out the plate load resistor or to short the grid to B-. You can also kill a stage by shunting a large paper capacitor (.25 mfd or larger) from the plate or grid to B-.

In an ac receiver using a power transformer, you can kill a stage by pulling the tube out of its socket. This is possible because each tube in an ac set is connected in parallel with the filament supply, and removal of one tube will not upset the filament voltage of the other as it would in ac-dc receivers.

When using the stage-blocking method to locate hum or noise in a receiver, first determine whether the noise is in the rf or the af section. The easiest way to do this is to turn the volume control all the way down. If you can still hear the undesired signal in the set loudspeaker, it must be originating in the power supply or in the af stages; it is not coming from the rf section through the volume control. On the other hand, if the volume control setting affects the hum or noise, the undesired signal is passing through the volume control and is in some stage in the rf section.

Since the mixer and i-f amplifier cannot pass a hum (af) signal, the cause of hum in such a case will be in the second detector. Perhaps there is a leakage path inside the tube between a diode plate and the filament. There is one exception: if hum is heard only when a station is tuned in, further section localization is unnecessary. The fact that the hum is tunable shows that it is being modulated on the rf carrier in one of the rf stages. For further localization, you must use a signal tracer of the tuned type. However, this is generally unnecessary because there are only a few possible defects that will result in hum modulation.

If you isolate the hum to the af section, you can usually locate the defect without too much difficulty. If you cannot stop the noise completely by killing any one stage, this isolates the trouble to the power supply section and shows that the noise pulses are being fed into the plate circuit of each stage. The most likely parts to suspect here are the filter capacitors.

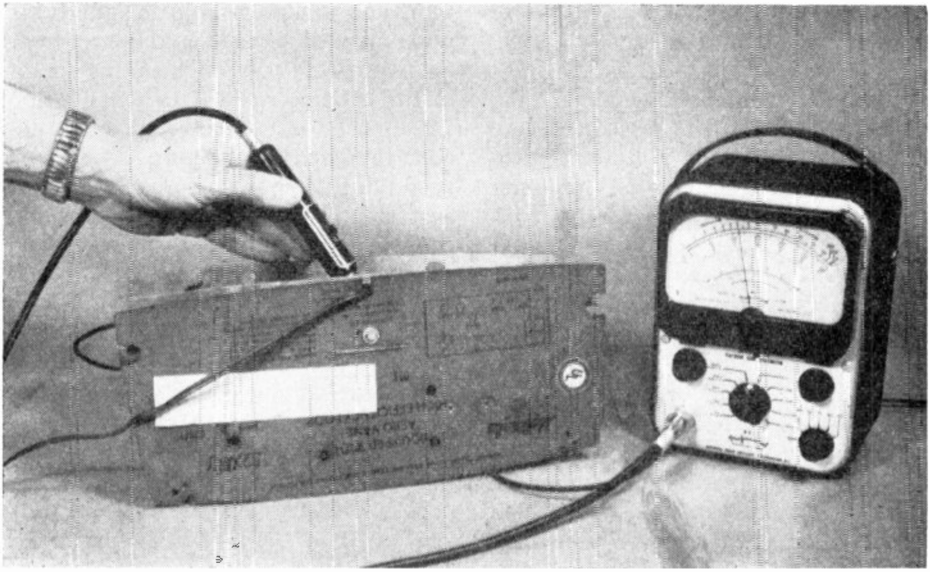
ELECTRODE VOLTAGE TESTS

Voltmeter tests in a defective stage naturally begin with a check of plate voltage, followed by measurements of the other electrode voltages in turn. The receiver should be on but not tuned to a station. Abnormal voltage or lack of voltage will lead you to suspect some part or series of parts of being defective, and further tests will then isolate that part. The parts to be tested will of course be those in the supply circuit where voltages are missing or abnormal.

Making voltage measurements has the advantage of checking the receiver while all parts are under normal voltage stress. This is valuable because many troubles, particularly shorts in capacitors, may appear only when full voltage is applied.

The serviceman has a wide choice of meters for use in voltage tests, but the meter should have a sensitivity of at least 20,000 ohms-per volt, and should have several ranges. The dc vacuum tube voltmeter can be used to measure all voltage with respect to chassis and does not usually load the circuit as does the ordinary voltmeter.

Always remember to start on the highest range of a multi-range meter in testing an unknown voltage, and to disconnect the meter from the voltage under test when changing ranges. Failure to follow these rules is likely to result in a burned-out meter or in arcing at the contacts of the range-changing switch.



Using a voltmeter to isolate the defective part.

What should be considered normal readings at the tube electrodes depends on the type of meter being used. The values shown in service manuals are generally based on measurements with a 20,000 ohms-per-volt meter or a vacuum tube voltmeter. Remember that voltages in radio circuits are in most cases dependent on resistor values, and that these can vary as much as 20% from the stated value.

If you keep these limitations in mind, you will find that as you gain experience in making voltmeter readings, using the dc voltmeter can be a fundamental part of your servicing technique.

ELECTRODE CONTINUITY TESTS

After signal tracing and electrode voltage tests, continuity tests with an ohmmeter must be added to make your general servicing technique complete. Ohmmeter measurements must always be made with the receiver turned off and preferably disconnected entirely from any source of power. If you fail to turn off the set, voltages across the parts being tested will not only give erroneous readings, but will probably damage the meter. After turning the receiver off, wait for a minute or so for the filter capacitors to discharge, or short-circuit them with a screwdriver or test lead to be sure they are not storing voltage.

The real value of a continuity test as a servicing procedure is that it gives a quick check of every part included in that circuit. This applies, of course, to every circuit having dc continuity. By testing for continuity from each positive electrode of the tube to the highest positive point in the power supply, and from each negative electrode to the highest negative point in the power supply, you can quickly discover whether any part of the dc supply lines is out of order. Checking all of these supply paths will cover most of the parts of a stage.

Many times you will find it most efficient to combine ohmmeter and voltmeter tests. However, some servicemen eliminate the voltmeter altogether and depend on the ohmmeter alone. They check the dc supply continuities from the tube to the power supply for opens, and check across from positive to negative to find shorts. These tests will be covered in detail later on, but you can easily see that the serviceman has some choice in his use of instruments. The voltmeter may be used to find trouble and the ohmmeter to check parts, or one instrument alone can be used. As you become more experienced, you may find that one or the other works better for you. However, the serviceman who can use either instrument as the need arises will never be at a loss for means of finding the defective part in a receiver.

FINDING THE DEFECTIVE PART

When effect-to-cause reasoning or an inspection for surface defects does not lead you to the defective part, you should first localize the trouble to a section and then to a stage in the receiver.

After finding the defective stage, you can again use effect-to-cause reasoning, by trying to imagine a part defect that could cause the particular symptom you wish to correct. You might decide that a leaky capacitor could be causing the trouble, but an open in the same capacitor would result in an entirely different symptom. Thus, you would check the capacitor only for leakage. It would be a waste of time to check it for an open, for a loss of capacity, or for a high power factor. If you had some other symptom, you might be able to ignore the possibility of leakage, and concentrate on a possibility of high power factor in the capacitor.

Suppose the suspected part is difficult to reach for testing. Then you need additional facts to back up your suspicion of the part. Then you would consider the effect of the suspected part trouble on the operating voltages of the stage and on the stage circuit resistance values and check the voltages and the resistance values. If they indicated trouble in the suspected part, it would be worthwhile to make the necessary arrangements to check the part, or if necessary to try another part.

Sometimes you will not get any ideas as to the possible cause of the trouble. Then you should check the operating voltages in the defective stage and the point-to-point resistance values. These are checked against what you think should exist or, if they are available, against the manufacturer's published values. Often there will be a variation in the measured values that will point to a possible part defect.

To service receivers in this way, you can see that you must not only know the purpose of each and every part in the defective stage but must also know what will happen if the part changes in value, shorts, or becomes open. You must also know how any of the possible defects in a part will change the operating voltages or circuit resistance values. There are parts whose failure, although affecting stage operation, will have no effect on normal voltage and resistance values, and you must be aware of this.

Your study of fundamentals in earlier lessons will give you the necessary background to begin servicing in this way. Experience will also be a great teacher. As you start servicing receivers, your ability will increase with each job. You must have a thorough knowledge of Ohm's Law and current and voltage distribution to interpret the meaning of variations in the voltage and resistance measurements in a defective stage.

There will be occasions, which will become rarer as you gain experience, when you get no ideas or recognize no clues as to the cause of the trouble in a defective stage. Voltage and resistance tests should then be made to see if a clue will turn up. Sometimes no clue will appear, and you will have to check individual parts in the stage. If there are some parts you are not able to check using the test instruments you have on hand, substitute new parts in their place. In this way, the most baffling troubles can usually be cleared up.

Testing all the parts in a stage and trying new ones is certainly not a scientific or profitable approach to the problem, and an expert will avoid this method as long as he has any ideas with which to work. It is expensive and time-consuming to try new i-f transformers, output transformers, or loudspeakers.

In most cases, if the serviceman must fall back on the hit-and-miss method of checking all parts, he has not interpreted the results of his tests correctly or he had made the wrong tests. Let us look at some examples where additional tests or clearer thinking could have avoided much unnecessary work and wasted time

The defect in the first case that we will discuss is rather unusual, but one that you may encounter in your service work.

Case No. 1. Weak reception; set almost dead.

Circuit Affected: Af section wired exactly as shown in Fig. 3.

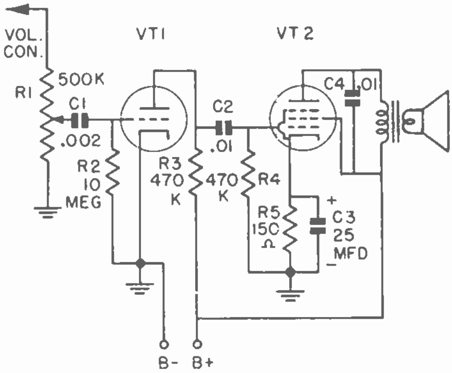


FIG. 3. Af section of receiver having weak reception.

Circuit Disturbance Test: Touching volume control resulted in very weak speaker buzz. Touching the control grid of tube VT1 caused no change in the level of the buzz. Shorting the control grid of VT2 to the cathode produced a loud click in the speaker.

Diagnosis: Trouble in first af stage.

Tests: Tried new tube for VT1; plate-to-cathode voltage normal; value of R1, R2, and R3 normal as checked with ohmmeter; C1 and C2 checked by shunting with test capacitors; filament voltage of VT1 found to be normal.

Conclusion: Since all of the tests given above were negative as far as showing up the trouble was concerned, it was obvious that the difficulty was not in the first af stage as suggested by the circuit disturbance test. Further testing showed the value of VT2 grid resistor, R4, to be 470 ohms. As you have learned, the grid resistor in this type of output stage should be anywhere from 100,000 ohms to 470,000 ohms. So the 470-ohm resistance is much too small. With such a low value of grid resistance practically all signals were being dropped across C2 and very little across R4. Only the signals across R4 are amplified by VT2.

This can happen in actual radio and TV servicing if the receiver has been worked on previously by the set owner or by someone who did not know how to read the resistor color code. Often these sets are the most difficult to repair because of the errors in wiring and parts values you may find in them. In extreme cases, you may have to consult the schematic diagram of the set and check the circuit wiring and parts values before you can repair the defect.

This case also brings out another important servicing point. The results of the circuit disturbance test were misleading because they indicated that the defect was in one receiver stage when it was actually in another. Therefore, one of the other test procedures would have been more effective in localizing the defect. It is true that touching the control grid of VT2 produced only a slight buzz in the loudspeaker, but no great amount of buzz was expected. On the other hand, shorting the control grid of VT2 to its cathode produced a loud click in the speaker, showing that VT2 would amplify anything fed to it. A check with a signal tracer would have at once shown a strong signal at the plate of VT1 and a weak signal at the control grid of VT2. This would have indicated a check of C2 and finally of R4.

An actual signal tracer would not have been needed because an ac vacuum tube voltmeter would have shown the much stronger signal at the plate of VT1 than at the control grid of VT2.

Case No. 2. Signal badly distorted as if some tube were biased almost to plate current cut-off.

Circuit Affected: The af circuit shown in Fig. 4.

Clues: Touching the control grid of VT1 and the chassis with hand cleared up distortion and permitted normal operation. A signal tracer showed distortion first appeared at the plate of VT1. Shunting C6 with a 100,000-ohm resistor cleared up the trouble as did shorting resistor R8.

Conclusions: The distortion occurs

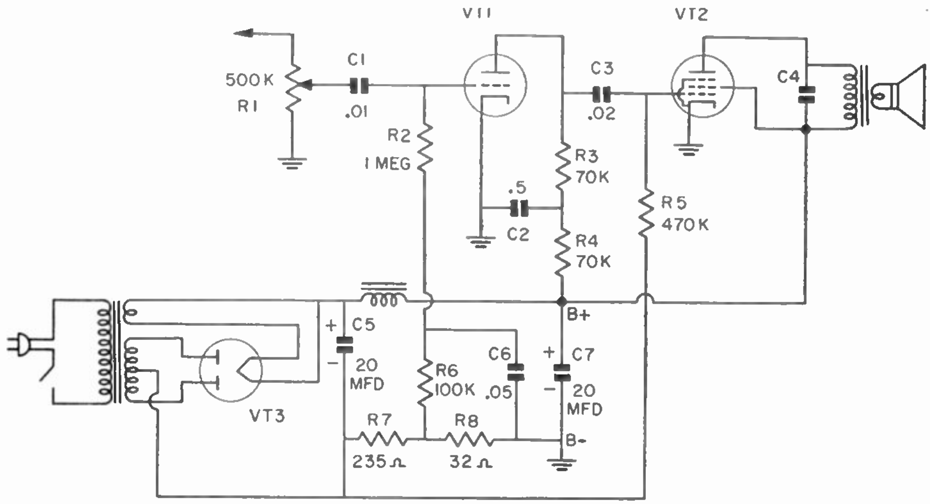


FIG. 4. Power supply and af circuit of a receiver.

in the grid circuit of VT1, and since reducing the bias (by touching the control grid and chassis, by shunting a resistor across C6, or by shorting bias resistor R8) clears up the trouble, it is apparent that VT1 is overbiased. The question is: Why is VT1 overbiased?

This circuit has been used in thousands of receivers. It was popular for years with many set manufacturers. When it was discovered that the first af tube could be self-biased by using a grid-to-cathode resistor of several megohms, the fixed bias method shown in Fig. 4 fell into gradual disuse.

We chose it here for an example because there are many receivers using this circuit still in existence, and a similar bias arrangement is being used in some TV receiver circuits today. It also permits an excellent example of effect-to-cause reasoning.

Hundreds of cases of distortion in sets using this circuit were "repaired" by shorting out R8 or by connecting a resistor across C6. Although this cleared up the distortion temporarily, more serious defects developed, and the customers often finally had to pay for a new power transformer, rectifier tube, or other part that would not have been damaged if the original serviceman had exercised a little effect-to-cause reasoning.

Finding that the voltage across R8 was excessive, the good serviceman would have realized at once that either R8 had increased in value or that excess current was flowing through this resistor. He knows this from Ohm's Law, which states that voltage equals current times resistance. For the voltage to increase, either the current or the resistance must increase. The first test to make would be to measure the value of R8 with an ohmmeter since these resistors can increase in value. If R8 had a normal resistance, the thing to look for would be a possible cause of excess current through R8.

Looking at the partial schematic in Fig. 4, you can see that the plate currents of VT1 and VT2 flow through resistors R7 and R8. Anything that caused abnormal plate current would increase the voltage drop across R7 and R8. Also a short, or excess leakage in output filter capacitor C7 would result in excess current through R7 and R8.

An ohmmeter connected from B+ to the chassis with the set turned off will show if excess leakage is present. If the resistance measured is correct, it follows that the tubes must be drawing excess plate current. Obviously, VT1 does not have excess plate current because it is biased almost to the plate current cut-off point.

Since the voltage across R7 is also excessive and tends to overbias VT2, how could it have excess plate current? An examination of the diagram and a little thought will tell you that leakage in coupling capacitor C3 will place a positive voltage on the control grid of VT2. The resulting increase in bias voltage across R7 and R8 will not overcome the positive grid voltage, and the plate current of the output tube will be abnormally high. Following this line of reasoning, you would check C3 for leakage and if necessary replace it.

Gas in VT2 would also cause the same thing, since it too would produce the positive voltage across R5 and would result in abnormally high plate current and excess bias voltage on VT1. Thus, a defect in one stage can cause a symptom in another stage. This is a very worthwhile point to remember.

A similar condition, in which the distortion clears up when the bias is reduced, can occur, but in this case the bias voltage across R8 might be normal. Again, just a little thought can point out the defective part.

If the normal fixed bias is too high for a tube, it indicates that the plate voltage is too low. A check of the plate voltage would confirm this reasoning, and you would find it to be below normal.

An examination of the circuit would show that the trouble could be due to a very large increase in the value of R3 or R4 or to leakage in the bypass capacitor C2. Since leakage in the capacitor is probably the cause of the trouble, disconnect one capacitor lead from the circuit, and check the part with an ohmmeter.

Modern radio receivers usually do not have circuits as complicated as those in Fig. 4. However, there are many of these receivers still being serviced, and in TV sets you will find many stages whose operation is dependent upon circuits in other stages or even in other sections of the receiver. It always helps to study the circuit diagram of the set to see what possible defect you can imagine that could have a bearing on the trouble you wish to correct.

Defects in the RF Section

Now we are ready to examine the parts in the various stages of a typical, modern ac-dc receiver. We will go through each stage of the set shown in Fig. 2, and will consider the troubles that could be caused by defects in the various parts. In this way, you will see how the defects would be located and tested by a service expert.

PRESELECTOR-MIXER STAGE

The preselector and mixer stages are grouped together in Fig. 5 because the preselector in this particular receiver is a part of the mixer. It also acts as the supply link for the application of avc voltage to the mixer grid.

The Loop Antenna. Generally, the only trouble that will develop in a loop antenna is an open circuit. This may result in a dead receiver, but is more likely to cause squealing and hum modulation. Touching your fingers across the rotors and stators of the rf section of the tuning capacitor may clear up the squealing and hum, but it will not bring the receiver gain up to normal.

To check for an open in the loop, turn the set off, and use your ohmmeter to check from the control grid of the mixer or from the stator of the rf tuning capacitor to the avc circuit. The hot side of the volume control (the point marked A in Fig. 2) is a reference point that is easy to find.

In this test, you are interested only in finding out whether the loop an-

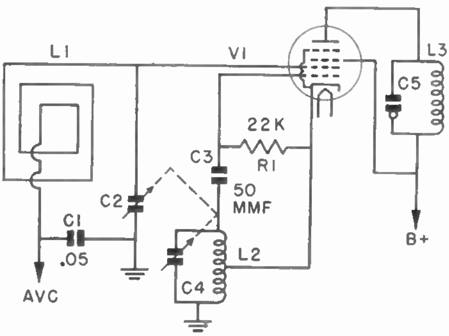


FIG. 5. Preselector-mixer stage.

tenna has continuity, not in the exact dc resistance value of the loop itself. The exact resistance cannot be measured because of the presence of the avc filter resistor, which generally has a value of about 2 meg as compared to only a few ohms for the loop. However, if the meter shows continuity, you know that the loop is not open.

The loop may absorb moisture, which will reduce its Q. If the receiver complaint is weak reception, and you find that the rf trimmer peaks very broadly even at the high-frequency end of the dial, you should try a new loop. The average serviceman does not have facilities to check the Q of circuits, and set manufacturers do not publish Q values.

The AVC Bypass Capacitor. The fixed capacitor, C1, in Fig. 5, connected from the loop to the chassis, offers a low-impedance path in the resonant circuit consisting of the loop and the tuning capacitor. The avc bypass in addition acts with the avc filter resistor (R4 in Fig. 2) to deliver a pure dc, free from af and rf ripple, to the mixer and i-f control grids.

The avc bypass capacitor can become open, leaky, or shorted. If the capacitor becomes open, very little signal will be fed to the mixer input and the gain of the receiver will be quite low. A circuit disturbance test may show nothing wrong, but a signal tracer will indicate little signal voltage at the mixer grid. You will not be able to peak the rf trimmer on the tuning capacitor. To check the capacitor, shunt it with another of about the same size known to be in good condition. If the capacitor under test is open, the volume will increase when you put the test capacitor in the circuit..

If the avc bypass capacitor becomes leaky or shorted, the gain will be abnormally high, and oscillation may take place. There will be no avc on either the mixer or the i-f stages, and overloading, distortion and/or blasting may occur when you tune from a weak to a strong station. This type of reception is characteristic of a defect in the avc circuit, which completely removes the control voltage.

To check for this, measure the resistance from the mixer control grid to B-. With the tubes cold or removed, it should be over 2 meg, the value of the avc filter resistor and the volume control. If the resistance is considerably less, disconnect one lead of capacitor C1 so it can be individually checked.

If someone has replaced this capacitor with one of insufficient capacity, af signals may be fed back to the mixer and i-f tubes, causing the gain to decrease. In noisy locations, the momentary avc surges due to noise will be fed back and the gain will be drastically reduced.

RF Tuning Capacitor. The plates of the rf section of the tuning capacitor, C2, may be bent and may short out at some dial settings. Dust and dirt may also accumulate between the plates, causing partial shorts.

Partially shorted tuning capacitor plates show up as noise when the receiver is tuned. If the short is complete, the receiver may go dead at the dial settings where the short is present. You can usually see the bent plates that are causing the short. You can use a pen-knife to straighten them. You can blow the dust or dirt out, or if the plates are spaced sufficiently far apart, run a pipe cleaner between them to remove the dirt particles.

If you cannot see a short, disconnect the lead to the stator of the tuning capacitor and connect a high-range ohmmeter between the stator and the rotor. You should not get a meter reading if the part is not shorted. If you get a reading, continue working on the capacitor until the reading disappears.

The Mixer Tube. Low emission in the mixer tube will result in either a dead set, due to oscillator failure, or in weak reception. If the cause of weak signals or a dead set is traced to this stage and nothing else seems to be wrong, try a new tube in the mixer circuit.

Gas in the tube can cause weak signals, a positive mixer grid voltage, and perhaps hum modulation. When the mixer grid is positive, try a new tube. A gassy i-f tube will also make the mixer grid positive, because the two grids are tied together through their tuned circuits.

Cathode-to-heater leakage will short out the feedback portion of the oscillator tank coil and will stop the oscillator. If the parts in the oscillator circuit seem to be in good condition, try a new tube.

The Oscillator Grid Resistor. If the value of resistor R1 in Fig. 5 increases considerably, the oscillator will block intermittently and the reception will be chopped up. If the resistor opens, the oscillator may block or may not operate at all. If the resistance is too low, the oscillator will not work. When looking for trouble in the oscillator circuit, be sure to check the value of the oscillator grid resistor with an ohmmeter.

Oscillator Grid Capacitor. The oscillator grid capacitor, C3, in Fig. 5, seldom becomes defective. However, the capacitor may short or develop leakage which will stop the oscillator. An open in the capacitor will also stop the oscillator or make it very weak. Check for leakage or a short with your ohmmeter. If you think the capacitor may be open, try another. The value is not critical; any value between 25 mmf and 50 mmf will make a satisfactory replacement.

The Oscillator Coil. The oscillator coil, L2, in Fig. 5, sometimes opens. When you have oscillator trouble, you should always check the oscillator coil with an ohmmeter. The coil may also absorb moisture and develop a low Q, killing the oscillator. If everything else, including the tube, checks all right, try a new oscillator coil even though the original is found to have continuity.

The Oscillator Tuning Capacitor. The oscillator section of the tuning capacitor, C4 in Fig. 5, is subject to the same troubles as the rf section. If the oscillator seems to be dead, try shorting the oscillator tuning capacitor with a screwdriver blade. If no noise is heard, look for a short between the capacitor plates.

The First I-F Transformer. The first i-f transformer is common to the mixer and i-f stages. The windings may open completely or partially, or moisture absorption (rare in modern parts) may cause the trimmer adjustment to be abnormally broad. As a rule, you will have little or no trouble with the adjustments.

A partial open in the primary winding (L3) will result in machine-gun-like bursts of static. Check for this condition by measuring the mixer plate voltage. If the voltage varies in time with the noise, the primary is probably defective and should be checked with an ohmmeter. With the set off, connect the ohmmeter test leads between the mixer plate and the screen. If the resistance is high or varies, the transformer should be replaced. An idea of the correct resistance for the winding may be had by checking the secondary. All i-f transformer windings in a receiver should have about the same resistance.

The secondary winding, shown as L4 in Fig. 6, may be open completely but not partially. An open winding, which is very rare, will kill reception or make it quite weak. Check from the

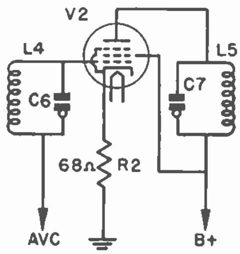


FIG. 6. I-F Amplifier.

i-f control grid to the avc line with your ohmmeter to see if the winding is open.

THE I-F AMPLIFIER

Fig. 6 shows the i-f amplifier stage. We have included the secondary of the first i-f transformer, even though the transformer is common to this stage and to the mixer stage.

The I-F Tube. The i-f tube, V2 in Fig. 6, may have low emission or excess gas, just as the mixer tube described earlier. Check the tube and replace it if you find that it is bad. Cathode-to-heater leakage may cause hum modulation or could prevent the mixer and first i-f tubes from lighting. A short between the plate and the suppressor grid or between the suppressor and screen grids could cause the cathode resistor R2 to burn out. If this happens, be sure to check the tube before installing a new resistor in the circuit.

The I-F Cathode Resistor. As pointed out above, the resistor may open because of a defect in the i-f tube. If the resistor opens, it will remove plate-to-cathode voltage and the receiver will be dead. The trouble may be isolated to this stage by means of a circuit-disturbance test. An open cathode resistor will be indicated by excess cathode voltage and no continuity between the cathode and B-.

If the resistor increases in value, the stage may be weak or dead. A decrease in the resistance value or a short may not produce any symptom. In some cases, however, a low value cathode resistor could cause i-f oscillation.

The Second I-F Transformer. The defects that can occur in the second i-f transformer are the same as those described earlier for the first i-f transformer. Again the primary may partially open or the secondary may open completely.

SECOND DETECTOR

Although the second detector and the first af amplifier are actually in

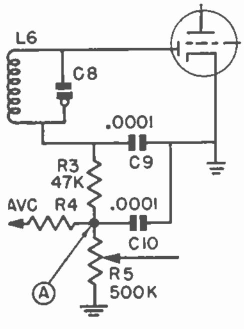


FIG. 7. The second detector circuit.

one tube, the af amplifier is in the audio section of the receiver, not the rf section, so we will consider only the second detector here. Fig. 7 shows the second detector circuit.

The I-F Filter Resistor. If resistor R3 opens, the set will be dead.

However, an open in this part is rare. A marked increase in the value of the resistor is also rare; but if it occurred, the volume would be reduced because more of the signal would be dropped across this resistor than across the volume control. The resistor usually has a value of about 47,000 ohms.

The I-F Filter Capacitor. Defects in capacitors C9 and C10 are rare. However, an open in the output capacitor, C10, could result in oscillation and overloading of the first af tube with i-f signals.

An open in input capacitor, C9, would reduce the signal applied between the plate and cathode of the detector and would lower the detector output. A signal tracer would show normal signals at the diode plate, but the avc voltage and audio voltage developed across the volume control would be lower than normal. A test capacitor shunted across the suspected one would clear up the trouble.

The Volume Control. If you hear noise when you rotate the volume control shaft, you usually will not have to make further tests. Just install a new control.

The control may also be open. The effect is the same as if the avc filter resistor opens, but you may hear hum which will vary with the volume control setting. In such a case, check the control with an ohmmeter. The resistance of the control is unimportant. A control having any value from 250,000 ohms to 2 megohms will make a satisfactory replacement.

The Second Detector Tube. Cathode-to-heater leakage in tube V3 may cause hum. If you find that the more common defects, such as defective filter capacitors are not causing the hum, try a new tube. Low emission will result in low gain in the stage and higher than normal plate voltage. If the plate load resistor has the correct value, high plate voltage indicates that the plate current is lower than normal, and the tube is probably bad.

Leakage between the diode plate and the filament will also cause hum. Thus, try a new tube if the volume control varies the hum and is not itself defective. A short between the diode plate and the cathode would kill reception and no avc voltage would be developed. This defect is unusual. However, if you suspect that this is the trouble, try a new tube.

Defects in the Audio Section

The first audio amplifier tube is in the same envelope as the second detector tube, which you studied in the last section. Let us take up the other parts in the first af stage now.

FIRST AF STAGE

Fig. 8 shows the schematic of the first af stage. We have omitted the connection to the diode section of the tube, which you have already studied.

The Grid Coupling Capacitor. An open in grid capacitor, C11, will make the audio response very weak. You will hear a loud buzz when you touch the grid side of the capacitor, but only a weak signal when you touch the volume control side. Shunting a capacitor across an open capacitor will cause the set to operate normally.

Leakage in the capacitor will cause distortion when the volume control is advanced, because the negative avc voltage developed across the volume control will be applied across R6 and over-bias the stage.

The Grid Resistor. Trouble seldom occurs in resistor R6 in Fig. 8. If the resistor becomes open or increases to a very high value, hum may result or the stage may block, killing reception. A check of the control grid voltage would show that it is abnormally high. This is true, however, only if you use a vacuum tube voltmeter. If the resistance is too low, insufficient bias will be developed, and the stage may overload and distort on strong signals. This is a point to check if the grid coupling capacitor proves to be in good condition.

The Plate Load Resistor. If resistor R7 became open, the first audio amplifier stage would be dead. The best isolation procedure to use here is the circuit disturbance test. Of course, you could also measure the plate voltage with a voltmeter. No voltage on the plate would indicate that the plate load resistor had opened up.

A marked increase in the value of resistor R7 might cause audio oscillation or might reduce the gain, depending on the amount of change and on the circuit layout. Low plate voltage indicates the possibility of excess resistance. You can use an ohmmeter to check the value of the part.

If the plate load resistor decreases in value, the stage gain will be low and the plate voltage will be higher than normal.

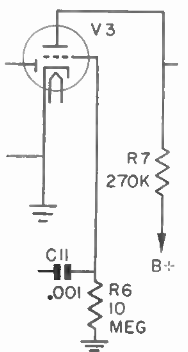


FIG. 8. First af stage.

THE SECOND AF STAGE

The Grid Coupling Capacitor. Capacitor C12 in Fig. 9, used to couple the plate circuit of the first af stage to the grid circuit of the second af stage, frequently breaks down and becomes leaky. When distortion is the complaint, this is the first part to check. Frequently, leakage in the coupling capacitor will cause gas to be produced in the output tube because of the positive control grid voltage, which is the result of leakage.

Both conditions can be checked by connecting a dc voltmeter across the grid resistor, with the positive meter

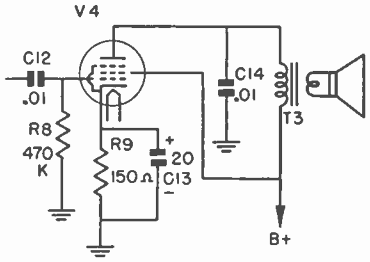


FIG. 9. The second af stage.

lead on the grid end of the resistor. No voltage should be present. If you measure a positive dc here, either the capacitor is leaky, the tube is gassy, or both. To find out which is defective, just cut one lead of the capacitor (whichever is more convenient) close to its terminal lug so it can be resoldered if the capacitor proves to be good. If the voltage drops to zero, the the capacitor is leaky, and the tube is not gassy. In this case install a new capacitor.

If the voltage is unchanged, the capacitor is good, and the tube is gassy. In this case resolder the capacitor lead and install a new tube.

If the voltage drops when you cut the capacitor lead but some is still present, the capacitor is leaky and the tube is also gassy. Here replace the capacitor and the tube.

The Grid Resistor. Trouble in resistor R8 is very unusual. No voltage is present, and no defect can occur that will result in sufficient current flow to damage the resistor or to cause it to change in value. The thing to watch for is a part of the wrong value.

If the value of the grid resistor is too high, it can cause the output tube to become gassy. On the other hand, if the resistance is too low, the reception will be weak, and the low-frequency response may suffer. Exactly what happens depends upon the amount of change.

The Cathode Bias Resistor. Resistor R9 seldom changes in value, but it will burn out if the cathode current of the tube becomes excessive. By looking at the circuit in Fig. 9, you can see that a short between the plate and suppressor grid or between the suppressor and screen grids would apply the full B supply voltage to the cathode resistor. The excess current flow through the resistor, of course, would burn it out. If no such short exists, check the tube for gas or for a leaky coupling capacitor as soon as the set is turned on. The methods previously given should be used. This will avoid damage to the replacement resistor.

Also be on the lookout for a defective plate bypass capacitor connected from the plate to the cathode. The capacitor can be installed between the plate and cathode, plate and screen. or, as shown in the illustration as C14, from plate to B-. The action of the capacitor is the same in all three cases, but a short in the capacitor will cause damage to the bias resistor only if one end of the capacitor is connected to the cathode.

If a cathode bypass capacitor, such as C13, is used and the bias resistor opens, the leakage resistance of the electrolytic bypass will complete the circuit. Since its resistance is high, the bias voltage will be very high, causing distortion. When you suspect this trouble, check the bias voltage and the bias resistor.

The Cathode Bypass Capacitor.

Capacitor C13 in Fig. 9 may short, develop a high power factor, or may become open. The two latter defects result in similar symptoms. The stage gain will be below normal because degeneration will occur. Check for an open in the part by shunting the suspected capacitor with another electrolytic (capacity is not important). Be sure to observe the polarity markings of the test capacitor. The positive terminal invariably goes to the cathode. If the symptom disappears when you try the new capacitor in the circuit, the part should be replaced.

If the capacitor shorts, which is unlikely to happen, the bias will be removed, the plate current will be excessive, and distortion will result. The rectifier tube could also be damaged by the excess current drain. The tap on the rectifier filament could burn out, preventing the tube from lighting. When the rectifier filament tap burns out, check the cathode bypass capacitor to see if it is shorted.

The Output Tube. The tube in the audio output stage may become gassy as explained in the section under the grid coupling capacitor. This is a frequent occurrence.

Low emission will result in weak reception and insufficient bias across the bias resistor. If the bias is low, but the plate and screen grid voltages are normal, try a new tube.

Hum not due to an electrolytic filter defect is often caused by cathode-to-heater leakage in the output tube. Try a new tube in the stage when the complaint is hum.

The Plate Bypass Capacitor. Capacitor C14 in Fig. 9 is a weak point in the receiver because it frequently breaks down, especially if it is connected from the plate to B-. If the capacitor breaks down, no B+ will be applied to the tube plate. The drain on the power supply, due to a short in the plate bypass capacitor, may burn out the rectifier tube filament. Use an ohmmeter to check for a short in the B supply when the rectifier filament is open.

A short in this capacitor also could burn out the primary of the output transformer. Usually, however, the rectifier tube will be ruined before a short in the plate bypass will cause the output transformer primary to open. If there is no plate voltage and the plate bypass capacitor is shorted, be sure to check the output transformer primary.

In replacing the plate bypass, try connecting it between the plate and B-, and then between the plate and the screen grid. Use the latter connection if the results appear to be the same with either connection. If the capacitor is between the plate and screen grid, there will be less voltage across the capacitor, and the life of the replacement will be increased considerably.

If capacitor C14 is open, af oscillation may occur. Such oscillation will take place regardless of the tuning dial setting and will be controlled by the volume control setting. In such a case, try shunting a new capacitor across the suspect. If the trouble clears up, remove the old capacitor and install a replacement rated at 600 volts.

The Output Transformer. Little trouble is encountered in transformer T3, except that the primary may open as previously explained. Universal replacement transformers are available and come with instructions explaining how they should be installed. If you install a new transformer, keep the lead to the plate of the tube as short as possible. If the lead gets near the grid of the first af stage or the grid of the power output tube, audio oscillation may result. Before trying a new transformer, check the bias resistor, cathode bypass capacitor, and the plate bypass capacitor. Connect your dc voltmeter across the output tube grid resistor so you can see as soon as the tubes heat up whether the output tube is gassy or if the grid-coupling capacitor is leaky. Any of these troubles could damage the output transformer because of excess current flow in its primary winding.

With the output transformer primary open, the set will be completely dead, and no voltage will be applied to the plate of the output tube. A circuit-disturbance test will localize the trouble to the output tube. A continuity test with an ohmmeter between the plate and the screen grid pins of the tube will show an open circuit.

In an ac-operated receiver, the screen grid of the output tube will become red-hot if the transformer primary is open, because the screen grid would then be carrying both its normal current and the current that should flow to the plate. In an ac-dc set, the combined currents will not overheat the screen grid, because the plate and screen grid voltages are much lower than in an ac set.

The Loudspeaker. There are several defects that may occur in loudspeakers. First, the voice coil may be open. This can be found with a circuit disturbance test. However, you can also spot an open voice coil by watching the pilot lamp. With the volume control turned all the way up, the pilot lamp in an ac-dc set will flicker when you tune to a powerful station, because of the variation in the output tube plate current flowing through the rectifier tube filament and the pilot lamp.

If you notice this flickering when a set is dead. you know that signals are present up to the plate of the output tube. This shows that the primary of the output transformer is all right. Since trouble is rare in the secondary of such transformers, the voice coil is probably open. Check for this by disconnecting one voice coil lead and measuring between both voice coil leads with a low-range ohmmeter. No continuity shows that the voice coil is open. If you cannot make repairs easily, install a new loudspeaker.

If the pilot lamp circuit is designed so that the output tube plate current does not flow through the pilot lamp, you must use a circuit disturbance test to localize an open voice coil.

Most of the other defects that can occur in a loudspeaker, such as off-center voice coils, loose cones and dust covers, particles in the air gap, etc., are discussed elsewhere in your course. The tests to use to localize the trouble are primarily mechanical.

Defects in the Power Supply Section

Most defects in the operation of an ac-dc receiver are due to power supply defects. In the vast majority of cases, the electrolytic filter capacitors are at fault.

Notice the two types of filter circuits shown in Fig. 10. The main difference between them is that a choke coil is used in Fig. 10A, and a resistor is used in the circuit in Fig. 10B. Both circuits, however, operate in essentially the same way.

The Electrolytic Filter Capacitors. The filter capacitors seldom short or become excessively leaky because they usually cause other receiver troubles before deterioration has progressed that far. Excess leakage is almost sure to ruin the rectifier, but before it does, the receiver reception will be weaker than normal because of the lower B+ voltage, and the hum level will increase.

To check for leakage in the capacitors, turn the set off and discharge them completely by shorting the capacitor terminals with a wire or a screwdriver blade for about thirty seconds. Then, make the ohmmeter connections so that the probe (positive lead) connects to B+ and the ground clip (negative lead) connects to B—. This connects the ohmmeter battery with the proper polarity across the capacitors. Convenient test points for B+ are the rectifier cathode shown in Fig. 10 or the screen grid of the power output tube. For B—, use the chassis if it is an electrical part of the circuit. If you are uncertain and it is an ac-dc set, use the lug of the ON-OFF switch going to the receiver circuits as B—. If the resistance reading is too low (less than 100 ohms), you are justified in taking the time and trouble to locate the positive leads of the electrolytic capacitors and to disconnect them for an individual check.

The electrolytic filter capacitors frequently develop high power factor or opens. One or both capacitors may be affected. If a filter capacitor is hot to the touch, it probably has high power factor. The best way to test the part is to substitute a good one in its place. On the other hand, if the receiver output is weak and the B supply voltages are low, the input capacitor is probably open. Don't take the trouble to locate the capacitor or its leads. Put the positive lead of the test capacitor on the cathode of the rectifier and the negative lead on B—. If the trouble becomes less bothersome or clears up, find the capacitor and replace it. If the two capacitors are in the

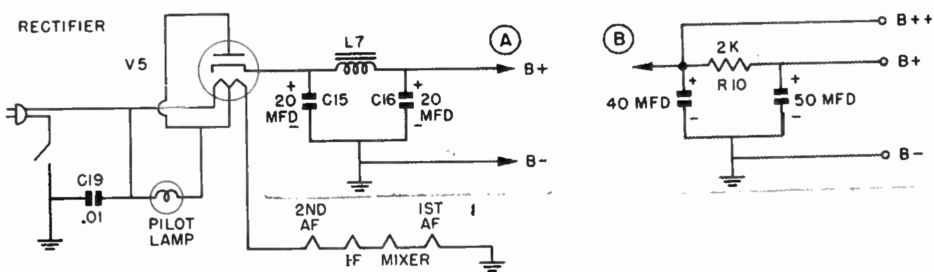
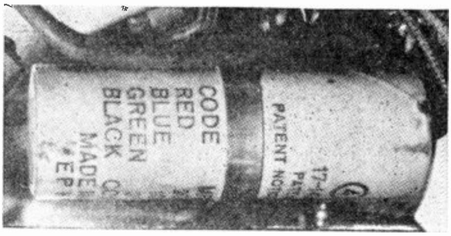


FIG. 10. The power supply. Two different filter circuits are shown. At A, a filter choke is used; at B, a filter resistor is used.

same container, always replace both capacitors at the same time to avoid a call-back. A 20-mfd, 150-volt electrolytic capacitor in good condition is satisfactory for *test* purposes on all filter capacitors you will find in ac-dc sets. The working voltage should be higher for a test capacitor used in ac-operated receivers.

Trouble in the output filter capacitor is characterized by hum, oscillation, and motorboating. Check this part in the same way as the input capacitor, but place the positive lead of the test capacitor at some point on the set side of the filter choke or resistor. For example, you can use the screen grid of the output tube as the B+ point.



When a capacitor is mounted like this, leakage may develop between the mounting strap and the case of the capacitor.

Sometimes, the symptoms definitely point to a defect in the electrolytic filter capacitors, but shunting the capacitors, even both of them simultaneously, will not clear up the trouble. When this happens, the positive leads of the capacitors are probably shorted together inside the capacitor case, and shorting the filter resistor or choke. To check this, find all leads of the original filter capacitors, disconnect them, and install test capacitors. If the trouble clears up, the original capacitors were at fault.

Sometimes leakage occurs between the capacitor and the strap that anchors the capacitor case to the chassis. This happens when cardboard encased capacitors are used. Move the case back until you expose the part of the case that was under the strap. If you see green corroded spots on the capacitor case, replace the capacitor.

When the common negative lead becomes open, the two capacitors will be connected in series across the filter element (choke or resistor). Again disconnect the positive leads, and install two test capacitors in the circuit. This is necessary to prove the capacitors are the cause of the trouble. Install new capacitors if the original ones are bad.

Filter Choke or Resistor. Note from Fig. 10A and 10B that either a choke or a filter resistor may be used in the filter circuit of an ac-dc receiver. The resistor is by far the more common. When it is used, as shown in Fig. 10B, the B+ lead of the output transformer primary is connected to B++ at the rectifier cathode. Since with this connection, the plate current of the output tube does not flow through the filter resistor, we can use a larger resistor and still get ample B supply voltage with low ripple output. AC ripple voltage is applied to the plate of the audio output tube, but the ripple voltage does not produce hum in the output. The other dc voltages must be free from ripple, or otherwise the hum will be objectionable. In this circuit, notice that the filter capacitors must have higher values than those used with a filter choke.

The defects that occur in the filter resistor are the same as those that can occur in any resistor in the set. If the resistor becomes open, check for a short in the B supply that could cause excess current drain, before installing a new one. Also look for excessive leakage or a partial short in the supply if you find that the value of the resistor has changed a large amount.

If the choke coil in Fig. 10A becomes open, check for a short in the B supply, and for possible causes of excess plate current drawn by the power output tube. Do not ignore the possibility of a short between the choke windings and its grounded core. Disconnect both choke leads, and check the continuity between either lead and the chassis to see if such a short exists. Trouble of this type is more common in TV sets and in ac-operated receivers where the dc voltage between the choke windings and the core are higher than in the standard ac-dc set.

The Rectifier Tube. The rectifier tube frequently loses emission, and causes the receiver to be weak or dead. A tube having low emission, of course, can be checked on a tube tester. However, if you do not have a tube tester, measure the voltage on the plate and screen grid of the output tube. Lower than normal voltage here could mean that the rectifier tube has low emission.

Most rectifier tube troubles in ac-dc sets are the result of an open filament tap. This can occur through a failure of the tube filament itself, a short in the power supply, or by defects that result in excess cathode current in the power output tube. All these trouble spots should be checked before considering repairs to be complete.

The Pilot Lamp. Pilot lamps frequently burn out. They may fail for internal reasons not connected with any other part failure. They may also burn out because of an open filament tap on the rectifier tube.

If no tubes light and the pilot lamp is burned out, check the rectifier tube filament continuity before you install a new pilot lamp. If the tap on the rectifier is open, and you install a new pilot lamp, it will burn out as soon as the receiver is turned on.

The On-Off Switch. The On-Off switch seldom causes trouble, but it may be sluggish when switched off, or fail to cut off power or turn it on. In such a case, remove the power plug from the wall outlet and connect a low-range ohmmeter across the switch terminals. The resistance should be zero when the switch is turned on, and infinite when the switch is turned off. If you don't get the correct readings, and the volume control and switch are controlled by the same shaft, install a new combination volume control and On-Off switch.

The Power Cord and Plug. The power cord may break in the molded rubber plug, preventing the tubes from lighting. In such a case, see if the insulation will stretch when you pull on either wire going into the plug. If so, the wire is broken. Cut off the old plug and install another.

Caution the customer against disconnecting the receiver from the power line by pulling on the cord. This will cause the wires to break near the plug. To disconnect the receiver, grasp the plug in the fingers and pull it out of the wall outlet.

The Power-Line Filter Capacitor. A small value paper capacitor like capacitor C19 is used in receivers to prevent or decrease the effects of noise and unwanted rf signals from causing interference in the set. Defects rarely occur in this part. If it should short, the line fuse in the customer's home would blow out. An open in the part would permit interference signals to enter the set from the power line and cause the receiver noise to increase.

FIG. 11. The NRI Professional filament checker shown above can be used to quickly locate a tube with an open filament in a series filament string.

The Tube Filament String. An open in the filament string prevents all of the tubes from lighting. This is a frequent occurrence. Servicemen, after inspecting the power cord, check the tube filaments one at a time. This can be done with an ohmmeter, or with the convenient filament checker shown in Fig. 11. If the rectifier tapped filament section is open, the test for excess current described previously should be made. If the other tubes are burned out, just replace them.

If you have continued trouble with a particular tube filament burning out, some of the other tube filaments may be partially shorted, causing excessive filament current. A tube tester is generally ineffective in locating such trouble. Check for it by measuring the filament voltage of the other tubes while they are in the receiver. If one tube has abnormally low filament voltage, replace that tube; its filament is partially shorted.

If you find that one or more tubes remain dark while the others light, one of the tubes has a cathode-to-heater short that is shunting the unlit tube filament to ground. The offender is the one in the string next to the first unlit tube. In Fig. 10, for example, if the mixer and first af tubes do not light, look for a cathode-to-heater short in the i-f tube. The cathode resistance of the i-f tube shown in Fig. 6 will limit this effect, but in many sets such a resistance is not used. The cathode is connected directly to B—.

LOOKING AHEAD

In this lesson we have given rather thorough coverage to the difficulties that may occur in an ac-dc receiver, and the methods of finding the defective component. The ideas in this lesson may be applied to more complicated receivers, but we will have a more detailed study of service problems in ac, auto, and portable receivers later in the course.

In the following lessons, we will describe in more detail than we have been able to in these introductory lessons the probable causes of hums, squeals, motorboating, distortion, noisy and intermittent reception, and tuning circuit troubles. These lessons will demonstrate how to locate the receiver troubles in the least amount of time.

Lesson Questions

Be sure to number your Answer Sheet 37B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. Which step in the Professional Servicing procedure, if used effectively, can save the most time in locating the cause of the trouble in a defective receiver?

2. What is the effect on the B+ voltage and overall receiver performance of an open input filter capacitor in the power supply of an ac-dc receiver?

3. What receiver circuit would you suspect is defective if you get very loud reception and sometimes distortion on strong local stations when you tune across the dial?

4. What effect will be produced in the receiver reception when a defect in the oscillator circuit kills the oscillator?

5. What is the advantage of a tuned signal tracer over an untuned signal tracer in locating a defective section in a receiver?

6. Suppose capacitor C2 in Fig. 4 short circuits. How would it affect the receiver reception, and what voltage reading would you get if you measured from the plate of VT1 to B—?

7. Which stage isolation procedure is the easiest to use in localizing the trouble in a dead receiver?

8. Which is the most easily identified B— reference point in an ac-dc receiver where the chassis is not an electrical part of the circuit?

9. Suppose capacitors C11 and C12 in Fig. 2 are both leaky. How does the voltage polarity across resistor R6 due to leakage in C11 differ from the voltage polarity across resistor R8 due to leakage in C12?

10. Suppose you are carrying out a stage-blocking procedure to isolate the source of excessive hum in an ac-dc receiver. The hum, however, can still be heard in the receiver output when you block the grid and plate circuits of each stage in the set. Which receiver section would you suspect to be the source of the hum?

DIG A LITTLE DEEPER

A poor South African farmer struggled for years to gain a living out of his rocky soil, then finally gave up in despair and sought his fortune elsewhere. Years later, more wealth was being dug out of his rocky old farm every day than he had ever dreamed existed. His farm had become a diamond mine!

Many of us struggle along just like that poor Boer farmer, never dreaming that success could be ours if we dug a little deeper right where we are. Millions of men are just barely getting along today, when they have the ability to do much better things, simply because they lack confidence in themselves. They are victims of mental defeat; they don't believe they can do anything better.

If *you* lack self-confidence—if you lack a sense of mastership, a consciousness of power, and a victorious mental attitude, begin now to cultivate self-confidence. How? Make your decisions with confidence and speed, and stick to them. Dig into your work a little harder, keep going a little longer, and soon you'll have the self-confidence which carries you speedily to success.

J. E. Smith

TUNING CIRCUIT TROUBLES

ALIGNMENT

38B

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STUDY SCHEDULE NO. 38

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

FM4M1258

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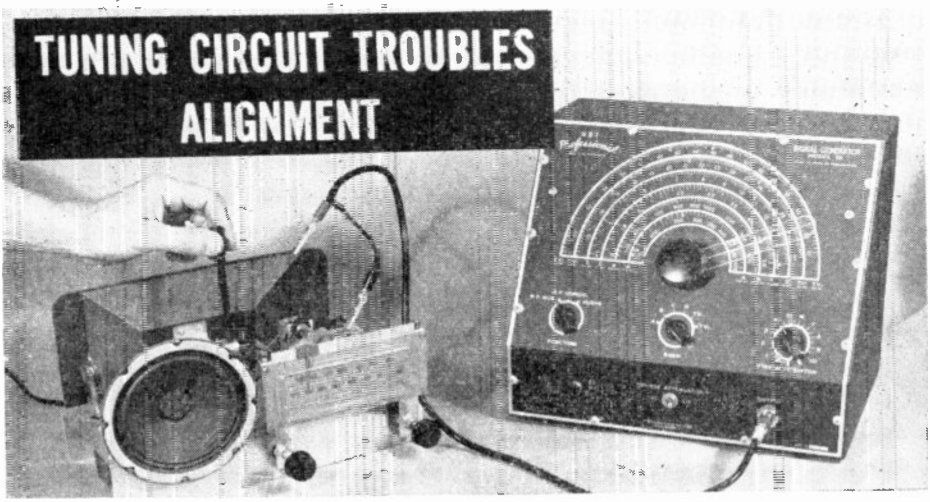
TUNING CIRCUIT TROUBLES
ALIGNMENT



ALIGNING a receiver means adjusting various tuned circuits to resonance at predetermined frequencies, so that the receiver will respond properly to the desired signal at the correct dial setting.

In this lesson, we will concentrate on AM and FM receivers. You will learn about aligning TV receivers in a later lesson.

Aligning a superheterodyne receiver can be very simple or it may be quite complicated, depending entirely on your knowledge of the subject. This lesson contains all you need to know about radio receiver alignment. If you learn the material in it, you will find that aligning most receivers is an easy job.

To align a superheterodyne receiver, you must know just what circuits have to be tuned, and how the adjustments are made. First, let us see what is involved.

As you know, the loop antenna system of a radio set picks up energy from any nearby station putting out a signal. The receiver must separate the desired signal from all others that it is picking up. This is done by circuits that can accept the desired signal and reject all others. These are called "tuned" circuits because they can be tuned to the desired signal.

In the modern broadcast superheterodyne, at least five tuned circuits, not including the local oscillator, are used for signal selection. This was not always true. A very brief review here of the development of tuning circuits used in radio receivers will help you to understand the problems associated with modern set alignment.

TRF RECEIVERS

When radio broadcasting began, there were only a few stations on the air. These were well separated both geographically and in frequency. The desired station could be selected by varying the capacity in a single tuned circuit with one control knob.

As more stations began broadcasting, additional tuned circuits, each with its own control knob and scale, were added to receivers. Soon, tuning a radio set became a complicated procedure.

To make the receivers more commercially acceptable, simplification in tuning became an absolute necessity. To get single-dial control, manufacturers used tuning capacitors with several individual sections on one shaft. As the shaft was rotated, the capacity of the various sections was varied the same amount, so that at any

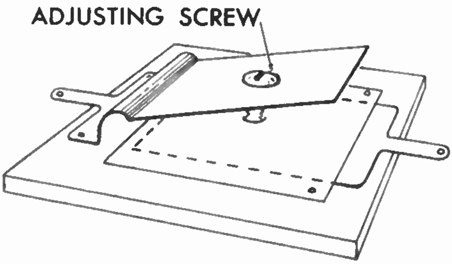


FIG. 1. A trimmer capacitor like this has a screw adjustment that varies the capacity.

point in the rotation, the different sections of the capacitor were practically identical in capacity. The coils used with them had to have practically identical characteristics.

With identical capacitor sections and identical coils, the resonant frequencies of the sections would be the same. In other words, all the circuits were automatically adjusted to the same station, and it was no longer necessary to tune each circuit separately. The circuits were set to "track".

Slight variations in capacitor and coil values were compensated for by means of a semi-fixed capacitor of the type shown in Fig. 1, mounted on and across (in parallel with) the variable capacitor for each tuned circuit. These trimmer capacitors were the first aligning adjustments. They presented no particular problem, because it was only necessary to tune in any station at the correct dial setting and to adjust the trimmers for maximum sound from the sound reproducer. In these early single-dial receivers, each tuned circuit accepted the frequency of the desired station and rejected all others. These sets were known as tuned radio frequency (trf) receivers.

As the number of broadcast stations increased, poor selectivity became a common complaint. If two stations broadcast at frequencies only a few hundred kilocycles apart, they were apt to come in at the same dial setting. To avoid this, more tuned circuits were added, until five-section tuning capacitor gangs were quite common. Even so, strong local stations often interfered with each other. The wiring in the set would act as an antenna and pick up stations, thus defeating the purpose of the tuned circuits. Expensive and bulky shielding became necessary to prevent this. Consequently, the cost of receivers increased sharply.

THE SUPERHETERODYNE RECEIVER

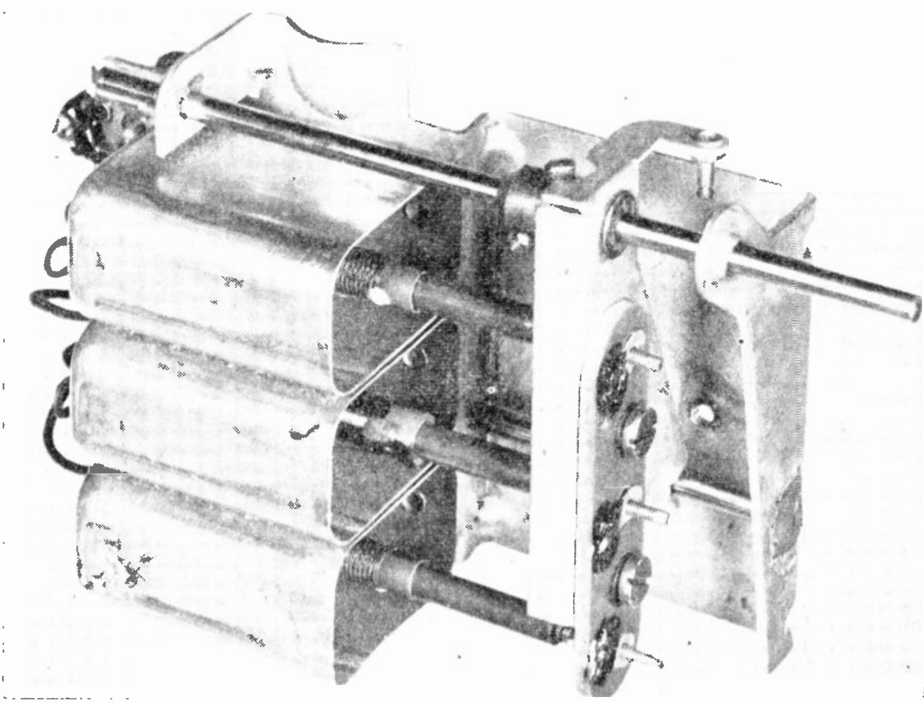
At about this time the superheterodyne receiver was introduced. This receiver solved the problem of selectivity. The cost of the sets decreased because a large amount of shielding was not needed. Since the frequency of the i-f amplifier was outside the broadcast band frequency, the set could not pick up stations through its wiring. Thus, cheaper chassis with less shielding came into gradual use. The trf receiver gradually fell into disuse, and today it is no longer being made at all.

Since you are familiar with the principles of the superheterodyne receiver from earlier lessons, we will not make a detailed review of its circuit operation at this time; we will cover only the points that are related to alignment problems, and discuss some of the adjustments you will have to make. There are small variations in the number and type of adjustments in different receivers, but the basic superheterodyne circuit and adjustments are always essentially the same.

The main purposes of aligning a receiver are to adjust it for maximum performance and to make the dial indicate the frequency of the station being received with 2% or 3% accuracy. The adjustments in most superheterodyne sets are made by trimmer capacitors, in the i-f amplifier, the oscillator, and the preselector sections. In the i-f section, the trimmers are on top of the i-f transformer cans. In the preselector and oscillator circuits, the trimmers are usually on the tuning capacitor.

Although most receivers use variable capacitors and trimmers for tuning and alignment, some receiver manufacturers prefer inductance tuning, sometimes called permeability tuning. As you have learned, the resonant frequency of a tuned circuit can be varied by varying either the capacity or the inductance. The inductance of the coils in the tuned circuit is varied by moving powdered iron cores in and out of the coils. Pushing the core further into the coil increases the inductance and lowers the resonant frequency. The capacity in the circuits is usually provided by fixed capacitors. In the preselector and oscillator circuits, however, trimmer capacitors are also used.

The cores in the i-f transformer are generally threaded so that they can be screwed in and out of threaded coil forms. Usually the adjustment for one winding of the transformer is on top of the transformer and the other is at



An example of a permeability tuner. This is used in some sets instead of a tuning capacitor.

the bottom, and reached from underneath the chassis.

The oscillator and preselector sections in a receiver are not tuned to the same frequency. The preselector is tuned to the frequency of the desired signal, and the oscillator is tuned to the frequency of the desired signal *plus* the i-f. Therefore, although both sections must be tuned over the same number of kilocycles, the actual frequency of the oscillator section is higher. For example, if the range of the preselector is from 550 kc to 1600 kc, and the receiver has an i-f of 450 kc, the range of the oscillator would have to be from 1000 kc to 2050 kc. In each case the range of frequencies covered is 1050 kc.

As you have learned, the same amount of capacity has more effect at high frequencies than at low frequencies; therefore, the capacity range of the tuning capacitor in the oscillator section must be smaller than the capacity range of the tuning capacitor in the preselector section, and the two capacities must always be in the proper proportion to each other.

In modern receivers this is accomplished by specially cut plates in the oscillator section of the tuning capacitor, smaller than those in the preselector section. However, in older receivers, which you may sometimes have to service, the two sections of the tuning capacitor were the same size, and a semi-fixed capacitor, similar to a trimmer, was used in series with the oscillator section of the tuning capacitor. As you have learned, when a capacitor is added in series with another capacitor, the capacity is lowered. This extra capacitor is called a "padder". When the padder is properly adjusted, the oscillator frequency will be above the preselector frequency by the i-f value of the receiver over the entire tuning range.

Let us sum up the adjustments you would make in aligning a radio: either trimmer adjustments or powdered iron core adjustments in the i-f transformers, trimmer adjustments and sometimes both trimmer and core adjustments in the oscillator and preselector, and if the set uses identical tuning capacitor sections, an oscillator padder capacitor. As we have said, the padder capacitor is not used in most modern receivers. The oscillator tuning capacitor plates are shaped to compensate automatically for the difference in frequency between the oscillator and the preselector so that the circuits will have the correct frequency relationship over the tuning range of the receiver.

Before we take up a detailed alignment procedure for the various receiver sections, let us discuss some of the symptoms that can be caused by misalignment. In the following section of the lesson, we will discuss only the symptoms that are the result of misadjustment of a trimmer or padder capacitor or a powdered iron coil core in the various receiver circuits. Defects, of course, can occur in the receiver tuning circuits just as in any other receiver circuit. The actual defect may be an open circuit, a short circuit, increased series resistance, change in the Q of a coil, or any number of other defects, but we will not be concerned with defects of this type here. These troubles cannot be repaired merely by realigning the set. You must use effect-to-cause reasoning to isolate the defect to a receiver section, stage, and circuit.

Symptoms of Misalignment

You can save a great deal of time in your service work if you know which symptoms can and which symptoms cannot be caused by misalignment. The alignment of the average receiver is so simple that this procedure can be made a part of each service job. However, never touch the alignment adjustments unless you are sure that there is no other defect in the set that could cause the same symptom. If the symptom is hum, lack of audio gain, static, noise, or intermittent reception, repair the defect first, and then realign the set. Let us take the alignment adjustments in each section of the receiver, and learn what to expect when the circuits are misaligned.

THE I-F AMPLIFIER

There are many degrees of misalignment in the i-f amplifier. The tuned circuits in an i-f amplifier may drift slightly as the receiver ages. Fatigue may reduce the spring tension in a trimmer or vibrations may move the powdered iron slug in a tuned coil slightly. If either of these happens, one circuit might be tuned to a higher frequency and another to a lower frequency. This would cause a slight reduction in selectivity and could result in interference between stations operating on adjacent channels. Also, when the circuits are misaligned in this way, there will be a loss in sensitivity, characterized by weak reception.

If all the circuits shift in the same direction, the i-f amplifier will be peaked at the wrong frequency, and stations will not be received at the proper dial settings. The tracking and the low-frequency sensitivity will be poor. Readjustment of the oscillator trimmer will make stations come in at the correct setting at the high-frequency end of the dial, but they will still be off at low frequencies. The sensitivity at these low frequencies will also be below normal.

Usually, this is about all that can happen to the alignment of an i-f amplifier. However, the transformer trimmer adjustments are located where someone may tamper with them. Perhaps the customer has seen a serviceman touch up a trimmer and noticed that the volume increased. He tries to do the same thing, with disasterous results to the alignment. The customer usually goes from one trimmer to the other until it is impossible for him to return them to their original settings. This is not serious, from the serviceman's viewpoint. With his signal generator he can quickly reset the trimmers to the right frequency. However, if permeability tuning is used, the customer may tighten the slugs so much that he will damage the adjustors. When this happens, the i-f transformer must be replaced.

A typical permeability tuned i-f transformer is shown in Fig. 2. Notice

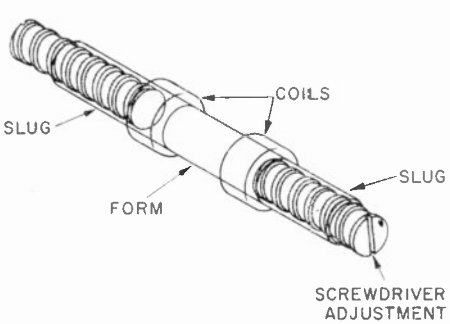


FIG. 2. A phantom view of a permeability-tuned i-f transformer showing the form, the coils, and the iron cores.

that there are two powdered iron slugs in the coils. The outsides of the slugs are threaded to fit into the threads pressed in the cardboard form on which the coils are wound. If the slugs are turned in until they touch, and additional pressure is applied, two things may happen. First, the slot in the end of the slug into which the alignment tool fits may break, making it necessary to replace the transformer. If the slot does not break, the threads pressed into the hollow cardboard form will straighten out, and you will not be able to move the slug in or out. Repair is not possible. Watch for this when you adjust such slugs. If you feel the slugs touching each other, don't force the adjustments or you may have to install a new transformer.

Mica compression trimmers can usually be forced tight with a screwdriver without breaking. However, sometimes the mica between the trimmer plates will break, creating a short or making it impossible to adjust the trimmer correctly. If this defect occurs in an i-f trimmer, the transformer will have to be replaced.

Another thing that may happen is that the local oscillator may cease to function and the customer may notice that all he can pick up is a weak station at the low-frequency end of the dial. If the i-f amplifier is then adjusted to a higher frequency, the gain at the low-frequency station will increase to the point where the station comes in at any dial setting. No great harm results, but the serviceman has two jobs (repair of the oscillator and realignment of the i-f amplifier) rather than one. Also if he does not recognize the condition, he may waste time in needless troubleshooting.

Tampering with the i-f transformer trimmers can also cause the i-f amplifier to be tuned to about twice its normal frequency. Let us see what effect this would have. Stations that are picked up will be weak, because the correct i-f will still be formed in the mixer, and its second harmonic, which is weaker, will act as the i-f and will pass through the i-f amplifier. When the receiver is tuned to a dial setting of about this same frequency, the mixer itself will go into oscillation, acting as a tuned-grid, tuned-plate oscillator, and the receiver will squeal. This will happen over the middle section of the tuning range and will not be confined to a single dial setting. When the preselector circuit (usually the loop if one is used) acts as a part of the oscillator tuned circuit, the frequency will change if your hand is brought near the loop. This will vary the pitch of the squeals from the loudspeaker. In such a case check the i-f alignment. On the other hand it is natural for the squeal to vary when your hand is brought near the local oscillator coil. Disregard this effect, as it is meaningless in diagnosing trouble.

Improper alignment will sometimes cause oscillation in an i-f stage. If the secondary of an i-f transformer is tuned away from resonance, the primary plate load impedance increases sharply, and the stage gain may increase to the point where oscillation will occur. Realignment will clear up this condition.

In the illustration in Fig. 2, each i-f transformer winding is tuned by a separate powdered iron slug. In adjusting a slug, it is possible to turn it until it is all the way into the form and comes out the other side of its coil. If this is done with both cores, a peak may be obtained. The amplifier will be aligned properly, but the coupling between the two coils will be changed. The i-f amplifier will tune broadly. This may cause adjacent channel interference. The correct adjustment is the one that enables you to peak the coil with the slug turned farthest out of the coil.

If the i-f shifts about 10 to 20 kc, it may result in incorrect tracking at the low-frequency end of the dial. If the shift is much greater, the receiver may be completely dead.

To sum up, look for the following symptoms when considering the possibility of i-f misalignment:

1. Low sensitivity.
2. Poor selectivity (noted on stations separated by 10 or 20 kc).
3. Oscillation over entire dial.
4. Oscillation over a section of the dial. (Squeals at the low-frequency end are due to image interference and are natural in some localities, because of the frequency assignment of local stations.)
5. Low sensitivity at the low-frequency end of the dial caused by poor tracking of the preselector and oscillator. (Only on those sets using special-cut oscillator tuning capacitor plates.)
6. Receiver dead—sounds alive but no stations are picked up. (Be sure to check the oscillator operation before you realign the set.)

THE OSCILLATOR

Since the oscillator sets the point on the dial at which stations will be received, if it is misaligned, stations will be received at incorrect dial settings, and reception will be weak. This is true, whether the adjustment is a trimmer, a powdered iron core, or a padder.

As you know, the oscillator frequency in the average receiver is above the incoming signal by the i-f value. However, it may be possible to adjust the oscillator trimmer so the oscillator frequency will be below the desired station. Either adjustment will give satisfactory reception at the high-frequency end of the dial. However, if the trimmer capacity is increased sufficiently to make the oscillator resonate below the desired station, the oscillator frequency will not decrease at the correct rate as the set is tuned to the lower frequencies. Let us see why. The capacity of the trimmer will be so much larger than that of the tuning capacitor that changing the capacity of the tuning capacitor will have little effect on the total capacity. Therefore, the resonant frequency of the oscillator will remain about the same.

Let us take an example. Suppose the desired signal is 1500 kc, and the receiver i-f is 262 kc. If the oscillator is set so that the resonant frequency of the oscillator will be the desired frequency minus the i-f, it will be 1238 kc. With the trimmer capacity set so high, the oscillator frequency will remain at approximately 1238 kc no matter where the set is tuned. Therefore, at a station near 1238 kc, the desired signal and the oscillator frequency will be equal; and at a station near 976 kc, the oscillator frequency will be above the desired frequency by the i-f. We speak of this action as cross-over because the oscillator is first below and then above the frequency of the preselector. It is characterized by normal sensitivity at the extreme ends of the dial, and low sensitivity toward the middle of the dial. Usually, a receiver with crossover will be dead at the middle section of the dial.

This trouble is seldom found in modern receivers that have an i-f of about 450 kc, and there is not enough adjustment in the oscillator trimmer to permit the oscillator to be either above or below the desired station by the i-f value. However, cross-over is a common occurrence in sets with permeability tuning in the oscillator and in sets using low intermediate frequencies—175 kc or 262 kc. In all-wave receivers, it is easy to set the oscillator either above or below the incoming signal so you will have to be careful when working on them.

When an adjustable slug is used in the oscillator circuit and a trimmer is

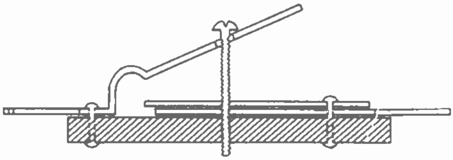


FIG. 3. With the plates all the way open like this, the trimmer is at its minimum-capacity position.

provided, the trimmer is always adjusted at the high-frequency end of the dial and the slug at the low-frequency end.

If you find that there are two settings of a trimmer that permit a signal to come through, use the setting with less capacity, that is, with the plates open wider. An example of the minimum capacity position is shown in Fig. 3. Then you know the oscillator is above the incoming signal. If you choose the maximum capacity setting, the oscillator frequency will be below the desired station.

THE PRESELECTOR

The preselector tracks the dial—that is, the dial shows the frequency to which the preselector is supposed to be tuned. In most sets there is only one preselector trimmer.

Misalignment of the preselector trimmer does not affect the point on the dial at which stations are received. However, if the trimmer is not adjusted correctly, the sensitivity will be low and you may hear converter hiss (a rushing noise) when stations are tuned in.

Since a trimmer adjustment is more sensitive when the circuit capacity is low, the trimmer adjustments for both the oscillator and preselector are usually made near the high-frequency end of the tuning range. If the adjustment is made at the extreme end of the range, however, the tracking error over the low-frequency end will be greater than if an alignment point is chosen some small distance from the extreme high-frequency end of the tuning range, for instance 1400 kc or 1500 kc for the broadcast band. If there is a short-wave band on the same receiver, it is a good practice to align the rf and oscillator trimmers with the tuning capacitor gang in the same positions as when the broadcast band was aligned.

On some sets, both the preselector and the oscillator coils have tuning slugs in addition to the high-frequency trimmers. If an adjustable slug is used in the preselector coil, it should be set at the low-frequency end of the dial. This will insure correct tracking of the preselector, the oscillator, and the dial.

The wave trap is another adjustment you may find in the preselector section of some older receivers. It is a tuned circuit, composed of a coil and a trimmer, which is connected between the antenna and the input of the set, and is tuned to the i-f used in the set. The purpose of the wave trap is to trap or attenuate any signal of the same frequency as the i-f amplifier before it can reach the mixer. If the wave trap is not correctly adjusted, interference, usually by a code station, will blanket the entire dial, regardless of where the receiver is tuned. Unlike the trimmers, the wave trap is adjusted for minimum rather than maximum output.

Wave traps are found in receivers using antenna coils rather than loops, and in sets using a stage of rf amplification ahead of the mixer. In a modern set in which the loop is connected directly to the mixer input, a wave trap cannot be effectively installed. However, they are generally unnecessary since a loop antenna is tuned and will reject signals at the receiver i-f. On the other hand, a straight wire antenna will pick up all signals, and if there is a code station nearby operating at the i-f of the receiver, interference may result if there is no wave trap. In a great many locations, such interference is not present. If you find that such is the case in your locality, you may ignore the wave trap adjustments.

Equipment Required for Alignment

Touching up the trimmers on a typical ac-dc set tuned to a station can ordinarily be done without any equipment except a small screwdriver. However, when more than just a touchup is required, you will need a signal generator, an output meter, and perhaps a special alignment tool.

In this section we will describe the various types of alignment tools used in aligning AM and FM radios. Then you will learn which type of signal generator to use and the frequency range it should have for aligning the various receiver sections. You will also learn where to connect the output meter to get the most reliable indication.

ALIGNMENT TOOLS

The process of adjusting a trimmer capacitor or powdered iron core of a coil for maximum output is known as peaking. When the adjustment has been made for maximum output, the trimmer or core is said to be peaked. This is done by turning the adjustment continuously in one direction, which will increase the output of the receiver up to a certain point, beyond which the signal will begin to drop again. The adjustment is then turned back to the point where the signal was maximum.

One type of variable core is fastened on a plunger held by a friction locking nut. To adjust the core, the nut is released, and the plunger is then pushed in or pulled out, and the nut is retightened.

However, most adjustments of either trimmers or variable slugs are made with an ordinary screwdriver or hexagonal socket wrench. If the transformer or other device being adjusted is grounded, any ordinary screwdriver or socket wrench of a suitable size can be used for alignment. However, if the adjustment is not grounded, the metal screwdriver or socket wrench and the operator's hand will add capacity to the circuit. When the tool is removed, the circuit will no longer be peaked. It is possible to compensate for this by over-adjusting; but that takes a good deal of skill and luck. To avoid such a time-consuming procedure, servicemen use a tool made of a rod of Bakelite, fiber, bone, or other insulating material. The rod has a very small metal screwdriver blade or a suitable socket at one end for adjusting purposes. Since the body of the rod is an insulating material and there is only a very small amount of metal

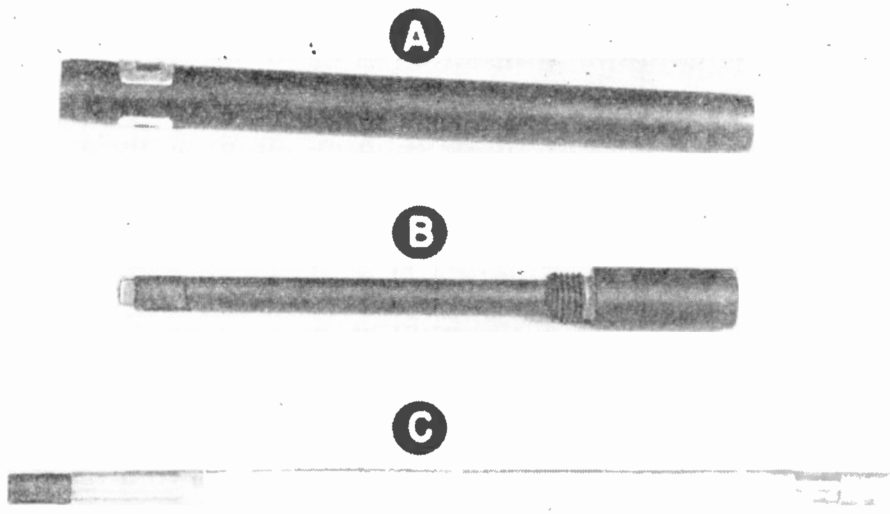


FIG. 4. Aligning tools. A, is a bone or fiber hex wrench; B, a bone or fiber tool with a small metal screwdriver tip; C, a tuning wand.

in the device, capacity effects are practically eliminated. Typical alignment tools are shown in Figs. 4A and 4B.

Another interesting alignment tool is the tuning wand shown in Fig 4C. It consists of a fiber or plastic rod with a band of brass at one end and steel or powdered iron at the other. When the brass end is inserted into a coil, it causes the coil inductance to decrease. Insertion of the end containing the powdered iron increases the coil inductance. Thus, when a tuned circuit is adjusted properly, inserting either end will change the inductance and throw the circuit out of resonance, causing the output to decrease. If inserting one end of the wand increases the output, and inserting the other end decreases the output, then the tuned circuit is not in resonance and must be aligned.

Actually, these wands are not in wide-spread use, except in aligning some TV and FM receiver coils, because it is just as easy to turn an adjustment slightly to see if the output increases or decreases. Most servicemen use ordinary screwdrivers and socket wrenches for alignment since most trimmers are grounded and the metal tool is not inserted far enough into the coil to vary its inductance. However, it is a good idea to have one of the inexpensive non-metallic alignment tools which consists of a combination screwdriver and hex wrench, as there are times when they are required.

THE SIGNAL GENERATOR

The type of signal generator used to align TV sets is somewhat different from that used for radios. You will learn about them later in your course. For now we will consider only the type used for AM and FM radios.

A signal generator used in radio servicing must be able to produce signals from about 170 kc to at least

110 mc, which will include the lowest i-f used in AM radios (175 kc) to the highest broadcast frequency used in FM receivers (108 mc). Actually, a calibrated frequency is needed only for i-f alignment. Broadcast station signals can be used for aligning the preselector and the oscillator. However, all signal generators are made to produce these high frequencies so that the instrument can be used to make signal injection tests in the preselector and oscillator sections.

All signal generators to be used for alignment have provisions for modulating the rf test signal with an audio signal of about 400 cycles per second. With today's receivers, a modulated signal is not really necessary because alignment can be made by measuring the avc voltage in the set rather than by listening to the audio signals from the loudspeaker. Actually it makes no difference whether the signal is modulated or unmodulated during alignment. If you want an audible output, you modulate the rf signal. In the better signal generators, the audio signal by itself is available for signal injection tests in the af amplifier.

The signal generator is equipped with an attenuator, corresponding to the volume control on a receiver. The attenuator makes it possible to adjust the strength of the signal fed from the signal generator. Sometimes, two separately adjustable attenuators are used—one for making large adjustments in signal strength and one for fine or small adjustments. You determine the required strength of the signal from the generator by the action of the receiver being aligned, as you will see later.

To get the necessary frequency coverage, a band switch is required to change the coils for various ranges in the signal generator. For example, the first range may be from 170 kc to 550 kc. Before you can tune to any frequency between these values, you must set the band switch to this position and adjust the tuning knob of the signal generator until its pointer is over the desired frequency on the dial scale. The next range might cover 550 kc to 1600 kc, the third range 1600 kc to 5 mc, the fourth 5 mc to 15 mc, the fifth 15 mc to 30 mc, and the last 30 mc to 60 mc. You can use the second harmonics of the last range to get a frequency coverage of from 60 mc to 120 mc for preselector-oscillator alignment in all short-wave AM and FM receivers.

Only two leads are used to feed signals from the generator to the receiver. One lead is the "ground" lead, and connects to B— on the receiver; the other lead is known as the "hot" lead, and is used to feed signals into the i-f amplifier or the preselector. Just where the connections should be made in the receiver circuits will be described later.

The illustration in Fig. 5 shows a signal generator of the type used in radio service shops. Let us describe the purposes of the various knobs.

The function switch on the left-hand side of the panel can be set to produce either an unmodulated, a modulated, or a fixed-frequency audio signal. The range switch is also provided so that you can choose the correct frequency range, and the tuning knob is used to set the tuning capacitor in the signal generator to produce any frequency covered by the band in use.

The signal output from the instrument in Fig. 5 is controlled by two attenuators. The coarse attenuator, which in this instrument is a switch in the lower center portion of the panel, produces large changes in signal strength output; the fine attenuator produces small changes in the out-

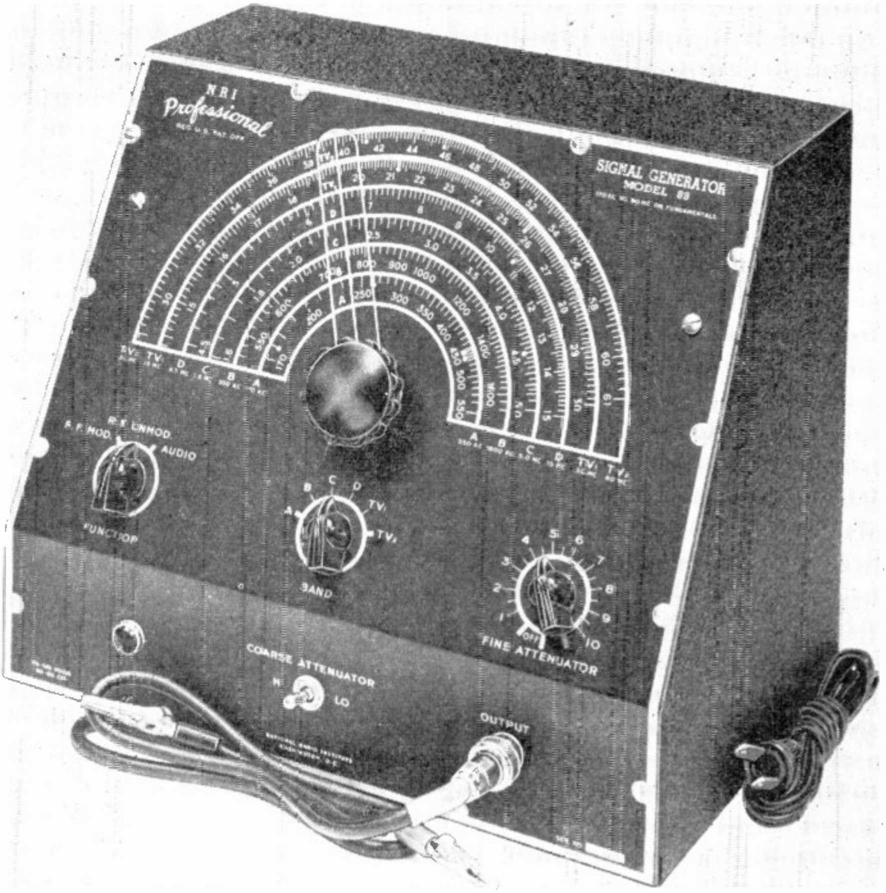


FIG. 5. A typical signal generator, the NRI Professional Model 89.

put selected by the coarse attenuator control. Notice that the fine attenuator is also used to turn the generator on and off.

The output leads terminate in clips that can be easily attached to the receiver circuits.

There are, of course, slight variations in the controls in signal generators of different manufacture, but basically, they are all similar to the one shown in Fig. 5.

If you purchase a signal generator, you will receive with it instructions on setting the various control knobs. However, you can usually see what the various adjustments are used for by merely studying the signal generator panel.

OUTPUT METERS

In aligning a broadcast receiver that does not have a wave trap, all adjustments are made to increase the receiver sensitivity. When the receiver sensitivity increases, the sound from the loudspeaker also increases. It may seem that you could just make all adjustments using a modulated signal, for maximum sound from the loudspeaker. Many servicemen do depend on their ears alone during alignment. However, a great deal of experience is required to notice small changes in the sound output, and the adjustments must be made with a small signal fed into the receiver to keep the receiver audio signal at a low value. This is necessary because the ear is not sensitive to small loudness changes at high volume levels.

Unless you have experience in aligning by ear, use a meter to indicate when the alignment adjustments have produced maximum sensitivity.

Years ago, before avc systems were developed, the only way to judge receiver sensitivity was by measuring the strength of the demodulated signal in the audio system. In fact, if you modulate the rf signal with a constant amplitude audio signal, and feed it into the receiver input, you can determine the sensitivity of any type of receiver by measuring the audio voltage at the output of the audio amplifier. This ac signal exists at the plate and grid circuits of all audio tubes and across the loudspeaker voice coil. The points that can be used for making output meter connections are marked B, C, D, E, and F in Fig. 6. Because it is easy to get at the voice coil terminals, the audio voltage is generally measured at point F. It is also often measured at the plate of the final power output tube, point E. The voltage, however, is generally too weak at preceding points to give useful information.

The audio signal is an ac voltage, and hence an ac voltmeter must be used to check its value. The audio voltage at the plate of the output tube may be between 100 and 200 volts. Here a meter range must be chosen that will not permit the meter pointer to be driven off-scale.

If you are using a vtvm, simply connect it in the circuit and watch the meter pointer during alignment. On the other hand, if you are using an ordinary ac voltmeter at point D or E, some of the current in the circuit will flow through the meter movement. For this reason, a .1-mfd, 600-volt capacitor must be placed in series with one meter lead when this type of meter is connected from point E to B— or from point D to B—. The capacitor blocks the tube dc plate

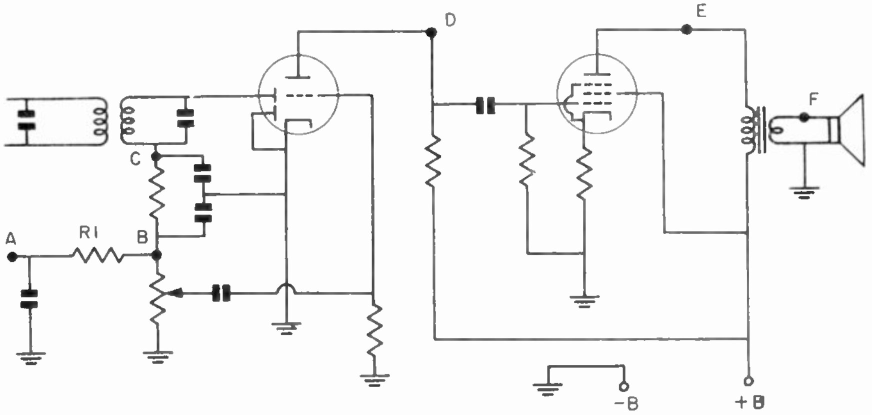


FIG. 6. Typical output meter connections are at points A, B, C, D, E, and F. There are ac voltages at B, C, D, E, and F; and dc voltage at A, B, and C.

voltage, but allows the ac signal voltage to be applied to the meter. This precaution is not necessary if the meter is connected at the voice coil since dc is not present at this point. With a vtvm, a blocking capacitor built into the meter circuit eliminates the necessity for an external capacitor. In many manufactured multimeters not using the vtvm circuit, a special output jack is provided, which automatically connects a blocking capacitor in series with the meter.

In modern superheterodyne sets, it is not necessary to measure the audio signal strength to determine the receiver sensitivity. This method is much less satisfactory than a check of the dc avc voltage; the avc voltage varies directly with the receiver sensitivity. Thus, by making the alignment adjustments for maximum avc voltage, maximum sensitivity is assured. Furthermore, if you measure the avc voltage, you can turn the volume control of the receiver all the way down during alignment so there is no sound from the loudspeaker to distract you.

The avc voltage can be checked between B— and points A, B, or C shown in Fig. 6. The connections are generally made from point B to the B— side of the circuit, because point B is the hot terminal of the volume control and is easy to locate. Point C may not be easy to find and might even be inside the last i-f transformer shield can. Point A is often used if the volume control does not serve as the diode load resistor. You can easily find point A by tracing from the black lead of the first i-f transformer (not shown in Fig. 6) to resistor R1.

The chassis, of course, is used only when it is an electrical part of the circuit. If the chassis is not an electrical part of the circuit, then the negative lead of the output meter must be connected to B—. This applies to both types of output meters.

When reading the output meter, remember you are looking for maximum meter response rather than any particular amount of response. You do not care whether the output meter reads 10 volts, or 12 volts, or 25 volts, just so you get the maximum meter indication possible for any particular trimmer. Actually, a serviceman does not look at the meter scale, much less attempt to read the voltage during alignment. He just watches the meter pointer, and makes the adjustments for greatest movement of the pointer to the right.

Aligning AM Receivers

Alignment of AM broadcast receivers is usually not a difficult job. There is a definite sequence of adjustments that you must make, and certain precautions that you must keep in mind, however, to align the receiver circuits quickly and accurately. For example, you should align the i-f amplifier section first. Then, you should adjust the oscillator, and finally the preselector section. Also, both the set and the signal generator should be turned on for at least a half hour before you begin the alignment, so that the set can be aligned at its operating temperature. The heat produced by the set during operation may change the values of trimmers and other parts slightly. These points and others will be covered in this section.

I-F AMPLIFIER ALIGNMENT

Suppose you are to align the tuned circuits of a typical AM receiver as shown in Fig. 7. The i-f amplifier is always aligned first. To do this, you must connect an output meter to the receiver, feed the correct i-f signal into the set, and adjust the trimmers for maximum output. This sounds easy, but there are a number of points to be considered. Let's list them in order:

1. How is the signal generator connected to the set?

2. What output meter connections should be used?

3. What is the i-f value of the receiver?

4. Where should the receiver tuning and volume control knobs be set?

5. What should be done if a signal of the correct intermediate frequency does not result in any output?

6. Where should the signal generator attenuator controls be set?

7. Where are the trimmer adjustments located?

8. Is it necessary to adjust the trimmers in any particular order?

When you know the answers to the above questions, you will find any i-f alignment job on a broadcast receiver to be quite easy.

Connecting the Signal Generator. The first thing to do is to connect the signal generator so it will feed a signal into the input of the i-f amplifier. There are a number of points where you can make the connections, but there is no one best connection for all receivers. The method most often used is to clip the ground lead of the signal generator to the frame of the tuning capacitor, and the hot lead of the signal generator to the mixer control grid circuit. The most convenient point for this connection is at the hot trimmer lead of C2 on top of the tuning capacitor gang. C2 is easy to locate because it is over the preselector section of the gang, and the plates in this section are physically larger than those in the oscillator section.

Frequently such a connection will result in so much hum from the loudspeaker that you will not be able to hear the modulation from the signal generator. The hum is caused by a difference in ac potential between the chassis (ground lead) of the signal generator and the receiver. It commonly occurs in ac-dc and three-way portable sets. The hot signal generator lead is at the same potential as the signal generator chassis as far as 60-cycle ac is concerned, and the hum gets into the set by way of the signal generator hot lead. A small capacitor of

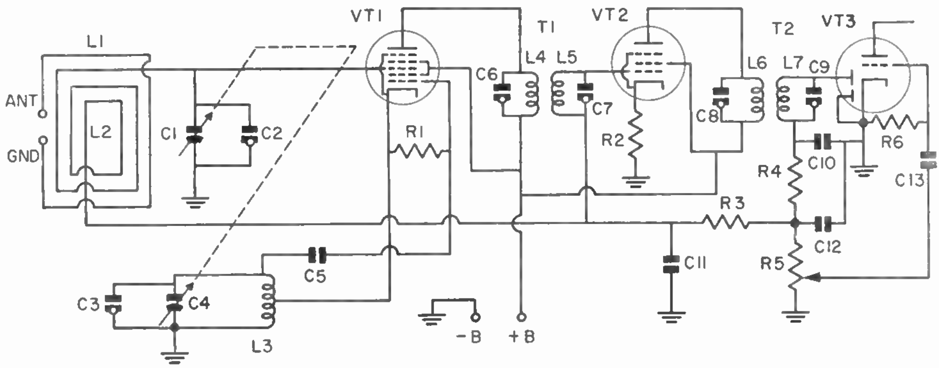


FIG. 7. The rf section of a typical broadcast receiver.

about .001 mfd or less will block out the 60-cycle ac and permit only the i-f signal to be fed into the set. You must solder one lead of the series capacitor to the hot lug of C2-C1. Another way to avoid this hum is to use an isolation transformer between the receiver and the power line. This is very satisfactory if such a transformer is available. Since these transformers have other uses, it is a good investment.

Another method of reducing hum is to connect the signal generator to the antenna and ground terminals of the loop. These are abbreviated ANT and GND in Fig. 7. The coupling between the single turn L1 to which the antenna and ground terminals connect, and L2 will block a signal with a low frequency such as 60 cycles, but will permit the i-f signal to be fed into the mixer input. This method is often used and is satisfactory if sufficient signal reaches the mixer to result in an output signal or reading.

Some receivers do not have antenna and ground leads. Then you must clip the signal generator ground lead to the receiver chassis or to the frame of the tuning capacitor and place the jaws of the hot lead on the loop frame, over one or two loop wires. If these wires are insulated so there is no direct connection between the hot lead and the wires, the method is very satisfactory and easy to use.

It is also possible to feed the signal into the plate circuit of the mixer stage without making a direct connection. This can be done by slipping a shield over the mixer tube, so that the shield does not ground to the chassis. Then, connect the hot lead of the signal generator to the shield and the ground lead to the receiver chassis. The capacity between the shield and the plate will induce a signal in the plate circuit. This method is commonly used in TV and FM alignment. The coupling is so slight that the primary of the first i-f transformer will not be loaded, and you can peak the trimmer without fear that the tuning will change when the shield is removed.

In some cases, transformers T1 and T2 are so far out of alignment that a signal fed to the input of VT1 in Fig. 7 will not pass through the amplifier and there will be no output. In this case you can roughly align the trimmers, or you can align T2 with the signal generator first, and then align T1.

To align T1 and T2 to roughly the same frequency, when the transformers use trimmers, screw all four trimmers up tight and then back each of them off about one-eighth to one-quarter of a turn. The circuits will be roughly tuned to about the correct frequency, and the signal generator will force the signal through the amplifier. Then the transformers can be exactly aligned to the correct i-f value. This method cannot be used on amplifiers having adjustable powdered iron cores in the i-f transformers because there is no way to preset these cores. In such a case, the i-f transformers must be aligned one at a time.

If you want to align T2 by itself, first connect the ground lead of your signal generator to B—, and the hot lead either directly or through a small capacitor to the control grid of VT2. Then align T2 by peaking its trimmers for maximum output. After the trimmers are peaked, feed the i-f signal from the signal generator to the input of VT1 as previously described, and adjust the trimmers for T1 for maximum output.

Connecting the Output Meter. The output meter connections have been previously described. Connect a vtvm or high resistance dc voltmeter across the diode load, which is the volume control marked R5 in Fig. 7. The polarity of the hot terminal of R5 in this circuit will be negative with respect to its grounded end.

Finding the I-F. The manufacturer's alignment instructions will always give the i-f value used in the receiver. If these instructions are not available, it is usually rather easy to find the proper i-f value. Connect the signal generator to the input of the receiver by any of the methods just described. Start with the signal generator tuned near 500 kc, and reduce its frequency slowly but steadily. The first signal that comes through the set when proceeding from 500 kc downward is at or near the correct i-f value. In the past, intermediate frequencies of 175 kc, 262 kc, 370 kc, 455 kc, 460 kc, 465 kc, and 480 kc have been standard. If the value indicated by your signal generator is near one of these frequencies, you can shift to this standard frequency and proceed with the alignment. If there is any doubt whether or not this is the correct signal to use, tune the receiver over a 20 or 30-kc range. If the signal varies or disappears, a signal generator harmonic is coming through the regular preselector channel. On the other hand, if the signal strength remains about the same, the signal coming through is at the correct i-f value.

The possibility of the signal generator harmonics beating with the local oscillator to produce an i-f signal that will go through the i-f amplifier can be troublesome. You can tune the receiver as suggested above, or you can stop the local oscillator by placing your finger on the rotor and stator plates of the oscillator tuning capacitor. If the signal comes through unchanged, it is not due to a beat. However, if the signal disappears or changes, a beat is involved, and you should tune the receiver to a point where this does not occur.

Setting the Receiver Controls and the Signal Generator Controls. When aligning the i-f section, tune the receiver to a point at the low-frequency end of the dial where a station does not come in and where the oscillator does not beat with the test signal or with its harmonics. Some servicemen stop the oscillator during the entire i-f alignment by soldering a wire across the oscillator tuning capacitor, or by slipping a metal screwdriver blade between the oscillator tuning capacitor plates. If you use the latter method, you must be careful that you do not permanently spring the plates out of position so that they need to be restraightened.

The receiver volume control can be set wide open or turned all the way off. Most servicemen leave the volume control wide open, because they want to hear the signal generator modulation during alignment. The loudness of the sound is then controlled with the signal generator attenuator. This is a good procedure, because it will prevent you from feeding too much energy into the receiver. Generally, you will keep the sound down to a point where it can barely be heard. Only a small amount of energy is entering the i-f amplifier and, therefore, the amplifier will not be overloaded.

Finding the I-F Adjustments. The next problem is to find the i-f adjustments. In practically all ac-dc sets, the trimmers are on top of the i-f shield cans, as shown in Fig. 8. If slug-tuned i-f transformers are used, one adjustment will be on top and one on the bottom of each can. In a few very old sets, the i-f trimmers are not in the shield cans, but are located nearby. They can be found from the manufacturer's service information, or by tracing the wiring.

The trimmer capacitors need not be adjusted in any particular order, and you do not need to know which trimmer tunes the primary and which tunes the secondary. During alignment you will go over the adjustments a number of times. The actual alignment of the i-f amplifier is a very simple matter.

With the output meter and the signal generator properly connected, and the correct i-f signal coming through the amplifier to produce sound in the loudspeaker and an output indication on the meter, adjust the trimmers one

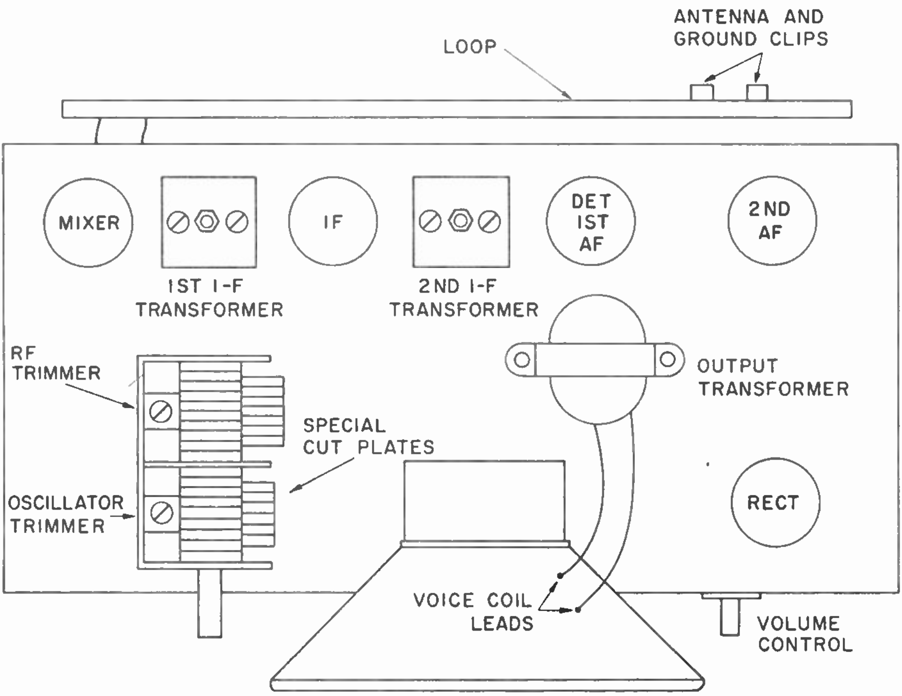


FIG. 8. Top of a typical ac-dc chassis, showing the location of the various trimmers.

at a time in any order to increase the receiver sensitivity. As the gain increases, the output also increases. Turn the signal generator attenuators down so the sound does not become unpleasantly loud and so the ac voltage remains near its original value. When you have peaked each trimmer, go over all the adjustments again to see if a further improvement can be made. When no further adjustment will increase the output of the i-f amplifier section, the trimmers are properly peaked and the adjustments should not be touched again.

To sum up, the following are the points to watch when aligning an i-f amplifier in an AM broadcast receiver:

1. Feed the signal generator into the amplifier in such a way that hum does not occur.
2. Tune the receiver to a point where a station is not received and where the local oscillator does not beat with harmonics of the signal generator to produce an i-f signal.
3. Determine the correct i-f value from the manufacturer's instructions or experimentally.
4. Reduce the signal generator output as the receiver sensitivity increases. Use just enough signal so the output can be identified.
5. Do not touch the tuning knob of the signal generator once you have started alignment. If you do so, it is very likely that you will not be able to reset the knob to the same position, and you will have to realign the entire i-f amplifier section.
6. Go over all adjustments at least twice to overcome any interaction between them.
7. When the i-f trimmers have been peaked, do not touch the adjustments again.

ALIGNING A VARIABLE SELECTIVITY I-F TRANSFORMER

In a high-fidelity receiver, the i-f stages are designed to pass a wide band of frequencies. This is usually accomplished by the use of critical coupling between the primary and secondary coils of the i-f transformer. However, a wide pass band is not desirable in a receiver intended also to pick up distant stations located on the dial near powerful local stations. Therefore, such receivers have a control of selectivity from peak to near flat response. Several methods for obtaining variable selectivity are shown in Fig. 9. Although they are not found in the latest high-fidelity sets, where special tuners operating in the FM bands are generally used, there are many in old AM receivers still in use, and you should know how to align them.

Elsewhere in the course you will learn to use a cathode-ray oscilloscope for band-pass alignment. This visual method allows you to see the resonant response curve of the rf system. In this lesson, however, we will consider only systems in which a peak adjustment is made in the peak position of the system, and band-passing is automatically obtained when the switch is placed in the high-fidelity position. When you have to align a receiver containing a variable coupling i-f transformer, set it for selective reception, and align the section for maximum output.

Fig. 9A shows a double-tuned resonant transformer with variable coupling between primary coil L1 and secondary coil L2. To make a peak alignment, set the control for minimum mutual inductance and adjust

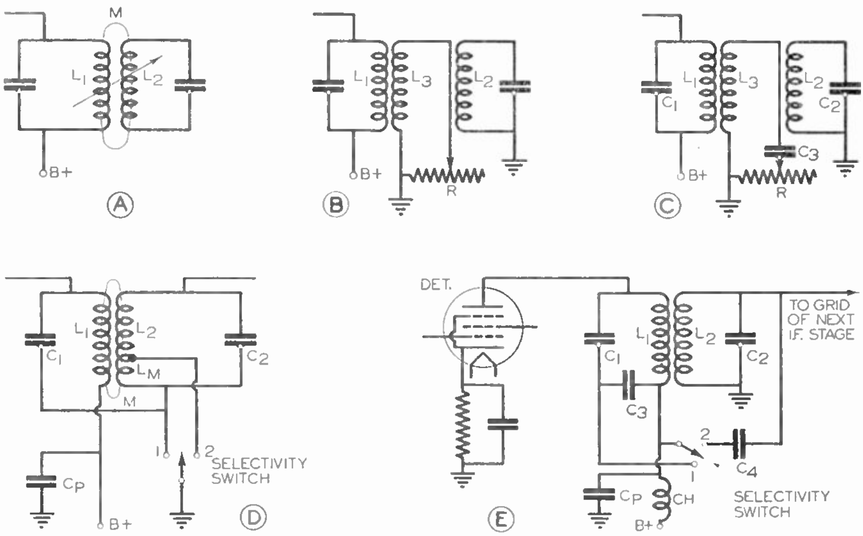


FIG. 9. Several examples of methods used for variable selectivity.

the trimmers for maximum output. Band-pass action is produced automatically as the control is adjusted for increased M (highest magnetic flux linkage between the windings).

When a critically-coupled, double resonant circuit is peaked, the response may be made broad by loading the circuits with resistance. A third winding, shown in the circuit of Fig. 9B, is sometimes used to introduce loss, which is equivalent to loading the transformer with a resistor. When R is zero, coil L3 is short-circuited and, through mutual coupling, acts as a load on both tuned circuits, giving broad response. When R is at its maximum resistance value, negligible loading exists, and the circuits can operate with peak response.

To align an i-f stage with this i-f transformer, set R at its maximum value, and adjust both trimmers for maximum output. Band-pass action is then obtained by decreasing the resistance of R.

The circuit shown in Fig. 9C is a similar band-pass circuit. In this example, there are three resonant circuits, L1-C1, L2-C2, L3-C3. When C3 is properly adjusted, the third winding introduces reactance into the other two circuits, so as to provide double peak response. Increasing the resistance of R reduces this apparent detuning of input and output resonant circuits, and returns the system to peak response. Note that this i-f transformer has three trimmers mounted on it. Do not, however, mistake a combination AM-FM i-f transformer for one of these. We will take up alignment of combination AM-FM receivers later.

To adjust the circuit, set R at maximum resistance, and adjust trimmer capacitors C1 and C2 for maximum output. Reset R for minimum or zero resistance, and adjust C3 for minimum output.

Some receivers have a fidelity control with two positions, a selective position and a high-fidelity position. Two such circuits are shown in Figs. 9D and 9E. In both circuits, the selective reception is obtained in position 1; so use this position for peak alignment.

With the switch shown in Fig. 9D in position 2, coil turns LM are added in the L1-C1 circuit, lowering the resonant frequency of the primary circuit. The primary current flowing in LM and closely coupled to L2 is out of phase with the secondary current. The out-of-phase current reduces the flux in L2, reduces its inductance, and increases the resonant frequency of the secondary circuit. This produces double-peak response automatically by resonating one circuit above and the other circuit below the i-f peak value.

In the circuit shown in Fig. 9E, with the switch in position 1, C3 is shorted and capacitor C4 is inactive; the circuit is then peaked. With the switch set in position 2, C3 is in series with C1, which reduces the circuit capacity, and increases the resonant frequency. At the same time, C4 shunts C2, and thus reduces the resonant frequency of the secondary. This provides double peak response.

PRESELECTOR AND OSCILLATOR ADJUSTMENTS

One purpose of aligning the preselector and the oscillator in any radio receiver is to make stations come in at the proper dial settings. Thus, you should make certain the dial pointer is correctly set before aligning this section of the receiver. With the tuning capacitor plates fully meshed, the pointer should be directly over the marker to the left of 55 (550 kc), if the scale runs from left to right. The general procedure is to turn the tuning capacitor shaft until the plates are fully meshed. Then slip the pointer along the cord so that it is over the last mark at the low-frequency end of the dial as shown in Fig. 10. If there is danger that the pointer may shift, seal it in place with a drop of fingernail polish. The same procedure is used on FM and short-wave receivers. On multiband sets, the adjustment is made on only one band, generally the broadcast band.

Now let us discuss the trimmer alignment procedures for the oscillator and preselector sections in an ordinary ac-dc set. We will discuss the alignment of sets using slug tuning and padder and wave trap adjustments later.

Trimmer Adjustments. The oscillator trimmer capacitor shown on the tuning capacitor in Fig. 8 is adjusted to bring in a high-frequency signal at the correct dial setting. Then the preselector trimmer is adjusted for maximum output at a somewhat lower dial setting.

Servicemen generally use broadcast stations rather than a signal generator for setting the padders and trimmers in tuners of broadcast sets. If you have a station near you in the high-frequency end of the dial near 1500 kc, and another station near 600 kc, your signal generator is necessary only to identify the stations.

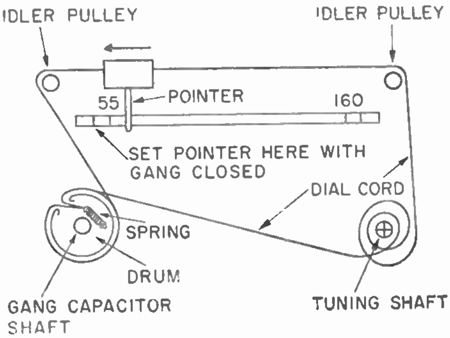


FIG. 10. With the tuning capacitor fully closed, the dial pointer should be over the first mark at the low-frequency end of the scale.

If you can definitely identify the

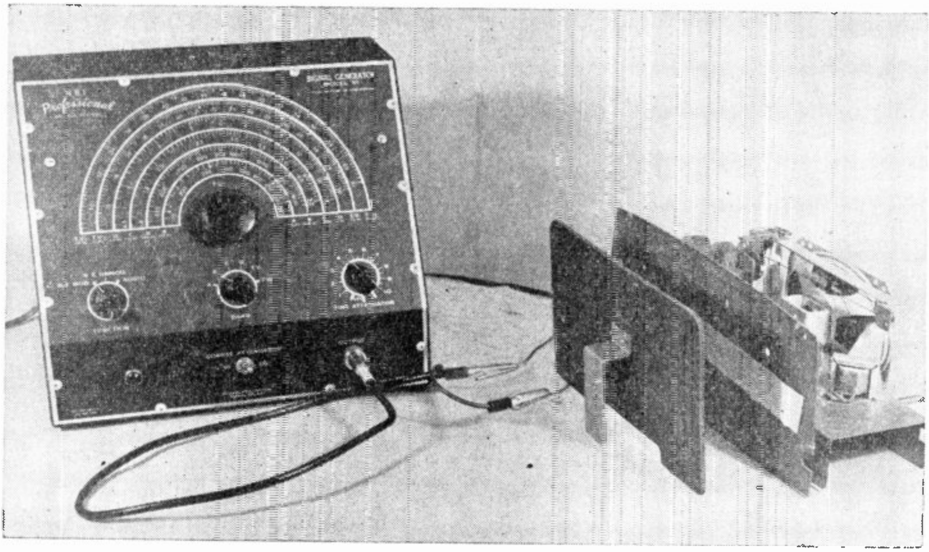


FIG. 11. How to place a test loop with respect to the receiver loop when using it for alignment.

station, tune it in and proceed to align the oscillator. However, if you are not able to identify the high frequency station, connect the signal generator to the receiver input, tune in what you believe to be a station operating at or near 1500 kc, and then swing your signal generator tuning knob back and forth across this frequency. If the modulated 1500-kc signal from your signal generator comes in at the same place as the station program, you know the frequency of the station and can proceed to use it as a signal source when aligning the set.

Of course, you can use your signal generator to align the oscillator and preselector instead of using broadcast stations. There are several ways in which the instrument can be connected. For example, the signal generator can be connected to the receiver by attaching the ground lead to the receiver chassis or B—and the hot lead to the loop frame. It should not be necessary to have the hot lead in direct contact with the loop. If the receiver has antenna and ground terminals, the signal generator leads may be connected to them. If in such a case you use the signal generator for the complete alignment, be sure to touch up the preselector trimmer when the receiver is connected to its antenna and a station is tuned in. This slight readjustment will eliminate the detuning effect of the signal generator on the tuned circuit and will give the best results with that particular antenna.

Another method of feeding the signal generator output to the set is to radiate a signal into the receiver loop antenna. This can be done by constructing a loop consisting of a few turns of wire on a cardboard form, and connecting the two leads of the loop thus formed to the signal generator. A loop discarded from an old receiver but not open will be satisfactory to use for this purpose. Fig. 11 shows how the test loop should be placed with respect to the receiver loop. Energy radiated from the test loop will be picked up by the loop antenna of the set being aligned. Keep the test loop at least several inches from the receiver loop so as not to introduce undesired reactance into the receiver circuits being aligned. Do not change the relative positions of the receiver loop and the test loop after you start the alignment.

If the receiver loop is not mechanically fastened to the chassis, place it so that it is in about the same position as when the receiver is in its cabinet.

To adjust the receiver circuits using a station signal, you will have to measure the avc voltage. To do this, connect a dc voltmeter across the diode load. It is not satisfactory to measure the audio signal at the voice coil leads, because the strength of the modulating signal from the station will vary constantly, and it will be impossible to tell when the set is aligned for maximum sensitivity.

After you have a signal, either from a broadcast station or from your signal generator, at the receiver input and the output meter connected properly, you can proceed to adjust the oscillator and preselector trimmers. To set the receiver oscillator, tune the receiver to a station at the high-frequency end of the dial, around 1500 kc. If you are using your signal generator, set both the receiver and the signal generator at 1500 kc. Adjust the oscillator trimmer so the signal is picked up. If you are able to pick up the signal at two settings of the oscillator trimmer, use the one having less capacity (the plates open wider).

Now tune to a signal 100 or 200 kc lower in frequency, and adjust the preselector trimmer for maximum indication on the output meter connected across the diode load.

Next, check the tracking by tuning the receiver and signal generator to the low-frequency end of the band, around 600 kc. If available, a broadcast station can be used. Adjust the preselector trimmer to see if it is peaked. If it is within ⅛ of a turn of peak output, the oscillator and preselector are tracking as well as can be expected. However, if you have to tighten the screw on the preselector trimmer capacitor a large amount, the i-f is too low for the particular preselector and oscillator coils being used. You can go back over the i-f alignment and increase the i-f 5 or 10 kc. Then, when you readjust the oscillator and preselector trimmers at the high end, you should find the tracking improved at the low end.

Of course, if you have to loosen the preselector trimmer excessively when checking the tracking at the low end, the i-f is too high and should be lowered. Remember that this applies only to sets using specially cut oscillator plates. In the vast majority of these receivers, correct tracking will be obtained the first time if the i-f amplifier has been aligned to the frequency specified by the manufacturer.

This completes the alignment on sets that do not use the low-frequency oscillator padder or slugs in the cores of the oscillator and rf coils.

Padder and Permeability Adjustments. The preliminary trimmer adjustments of receivers containing a slug-tuned oscillator coil or a padder capacitor are the same as described in the preceding section. The trimmers in the oscillator and preselector sections are adjusted first at the high-frequency end of the dial. Then, the padder capacitor or the permeability adjustments are made with the receiver tuned to the low-frequency end, around 600 kc. These adjustments, usually called 600-kc rocking adjustments, are used primarily to improve the preselector and oscillator tracking at the low-frequency end of the dial.

Fig. 12 shows a circuit using slug tuning in the oscillator coil and in the i-f transformers. The symbol on the diagram of three parallel lines with arrows through them is one method of indicating an adjustable core.

Capacitors C1 and C3 are the gang tuning capacitors, C2 is the rf or preselector trimmer, and C4 is the oscillator trimmer. C5 and C6 are fixed capacitors; the i-f transformer is peaked by means of the adjustable cores. Coil L2 capacity-couples the oscillator grid to the oscillator coil. It serves the same purpose as capacitor C5 in Fig. 7.

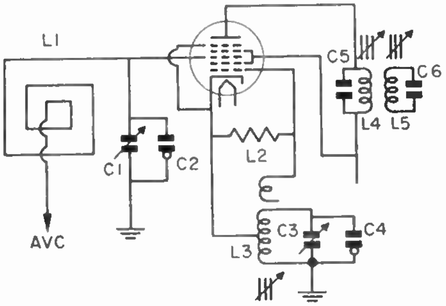


FIG. 12. Slug tuning in the oscillator coil and i-f transformer.

Fig. 13 shows an oscillator circuit similar to that used in Fig. 12, except that instead of slug tuning in the oscillator coil, there is a padder capacitor, C7, in series with the oscillator tuning capacitor C3 and the coil L3. Although the padder adjustment is rarely used in sets manufactured today, you may find it in some of the older sets, so you will need to know how the adjustments are made.

The 600-kc Rocking Adjustment. After you have adjusted the oscillator and preselector at the high-frequency end of the dial, there will usually be a small amount of mistracking at the low-frequency end. You cannot adjust the preselector to compensate for the tracking error, because any adjustment you make will also change the preselector tracking at the high-frequency end of the dial. In receivers using padders or slug adjustment, however, the oscillator frequency can be changed at the low-frequency end of the dial without appreciably affecting the high-frequency dial setting.

The preselector will be tuned to exactly 600 kc at only one dial setting. Your job is to locate this correct setting so that you can make the oscillator adjustment at this point. When both the oscillator and the preselector are tuned to this same setting, they will track at both the high-frequency end and the low-frequency end of the dial.

You could turn the dial to 600 kc, and adjust the padder or slug so that a signal of 600 kc would come in at exactly that dial point. However, if you made the adjustment in this manner, you would not get all the possible gain at the low frequencies. Instead, you should try many dial settings to find the point at which the preselector is tuned to 600 kc. Let us see how to do this.

Pick up a station at 600 kc, or a signal from your generator at or near 600 kc. Use a slightly higher signal generator frequency if there is an interfering station at 600 kc. Connect your output meter across the diode load and note the meter reading. Now tune the receiver to a frequency slightly higher or lower (about 5 kc) and adjust the oscillator padder or slug for maximum

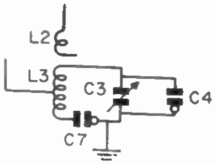


FIG. 13. The circuit in Fig. 12 may use a padder capacitor, C7, as shown above, instead of slug tuning.

output. If the output meter reading increases, the preselector is tuned nearer to the desired frequency. If the reading decreases, you have tuned the preselector away from the desired frequency by adjusting the dial. Continue turning the knob and readjusting the oscillator low-frequency padder or slug until you get no further improvement in output reading. Now, the oscillator and preselector are tracking each other perfectly at the low frequencies, regardless of the actual dial reading.

This does not complete the adjustment, however. The variation in the oscillator tuned circuit at the low frequencies will have some effect on the high frequencies, and will cause mistracking between the oscillator, the preselector, and the dial at the high end. Return the dial and signal generator setting to the high-frequency adjustment spot. Do not touch the *preselector adjustment.* Tune to the correct dial setting, and adjust the oscillator high-frequency trimmer until the signal comes in. Return to the low-frequency spot, and go through the oscillator low-frequency adjustment again. Continue making the two adjustments at the high- and low-frequency ends of the dial until you find that the low-frequency adjustment does not make necessary a readjustment of the oscillator high-frequency trimmer. When this occurs, the oscillator and preselector are tracking each other over the tuning range of the receiver and are exactly tracking the dial at the high frequencies. Any mistracking at the low-frequency end of the dial will be slight and can be ignored.

Instead of shifting the dial setting a few kilocycles at a time when adjusting the oscillator at low frequencies, you can "rock" the dial as follows. Turn the receiver tuning knob slowly and continuously back and forth across the setting of the desired signal, first turning the oscillator adjustment in, noting the output reading, and then turning it out. As the output reading increases, you decrease the movement of the tuning knob until it comes to rest at the point of the maximum output. Either method is satisfactory. Use the one that is easiest for you.

The following are the steps to take in adjusting a receiver having a padder capacitor or slug tuning in the oscillator circuit:

1. Adjust the oscillator and preselector trimmer capacitors at or near 1500 kc.

2. Tune to about 600 kc, rock the receiver tuning knob, and adjust the oscillator padder or slug for maximum output.

3. Reset the oscillator trimmer to track the dial at the high frequency in use.

4. Repeat Steps 2 and 3 only until no further improvement is noted.

Wave-Trap Adjustment. The last step in receiver alignment is adjustment of the wave trap. If you find from the schematic that there is a wave trap, you will find the adjustment on the chassis near the antenna coil. Connect the signal generator to the antenna and ground terminals of the receiver, and feed the i-f signal into the set. Then adjust the wave trap to give *minimum* response on the output meter. This completes the alignment of the standard AM broadcast receiver.

Aligning FM Receivers

The alignment procedures for an FM receiver are similar to those for an AM receiver. It is standard practice to align the i-f amplifier of an FM receiver before the preselector and oscillator circuits. The main difference is the additional adjustments in the FM detector that are not found in the AM detector. These must be made after you have aligned the i-f section.

Two different types of detectors have been widely used in FM receivers. These are the ratio detector and the discriminator shown in Figs. 14 and 15. These two detectors have been covered in earlier lessons, and you should be familiar with their operation. You should remember that when the discriminator is used alone, it will pass noise pulses, while the ratio detector is relatively insensitive to noise pulses in the received signal. To avoid noise when a discriminator is used, the signal is applied to the discriminator through a limiter stage, which clips off any peaks on the FM signal.

I-F AMPLIFIER— FM DETECTOR ALIGNMENT

The basic procedures for aligning the i-f amplifier section of an FM receiver are essentially the same, regardless of whether the set uses a discriminator or a ratio detector. The procedures for adjusting the detectors vary. We will first consider discriminator alignment, then we will discuss ratio detector alignment.

You can tell whether a set uses a discriminator or a ratio detector because in the ratio detector, one outside lead of the last i-f transformer secondary connects to a diode plate, and the other connects to a diode cathode, but in the discriminator both outside transformer leads connect to diode plates.

The frequencies used in aligning an FM receiver are much higher than those used in an AM set. Therefore, small variations in the receiver and signal generator oscillator frequencies will affect FM alignment more than

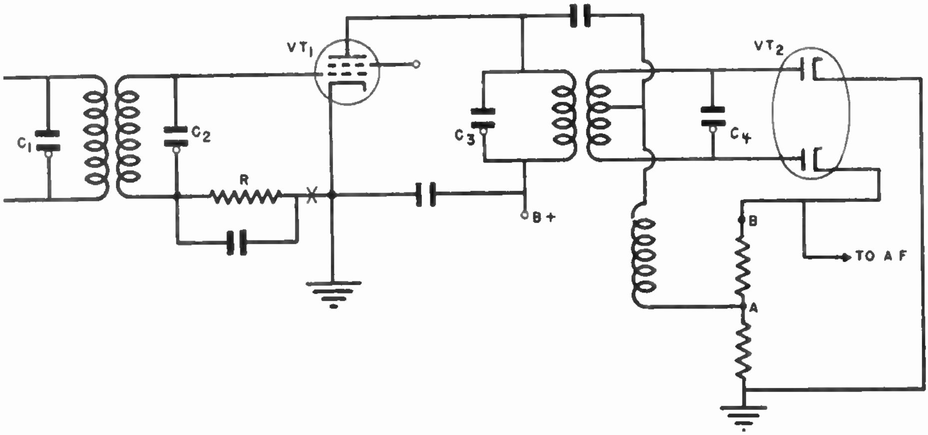


FIG. 14. An FM discriminator circuit.

AM alignment. It is very important that you turn both the receiver and signal generator on for at least thirty minutes before you make any adjustments.

Discriminator Alignment. In most FM receivers, the i-f section up to the input of the limiter tube is aligned first, then the output of the limiter and the input of the discriminator are aligned as a separate step.

In many cases, FM receivers use tuned circuits that are loaded by resistors. Hence, they have a broad peaked response. For this reason, it is possible to align an FM receiver by using a standard signal generator, the same kind you would use on an AM receiver, as long as it covers the required frequency band.

Since the trimmer adjustments are relatively broad, you must have some means of indicating the output. This is done by measuring the limiter grid current. The limiter grid current is used for two reasons. First, the limiter grid current varies directly with the signal strength. Secondly, since the limiter draws a grid current of 50 microamperes or more when stations are tuned in, it loads the preceding resonant circuits. By feeding a signal from a signal generator into the set during alignment, it is possible to duplicate this loading. You would, therefore, measure the limiter grid current to be sure it is normal and to make sure the limiter input circuit is properly aligned.

A recommended output indicator is a microammeter having a range of about 200 microamperes. If one is available, it can be inserted in the grid return circuit at the point marked X in Fig. 14. It should be bypassed by a .05-mfd capacitor.

Instead of measuring the limiter grid current, you can use a vacuum tube voltmeter or a 20,000 ohm-per-volt multimeter to measure the voltage drop across resistor R caused by the limiter grid current. The voltage should be at least .00005 (50 microamperes) times the resistance of R in ohms. Connect the positive meter probe to the ungrounded end of resistor R.

For alignment, the signal generator is connected to the receiver by any of the methods described for broadcast AM receivers. Making the connection to an ungrounded shield placed over the mixer tube is very satisfactory.

After connecting the signal generator and the output meter to the set, align the i-f amplifier section. Tune the signal generator to the i-f of the set; this is generally 10.7 mc. Adjust the i-f transformers for maximum meter reading. Reduce the signal generator output if the grid current exceeds the range of your output indicator. When you reach the limiter input, be sure that at least 50 microamperes of current is flowing before you adjust the trimmers corresponding to C1 and C2 of Fig. 14.

If the i-f amplifier is so badly out of alignment that you cannot get an output indication, start with the hot probe of the signal generator connected to the control grid of the last i-f tube (the one just ahead of the limiter), and then work back a stage at a time, aligning each stage as you go. Finally, you can make an over-all i-f alignment from the mixer to the input of the limiter. You cannot preset the trimmers as in the i-f amplifier of an AM receiver, because a slight variation in the adjustment of the trimmers will cause such a wide variation in tuning that the signal may not go through the amplifier.

When the i-f amplifier has been aligned satisfactorily, remove the output indicator from the limiter stage. If you used a microammeter in the grid circuit, remove the meter and resolder the circuit connections.

You are now ready to adjust the output of the limiter and the input of the discriminator. Leave the signal generator connections and its frequency setting just as they were for the limiter and the i-f adjustments. You will need either a vacuum tube voltmeter or a high resistance multimeter as an output meter. Connect your meter between point A and ground in Fig. 14, with the negative probe at point A. Then, adjust capacitor C3 for maximum meter reading.

Remove the meter probes from the circuit, and adjust the zero set on the meter so that the pointer reads center scale. This center-scale reading then corresponds to zero voltage. Readings to the left correspond to negative voltages; those to the right correspond to positive voltages. Connect the negative meter probe to point B and the positive probe to ground.

Now adjust capacitor C4 for zero reading on the output meter or for a reading as close to zero as possible. Remember, zero is now in the center of the meter scale. Theoretically, the reading should decrease to zero, but if it does not, use the adjustment giving the lowest meter reading. This completes the i-f, limiter, and discriminator adjustments, and none of these trimmers should be touched again.

Ratio-Detector Alignment. In a set using a ratio detector, a limiter stage is not generally used. In aligning such a set, all the i-f amplifier adjustments are set for maximum output before the secondary of the ratio-detector transformer is adjusted.

An output meter must be used when peaking the i-f amplifier trimmers. A vtvm connected across electrolytic capacitor C7 is ideal. A 20,000 ohm-per-volt voltmeter is also satisfactory, but it is not as good as a vtvm because it cannot be adjusted for center-scale zero readings. The polarity of the test leads of the meter should be the same as that marked on capacitor C7. Use a modulated signal from your signal generator, and connect the output of the signal generator to the receiver as described for AM receivers or feed the signal in by placing an ungrounded shield over the mixer tube.

Set the attenuator control on the signal generator for about 3 volts across C7, and adjust the various trimmers for maximum output voltage. As the sensitivity of the receiver increases, as indicated by a rising voltage, reduce the signal generator output until there is approximately 3 volts across capacitor C7.

This completes the alignment of the i-f amplifier, and only the secondary of the ratio detector transformer

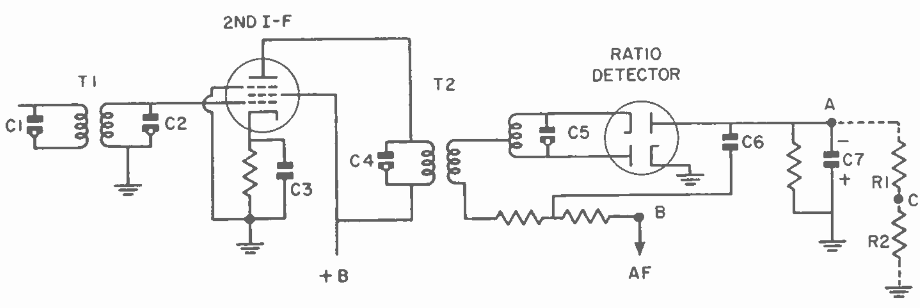


FIG. 15. A ratio detector circuit.

(T2) needs to be adjusted. One way of doing this is shown in Fig. 15. To use this method, connect two 100,000-ohm resistors, R1 and R2, into the circuit as shown by dotted lines in Fig. 15. Connect the meter between point C and ground, and adjust the secondary of the ratio-detector transformer. There may be a trimmer adjustment, such as C5 in Fig. 15, or there may be an adjustable slug. Whichever it is, adjust it for zero voltage. This completes the i-f alignment. Remove resistors R1 and R2 from the circuit.

It is not necessary to use an output meter or to install the two resistors when adjusting the secondary of a ratio-detector transformer. Most servicemen make this adjustment simply by turning the adjustment screw or slug until the audio modulation disappears or is at a minimum. There will be two or more points at which audio output is lower. However, you can recognize the correct point, because as you approach it, the output drops rapidly; also, the output at the correct point is much lower than at any incorrect point.

When adjusting the trimmers or cores of the first and second i-f transformers (not the ratio detector transformer T2 in Fig. 15) some manufacturers suggest alternate resistor loading of the windings to provide accurate observation of the peaks. In general, this is not necessary and need not be done unless the manufacturer specifically suggests it, and unless you find that adjusting one winding upsets the adjustment of the other winding on the same transformer. If the transformer windings are over-coupled, the adjustment of one winding will upset the adjustment of the other.

When the alternate loading method is used, a resistor of about 680 ohms is put in to load the plate winding of a transformer, while the grid winding of the *same transformer* is being peaked. Then the grid winding is loaded with the resistor while the plate winding is peaked. Only one winding is loaded at any one time. The resistor is installed in the circuit by temporarily soldering it to the transformer terminals or across the transformer leads. Be sure to remove the 680-ohm resistor after you have aligned the first two i-f transformers. It is not used when adjusting the transformer feeding the detector.

While you are aligning the i-f amplifier section of an FM set, you must not touch the signal generator tuning. If you shift the signal generator frequency during i-f alignment, you will have to repeat the entire process from the beginning.

FM PRESELECTOR-OSCILLATOR ALIGNMENT

The oscillator and preselector sections of an FM receiver are aligned in much the same way as those in an AM receiver. As in an AM receiver, the oscillator is adjusted to bring in a station near the high-frequency end of the dial. This would be approximately 106 mc for FM. The preselector trimmers are adjusted for maximum output at the same frequency. If any low-frequency adjustments are required in the preselector, they can be made in the vicinity of 90 mc. These signal frequencies compare to the 1500-kc and 600-kc signals used in an AM receiver.

Signal Generator Connections. The signal generator connections to the antenna input terminals of an FM receiver must be made through a dummy antenna to place the proper load on the receiver input circuit. The dummy antenna is made by connecting resistors to the receiver antenna terminals. If the receiver uses dual antenna posts, as shown above in Fig.

16, connect a 150-ohm carbon resistor in series with each of the leads of the signal generator. On the other hand, if the set uses an antenna terminal and a chassis ground, as shown below, connect a 300-ohm carbon resistor in series with the hot signal generator lead and the receiver antenna terminal; connect the ground lead of the signal generator directly to the receiver ground terminal.

additional rf trimmer capacitor adjustment to make on the gang tuning capacitor. This is of little importance, because all the trimmers in the preselector section are adjusted for maximum output at the same frequency, approximately 106 mc.

Unless the manufacturer's instructions state otherwise, you can assume that the oscillator frequency is higher than that of the preselector. Consequently, if in adjusting the trimmer, you find maximum output at two points, use the one where the capacity is lower.

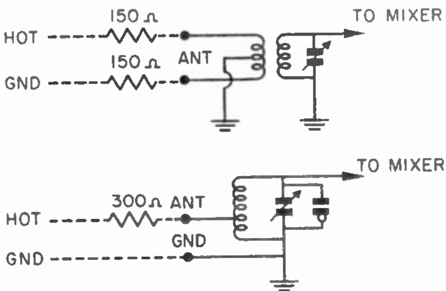


FIG. 16. Signal generator connections to the antenna terminals of an FM receiver are made through a dummy antenna. If the receiver uses dual antenna terminals, a 150-ohm carbon resistor is used in series with each signal generator lead as shown above; if it uses one antenna terminal and a chassis ground, connect a 300-ohm carbon resistor in series with the hot signal generator lead as shown below.

Output Meter Connections. The output meter connections are made at the same points in the receiver as for aligning the i-f section of the receiver. That is, if the set uses a discriminator, the output meter should be connected to measure the limiter grid current or the voltage from point A to ground in Fig. 14, and if it uses a ratio detector, the meter should be placed across the detector electrolytic capacitor, and the adjustments made for maximum voltage at this point.

Many FM receivers have an additional stage of rf amplification in front of the mixer. In that case, there is an

In a few cases, the manufacturer may suggest an adjustment of the preselector and oscillator coils at the low-frequency end of the dial to improve the tracking. Padders are not used, and the adjustment is made by spreading or squeezing together the few turns of which these coils are composed. If you carry out this part of the alignment procedure, you will find that a tuning wand is a time saver.

As you learned earlier, if the circuit is correctly aligned the receiver output will always decrease when you insert the wand in the coil, regardless of which end of the wand you insert. However, if the output increases when you insert the brass end, less inductance is required, and you should spread the coil turns apart slightly. Make the adjustment and recheck with the tuning wand. If inserting the end containing the powdered iron core causes the output to increase, more inductance is required, and you will have to squeeze the coil turns together a slight amount.

After the coils are adjusted, you should then go back and readjust the oscillator and preselector trimmers at 106 mc. Then return to 90 mc and recheck the coils. When further adjustment does not result in any improvement, you know the receiver is properly aligned.

Aligning Special Receivers

In preceding sections of this lesson, we have given alignment instructions for each section of AM and FM receivers, and have pointed out some of the variations you will find in the alignment procedures. Now we will describe how to align combination AM-FM sets and all-wave AM sets. You will learn how to avoid excessive interaction between the tuned circuits during alignment. Also, you will find out how to do the job in the least time.

COMBINATION AM-FM RECEIVERS

Because the two bands in an AM-FM receiver use separate i-f transformers, there is little interaction between the 10.7-mc i-f of the FM section of the receiver and the relatively low i-f in the AM section. There is a slight interaction of adjustments on the tuning capacitor between AM and FM, however, even though separate tuning capacitor sections and trimmers are used for each band. If a large amount of adjustment is required in any circuit, all other adjustments should be checked in the following order, unless the manufacturer's instructions suggest some other procedure.

1. FM i-f amplifier and detector adjustments.
2. AM i-f amplifier adjustments.
3. AM oscillator and preselector adjustments.
4. FM oscillator and preselector adjustments.

The procedures to use in the various sections were discussed in detail earlier in this lesson. Therefore, we will not go through them again here. Follow the instructions, and you should have no trouble aligning an AM-FM set. There are a few additional points that you will need to know, such as where to set the band switch and how to identify the various adjustments. Let us discuss these now.

When making adjustments, the band switch must be set to the band being aligned. Ignore the trimmers or core adjustments for the other band.

If possible, get the manufacturer's instructions so you can identify the various trimmers. However, even if you cannot get the manufacturer's instructions, you can soon tell which trimmers are used in which band because only those used in the band to which the switch is set will peak. For example, if you start the alignment on FM, you will find that only some of the trimmers will peak. You will know that all other trimmers on i-f cans are for the AM section. You can identify the oscillator and preselector trimmers in the same way.

You can identify the adjustment for the secondary of the detector transformer in the FM section because it is the only one on which the output meter will swing either positive or negative from zero. If you are using a modulated signal, this adjustment is the one which will give the minimum sound output. The sound in the output will increase as you adjust the trimmer to either side of the zero adjustment point.

If you have to identify the various adjustments in this manner, it is a good idea to make a rough sketch to identify them so that you will not make any mistakes during the alignment procedure.

An example of a combination AM-FM receiver is shown in Fig. 17. Notice that this set uses a stage of rf amplification in front of the mixer, and that additional sections are included in the tuning capacitor gang to tune the input of the rf amplifier stage. These sections are labeled "AM ANT" and "FM ANT" to distinguish them from the sections used between the rf amplifier and the mixer. The latter sections are labeled "AM RF" and "FM RF".

Separate i-f transformers are used for the two bands of the receiver shown in Fig. 17. All the transformers are permeability tuned, and the locations of the primary and secondary adjustors are indicated on the diagram.

As we have said, any receiver, including the combination AM-FM receiver, is aligned a section at a time. You align the i-f amplifier and detec-

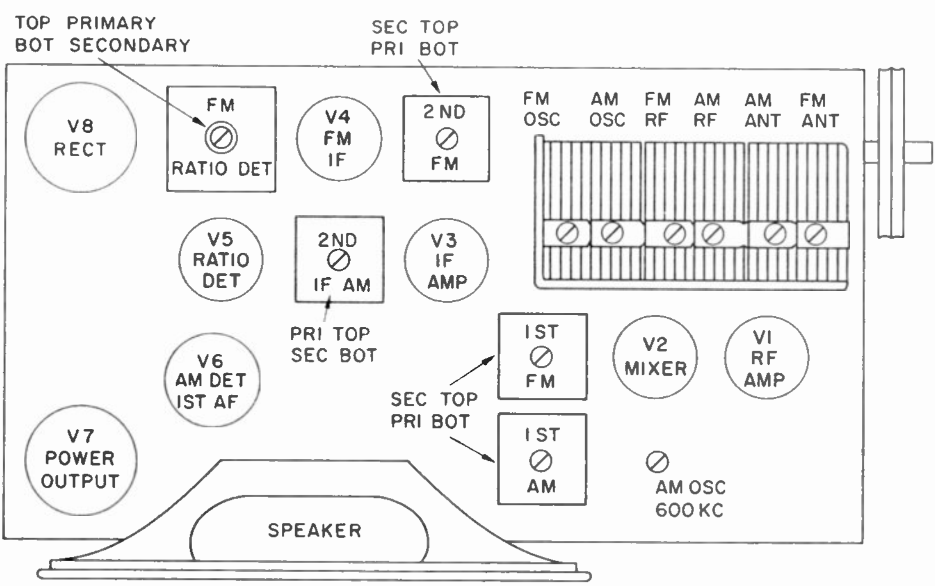


FIG. 17. A combination AM-FM receiver showing location of adjustments.

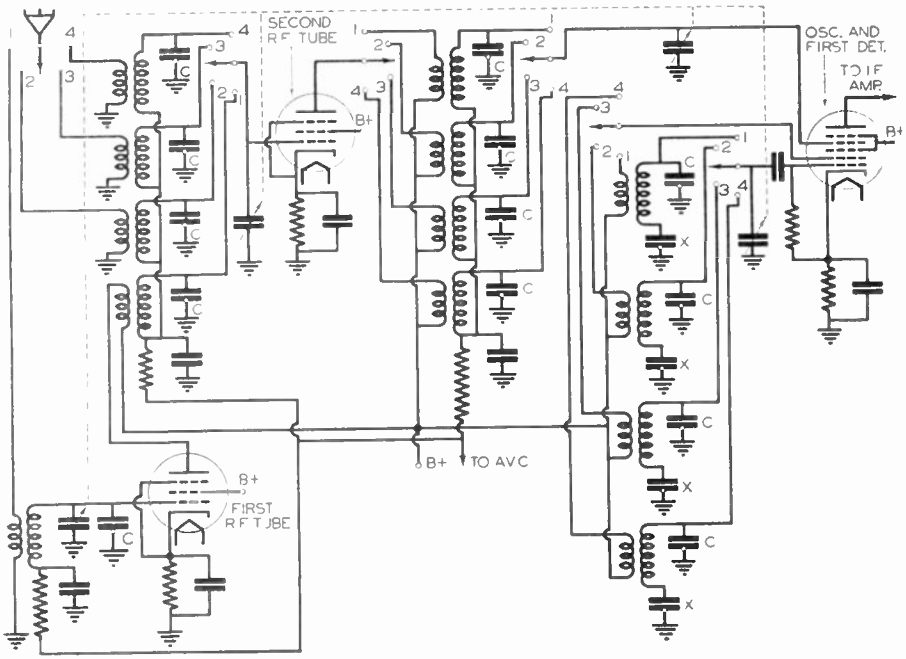


FIG. 18. An all-wave receiver with independent bands.

tor in the FM section first, and then the i-f amplifier in the AM section. Then you align the oscillator and the preselector in the AM section and then the oscillator and the preselector in the FM section.

Notice also in the diagram in Fig. 17 that there is a 600-kc oscillator rocking adjustment for the AM band. This adjustment is made to permit accurate tracking on the low-frequency end of the dial.

Align each section as described in this lesson. Make the adjustments carefully, and you should have no trouble even in the most complex alignment jobs.

ALL-WAVE RECEIVERS

With an all-wave superheterodyne, which is not common today, the i-f stages are always aligned first in the usual manner. Then, the rf adjustments for each band are made independently. Often the band-switching circuit in an all-wave receiver makes it necessary to align the bands in a definite order. Two typical multiband circuits are discussed below.

Independent Bands. Fig. 18 shows a conventional, highly flexible preselector system for all-wave reception. Each of the bands except the highest one use one stage of rf amplification. The highest band, with the switches in position 1, uses an additional stage of rf amplification. Each tuned circuit in the preselector has a high-frequency trimmer, C. When a different range is switched in, another set of high-frequency trimmers is used. Hence, the readjustment of C for one band in no way affects another band.

The oscillator circuit for each range has its own high-frequency trimmer C and its low-frequency padder X. The tracking adjustment can be carried out in any order, because the bands are completely independent. Follow the usual procedure for each band, and make the adjustments at the high and low ends, as described for the single band AM set described earlier.

You may find a receiver with this preselector system that has trimmer capacitors on the gang tuning capacitors. They will be used to adjust only one of the ranges. Check to see which range does not have the high-frequency trimmers on the coils, and align this band first, using the trimmers on the ganged capacitors. As a rule, they will be used on the highest frequency range. If you use them to align the wrong band, you may add so much capacity to the circuit that you will not be able to adjust the trimmers for some other band to a low enough capacity for alignment.

Cascade Alignment. Some multi-band receivers were made in which all the preselector coils are wound on one form and all the oscillator coils on another form. This reduced costs, but introduced a problem in alignment that you should recognize. Such a construction is used in the circuit shown in Fig. 19. Oscillator coils L4, L5, and L6 are all wound on one coil form; preselector coils L1, L2, L3, and the broadcast primary coil L are all wound on another coil form.

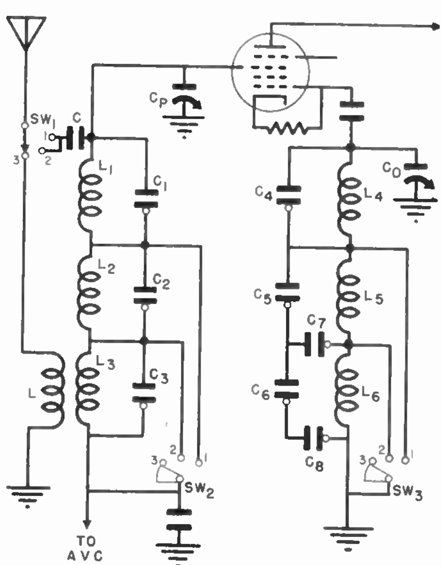


FIG. 19. The preselector and oscillator circuits of a receiver requiring cascade alignment.

Switches SW1, SW2, and SW3 together make up the wave-band switch. With the switches in position 1, the receiver is set to the highest frequency band. Notice that coils L3 and L2 are shorted by switch SW2, leaving coil L1 to be tuned by capacitor CP. The highest frequency preselector trimmer is C1. In the oscillator section, when switch SW3 is in position 1, it shorts coils L6 and L5, leaving coil L4 to be tuned by capacitor CO. The high-frequency trimmer is C4.

When all the switches are set to position 2, only coils L3 and L6 are shorted. In this position, coil L5 is the major oscillator inductance, but coil L4 is still in the resonant circuit and is also included in any tuning performed by CO. In this case, capacitor C4 (the trimmer) has the effect of reducing the effective inductance of L4 for this band. Similarly, preselector coil L2 is the major inductance, but L1-C1 is also in the tuning circuits. So, if you adjust band 2 first, and then band 1, adjusting capacitors C1 and C4 will upset the previous alignment. Therefore, align the high-frequency band first; all the trimmers for the other bands are then shorted and are of no importance.

When bands 1, 2, and 3 are adjusted in order, each adjustment is made to include the next one. That is why it is called cascade alignment.

To align this all-wave preselector, connect the signal generator to the receiver input. Set the receiver at a frequency near the high-frequency end of the highest frequency band, set the signal generator to the same frequency, and adjust C4 and C1 for maximum output. There is no low-frequency oscillator padder capacitor in this band.

Next, align band 2, the L2-C2 and L5-C5 circuits. Leave the dial pointer set in approximately the same position at the high-frequency end as for band 1, and reset the signal generator to the frequency at which the pointer is set. Adjust C5 and C2 for maximum output. Under no condition should you touch trimmers previously adjusted. Set both the receiver and the signal generator to a low frequency, and make a rocking adjustment with C7 for maximum output. Check alignment at the high-frequency end, and adjust C5 if necessary.

The third broadcast band is handled in the same way, by adjusting C6 and C3 at the high-frequency and C8 at the low-frequency points.

Reasonable dial tracking can be expected on band 1, without a padder capacitor, because of careful manufacture and the proper choice of the oscillator coil value. The low frequency padder C7 in the second highest band may be omitted in some receivers or may be a fixed capacitor. If the trimmers are mounted on the variable capacitor, use them for aligning the highest frequency band.

Special Data on All-Wave Receivers. Identifying trimmers on an all-wave receiver is quite a problem. The trimmers may be mounted on strips in some definite order, or they may be scattered throughout the set. If at all possible, get the manufacturer's instructions for such jobs. Otherwise, you will have to spend some time finding the proper adjustments. This problem is complicated by the fact that padder capacitors, or even high-frequency trimmers, may not be used on all bands.

You may be able to identify the trimmers by tracing from the coils, if the coils are not in shields. Sometimes you may also be able to trace them to the band switch and identify the trimmers.

If you cannot identify the trimmers in this way, turn the band switch to the highest frequency band, tune in a signal, and then touch the trimmers one after the other with a metal screwdriver. You will hear noises or detune any signals being received when you touch the trimmers in that band. Repeat this procedure for the other bands to identify the remaining trimmers.

Padder capacitors usually have more plates than the trimmers. However, you cannot always use this as a means of identifying the part. The trimmers themselves may be larger or have more plates for the lower frequency bands.

The manufacturer's instructions should give you any unusual data, such as if the oscillator frequency is below instead of above the incoming frequency, as in a few cases on the highest frequency short-wave band. If you have no instructions, you should go ahead with the standard procedure and note the results.

Be careful in adjusting the oscillator in the high-frequency (short-wave) bands, to avoid cross-over. If the i-f value is low compared to the frequency of alignment (usually 18 mc or higher), the usual two points of maximum response will be close together. Select the setting at which the trimmer capacity is less (plates farther open) when aligning, to keep the oscillator frequency above the incoming frequency. Then check the response at the low-frequency end of the band.

You may hear a third signal between the two strong ones. This results if the incoming and local oscillator signals differ by one-half the i-f value, producing a signal that the frequency converter may double. If you keep the level of the signal generator down, this signal can be readily detected by its low output.

SUMMARY

Most of your alignment work will be on the typical 5-tube ac-dc receivers and the three-way portable receivers. Most of the jobs will be extremely simple and in many cases only a touch-up without a signal generator and an output meter will be required. At the start, however, we suggest that you use both an output meter and a signal generator in all cases to familiarize yourself with the correct procedures.

The alignment of FM and combination AM-FM receivers is a little more difficult, but if you take your time, you should have no particular trouble.

The number of all-wave receivers in use is steadily decreasing, but alignment instructions on such sets are still available. You should get the instructions when possible so that you can refer to them and quickly identify the adjustments. After that, the actual alignment will be simple.

Lesson Questions

Be sure to number your Answer Sheet 38B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. What are the two main purposes of aligning a radio receiver?
2. What is the purpose of having specially cut plates in the oscillator section of the gang tuning capacitor?
3. Suppose the sensitivity of the receiver you are working on is very poor, and you also notice that the selectivity is poor. What would you do to correct the conditions?
4. What precautions would you take to make sure the oscillator frequency in a receiver is above the frequency of the incoming signal?
5. Briefly tell what is meant by "peaking".
6. In aligning modern AM superheterodyne receivers, which output indication is more satisfactory: measuring the sound output with an output meter, or measuring the avc voltage with a vtvm?
7. List the sections of a modern AM superheterodyne receiver in the order in which they are usually aligned.
8. How can you determine the i-f value used in an AM receiver if you do not have the manufacturer's service sheet and the frequency is not marked on the receiver chassis?
9. What are the two reasons why the limiter grid current is used in an FM receiver as an output indication during the i-f amplifier alignment?
10. At which end of the receiver dial do you adjust the oscillator trimmer capacitors in an AM or an FM receiver?

MAKE BELIEVE IT'S TRUE

A young man once asked a successful friend to state just one rule for success. "*Look as though you have already succeeded,*" the friend advised. Following this rule eventually made this man president of a great bank in New York City.

As Shakespeare expresses it: "*Assume a virtue if you have it not.*" Dress like a successful man, act like a successful man. Be successful in all your thoughts, and you will be successful in the world as well.

David V. Bush states this same thought in this way: "*If we think poverty thoughts, we become the sending and receiving station for poverty thoughts. We send out a 'poverty' mental wireless, and it reaches the consciousness of some poverty-stricken 'receiver.' We get what we think. If we are going to be timid, selfish, penurious and picayunish in our thinking, these thought waves will go forth until they come to a mental receiving station of the same caliber. 'Birds of a feather flock together,' and minds of like thinking are attracted one to the other.*"

Once your learn that you have a legitimate control over your own affairs, that you have the right to win, *you will win.*

J. E. Smith

HOW TO ELIMINATE HUM, SQUEALS, AND MOTORBOATING

39B

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Study Schedule No. 39

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. **Introduction** .... Pages 1-4

A general discussion of hum and what is to be covered in this book is given in this section.

☐ 2. **Causes of Hum in the Power Supply** .... Pages 4-8

Defects in vacuum tube and selenium rectifiers, filter capacitors and filter resistors are considered as causes of hum.

☐ 3. **Causes of Hum in Signal Circuits** .... Pages 9-17

Defects in control-grid circuits, poor connections, improper ground connections and cathode-to-heater leakage are discussed, and then causes of modulation hum are taken up.

☐ 4. **Causes of Hum in AC Receivers** .... Pages 17-21

Here you study decoupling circuits, reversed hum-bucking coil, inductive coupling, unbalanced push-pull output tubes, and mechanical hum.

☐ 5. **Localizing Hum** .... Pages 21-26

You learn the procedures for localizing both steady hum and modulation hum.

☐ 6. **Oscillation, Squealing, and Motorboating** .... Pages 26-36

You study causes of oscillation in the rf and af sections of both ac-dc and ac receivers, and also squeals and howls not due to receiver defects.

☐ 7. **Answer Lesson Questions.**

☐ 8. **Start studying the next Lesson.**

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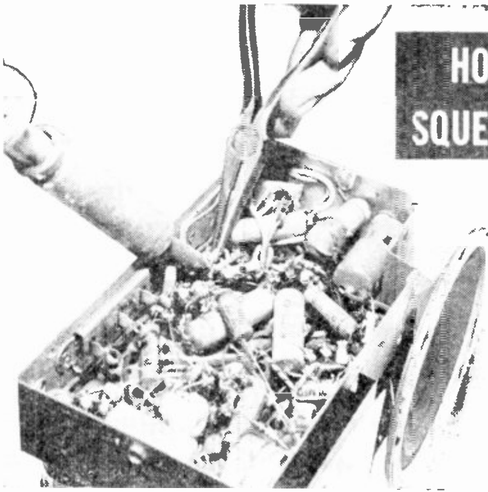

HOW TO ELIMINATE HUM, SQUEALS, AND MOTORBOATING

ALTHOUGH hum is a very common service complaint, there is no definite point at which we can say it is there or it is missing. Only a battery-operated set can be completely humless; there is always some residual hum in even the best receiver operating from a power line or a power converter. The object in servicing a set for hum is not to remove the hum altogether, but to reduce it to an acceptable level. This lesson will teach you the many ways in which this can be done.

In this lesson you will also study unwanted oscillation in receiver circuits, which produces squeals and motorboating in the output. As you will learn later, any stage in a receiver can go into oscillation under certain conditions. Some defects cause the rf or the af section to oscillate independently, some cause both sections to oscillate at the same time. The oscillation can be confined to one stage, or it may take place in several stages in the same receiver section. The causes of unwanted oscillation and the procedures to follow to locate the defect in a receiver will be discussed in the last part of this lesson.

Let us take up hum, first. You can learn to recognize hum very easily. Listen carefully to the output of any properly operating power line receiver when the surroundings are quiet and no program is coming through the loudspeaker. Turn the volume control to zero to eliminate stray noises and other signals. You will soon become conscious of a low-pitched humming sound, if your ears can hear low-frequency sounds. If the receiver is out of its cabinet, the lack of baffle may prevent the loudspeaker from setting up sound waves at the hum frequency. In such a case, touch the cone lightly with your finger tips. Any vibration you feel is due to hum voltages in the voice coil.

The type of hum we will be concerned with in this lesson usually has the same frequency as the power line and its source is the power line. In some cases, the hum frequency may be a multiple of the power-line frequency. This is true in receivers using full-wave rectification. Then the ripple in the power supply will have a frequency of 120 cycles per second rather than 60 cycles per second as in an ac-dc receiver using half-wave rectification.

IDENTIFYING THE FREQUENCY OF THE HUM

It will be worth your while to become acquainted with the difference between 60-cycle and 120-cycle hum. You can do this easily, if you can find a set using a power transformer (an ac receiver). Such a set uses full-wave rectification. Find the filter choke or filter resistor and measure the dc voltage across it, noting the polarity of the voltage. Next, connect an electrolytic capacitor across the filter resistor or choke. Be sure to use the correct polarity. The capacitor will nullify the effect of the filter element, and you will hear considerable hum from the loudspeaker. This will be a 120-cycle hum. Next, remove the capacitor and connect a small paper capacitor, .01 to .1 mfd, between the hot side of the volume control and the ungrounded filament lead of the first af tube. This will supply a 60-cycle signal to the volume control; and by turning the volume up slightly, you will be able to hear the 60-cycle signal reproduced by the loudspeaker. Once you have heard the difference between 60- and 120-cycle hum, you will find this knowledge an aid in servicing ac receivers. If you hear a 120-cycle hum, you know that the trouble is due to a defect in the B supply, whereas if you hear a 60-cycle hum in an ac-operated receiver, the hum is probably coming from a 60-cycle source directly—at least it is not due to an ordinary power supply filter circuit defect.

NORMAL AND EXCESSIVE HUM LEVELS

Usually the hum level is considered satisfactory if the hum is not noticeable when the device is in normal operation, but this standard allows wide variations in the amount of hum present. For example, an outdoor public address system can have more hum than a radio receiver, because in its normal use, surrounding noises will make hum less noticeable.

Incidentally, there may be considerable difference between the amount of ac hum *voltage* in the output circuit and the amount of hum *sound* actually coming from the radio loudspeaker. Inexpensive table model receivers give relatively little hum output, because the speaker and the output transformer are not designed to favor the passage of low frequencies. As a result, a defect must usually be quite serious before the hum level rises an appreciable amount. On the other hand, even an extremely small amount of voltage at the voice coil of a loudspeaker in a high-fidelity system may produce a relatively large amount of hum sound, both because the system is capable of reproducing low frequencies, and because the speaker baffle or speaker cone may have a response peak at low frequencies or have resonant points at or near the hum frequency.

Practical experience is the only guide to the amount of hum normally found in any particular kind of set. Make a point of noticing the hum level of radio receivers you service for other complaints so you will learn to know the amount of hum to expect in various models.

If you have a very sensitive ac voltmeter like those used in the better vacuum tube voltmeters, you should make it a point to measure the ripple voltage at the filter output of various sets so you will know what to expect. Also measure the input ripple voltage and any ac voltage at the plate of the power output tube when a signal is not being received. These values will be helpful in trouble-shooting for hum in defective receivers and, as we will show later on, will be useful in localizing hum to a section or stage in a set.

Remember—the amount of hum permissible depends to a great extent upon the listener. Some ears do not hear low-frequency sounds well. If you find that you cannot hear hum unless you bring your ear quite close to a loudspeaker, be careful about handling customer complaints; your customers may hear hum much more readily than you do. In such a case a knowledge of the amount of ripple voltages normally present throughout a receiver is quite helpful.

Usually you will be asked to service a set for hum only if some defect or change in the circuit has raised the hum level to an abnormal degree. Surprisingly large amounts of hum may be tolerated by the receiver owner until his attention is called to the fact that the receiver is humming, or until some defect suddenly causes an even louder hum. But once he has become definitely conscious of the hum, he may then be so critical that he listens for the hum instead of the program.

Incidentally, when you are working on a receiver with an elusive case of hum, you may yourself reach a point where even a normal hum level seems excessive. Getting away from the receiver for a while will frequently restore your sense of proportion. This will often work for the customer—just keeping the radio in your shop for an extra day or two, so that he begins to forget the hum annoyance, may satisfy a customer if his radio is apparently normal and the usual hum elimination procedures do not lower the hum level.

Before we study hum location procedures, we will review the causes of excessive hum in the radio circuits. This will make it easier for you to see just what must be done to localize and eliminate hum troubles quickly. This material also applies to TV sets, since the audio systems of TV receivers are similar to those in radio receivers, and the low voltage power supply in most TV sets is about the same as that of an ac radio receiver. For this reason we will give considerable information on ac sets which use power transformers, although these do not make up the bulk of the radio receivers you will service.

In this lesson, we have assumed that a standard 60-cycle power line is used. If some other line frequency is used, then the frequencies will be different. For a 25-cycle line, the frequencies will be 25 and 50 cycles instead of 60 and 120 cycles as in these examples.

WHAT IS HUM?

Hum is an interfering signal which in one way or another comes from the power line. Hum may modulate rf signals from broadcast stations that are picked up by the power line. In this case, the power line acts as an antenna. These signals, carrying the hum along with the regular program modulation may enter the preselector of a receiver directly, through reradiation from the power line, or through the power supply of the receiver, or the hum may be modulated on the carrier in the receiver circuits. Any of these result in tunable hum. Tunable hum is heard only when a station is tuned in.

Most hum is of the non-tunable type, in which the hum gets into the loudspeaker voice coil directly or enters a grid-cathode circuit, where it is amplified. If the hum is in the receiver power supply, the variations in the plate voltage caused by the hum will be transferred to the grid of the following stage where it will be amplified.

Hum can enter the grid-cathode circuit of the tube from the filament supply. Such hum has the same frequency as the power line, regardless of the type of rectification used.

As a quick check before you remove

the chassis of an ac-dc set from the cabinet, reverse the ac plug in the wall outlet to see if this has any effect on the hum level. Some receivers will produce hum when the ac plug is connected to the ac line in such a way that the high side of the line is connected to B— in the receiver. When the plug is reversed, the hum will disappear, or at least it will decrease in strength. When servicing a receiver, always insert the plug so that the hum is at a minimum. In this way, you will save considerable time.

Let us now study some of the most common defects resulting in hum.

Causes Of Hum In Power Supply

Diagrams of two power supply systems widely used in ac-dc receivers are shown in Figs. 1 and 2. We will use these diagrams in describing the power supply defects resulting in hum.

VACUUM TUBE RECTIFIERS

The purpose of any rectifier is to provide, from an ac source, a one-way flow of current to charge the input filter capacitor in the power supply.

Cathode-to-Heater Leakage. In a tube rectifier, shown in Fig. 1, leakage can develop between the cathode and the heater, which will apply ac directly along with rectified dc to filter capacitor C1. If sufficient leakage develops, hum will result. If a direct short occurs, C1 will be ruined and the hum will be excessive. Cathode-to-heater leakage can be found by checking for leakage in a tube tester or by substituting a new tube.

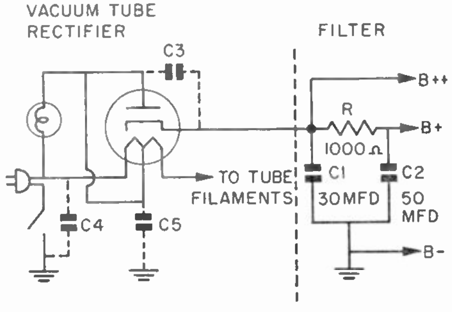

FIG. 1. Power supply of an ac-dc receiver using a vacuum tube rectifier.

Leakage Between Socket Pins. Another point to watch is leakage between tube socket terminals on the rectifier. All of the terminals on the rectifier socket are not needed by the rectifier, and some of the spare terminals may be used as tie points. Leakage between the terminals at a high ac potential and the tie-point terminals, due to excess rosin and dirt, may cause hum.

Sometimes you can burn up the excess rosin by applying a hot soldering iron to the terminals. However, if there is a large amount of dirt between the terminals, you will have to scrub the bottom of the socket with a toothbrush dipped in carbon tetrachloride or some other solvent. In extreme cases where you can actually measure leakage with your ohmmeter, you will have to install a new socket.

If you measure the leakage resistance, disconnect anything connected to the terminals between which tests are being made. This will keep you from getting a false reading through some external circuit. Trouble of this type is unusual, but you should be aware of the possibility and know what to do about it.

SELENIUM RECTIFIERS

A selenium rectifier, shown in the power supply in Fig. 2, sometimes loses its ability to act as a one-way device,

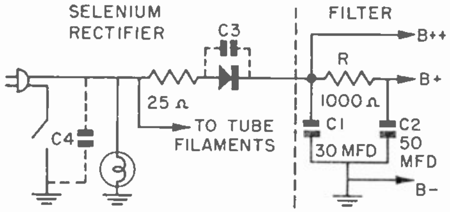

FIG. 2. Power supply of an ac-dc receiver using a selenium rectifier.

and may start passing current in the reverse direction in sufficient quantities to cause considerable hum. The B supply voltage will generally be below normal when this takes place. Also, if the reverse current becomes great enough, the electrolytic capacitors in the filter circuit may be permanently damaged by the application of ac. A smell like that of rotten eggs around a selenium rectifier indicates that it has failed. The only sure check is to substitute a new rectifier and note the results.

Testing Selenium Rectifiers. There are special selenium rectifier testers on the market, but many servicemen find it just as easy to substitute a new rectifier for the suspected one. To prepare a selenium rectifier that you can use for test purposes, use a rectifier rated at about 65 ma, and solder leads to each of its terminals. Then, attach an alligator clip to the end of each lead as shown in Fig. 3A. After you have assembled the test unit, you can easily check the rectifiers used in ac-dc sets. Just remove the leads from one terminal of the suspected unit, and clip the test unit into the circuit. Make sure you connect it with the same polarity as the original part. If the receiver now operates normally, install a new selenium rectifier.

FILTER CAPACITORS

Hum in the power supply is usually due to a defect in the filter circuit rather than to trouble in the tube or selenium rectifier. The filter circuit in Figs. 1 and 2 is the most widely used in ac-dc sets, and the one we will use in this discussion. You may find receivers using variations of this circuit, but the basic operation will be essentially the same.

Note that instead of the conventional choke used in some of the older ac-dc receivers and in most ac and TV sets there is a filter resistor R. The plate of the audio output tube is fed from the input of the filter, where the ripple voltage is rather high, so the tube plate current does not flow through filter resistor R. As a result, the dc voltage drop across R is reduced, which is desirable because a large value of R will give efficient filtering and still leave enough plate voltage for the other receiver tubes. There may be 7 to 10 volts of ripple applied to the plate of the output tube, but since a tube amplifies signals applied to its grid rather than to its plate, no hum develops. Furthermore, the output transformer to which the hum ripple voltage is then applied is a step-down device, so the resulting hum current is too slight to result in audible hum in most receivers.

If, on the other hand, we were to ap-

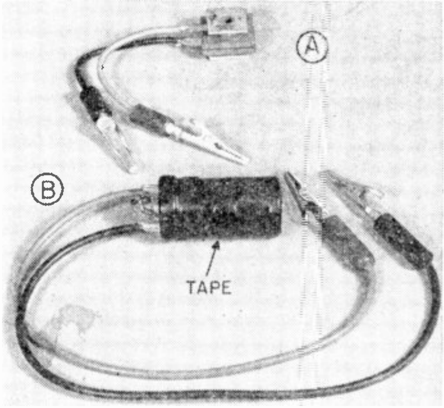

FIG. 3. You can make up two test parts like this to speed up your servicing. A, a selenium rectifier, and B, a test capacitor.

ply this same ripple voltage to the screen grid of the output tube, it would be amplified, and hum would result. There would be even more hum if the plate of the tube preceding the final power amplifier were fed from the input of the filter. Then, the hum would be transferred from the plate of that tube directly, along with desired signals, to the control grid of the power output tube. For this reason, only the power output tube can be fed from an unfiltered source; all other tube plates and screens must receive pure dc, as free from hum as possible.

Since the filter is supposed to remove ripple and deliver hum-free voltage to the plates and screens of the receiver tubes, it is logical to suspect the filter first when hum is the complaint.

In the filter circuit itself, defects in the filter capacitors are the most frequent cause of hum. If the receiver is not used for long periods of time, the dielectric film in the electrolytic capacitors will deteriorate and they will lose capacity. This is not likely to happen if a receiver has been in normal use. It can also occur in replacement capacitors that have been sitting on the shop shelf. If these capacitors are installed in a receiver, the film will gradually build up with the application of voltage, and in an hour or so the capacitors may be normal. This is worthwhile to try if hum results when new capacitors are first put in a set.

The dielectric material can also dry out because of the heat in the chassis; this, too, results in lowered capacity. Drying out often increases the power factor, giving the same effect as placing a resistor in series with the capacitor plates. All these will cause hum, and are the most common troubles encountered in servicing.

Checking Filter Capacitors. You can check for loss of capacity by shunting a good test capacitor across each suspect. Check a capacitor having a high power factor by substituting a good one in its place. If the trouble clears up, partially or completely, the capacitor under test is defective.

Fig. 3B shows how to assemble a capacitor that you can use for test purposes. The unit does not have to have the same capacity as the capacitor it shunts, but it should have the same or a higher working voltage. Servicemen often use a 20-mfd or 30-mfd capacitor; this is sufficient even when the capacity of the unit under test is considerably more. The test capacitor should be rated at 450 volts. Then, it can be used for ac-dc, straight ac, and TV sets.

If you use a cardboard encased test capacitor, its leads will generally be long enough to span across the leads or terminals of the capacitor to be tested. A metal-clad test capacitor will also be satisfactory, but leads should be permanently soldered to the capacitor terminals, and a jaw clip should be placed on the end of each lead. Be sure to cover the metal case, which is generally the negative terminal, with rubber tape so that it cannot short to the receiver chassis when in use. Use a red lead for the positive terminal and a black lead for the negative terminal to make it easy to identify the polarity. The test leads must be connected with the same polarity as the terminals of the capacitor in the set. Otherwise, the test capacitor may be destroyed by the application of negative voltage to its positive terminal.

Multi-Section Capacitors. The capacitor defects just described do not by any means exhaust the list of troubles found in electrolytic filter capacitors. Most capacitors used in the filter circuits contain several sections in a single container. Some defects cause interaction between these sections. In such a case, shunting one capacitor will have no effect on the hum level, and this may lead you to believe that the trouble is elsewhere in the receiver. As you get practical experience, you will be able to judge whether it is worthwhile to pass up the possibility of trouble in the capacitor block.

At the start of your career, however, you will save much time if you check the entire block of capacitors when shunting a single section of the block does not eliminate the trouble. To make this check, remove all of the old capacitor leads except one (any one lead may be left connected in the receiver), and temporarily put new capacitors in the circuit. Your regular test capacitor may be one of the new capacitors. If this clears up the trouble, the capacitor block is defective and a new one should be permanently installed. If necessary, separate capacitors can be substituted.

Sometimes you may find that only one of the sections is defective. If you just cut the lead or leads to the bad section and connect a single replacement, the set may work fine for a while. However, doing this is asking for trouble because the set will soon come back with the same complaint. The customer will find it very hard to believe that additional charges are justified. Therefore, if one capacitor in a group is defective, replace all of them.

Let us see what can happen in a capacitor block to cause trouble. A typical capacitor block is shown in Fig. 4. These may be the capacitors used in the filter section of Figs. 1 and 2. Through corrosion or a mechanical defect, the common negative lead may open inside the case. If this happens, neither capacitor connects to B−, but their common negative plate puts them in series across the filter resistor. This will remove all filter action and practically no ac voltage (ripple) will be dropped across the resistor. Consequently, the hum level will be as high at the output of the filter as at the input.

Since the input filter capacitor is no longer in the circuit between the rectifier cathode and B−, the B supply voltage will be quite low, causing either weak reception or a dead set. You can increase the dc voltage by shunting C1 with your test unit and the receiver gain will increase to normal. However, C1 and C2 are still acting as a bypass across R, and the increased gain will cause more hum rather than a reduction in hum with the test capacitor in place. This is a pretty sure sign that both electrolytics should be removed and replaced.

Most modern ac-dc sets do not use the chassis as an electrical part of the circuit. When replacing defective electrolytics, be sure that the negative leads are connected to B−. If the connection is made to the chassis when the chassis is not an electrical part of the circuit, the effect is the same as an

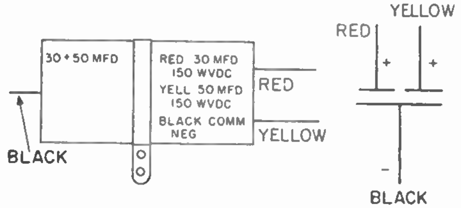

FIG. 4. A two-section electrolytic capacitor with a common negative lead.

open in a common negative lead of an electrolytic. The hum in such a case will be excessive, and the B supply voltage will be abnormally low.

Another failure that is common is an internal short or leak between the two positive plates. When this occurs, the dc voltages will be normal but there will be no hum reduction across R. Also, there will be no appreciable reduction in the hum level when you shunt either or both capacitors. You can find the trouble only by removing the leads to the old capacitors and trying new capacitors.

The action of the electrolyte on the cardboard case frequently results in a short between the case and the capacitor plates. If this occurs under the metal mounting strap, the two plates are coupled together at this point, and the filtering action of R is again shunted out.

You can tell if such leakage has developed by inspecting the case under the mounting strap. If such leakage has developed, there will be green corroded spots on the surface of the capacitor case.

Sometimes just moving the capacitor case with respect to the strap will restore normal operation. Some servicemen remove the strap and allow the capacitor block to hang by its leads in the hope that no more trouble will result. This is a bad policy, and the cost of a new electrolytic capacitor block is not worth the risk to your reputation as a reliable serviceman.

FILTER RESISTOR

The filter resistor is an infrequent cause of trouble. The resistor may decrease in value due to overloading, or someone may install a replacement that is too small. Check the resistance of the part with an ohmmeter, and compare your reading with that given on the schematic diagram of the receiver.

BYPASS CAPACITORS

If leakage develops in rf bypass capacitor C3 shown in Figs. 1 and 2, the rectifier will be shunted by the leakage in the capacitor, and as a result, ac will be applied to the input of the filter. Leakage in capacitors connected as shown by C4 and C5 would not result in ac being applied to the filter. (Note that C5 is used only in Fig. 1.) Trouble of this type is not common, but the possibility of a defect in C3 should not be overlooked.

Causes Of Hum In Signal Circuits

Although you will think of the filter section of the power supply, and particularly the filter capacitors first when you are servicing a receiver for hum, there are many other possible points where hum voltage can enter the receiver circuits. These must not be overlooked.

The wiring in a receiver chassis contains many hum fields. For example, electromagnetic and electrostatic lines of force at a frequency of 60 cycles per second exist near every lead or cable carrying ac. If you have a vtvm with a high resistance ac voltmeter, you can readily demonstrate this fact. Just let the ground lead of the vtvm hang free, set the range selector to a low voltage position, and hold the hot probe tip in your hand. You will find that your body picks up anywhere from a few volts to 20 or 30 volts ac.

It takes only a fraction of a volt at the input of an af amplifier stage to cause an unbearable hum in the loudspeaker. Fortunately, conditions are not as bad as the ac pickup of your body would seem to indicate. The wires and parts at the input of an af amplifier simply do not cover enough space to pick up much hum. Also, the impedance in the control grid circuit of a tube is generally too low to support much electrostatic hum induction. Most hum not due to filter trouble is caused by hum voltages applied directly in the grid-cathode circuit. However, with certain defects, hum fields from nearby wiring can be a problem.

CONTROL-GRID CIRCUITS

If the grid circuit of a tube (particularly a first audio tube) increases in impedance or becomes open, hum is practically certain to result. To see why, let's look at the circuit in Fig. 5. Here the stray hum field is represented by a generator G, and the capacity between the grid wiring and the hum source by a capacitor C.

Since the hum generator feeds into the voltage divider formed by C and R, the hum voltage divides between the reactance of C and the resistance of R. The capacity of C is very small, so its reactance is high at the hum frequency. The larger the value of R, the more hum voltage appears across it between the grid and ground, and the greater the hum output.

When the grid input circuit has low impedance (R is small), it takes a considerable amount of stray hum voltage to develop an appreciable hum signal at the grid. On the other hand, when the grid circuit has high impedance, very small amounts of stray hum voltage may cause trouble. Sometimes a set develops hum because of an increase in the grid circuit impedance; the most common cause of such an increase is a defective volume control. As the resistance element in the control wears, a poor contact develops between the rotating arm and the resistance strip, causing an increase in the resistance between the grid and ground. In many types, the strip may open; this, of course, increases the resistance a great amount.

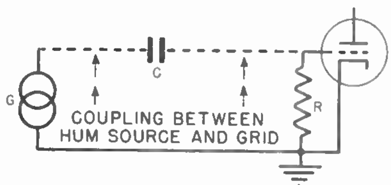

FIG. 5. Capacity coupling between the grid wiring and the hum source is shown by capacitor C.

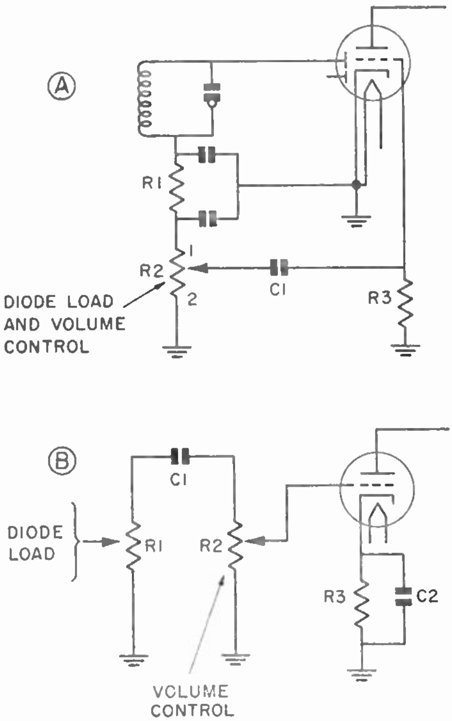

FIG. 6. Two methods of connecting volume controls.

This effect may even occur when the volume control is decoupled from the grid circuit, as in Fig. 6A. Here, the ac impedance between grid and ground is formed by the parallel combination of R3 and C1-R2. Since the capacitor reactance is negligible, R3 is in parallel with R2 when R2 is set for maximum volume at point 1. If R2 opens at the ground end, point 2, the ac impedance between the grid and ground will increase, because R3 will no longer be shunted by R2. The circuit impedance will also increase if R3 increases in value.

Similarly if C1 opens, hum will be produced because the impedance of the grid circuit will increase. Also, there will be no sound, because no signals will be fed from R2 to the grid of the first audio amplifier stage.

In a circuit like that shown in Fig. 6B, where the volume control serves as the grid resistor, a defective control can break the dc grid return path. The ac impedance rises to a high value, causing a loud hum. A volume control defect also produces a "floating grid" (no dc path for the electrons striking the grid to return to the cathode), and will frequently cause distortion as well as hum in the signal output. In either case, the volume will not be properly controlled, which is an additional clue to the trouble.

Hum may also become evident even though the impedance of the grid circuit has not increased, if the first af tube becomes gassy. Then the tube becomes extremely sensitive, and since the gain in the stage has increased, any slight hum voltage in the grid circuit which would otherwise be unnoticed becomes quite evident as hum in the loudspeaker. When you suspect this trouble, try a new tube.

POOR CONNECTIONS

It is possible for a poor connection to cause hum, particularly when the connection is common to more than

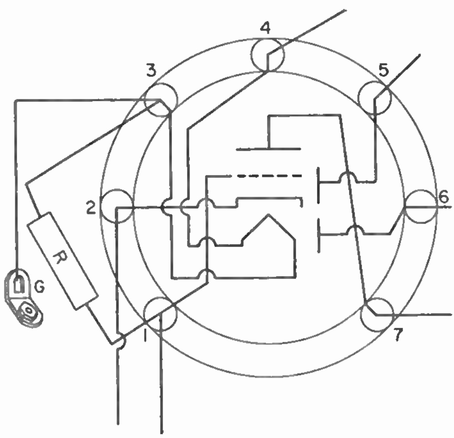

FIG. 7. A poor connection between tube pin 3 and ground lug G will introduce hum into the grid circuit.

one circuit, as shown in Fig. 7. Here the grid resistor R and one filament terminal must both be grounded. It may be difficult, because of other circuit parts, to solder the lower end of resistor R to ground lug G. For this reason it may be easier to connect it between pins 1 and 3.

As long as the ground at the chassis is in good condition, this will not cause any trouble. The wire between pin 3 and lug G is usually too short to have appreciable resistance, so there will be no voltage drop of any consequence between these points. However, suppose a poor connection develops at G. This is the same as adding a small resistor in the circuit between pin 3 and lug G. The ac filament current flowing through the resistance of this poor connection produces a voltage drop across it. If you trace from the grid to ground in Fig. 7, you can see that this ac voltage drop will be introduced into the grid circuit. Even a small ac voltage, if it feeds directly into the grid circuit, can produce a very loud hum. You can cure the condition, after isolating its source, by resoldering the connection or by using a different ground for the grid return.

Hum may also be introduced into a circuit by poor ground connection to a shield. A wire in a critical circuit is often shielded—particularly a grid lead if it must be run any great distance. The shield around the wire must be grounded to be effective. If the ground connection is poor or nonexistent, the effect of the shield is lost, and hum can be introduced into the shielded wire.

Sometimes, but not always, the shield must be grounded at both ends, as in Fig. 8, to reduce the hum level. A poor ground at points 2 and 3 at the ends of the shield can permit the shield itself to pick up hum voltages and to transfer them to the wire within.

IMPROPER GROUND CONNECTIONS

Stray hum currents in the chassis can cause voltage drops that can produce hum in the receiver circuits. For example, in Fig. 8 you can see that the filament current of the tube flows between points 4 and 5. Ordinarily you would not think of the current flow through the chassis as being important because the chassis of a receiver has a very low resistance. However, the current flow between these points may be high. This high current flow through the very low resistance between points 4 and 5 can cause an ac voltage drop across the chassis path.

Now, suppose you change the ground connection of the volume control from point 1 to point 5. From Fig. 8 you can see that the cathode is grounded at point 4. Any signal or hum between the control grid and the cathode, of course, will be amplified. Connecting the volume control to point 5 instead of point 1 puts the ac voltage drop between points 4 and 5 in the grid return circuit, and hum will be heard at all times regardless of the volume control setting.

In the same way, improperly connecting point 2 to the chassis where there would be an ac potential between it and point 3 would also result in ac flowing through the shield, and a hum voltage being introduced into the control grid lead.

Troubles of this type are not found

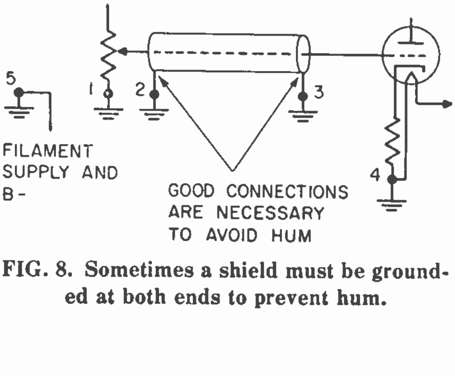

FIG. 8. Sometimes a shield must be grounded at both ends to prevent hum.

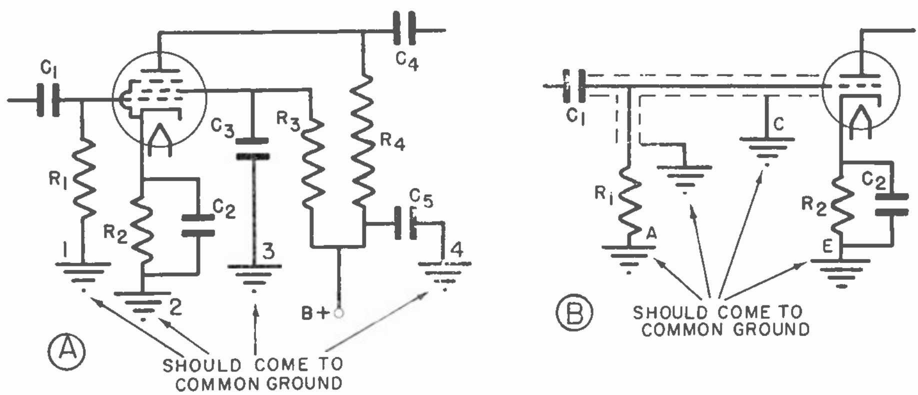

FIG. 9. Two examples of audio circuits. Using a common ground point prevents hum currents in the chassis from producing hum voltages in the stage.

in properly designed receivers, unless they have been worked on by someone who has carelessly made ground connections wherever convenient. To be on the safe side and to avoid trouble, do not change the ground connection points. Where possible always use the original points. If you do change them and then notice hum, remember that the choice of a grounding point can be the cause of the trouble.

The problem of stray hum currents in the chassis may become quite troublesome in high-gain audio amplifiers and high-fidelity work. Examples of audio circuits are shown in Fig. 9. In Fig. 9A, if terminals 1 and 2 are not grounded to the same point on the chassis, any stray hum currents between these points will produce a voltage drop in the chassis, which is effectively in series with the grid circuit and can cause hum.

There are four ground symbols shown in Fig. 9A. It is desirable to have all of these grounded parts in a single stage come to a single ground point. This kind of connection will remove the effects of stray chassis currents. Of course, these four terminals must each make good contact to the ground point, without any common lead, so as to avoid the situation shown in Fig. 7. In Fig. 7, the resistor R should be brought to the ground lug G directly instead of to pin 3 on the tube socket.

In a circuit like that shown in Fig. 9B, you may find four separate ground points. If hum is traced to this circuit, grounding all of the points shown to the same point will prove helpful. If the hum is caused by stray chassis current, removing ground C altogether may help.

Try shielding the leads subject to hum pickup to reduce the amount picked up. Shielding must be used with care, however, because there is a considerable capacity between a lead and its shield. This capacity shunts the circuit and will lower the high frequency response of an audio amplifier considerably. Therefore, use no more shielding than is absolutely necessary and use low-capacity cable, such as coaxial TV lead-in, if space permits. This type of cable has a large amount of insulating material between the inner wire and the shield, thus reducing the wire-to-shield capacity by increasing space between them. Sometimes you can avoid shielding altogether by rerouting the leads.

Stray capacity coupling may also prove annoying if you have filter capacitors and a cathode bypass capacitor in the same electrolytic capacitor block. In Fig. 10, the filter capacitors are C1 and C2; the cathode bypass is C3. The value of the cathode bypass capacitor will usually be about 20 mfd, so it will have a relatively low impedance to ripple current. However, if there is sufficient capacity coupling between the filter capacitor leads and this capacitor, shown by the capacitors marked C, an appreciable hum level may appear. This will certainly be true if the cathode bypass capacitor loses capacity or develops a high power factor. In such cases, using a separate capacitor for the cathode bypass, to get it out of the same container with the filter capacitors, will help considerably in lowering the hum level.

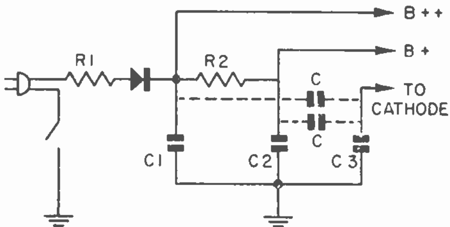

FIG. 10. If a cathode bypass capacitor, C3, is in the same capacitor block with the filter capacitors there may be enough capacity coupling to cause hum.

CATHODE-TO-HEATER LEAKAGE

Cathode-to-heater leakage in tubes is almost as frequent a cause of hum in ac-dc receivers as defects in the filter capacitors. Therefore, it is a good idea to check the tubes as soon as the electrolytics have been cleared of suspicion. Many servicemen will check tubes first, because it is easier to try new tubes than to check the filter capacitors.

With experience you will often be able to distinguish between tube and electrolytic capacitor trouble. Hum due to cathode-to-heater leakage in a tube is generally, but not always, louder than that resulting from a capacitor defect. Capacitor defects frequently lower the dc operating voltages, causing the receiver to operate at low volume levels. Cathode-to-heater leakage, on the other hand, seldom affects the dc voltages unless the power output tube is involved.

Let us see why cathode-to-heater leakage is such a potent source of hum in an ac-dc set.

A typical filament string as found in ac-dc receivers is shown in Fig. 11. Notice that the cathode and control grid return circuits to B− are also shown. Any ac signal between the grid and cathode of the tube will be amplified by the stage.

The point of highest ac potential with respect to B− is point A. Therefore, the closer a filament is to point A, the higher is the ac voltage from its filament to its cathode. When this ac voltage is high, only a small amount of leakage can cause considerable ac to appear in the control grid-cathode circuit for amplification.

The rectifier tube, of course, does not have a control grid. However, cathode-to-heater leakage in the rectifier can add to the ripple at the output of the B supply filter. The higher ripple voltage in the B+ circuit can cause hum in the receiver output.

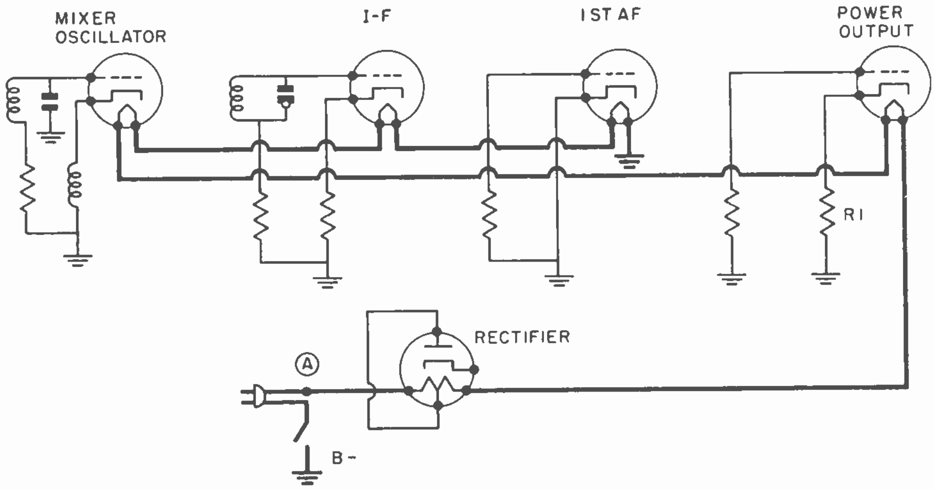

FIG. 11. Filament string of an ac-dc receiver.

Suppose leakage develops between the filament and the cathode of the power output tube. This means that the voltage from the filament to B— divides between the leakage path (filament to cathode) and the cathode bias resistor R1. Since R1 is in the control grid-cathode circuit of the tube, any ac across R1 will be amplified by the tube.

Of course, if R1 is bypassed by a large value capacitor, less ac will appear across R1, and the loudspeaker hum will be reduced. If the ac is great enough to overcome the dc normally across R1, the voltage polarity will be reversed each half cycle and current may flow through the electrolytic bypass in the wrong direction. This reverse current flow may damage the capacitor. Also, the bias may be reduced and the increased cathode current can lower the B supply voltage. Thus, cathode-to-heater leakage can cause hum, or hum with low volume and distortion. You may find one or all symptoms present.

Looking at Fig. 11, you may think that cathode-to-heater leakage in the first af tube could not cause hum because one side of the filament and the cathode are both connected to B—. This, however, is not the case. If there is a small amount of leakage resistance between the cathode and the ungrounded side of the filament, ac will flow through the cathode and its lead to ground. There will be sufficient resistance in the cathode lead to produce a slight ac voltage drop. Since this ac voltage drop is also in the control grid-cathode circuit, the ac voltage will be amplified by the first af tube, and then transferred to the power output tube for further amplification. Because the first af tube usually gives higher amplification than the other af tubes, it is more sensitive to hum signals. Again, the easiest check is to substitute a new tube, although testing the tube for shorts in a tube tester will also show up the trouble.

Cathode-to-heater leakage in the i-f tube will introduce ac into the control grid-cathode circuit. However, hum will probably not result because the following circuit is tuned to the i-f signal and cannot pass audio signals. However, if there are other defects that make the i-f stage act like a detector, hum modulation of the i-f signal will occur, resulting in tunable hum.

The cathode of the mixer-oscillator tube connects to ground through part of the oscillator coil. Cathode-to-heater leakage in this stage will shunt the oscillator coil. This will usually stop the oscillator, causing the receiver to be dead. If the leakage resistance is very high, however, the oscillator signal will be hum-modulated, again causing tunable hum. Since the operation of the mixer is nonlinear (it operates as a detector), it is easy for hum modulation of the i-f signal to occur at this point. We will discuss hum modulation in detail later in the lesson.

From the foregoing discussion you can see that if you suspect hum is caused by cathode-to-heater leakage in a tube, check the tubes in the af system, and the rectifier, first. Steady hum due to cathode-to-heater leakage in the i-f or rf tubes is extremely unlikely. Notice that we say extremely unlikely rather than impossible. As you gain experience, you will learn that few defects are impossible. If the defects you would logically suspect are not at fault, you should analyze the effect produced, and try to find some other defect that could cause the same circuit action.

For example, there could conceivably be leakage between the control grid and the heater of the i-f tube, due to dirt and grease between the tube socket pins. AC would be fed back through the avc circuit (not shown in Fig 11) to the input of the first af tube. In such a case, cleaning the tube socket will usually eliminate the hum. Of course, you would not be led directly to this tube by symptoms alone. It would probably be necessary to localize the point of hum entrance into the af amplifier before it would occur to you that a defect in the i-f stage may be the trouble. Later in this lesson, you will study hum localization methods.

MODULATION HUM

Hum that is tunable, that is, it can be heard only when a station is tuned in, is called "modulation hum." It can develop in the rf amplifier or outside the receiver. Since an audio signal will not travel through the rf or i-f stages by itself, except through the avc circuit to the volume control, it must mix with or modulate an incoming carrier to cause hum. Modulation hum can be heard only when you are tuned to a station; it is most evident during a pause in the program when a station is temporarily not modulating.

To have modulation hum, two conditions must exist. There must be a hum signal present in an rf or i-f stage, and the tube must be operating on the curved portion of its characteristic curve so that it will act as a detector

When an rf amplifier has a linear Eg-Ip tube characteristic, the presence of both rf and hum voltages will not ordinarily produce hum. If you were to take a cathode ray oscilloscope picture of the plate current when there are both ripple and rf components in a stage that is operating as a linear amplifier, the pattern would be as shown in Fig. 12A. As you can see, although the hum voltage is varying the rf signal, the amplitude (height) of the rf pulses remains exactly the same. That is, if you measure the distance between points X and Y and compare it to the distance M-N, or the distance S-T, you will find that they are the same. This means we have an audio voltage as well as an rf voltage, but it does not modulate the rf voltage. In the plate circuit of this stage, the tuned circuit will pick out the rf voltage, and the audio voltage will be ignored. Thus, a hum voltage introduced into a linear rf amplifier will not be passed on to the next stage.

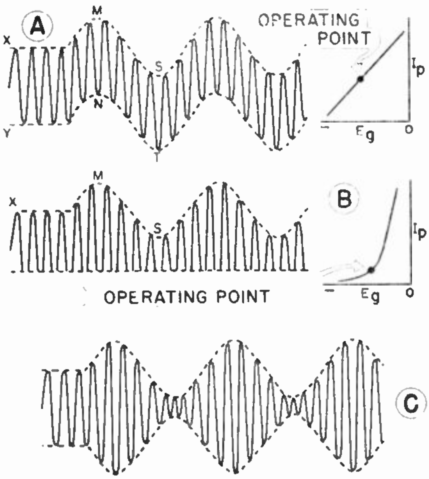

FIG. 12. How hum modulation occurs.

This does not mean, however, that only a detector stage can produce hum modulation. The Eg-Ip characteristics of all amplifiers, including those in the rf system, are not perfectly linear; so in practice we may get modulation hum from any amplifying stage. If the hum voltage is high enough to drive the tube into plate current cut-off, modulation hum can be produced in a stage that normally operates on the linear portion of its curve. This is not common, however.

Operating an amplifier at a curved point, as shown in Fig. 12B, permits normal variation in one direction, but tends to cut off variations in the other direction. This does not matter to the incoming signal, because the flywheel effect of the following resonant circuit will restore the original shape. However, if hum is introduced, the plate current will be as shown. Comparing the height at X, M, and S in this figure shows that the rf signal has been changed in amplitude by the hum voltage—in other words, it has been modulated. The following tuned circuit will now reconstruct a completely modulated wave like Fig. 12C, so the hum voltage will be carried along on the rf voltage just like any original modulating signal. At the detector, it will be demodulated, and the hum will be fed through the audio amplifier.

Causes of Modulation Hum. When you have a case of modulation hum, notice whether it is heard on all stations, only on certain stations, or just on one. These are important clues.

Usually, if the source is within the set, you will notice that the modulation hum is heard on all reasonably strong local and distant stations. The most common sources of such hum are cathode-to-heater leakage in the tube and a defective filter system in the plate supply for the oscillator stage. In older ac receivers, a separate resistor-capacitor filter combination is frequently used in the oscillator plate supply because any hum in the supply can modulate the oscillator voltage and mix with the incoming signal in the first detector.

If these points appear normal, then check the operating voltages carefully. Note in particular the grid bias and screen grid voltages in the rf amplifiers. Excess bias or lower than normal screen grid voltage can cause the tube to operate on the nonlinear part of its characteristic curve.

If modulation hum appears to be stronger at one end of the receiver dial, often some stage is regenerative, so it is easily affected by stray hum fields or hum voltages. Eliminating the cause of the feedback, by realigning the set or checking the bypass capacitors, will frequently remove the modulation hum.

If the modulation hum appears only on the stronger local stations, it may be originating outside the receiver. The power line picks up a considerable amount of rf energy; if the loop antenna is in poor condition, this power line rf may feed through the chassis to the input of the set. The power line may have nonlinear characteristics. Therefore, it is possible for these rf signals to arrive with a hum modulation and to be so much stronger than those normally picked up by the loop as to override them. Also, if the loop or the antenna system is near power lines, a poor connection may cause rectification and mixing right in the antenna system.

The cure is to go over the connections in the antenna circuit with a hot soldering iron, and to check the rf bypass capacitor at the input of the power line to the receiver. On an ac set try connecting a capacitor from each side of the power line to the chassis, and ground the chassis. On ac-dc receivers, only a single capacitor is required from the rectifier plate to B−. Never connect a ground to the chassis of an ac-dc set. However, try reversing the power plug at the wall socket. Sometimes this has considerable effect on hum modulation.

If modulation hum is heard on only one station, either the signals from that station are strong enough to drive one of the tubes into the curved region of its characteristic curve, there is external hum modulation, or the hum is originating in the station itself. Station hum is much more noticeable on high fidelity receivers because they have a better low-frequency response. To determine which of these possibilities is the cause of the hum, try another receiver at the location or move the suspected receiver to your shop. If you hear hum regardless of the location, the hum is probably originating at the station. If the test receiver hums at the location of the defect, overloading or external hum modulation is occurring.

If some nearby station or some very powerful station actually drives a tube into detection, the avc circuit should be inspected. Perhaps the avc filter capacitor is leaky, thus reducing the avc to that particular stage.

Since ac sets operate on power transformers, there are some causes of hum in ac sets that are not found in ac-dc sets. Let us take up some of these, now.

Causes Of Hum In AC Receivers

As you have learned, in an ac-dc receiver, an rf bypass capacitor is connected from the power line to the rectifier plate to prevent hum-modulated signals from entering the receiver. This is not done in ac receivers. The usual practice is to connect a capacitor from one side of the power line to the chassis, instead. Some receivers use a capacitor from each side of the power line to the chassis, such as C8 and C9 in Fig. 13. This arrangement is somewhat more effective. When a single capacitor is used, reversing the ac plug at the wall outlet will sometimes reduce hum and will sometimes affect the volume. Use the polarity of the ac plug that gives best results.

AC sets are subject to many of the same hum defects as ac-dc sets, both power supply defects and circuit defects that introduce hum into the control grid-cathode circuits. Cathode-to-heater leakage, however, is not as great a problem because the ac voltage between the cathode and the heater in ac sets is lower than in ac-dc sets.

The frequency of the ripple voltage in an ac receiver using full-wave rectification is 120 cycles. This frequency

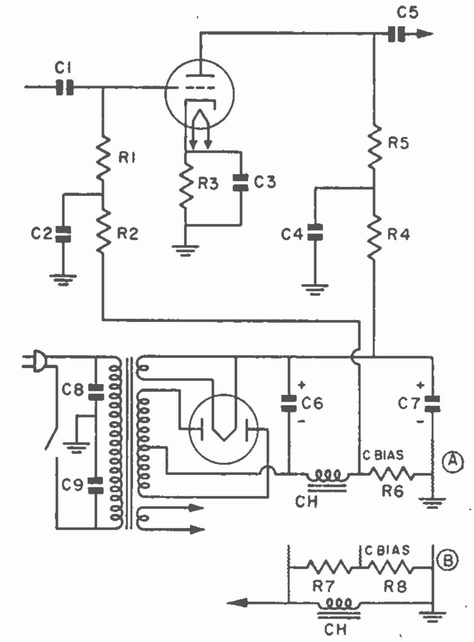

FIG. 13. Two widely used methods of obtaining C bias for control-grid circuits are shown at A and B.

is more easily filtered than the 60 cycles found in ac-dc sets. However, 120-cycle hum will usually receive more amplification if it gets into the af circuits, and will also be more easily reproduced by the loudspeaker.

Because the ripple frequency in the power supply circuit of an ac receiver is 120 cycles, smaller electrolytic filter capacitors may be used. However, there are defects that can change the operation from full-wave to half-wave rectification. For example, one of the plate-cathode sections of the rectifier tube may not operate, or there may be an open in half of the high-voltage secondary winding of the power transformer. The circuit will then act as a half-wave rectifier, and the filter system may be unable to eliminate the resulting 60-cycle ripple. Defects of this type are rare, but you should be on the lookout for them.

DECOUPLING CIRCUITS

Fig. 13 shows typical decoupling networks used in the control-grid and plate circuits of an ac receiver. Where steady hum is concerned, we are interested in decoupling networks in the af section.

Parts A and B in Fig. 13 show two widely used methods of obtaining C bias voltage for the control-grid circuits. At A the voltage drop across R6 is used; at B the voltage divider across CH formed by R7 and R8 furnishes the required dc bias voltage. In either case, a large amount of 120-cycle ripple voltage is mixed with the dc bias voltage and must be removed before the bias voltage is applied to the control grid of the tube. In Fig. 13, the ripple voltage is removed in the C bias circuit by the filter circuit formed by a high value resistor R2 acting with capacitor C2. The capacitor is generally a paper one and is much smaller than the electrolytics used in the B supply.

Although the primary purpose of C2-R2 is to prevent power supply ripple from reaching the grid, this filter also prevents signals applied through C1 from traveling back into the power supply. As you will learn later, this feedback voltage can produce degeneration or regeneration, depending on its phase. If there is an open in C2 or a short across R2, the ripple voltage normally existing across the dropping leg of the power supply filter choke will be applied to the control grid of the tube. This, of course, results in a high hum level at the loudspeaker.

Filter C4-R4 in Fig. 13 like C2-R2 acts to prevent any ripple across the output filter capacitor from being applied to succeeding stages in the circuit through C5. However, there is usually very little ripple across the output filter capacitor, and the main purpose of C4-R4 is to decouple the signals from the power supply to prevent feedback.

If the signals amplified by the tube are permitted to get back into the power supply, they may be transferred to some other stage and cause regeneration or degeneration. Again an open in C4 or a short across R4 will prevent the decoupling network from functioning. Shunting C4 with another capacitor of equal or larger capacity will restore normal operation if C4 is open. R4 can be checked with an ohmmeter.

REVERSED HUM-BUCKING COIL

Sets in use today generally have permanent-magnet loudspeakers, and hence require no hum-bucking coil. However, electrodynamic loudspeakers were widely used in older receivers, many of which are still in use.

In an electrodynamic loudspeaker, the magnetism needed to operate it is obtained by passing dc through the windings of a large coil, known as the field coil. These coils have considerable inductance, and were usually used also as filter chokes. Therefore, since considerable ripple current passes through the field coil, the variations in the magnetic field will produce ripple current in the voice coil, which in turn will produce hum from the loudspeaker. The purpose of the hum-bucking coil is to prevent the current variations in the field coil from causing a movement of the voice coil and cone.

The hum-bucking coil is wound around the end of the field coil, and is connected in series with the voice coil, as shown in Fig. 14. The number of turns in the hum-bucking coil are chosen so the same amount of ripple voltage is induced in it as in the voice coil. The two coils are connected in such a way that the induced voltages oppose each other. Consequently, no ripple current flows through the circuit, and the voice coil and cone do not move.

You can determine whether or not a hum-bucking coil is used by examining the voice coil connections. If there is no hum-bucking coil, the two voice coil leads will be connected to the secondary of the output transformer. If a hum-bucking coil is used, it will be in series with one output transformer lead and one voice coil lead. The other voice coil lead will be connected directly to the remaining output transformer secondary lead.

This method of preventing hum sounds fool-proof, but you will find in servicing that nothing is fool-proof. It is easy to reverse the hum-bucking or voice coil connections when replacing the output transformer. With the connections reversed, the hum will be twice what it would be if no hum-bucking coil were used. In such a case, hum will be heard as soon as the set is turned on—even before the tubes warm up. It is easy to check on the effectiveness of the hum-bucking coil; just short it out with a piece of wire. If the hum level rises, the hum-bucking coil is working properly. If the hum decreases, the hum-bucking connections should be reversed.

Do not attempt to add a hum-bucking coil to a loudspeaker not equipped

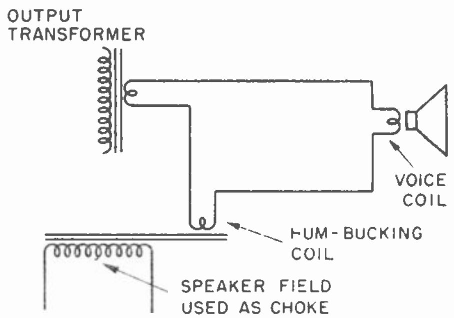

FIG. 14. The hum-bucking coil is connected in series with the voice coil. It is used only with an electrodynamic speaker.

with one. Also, if you replace an electrodynamic loudspeaker with a pm speaker, the hum-bucking coil is not furnished and is not required. The voice coil is connected directly to the output transformer secondary. Of course, in this case you must use a choke or resistor to replace the old loudspeaker field coil, and trial will show if increasing the filter capacity is necessary to compensate for any reduction in filter effectiveness.

INDUCTIVE COUPLING

Iron-core transformers and chokes have leakage magnetic fields in the space surrounding them, which frequently travel through the chassis. Most of the transformers and chokes use soft iron magnetic shields to limit this field, but even so, audio transformers must usually be placed well away from power transformers and filter chokes to avoid hum pickup.

When you are replacing an iron-core choke or transformer, if you cannot get an exact replacement, you must take special precautions not to introduce hum into the receiver. If you cannot get an exact replacement, you may find after making the installation that the leakage magnetic field of this particular part is different, or the shielding is poorer, so that there is some magnetic coupling to another circuit or part, and hum develops. The amount of hum increase will usually be slight, but it may be noticeable to the owner of the receiver.

Frequently, a simple change in the position of the transformer, such as rotating it or tilting it at an angle, will clear up this trouble. Usually, however, there are so many wires connected to such parts and the mounting space is so limited that this is not practical. If you cannot reposition the transformer, try using a shield. Soft iron is the best shield at these low frequencies. Make a practice of saving the cases from defective transformers for possible future use as shields for other transformers.

Since both inductive and capacitive coupling can exist between wires, any wires carrying large amounts of ac must be kept away from the grid and plate leads to prevent hum. Often the filament leads are twisted together to minimize induction from them to neighboring wires.

Because of inductive and capacitive coupling, you may accidentally raise the hum level by moving the wires about while hunting for trouble or while making a replacement. Be careful about this. Before moving wires apart, make a mental note of their exact location, and return them to these positions after you have made the repairs.

Set owners sometimes tuck lengths of the line cord into their radios. Watch out for this—the ac cord may be close enough to a tube grid or plate to cause hum.

UNBALANCED PUSH-PULL OUTPUT TUBES

When push-pull output tubes are used, any hum picked up in the grid circuits (not hum fed from a previous stage) will be canceled by the push-pull action. However, canceling occurs only if the two tubes give the same amount of amplification to the interfering hum signal. If one tube is better than the other, its hum output will be greater; and the difference, after cancellation has occurred, will be passed on to the loudspeaker.

Generally you can eliminate the hum by trying several tubes in the power output stage. However, sometimes the serviceman will have to test several output tubes in his tube tester until he finds two that give almost identical readings. Using tubes whose meter readings are equal or balance each other will eliminate hum picked up or introduced into the control grid-cathode circuits of the push-pull output stage. Watch for this in sets where a push-pull output circuit is used, particularly in high-fidelity equipment.

MECHANICAL HUM

All the examples so far discussed are classified as electrical hum, because they cause a hum voltage, which is reproduced as sound by the loudspeaker. Hum may also be caused mechanically by a vibrating part that produces sound directly. Almost invariably, mechanical hum is produced by an audio or a power transformer whose core laminations are so loose that they can vibrate under the influence of the varying flux. Sometimes a coil itself, which is loose on the core, will vibrate.

The source of mechanical hum can easily be discovered by careful listening. You can remedy it just as easily, either by tightening the clamping bolts or by driving a small wedge between the transformer laminations. If the coil is vibrating on the core, a small wooden wedge between it and the core will tighten it up. If you can get nothing driven between the laminations, painting the exposed edges with shellac will usually keep them from vibrating.

Localizing Hum

Some of the procedures, such as signal tracing and stage blocking, used for finding the cause of other circuit defects can be used to localize hum. However, signal injection, used to locate a weak or dead stage in a receiver, is of no value in localizing hum. In this section, we will discuss stage blocking and signal tracing techniques, and point out how to use an ac voltmeter to find where the hum signals enter the receiver circuits.

When hum is the complaint, it is seldom necessary to use a localization procedure. In ninety percent of the cases, routine tests of the filter capacitors and tubes show you the trouble. Only when these common defects are not present will you have to narrow your search by finding the point where the hum is entering the set.

In localizing hum, you should first confirm the customer's complaint and decide whether you have a case of tunable hum (hum modulation) or steady hum. Steady hum, the type that is present at all times, regardless of where the set is tuned, is the type you will most frequently find. Therefore, we will discuss the procedures you can use to localize the cause of steady hum first. Later in this section, we will discuss the localization procedures for modulation hum.

STEADY HUM

If steady hum is the complaint in the receiver you are servicing, you can begin to localize the hum source before you remove the set from the chassis. Turn on the set, and tune to a point on the dial where no signals are picked up. Then, turn the volume control from minimum to maximum, and back to minimum. If turning the volume control has no effect on the hum, you know that there is no hum voltage across the control. The hum is originating between the grid of the first audio stage and the loudspeaker. If adjusting the volume control does vary the hum level, you have localized the point of hum entrance to the volume

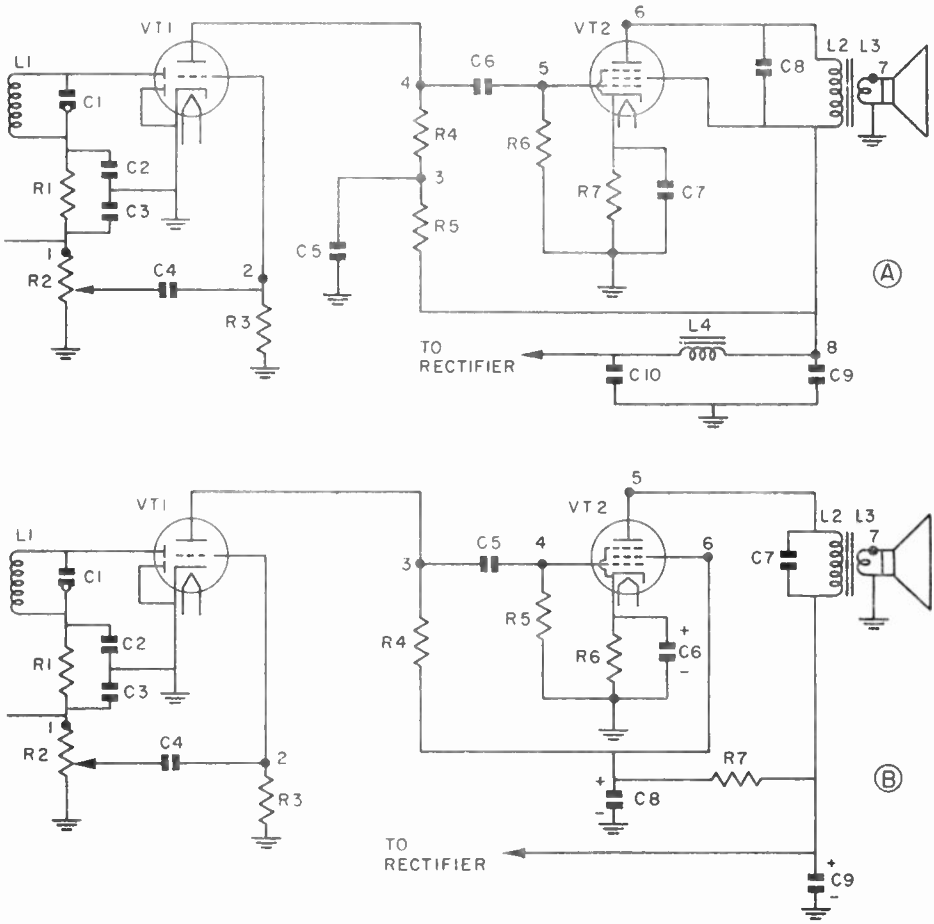

FIG. 15. The af section of (A) an ac receiver, and (B) an ac-dc receiver.

control. Then, it is only necessary to remove the chassis and find out if the control is open, or if some defect in a preceding circuit is causing an ac voltage across the control.

In an ac set using full-wave rectification in the power supply, find out by listening whether the hum has a frequency of 120 cycles or 60 cycles. If the hum is 120 cycles, look for a defect in the power supply that would permit the ripple voltage to get through the filter. If it is 60-cycle hum, it is coming directly from the power line or the filament circuit.

In ac-dc sets, the power supply ripple is the same frequency as the power line, and there is no positive way to tell, by listening, where the hum is originating.

Except for this, there is not a great deal of difference between hum localization in ac and in ac-dc receivers. In the ac set there are more parts to consider, particularly R-C filters; but on the other hand, stage-blocking techniques can be used more easily.

Fig. 15A shows the af section of a typical ac receiver, and Fig. 15B shows the af section of an ac-dc receiver.

Stage Blocking. Stage blocking consists of blocking the passage of hum signals in each stage, starting at the receiver output and working back to the input. If the hum stops when you block a stage, you know that the hum is not getting into the stages between that point and the loudspeaker. If, in proceeding toward the input of the af amplifier, you find that blocking one stage stops the hum, but blocking the stage ahead of it has no effect, you know that the hum is originating in the stage nearer the loudspeaker (the one in which the hum stopped).

To block a stage in an ac set, you can remove the various tubes from their sockets or short the grids of each tube to ground with a piece of wire or through a capacitor. As you know, you cannot remove the tubes in an ac-dc set. If you did, the set would be dead. Therefore, you can only short the grids in a set of this type.

Suppose you want to localize hum in the ac receiver like that shown in Fig. 15A by blocking the signals. The easiest way is to pull tube VT2 from its socket. If you still have hum from the loudspeaker, it is probably coming from the power supply. However, if you cannot hear the hum with VT2 out of its socket, replace VT2 and pull out VT1. If you now hear the hum, it is originating in the circuits of VT2 or is being fed to its grid from the power supply by way of R5, R4, and C6. Check this possibility by grounding the control grid of VT2. If the hum stops, check for an open in R6 or C5, or for a short in R5.

If the hum stops with VT1 removed, reinsert the tube and ground its control grid. If grounding the control grid stops the hum, check R3, C4, and R2. If the hum continues with the grid shorted to ground, there is a possibility of cathode-to-heater leakage in VT1. The easiest way to check for this is to try substituting a new tube.

Of course, it is not necessary to remove a tube to block a stage. Servicemen do it in ac sets because it is easy and fast. The stage-blocking technique that you can use in both ac and ac-dc sets is to short the grid circuits of each stage with a piece of wire or a large value capacitor.

If the receiver gets its bias voltage from a bias source, as was shown in A and B of Fig. 13, you should use a capacitor rather than a piece of wire. If you use wire, you will also short the bias circuit. The easiest way to carry out this procedure, therefore, is to short the grids of each stage to ground or B−, depending upon whether the set is ac or ac-dc, with a capacitor. The value of the capacitor can be anywhere from .25 mfd to several microfarads.

In either circuit in Fig. 15, connect the capacitor from the grid of VT2 to ground (or B−). If the hum disappears, move the capacitor to the grid of VT1. If you can now hear the hum, it is in the grid circuit of VT2 or is being fed into the circuit from the power supply. On the other hand, if shorting the grid of VT1 also kills the hum, check resistors R2 and R3, and capacitor C4. Also, check for the possibility of cathode-to-heater leakage in the first audio tube.

If you use a capacitor to block the various stages, you can also short the plate circuits of each stage to localize the hum source further. When you connect the capacitor into the plate circuit, the capacitor will become charged. Therefore, you must always discharge the capacitor before blocking the grid circuits. If you do not, a positive potential will be placed on the grids, and this potential could damage the tubes.

By blocking the signals in the grid and plate circuits in this way, you can quickly find out where the hum signals are getting into the set. This is the same procedure you would use in tracking down noise signals caused by a defect in the receiver circuits.

Signal Tracing. The serviceman has another method he can use to localize hum. This is signal tracing, which makes it possible to pick up the hum at the point where it is entering the amplifier circuits. To use this method, you will need a very sensitive pick-up device. The ideal instrument is a signal tracer equipped with a loudspeaker or with headphones.

The amount of hum at a given point is of no particular importance. What you are trying to find is the last point where hum is heard (working from the loudspeaker to the input), and the first point where hum is not heard.

When using a signal tracer in an ac-dc set like the one shown in Fig. 15B, you connect the ground lead of the signal tracer to B— and touch the hot probe to points of possible hum entry. These are points 6, 5, 4, 3, 2, and 1 in Fig. 15B. Any hum at point 7 must be fed from the output transformer because this is a pm loudspeaker, and there is no varying field to induce hum voltages in the voice coil. Hence, the voice coil would not be a point of hum entry.

Suppose we have a case of cathode-to-heater leakage in VT1. You will pick up a moderate hum signal at point 7 and a much stronger signal at point 5 because of the step-down action of the output transformer. If you get no hum when you connect the signal tracer to point 6, you know that the hum is not originating in the power supply.

Now, continue moving the signal tracer probe toward the receiver input. You will notice a weak hum signal at point 4 and about the same amount of hum at point 3. However, there will be no hum at point 2, and you have localized the trouble to VT1.

You can localize the trouble further. If you had found hum at point 6 and about the same amount at point 3, you would suspect a defect in the power supply. Since there is no hum at point 6, any hum at point 3 must be coming from VT1. Also, since none is present at point 2, you know that the hum is originating within the tube itself.

If the hum is due to excessive impedance in the control grid circuit of the first af tube, caused by an open in R3, you may find that it disappears when the signal tracer probe is touched to point 2. This is natural, because the input impedance of the signal tracer is in parallel with R3 and lowers the grid circuit impedance to the point where hum pickup no longer occurs. The trouble is automatically localized to this point by the fact that the hum stops when the signal tracer probe is touched to the control grid circuit.

Signal tracing for hum in an ac receiver, as shown in Fig. 15A, is similar to that just described. You check the hum level of the power supply at point 8, and compare this to sets in good condition that you have checked at other times. There will usually be some hum at point 8. There should be less hum present at point 3 if the RC decoupler consisting of R5 and C5 is in good condition. This completes the testing of the power supply system. You can now check the hum at points 7, 6, 5, 4, 2, and 1. Look for a point where there is hum, preceded by a point where there is no hum.

There are a few precautions to observe when using a signal tracer, particularly if it is equipped with a pair of headphones instead of a loudspeaker. The signal tracer may be more sensitive to hum voltages than the receiver amplifier. Since you hold the headphone close to your ear, hum levels will always sound louder from it than those produced by the receiver loudspeaker. Even the normal residual hum level may sound loud when you are listening directly to the receiver stages. Be careful not to confuse this hum level with the abnormal hum level for which you are looking.

Voltage Measurements. A low-range, sensitive ac voltmeter of the vtvm type is also helpful when checking for fairly high hum voltages in the power output stage and the power supply. An ac voltmeter, however, is not capable of measuring sufficiently low voltages to be of much value in locating small amounts of hum in the first af receiver stage.

If you have a good low-range, high-resistance ac voltmeter, you can try it out when confronted with hum problems to see if it has sufficient sensitivity to be useful.

The cathode ray oscilloscope is as useful in locating the cause of hum as a signal tracer, if the hum level is high enough to give a noticeable deflection. By using a 60-cycle sweep and noticing whether you have one or two-cycle patterns, you can tell whether you have 60- or 120-cycle hum. If two cycles appear, you have 120-cycle hum. This would indicate a power supply defect in an ac receiver using full-wave rectification. The hum in an ac-dc set, of course, will always be 60-cycle hum and will produce a single cycle on the oscilloscope screen.

By following these simple methods, you can find where the hum enters the amplifier and then concentrate on this section of the receiver.

MODULATION HUM

When you are tracing a steady hum, all interfering signals from radio stations must be tuned out. When you are hunting for the source of modulation hum, you need an rf voltage source. To isolate a defective stage, you can use a broadcast signal and a signal tracer with an audible output indicator, or you can use a signal generator.

If you use a signal tracer, first tune in some station that has the modulation hum. Then, start at the input of the receiver and move toward the output with the signal tracer, listening to the signals in the grid and plate circuits of each stage. As you move toward the output, the signal will be hum-free until you pass through the stage where the hum is introduced and is modulated on the carrier. Have the signal tracer tuned to the frequency of the incoming signal until you pass the first detector, then, change to the intermediate frequency of the receiver.

If you use a signal generator, tune the receiver away from the broadcast station. Starting at the second detector and moving back toward the input, feed the signal into the stage being tested, and listen to the output of the receiver. Turn on the audio modulation of the signal generator to make sure you are tuned to the proper frequency; then turn the modulation off so you can hear the hum. As you move back toward the input with the unmodulated signal generator, you will not hear hum until you have passed through the defective stage, provided no stage is overloaded. Of course, the signal generator should be set to the i-f value until you pass the first detector, moving back toward the input.

As you move toward the input, the signal strength will increase; this may overload some stage previously passed through, causing another modulation hum to be set up. To prevent such overloading, reduce the output of the signal generator enough, as you move back, so that the output of the set will be approximately constant. To check on this you can use a dc vtvm across the second detector diode load to measure the avc voltage.

When you reach the input of the first detector, be sure to change the signal generator to the frequency for which the receiver dial is set.

Once you have found the stage in which the modulation occurs, concentrate on it. Check the various parts to find which is defective.

COMMON CAUSES OF HUM

This table covers only the more common causes, with the most common first. If you do not find the trouble by checking these, use a localization procedure.

Type	*Location*	*Causes*
Steady 60-cycle (or 120-cycle if full-wave rectification is used) hum	**1. Power Supply 2. AF Stages**	**1. Defective filter capacitors. 2. Cathode-to-heater leakage. Open control grid return circuit. Open decoupling capacitor. Poor connection. Unbalanced push-pull tubes.**
Modulation hum	**1. RF Stages**	**1. Cathode-to-heater leakage. Improper dc operating voltages. Hum voltage in avc circuit. Open rf bypass at power line. Input to receiver avc circuit grounded.**
	2. Outside Set	**2. Power line modulation. Nearby fluorescent lamps. Poor ground if one is used. Reversed power plug at wall outlet. Defect at station.**

Oscillation, Squeals, Motorboating

Squeals and motorboating, when due to an internal receiver defect, are the result of excessive feedback or regeneration resulting in oscillation in some stage or section of the receiver.

The oscillation may be confined to the rf section or to the af section. If squeals, which vary in frequency, are heard as you tune past stations, the oscillation is occurring in the rf section, in some stage preceding the second detector. If tuning the receiver does not have a great deal of effect on the squeal, and particularly if the tendency to squeal cannot be stopped by reducing the setting of the volume control, the oscillation is in the af section of the receiver.

Motorboating is due to oscillation in either the rf or the af section, which is causing intermittent blocking of some stage. The R-C values in the grid circuit or in the plate circuit determine the frequency of the blocking, and hence, the frequency of the motorboating sound. However, the R-C network involved is not the cause of the oscillation. This accounts for the fact that shunting a capacitor from B+ to B− may change the frequency of the motorboating without stopping it.

In a well-designed ac-dc receiver, motorboating and squealing are not much of a problem. There are only a few defects that will cause oscillation.

If an ac-dc receiver has been working properly and oscillation suddenly starts, the first thing to check is the output filter capacitor. The signals from the plate and screen of each tube are impressed across this capacitor, and usually it has a very low reactance at rf and af frequencies. However, as electrolytics age, they become very poor at bypassing high frequencies although they may still be able to do an excellent job of filtering power supply ripple. To check for this, shunt a .1-mfd paper capacitor across the output filter capacitor. If this clears up the trouble, the test capacitor should be permanently installed. The best ac-dc receivers have such an rf bypass installed at the factory.

New tubes should also be tried because some defect may have raised the stage gain to an abnormal point, resulting in oscillation.

If the symptoms point to a defect in the af section, shunt the af plate bypass capacitors with others of about the same size to see if this clears up the trouble.

If the trouble occurred after someone else serviced the receiver, your problem becomes more difficult, because the previous serviceman could have made changes affecting the basic design.

AC-DC receivers, where the chassis is not connected directly to B− but is only bypassed to that point, must be carefully designed to prevent regeneration and hence the tendency to oscillate.

The isolation of the chassis from B−, which is usually one side of the power line, eliminates the shock hazard otherwise present if the chassis is connected directly to the power line. Every ac voltage and every signal voltage in the set causes small currents to flow through the capacity between the receiver parts and the chassis. This results in current flow through the chassis to the isolating capacitor and back to B−. As a result, voltages with a mixture of frequencies, amplitudes, and phases, which cannot be determined in advance, will be present across the isolating capacitor. This capacitor is also in the input of the receiver. Some of these voltages are regenerative, some degenerative, some cause trouble at only certain dial positions, others cause trouble at any dial setting. Moving the physical position of the capacitor or changing its capacity may result in uncontrolled feedback. When the capacitor has been replaced and oscillation results, try various chassis ground points to find the connection that causes least squealing or motorboating.

The fact that servicemen sometimes change circuit conditions so oscillation occurs means that the expert man should not only know what parts to suspect when a properly operating set starts squealing but should know a little about the problems of the designer and how oscillation can occur in a section or a stage.

Now let us discuss the causes of oscillation, squeals, and motorboating in the rf section of both ac and ac-dc sets. Later we will take up similar defects in the af section.

RF SECTION

You are of course familiar with the operation of the local oscillator in a superheterodyne. To have oscillation in the circuit, energy must be fed back from the output of the oscillator to its input, and this feedback must not only be of the proper phase to re-enforce the signals at the input of the oscillator but must also be strong enough to overcome the losses in the circuit. If any one of these three conditions is not met, oscillation stops.

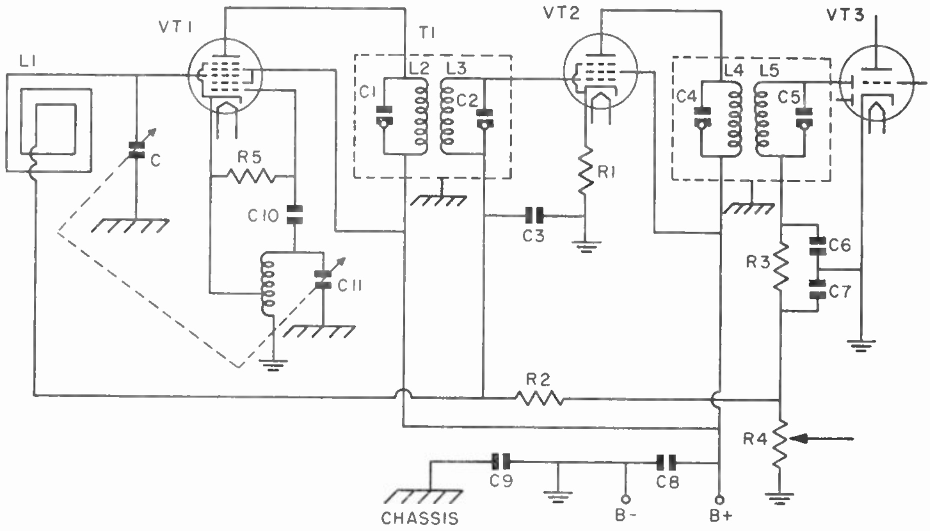

FIG. 16. A typical i-f stage.

The same conditions must be present if a single amplifier stage in a receiver goes into unwanted oscillation producing an audible beat (squeal) with the signal it is supposed to amplify. There is nothing you can do about the phase of the feedback. As a matter of fact, if you reverse the phase of the feedback, the stage gain and the signal strength will be greatly reduced. Therefore, to prevent unwanted oscillation in a stage, you must either eliminate the feedback path or reduce the amount of feedback to the point where the natural circuit losses will prevent oscillation from taking place.

First let us investigate the possible feedback paths in the typical i-f stage shown in Fig. 16. Remember, for the feedback to cause oscillation, it must take place from the output to the input circuit. The diagram shows that the two i-f transformers are shielded, so magnetic coupling from the coils of the output transformer cannot occur as long as both shields are grounded to the chassis. The magnetic fields around the leads from the transformers are too slight to induce voltage in other leads. This leaves capacity coupling as a means of feeding back energy from the output to the input.

If the plate lead of VT2 is run close to the control grid lead, there will be enough capacity between the two leads to feed considerable energy from the plate to the grid circuit. The stage will go into oscillation. You can reduce the feedback and stop the oscillation by separating the leads.

Actually there is a certain amount of capacity inside the tube between the plate and the control grid. The capacity is quite low because of the presence of the screen grid, and most of the feedback voltage will be dropped across the capacitive reactance.

Fig. 17 shows the part of the circuit in which we are interested. The plate and control grid are drawn as two plates of a capacitor to show that capacity exists between them. The large signal voltage across L4 is impressed across L3 through C8 and C3 and through the grid-to-plate capacity. The reactances of C3 and C8 are so small that as far as signal frequencies are concerned the lower ends of L3 and

L4 may be considered as being at B− potential. The reactance of the grid-to-plate capacity is very high compared to the reactance of L3, and most of the feedback voltage is dropped here, leaving only a small amount to be fed across L3. The voltage across L3 is ordinarily too small to sustain oscillation. However, if the reactance of the grid-to-plate capacity is reduced, the reactance of L3 is increased, or the signal across L4 is increased, the signal fed back may be large enough to cause oscillation.

The manufacturers try to keep the grid-to-plate capacity in their tubes below a certain level. Sometimes, however, a tube with excess internal capacity will get through, and this tube may oscillate in certain circuits.

In the older octal-based tubes, those with glass envelopes are usually interchangeable with those using metal envelopes. However, the interelectrode capacity of the GT type (glass) is considerably more than that of the metal type. Many stubborn cases of oscillation have been traced to glass tubes used to replace their metal equivalents in high gain rf circuits.

If the i-f transformers in Fig. 16 are replaced with others having a higher Q, the input and output impedances will increase. As a result, more signal will be produced in the plate circuit, and more of the feedback voltage will find its way into the input circuit. Uncontrollable oscillation may occur that no amount of bypassing or rearrangement of circuit leads will help. In this case you must use lower Q transformers or deliberately reduce the stage gain. This can be done by increasing the value of R1 in Fig. 16. If R1 is bypassed, removing the bypass capacitor will introduce degeneration which will also cut the stage gain.

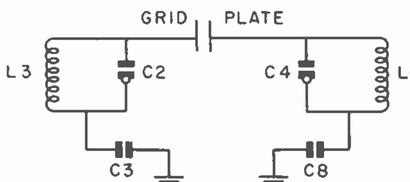

FIG. 17. The plate and control grid of VT2 drawn as a capacitor to show that there is capacity between them.

When replacing i-f transformers do not install ones with iron cores unless they were used originally by the manufacturer. Iron-core transformers generally have a much higher Q than the air-core, capacity-tuned type. The trimmer-capacitor tuned transformers are the most popular, and the kind you will find in most of the receivers you service.

Misalignment can also increase the grid and plate circuit impedance to the point where feedback becomes troublesome. If C1 and C5 in Fig. 16 are tuned slightly away from the resonant frequency and C2 and C4 remain peaked, the loading on the grid and plate tuned circuits will decrease. The impedances of the tuned circuits will increase, sometimes to the point where oscillation will occur.

Signal currents of course flow in the screen circuit, but no signal voltages can build up on the screen because it is held at the same potential as B− as far as signals are concerned. This, as stated previously, is accomplished by the bypass action of the output filter capacitor. If the capacitor fails as an rf bypass, then signal voltages will be applied to the screen grid. Since the capacity between the screen grid and the control grid is quite high compared to the plate-to-control grid capacity, there will be enough feedback from the screen grid to the control grid to result in oscillation.

The troubles just discussed result in oscillation in the i-f stage. Since no other stages are involved, this is known as single-stage oscillation. If two or more stages are involved, we have what is known as over-all oscillation, somewhat comparable to that which occurs in a multivibrator circuit. Over-all oscillation, however, is a rare condition in the rf section of a modern receiver. For over-all oscillation to occur, the stages involved must operate at the same frequency. In the modern receiver the mixer operates at one frequency and the i-f amplifier at another. Therefore, feedback from the output of the i-f to the mixer input will not result in oscillation.

In the af amplifier we have two stages—the first af and the power output stage, both amplifying the same signals. If energy from the plate of the power output tube is fed back so that it is in phase with the signal at the input of the first af, the entire audio section will go into oscillation. To prevent oscillation in the audio section, you must keep the plate and screen grid leads of the power output tube away from the first af control grid circuit, and use a good plate bypass on the power output tube.

Under certain conditions the rf section can go into over-all oscillation. If an unskilled person tampers with the i-f alignment, he may loosen the i-f trimmers until the i-f amplifier is tuned somewhere on the broadcast band. Then, when you tune the preselector to the low-frequency end of the band, the mixer input and the i-f amplifier will be working at the same frequency. Any feedback from the i-f output to the mixer input will result in oscillation. Also, the mixer can go into single-stage oscillation, because its input and output circuits are tuned to the same frequency. Any i-f signals flowing through the chassis and C9 to B— (see Fig. 16) will be in the mixer input circuit consisting of bypass capacitor C3, coil L1, and tuning capacitor C.

Thus, when oscillation occurs over the lower part of the dial (not at a single frequency only) suspect incorrect i-f alignment.

As you can see, not much can go wrong with a standard ac-dc receiver to cause oscillation. Older superheterodyne sets had a greater tendency to oscillate because there were usually two or more stages in the rf section operating at the same frequency. The old trf receivers were even worse in this respect than the early superheterodyne sets. In both types of receivers elaborate shielding was used around the tuning capacitor gang, the tubes, and the individual rf transformers. Also, RC decoupling circuits were used in the individual control grid, plate, and screen supply leads.

Most shields are made so they can be easily removed. If the connection between the shield and the chassis becomes corroded, producing a high-resistance rf joint, oscillation can take place in the receiver circuits. The best way to prevent oscillation is to use sandpaper to clean the contacts between the shield and the chassis.

An open bypass capacitor, particularly in the screen grid circuits, is another cause of oscillation. If the capacitor is open, the rf voltage can feed back through the power supply circuits to other receiver stages. Shunting a good capacitor across an open one will stop the oscillation and show that the capacitor under test should be replaced.

When a tuning capacitor with more than two sections is used, grounded springs wipe against the capacitor shaft at each section of the gang. A high-resistance contact here also causes oscillation. Scraping off the oxidation will clear up the trouble.

In many cases part connections are made to the chassis through rivets, and there are likely to be high-resistance rf joints at rivet connections. Where possible, securely solder the rivets to the chassis. Make sure the solder flows from the rivet head to the chassis.

In ac sets using 250 volts on the tube plates and about 100 volts on the screen grids, a bleeder resistor, such as R15 in Fig. 18, from the screen to chassis is used to keep the screen voltage constant. An open in this bleeder increases the screen-grid voltage and oscillation will take place because of excess gain in the stages.

Note how complex the circuits in the ac set shown in Fig. 18 are compared to those in Fig. 16. When oscillation takes place in an ac set, first check the screen grid voltage and the grounds on the various shields. Then, shunt a test capacitor across each of the capacitors in the set which would result in oscillation if defective. In this particular receiver, the capacitors to shunt are C4, C5, C10, C11, C17, and C18 in the screen grid and plate circuits of the various stages.

In many older ac sets, which usually contain many more amplifier stages than the modern ac-dc set, the position of the circuit wiring is critical. Therefore, when you repair the receivers, you must not re-route or change the position of the wiring, particularly in the control-grid, plate, and screen-grid circuits. The position of the wiring in an ac-dc set is not as important because there is usually less wiring in the circuits to serve as feedback paths.

When oscillation is the complaint, more than one stage may be involved. The symptoms will often tell you if it is the rf or the af section at fault. A large avc voltage will be present even when a station is not tuned in if the oscillation is occurring in the rf section. After you have located the defective section, you can then localize the trouble to the stage or stages in that section.

If you bring your hand near a stage that is oscillating, the frequency of the oscillation and the pitch of the squeal heard will change. This is a rough check to see which stage is at fault. Do not pay any attention to changes in the squeal that occur when you approach the local oscillator circuit. Here the effect is the same as if you were to shift the tuning knob of the receiver slightly.

AF SECTION

Many of the causes of oscillation in the af amplifier section of a radio receiver were discussed earlier in this section. Here we will take up the causes of parasitic oscillation in the audio output stage. Then, we will see how the inverse feedback circuit used in many af amplifiers can cause oscillation.

Parasitic Oscillation. Any unwanted self-sustained oscillation in a single stage is a parasitic oscillation, because it "lives off" the stage. However, servicemen use this term only to describe oscillation at some frequency to which the circuit is not tuned or which is outside the normal frequency band of the offending stage.

In radio receivers, this trouble is usually limited to the audio output stage, because it is usually the only stage where enough power is available to sustain such oscillations. A pentode output stage is particularly subject to these oscillations, because the stage has high gain, has a tube with a relatively coarse screen grid structure (so that the interelectrode capacity is high), and uses circuit elements that readily permit parasitic oscillation. This trouble is most common in ac sets and high-fidelity amplifiers when the output stage is run as a class AB or class B push-pull amplifier with a low

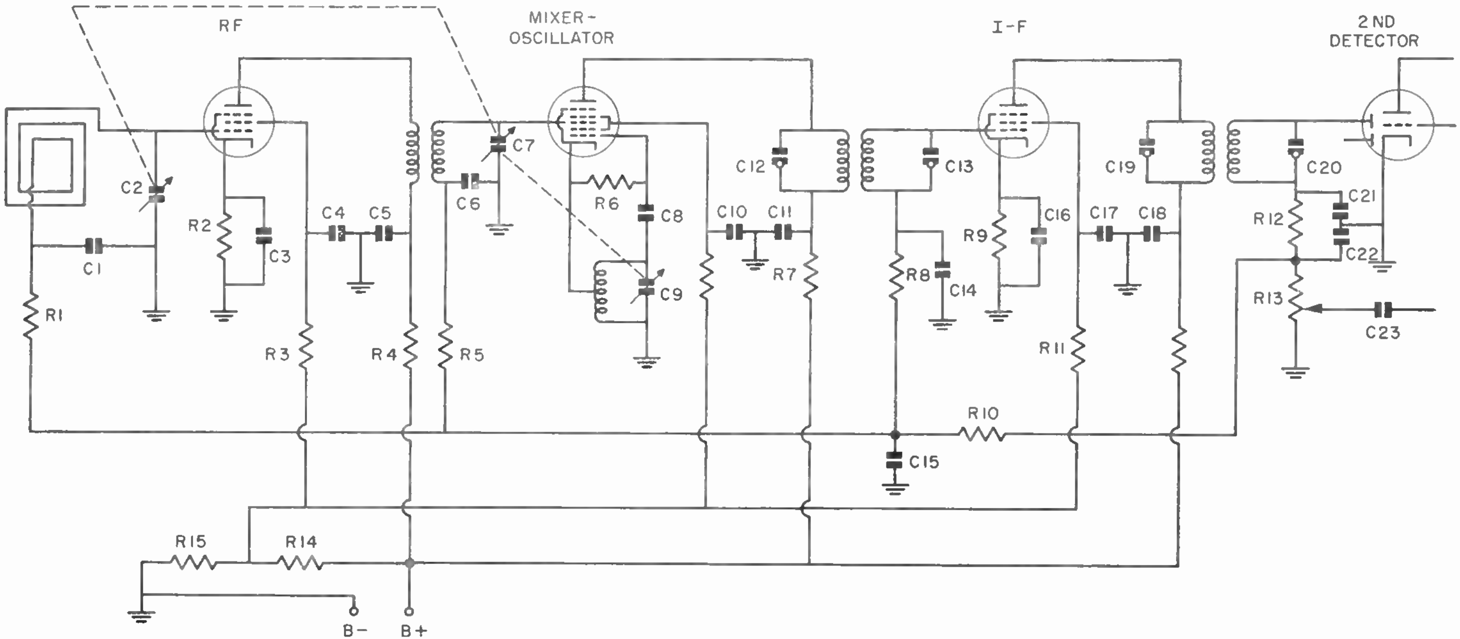

FIG. 18. The rf section of an ac receiver.

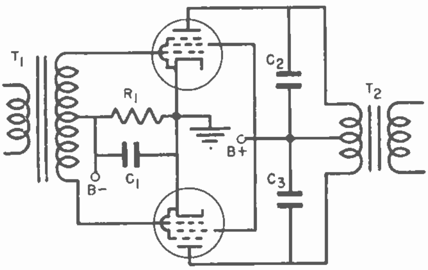

FIG. 19. A typical push-pull output stage.

resistance input transformer. A typical circuit is shown in Fig. 19.

The oscillation occurs at frequencies where the leakage inductance and distributed capacity of the transformers form resonant circuits, or where the transformer capacities remove the inductance effects. Then the grid and plate leads act as transmission lines because of their distributed inductance and capacity. The circuits act as tuned-grid tuned-plate oscillators that may produce oscillations well up in the short waves.

The trouble will even occur where resistance-coupled amplifiers are used to drive the output stage. The inductance and capacity of the grid leads act as the tuning elements in the control-grid circuit. Remember, even a short piece of wire has a definite inductance, and its reactance may become appreciable at extremely high frequencies.

Parasitic oscillation does not occur in every circuit, of course. It may occur in any circuit in which enough power is available, in which enough feedback exists, and in which the grid inductance and capacity can form a resonant circuit.

Parasitic oscillation causes severe distortion, weak reception, and perhaps a rushing noise or an exceedingly high-frequency whistle. The large amount of power consumed lowers all operating voltages. The output tubes may glow blue between their elements or even get so hot their elements melt. The rectifier tube, filter choke, power transformer, and output transformer will overheat because they will be passing excessive current. Of course, a blue glow on the glass envelope of the tube does not indicate a defect; but such a glow between the electrodes indicates the presence of gas and excess cathode current.

You can prevent parasitic oscillation by introducing suppression, making the plate bypass capacitor more effective, or by shortening the effective length of the grid leads so much that the tube will not be able to oscillate.

One of the most effective cures for parasitics is to insert resistors at the grid terminal of each tube as shown in Fig. 20. Resistors R2 and R3 should be between 100 and 1000 ohms. Use the smallest size that will eliminate the oscillation.

In a class B output stage, grid current will cause distortion if values above 500 ohms are used. Hence, if you need larger suppressors to stop the oscillation, use about 200 ohms, and consider the following procedures.

Manufacturers usually use capacitors such as C2 and C3 of Fig. 19 in circuits where parasitics may develop, to make the plate load more capacitive.

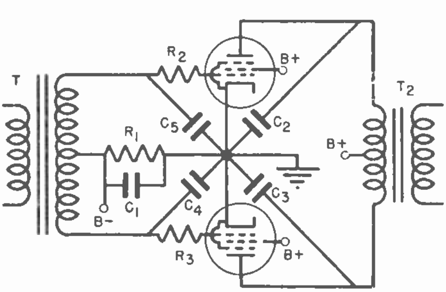

FIG. 20. Parasitic oscillation in an output stage can be cured by inserting resistors at the grid terminal of each tube as shown here.

Such capacitors should be connected at the tube socket and positioned so that the effective length of the plate lead is shorter. This will reduce further the inductance effects as well as the ability to feed back.

In the circuit shown in Fig. 19, the bypass paths from the plates run through capacitors C2 and C3 to B+, from B+ to B− by way of the output filter capacitor, and then to the cathode through capacitor C1. Bringing C2 and C3 directly to the cathode as shown in Fig. 20 eliminates a great deal of this path, and makes parasitic oscillation less likely. If C2 and C3 are used in this way, they must have voltage ratings of 600 volts or higher.

As an additional measure, grid capacitors of about .005 mfd each can be installed to change the grid resonant frequency, as shown by C4 and C5 in Fig. 20. Sometimes such capacitors are installed by the manufacturer. If used, C4 and C5 should return to the same cathode point as C2 and C3.

Remember that an electrolytic capacitor makes a very poor rf bypass because its inductive winding limits its effectiveness at high frequencies. For this reason, a paper bypass is connected across the output filter capacitor in many receivers; sets without this feature frequently prove unstable. In most modern receivers, however, the manufacturer usually does not install the bypass across the output filter. Instead, he assumes that an electrolytic capacitor is an adequate bypass for all frequencies that may be present.

Inverse Feedback Circuits. In many modern receivers inverse feedback is used in the af section of a receiver to improve tone quality and to reduce distortion. This feedback, instead of being regenerative and causing oscillation, is degenerative and reduces the gain. It practically wipes out any signals not originally at the input of the amplifier. Thus, any distortion caused by non-linearity in the amplifier is greatly reduced, which increases the fidelity of reproduction.

A typical circuit is shown in Fig. 21. Here part of the signal across the voice coil is fed back through a voltage divider network to the input of the amplifier. That part of the feedback voltage across R1 is in the grid circuit of VT1, and reduces the gain of the amplifier by cancelling out some of the incoming signal. If there are undesirable signals across resistor R1, such as harmonics, noise, hum, etc., produced in the amplifier stages themselves, the signals will be greatly reduced by the degenerative effect.

If the voice coil is connected proper-

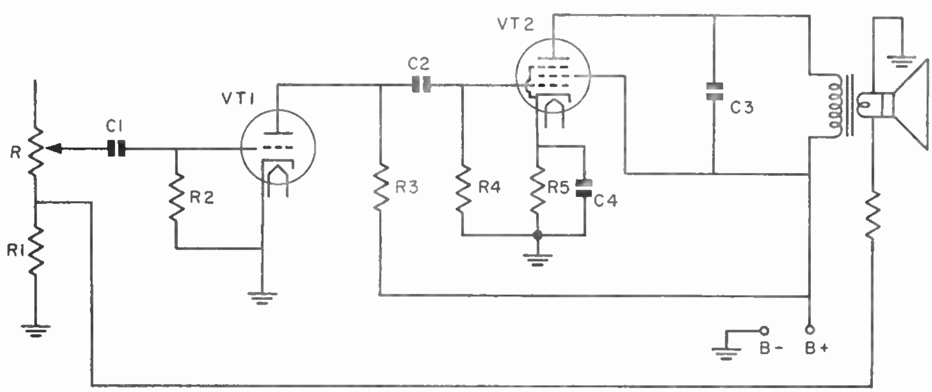

FIG. 21. A circuit using inverse feedback.

ly, the feedback is out of phase with the signals across R. This is necessary to get degeneration. If the connections are reversed at the voice coil or at the primary of the output transformer, the feedback will be in phase with the signal fed to the input of the amplifier, and over-all oscillation of the af amplifier will occur. Where this trouble is suspected, you can reverse the connections at the voice coil, or what is perhaps easier, to the primary of the transformer.

SQUEALS AND HOWLS NOT DUE TO RECEIVER DEFECTS

Since there are many different radio-frequency signals in the superheterodyne receiver, beats at the i-f can be formed between the local oscillator in the receiver and undesired station carriers, which get through the preselector and reach the mixer input.

Most modern receivers use only a single tuned circuit ahead of the mixer. Therefore, it is not possible to reject all the signals that can beat together and produce an i-f that will pass through the i-f amplifier. If the dial setting at which this occurs is not occupied by a desired station, no harm results. In this case, the high-frequency station is received at both the correct high-frequency point and at a low-frequency setting near the end of the dial. However, if a desired station operates at the low-frequency spot on the dial, you will hear a whistle or squeal with the program due to the interference between the station frequencies. This is called image interference.

The only cure is to turn the receiver cabinet so its loop will favor the desired station and tend to reject the signal from the interfering station. In outlying areas this can be very troublesome. Often if you move the set a few feet or a few yards away from the original position, you will change the strength of the image station and the amount of interference. This is particularly noticeable in some localities on an automobile radio. There is no real cure, but fortunately the FCC tries to assign the frequencies to the various stations in a particular locality so that interference will be held to a minimum.

Shifting the receiver i-f 5 kc or 10 kc will change the point on the dial at which the trouble occurs, but in most cases this throws the tracking off an appreciable amount.

If an outside antenna is used, image interference may be troublesome. However, with an outside antenna, a wave trap, tuned to the frequency of the interfering station, may be placed in series with the lead-in.

The use of an outside antenna to help pick up distant stations may result in adjacent channel interference, resulting in a 10-kc audio squeal (adjacent channels have a 10-kc separation). Interference will occur only in localities where stations on adjacent channels feed enough signal to the receiver so that some i-f carrier signal from each station reaches the second detector. Fortunately, interference of this type is not a widespread trouble. If it does occur, it will be worse at night and during the winter months when long-distance reception on the broadcast band is at its best.

A more serious difficulty is harmonic radiation from the horizontal sweep circuits of TV receivers. This causes squeals across the entire dial, spaced about 15 kc apart. In such cases, look for an operating TV receiver in another part of the house. Line filters sometimes help, and also greater physical separation between the TV and radio sets. Rearranging the yoke leads of the TV receiver, shielding the TV receiver, and installing a filter between the TV set and the wall outlet may help reduce the interference.

The local oscillator of a nearby radio receiver may also radiate a signal that is picked up with desired signals. In such a case you will hear a squeal having a frequency equal to the difference between the interfering signal and the carrier of the desired station. About all you can do is tune to a station where the squeal does not occur. Increasing the physical separation of the two receivers or turning one of the sets to take advantage of the directional characteristics of its loop will decrease the interference considerably.

If you learn to recognize squeals due to causes outside of the receiver, you may save hours of useless trouble-shooting. Generally if a set squeals at your customer's location but not in your shop, there is nothing wrong with it.

COMMON CAUSES OF OSCILLATION

This table covers only the more common causes, with the most common first. Use it as a guide and memory refresher. Localize the trouble first, then check for these probable causes.

Condition	*Location*	*Causes*
Audible at all times.	Audio Stages	Defective filter or bypass capacitors.
Squeals only when station is tuned in. Occurs on all stations.	I-F Stages	Open bypass capacitors; shielding missing or making poor contact; alignment off; excess screen grid voltage; low bias; leads improperly placed.
Squeals only when station is tuned in. Occurs mostly at one end of tuning band.	RF Stages	Open bypass capacitors; shielding missing or making poor contact; poor contact at tuning capacitor rotor shaft; excessive screen grid voltage; low bias; alignment off; leads improperly placed.

Lesson Questions

Be sure to number your Answer Sheet 39B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. Which components in the receiver power supply are the most frequent cause of hum in a receiver?

2. Which of the following is more subject to hum pickup: (1) low-impedance grid circuit; or (2) high-impedance grid circuit?

3. Suppose a receiver using the circuit shown in Fig. 6A hums, and no station can be received; what part would you suspect if shorting R3 kills the hum, but shorting R2 has no effect on the hum and does not produce a click in the speaker?

4. What two conditions must be present before modulation hum can be produced in an rf or i-f stage?

5. Why does cathode-to-heater leakage in a tube usually produce less hum in an ac set than the same defect in an ac-dc set?

6. What are the two purposes of the decoupling networks C2-R2 and C4-R4 in Fig. 13?

7. If you are not able to reduce or stop squealing in a receiver by tuning the set or varying the volume control, which receiver section, in addition to the power supply, would you suspect might contain the defect?

8. What are the two procedures that can be used to prevent unwanted oscillation in a receiver stage?

9. Why is over-all oscillation rarely found in an rf section of a modern superheterodyne receiver that is properly aligned?

10. Why are parasitic oscillations usually confined to the output stage of a receiver?

STICK—AND YOU'LL WIN!

"How can I be a success?" The simplest answer to that question is "finish whatever you start."

Until success is attained, the individual tasks confronting you are relatively unimportant in themselves. The really important thing is their effect upon you, what you *learn* from them, the *practice in succeeding* that you acquire in accomplishing these tasks.

We can always find plenty of reasons for quitting, but what do we accomplish, what do we learn by quitting? We only learn how to quit—how to fail.

If success in any undertaking is dependent upon effort (and we all agree that it is), then the more effort we make, the greater our success. You may not be able to trace the success present in every effort, but it is there just the same. You don't attain success in one jump. You succeed by degrees, and the degree of success is in exact proportion to the degree of effort.

J. E. Smith

HOW TO SERVICE DISTORTED, NOISY, AND INTERMITTENT RECEIVERS

40B

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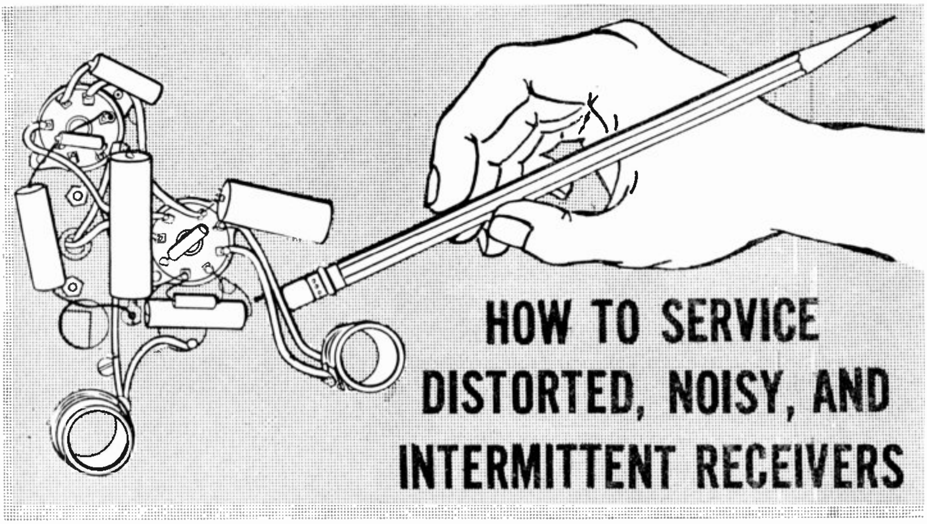

HOW TO SERVICE DISTORTED, NOISY, AND INTERMITTENT RECEIVERS

YOUR last few lessons have described the servicing procedures to use in locating and repairing various types of radio receiver complaints. You have studied the types of defects that may be found in the various receiver parts, and you have learned how to locate defects in receivers that hum, squeal, and motorboat. In this lesson, you will study the causes of distortion, noisy reception, and intermittent reception. You will learn several servicing techniques to use for each complaint. When you are doing service work, the more tests you are able to make to find the trouble in a receiver, the faster you will be able to make the repair. Remember, in receiver repairing, time is money.

Noisy reception and intermittent reception are often caused by the same defect. In both cases, the defect is not constant, but goes "on and off." The difference is chiefly in the frequency with which it does so. If the defect occurs rapidly, it results in noise; if it occurs very slowly, it results in intermittent reception. This is not always true. Some defects can cause one or the other complaint but not both.

In this lesson you will learn how to localize the defect by using voltage measurements, signal-tracing methods, and effect-to-cause reasoning. In the first section of this lesson you will study the causes and remedies of receiver distortion. Later you will study noisy and intermittent reception.

When a customer tells you that his receiver doesn't sound right, he means that the sound is distorted. He may say the set sounds as though the person talking had a "mouthful of mush," or the receiver sounds "tinny," or "boomy," or he may not be able to describe just what he finds objectionable.

It is impossible to eliminate all distortion completely; the receiver without any trace of distortion has not yet been made. Your job is to reduce the distortion enough to satisfy the customer.

When a customer complains about his receiver, be sure you find out exactly what he dislikes about its performance. You can't depend on your hearing; even when the receiver is working at its best, you may consider its output distorted; on the other hand, the customer may complain about distortion that you find unnoticeable. Much depends on what the customer has been used to in the past and the exact quality of his hearing. Remember that the untrained human ear can stand reasonable amounts of distortion indefinitely.

There are three types of distortion: *frequency*, *phase*, and *amplitude*. Let us see what they are, and which of them you will most often be called on to correct in your service work.

FREQUENCY DISTORTION

If a receiver or an amplifier does not pass all signal frequencies in the audio range equally, the result is frequency distortion. Sound audible to the human ear ranges from about 20 to 20,000 cycles per second. Ideally, transmitting and receiving equipment would transmit and reproduce frequencies in this range just as they were originally produced. Fortunately, a smaller frequency range than this will still give intelligible and entertaining programs. An ordinary inexpensive table-model radio receiver has a frequency range of about 100 to 3500 cycles per second; a high-fidelity receiver has a range of about 30 to 15,000 cycles per second.

A customer will usually describe frequency distortion as "tinny" or "boomy." Only the very worst cases of frequency distortion are usually brought to a service shop. Very few service shops have the equipment to measure the frequency range of a receiver. You will have to depend on your own ear. Since you will have no way of measuring the frequency range, you will have to make the receiver sound right.

PHASE DISTORTION

In any equipment using coils and capacitors, there is some phase shift in the transmission of different frequencies. Thus, several simultaneously transmitted frequencies may not end up with the same phase relationship, but may be advanced or delayed in time. Phase distortion is usually of very little importance in radio receivers, so we will not consider the matter here; you will meet it again in your studies of television.

AMPLITUDE DISTORTION

The signal waveform at the output of a transformer or tube does not always have the same shape as the signal at the input. The change in shape generally takes place at first at the positive and negative extremes of a cycle and appears to change the height or amplitude of the wave. For this reason, it is called amplitude distortion. It is the type of distortion most noticeable to the human ear, and hence, the type you will most often be called on to correct.

Whenever the shape of a wave is changed, the harmonic content of the original signal is changed. Because of the change in harmonic content, this form of distortion is often called harmonic distortion.

How Distortion Is Produced

Amplitude distortion exists when the wave shape at the output no longer resembles the wave shape at the input of a stage or section; the change in wave shape indicates that there are harmonics in the output that were not a part of the original signal. Frequency distortion exists when some frequencies are amplified more than others. Let us see what causes each of these effects.

AMPLITUDE DISTORTION

There will be amplitude distortion only if a part is non-linear; that is, it produces an output that differs from the input not only in amplitude but also in wave shape. The only common parts that can be non-linear are tubes, transistors, crystal diodes, large iron-core chokes and transformers, and a few special resistors called "thermisters."

Sometimes the non-linearity of a part can be useful. For example, it is the non-linearity of a diode that makes it useful. Thermisters are found only in a very few television sets, where their non-linearity can be used to provide voltage regulation.

Now let us see just how non-linearity in a tube or iron-core transformer can cause amplitude distortion. At the same time we will see why amplitude distortion does not occur in a resistor, capacitor, or air-core coil. A graphic presentation will show you most clearly.

Operating Characteristics. If a device has a straight-line operating characteristic curve like that shown in Fig. 1, there will be no distortion. Here, the sine wave signal 1-2-3-4-5 produces a wave shape 6-7-8-9-10 that is larger, but otherwise an exact duplicate. Any device or amplifier with a straight-line characteristic like this is said to be linear, and will faithfully reproduce the input signal.

Resistors, capacitors, and air-core coils all have straight-line characteristics. This means that the resistance of a resistor or the capacity of a capacitor does not change with wide variations in voltage.

In an air-core coil, since the magnetic path is air, its reluctance does not change if the magnetomotive force changes, so the flux varies in proportion to the magnetomotive force. As long as the change in flux is proportional to the magnetomotive force, the waveform of the secondary voltage will have the same shape as the waveform of the primary signal current.

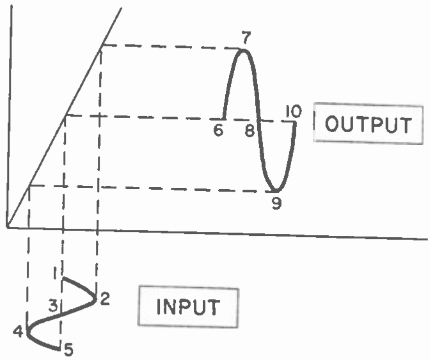

FIG. 1. A straight-line characteristic curve will give linear, distortionless output.

In an iron-core device such as an audio output transformer we have a somewhat different situation. Here, the reluctance of the core increases as the magnetomotive force increases, so the flux does *not* change in proportion to the magnetomotive force. In fact, if the magnetomotive force is made great enough, the reluctance will become so large that the flux does not increase at all, but remains constant;

this is called core saturation. When we have core saturation, the waveform of the secondary voltage will be flattened so that it is different from the waveform of the primary current, and we have amplitude distortion.

The strength of the magnetomotive force is determined by the combined strength of the ac signal current and

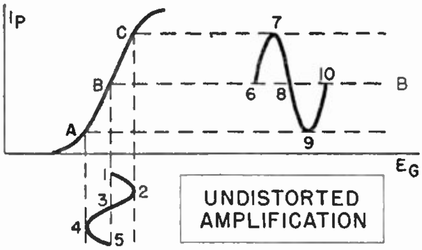

FIG. 2. A tube characteristic curve is never straight, but the center part is straight enough to give relatively undistorted amplification.

the dc flowing in the primary winding of the transformer. The reluctance of the core always increases when the magnetomotive force increases. No transformer is perfectly linear. In other words, there is always at least a small amount of distortion. In a well designed receiver, the distortion will be small, but if the direct current becomes too large, the core will become saturated, and there will be a considerable amount of distortion.

A vacuum tube is another part that does not have a straight-line characteristic. The Eg-Ip curve is never a straight line but is curved, as shown in Fig. 2. Part of the curve is straight enough so that operation on it will not produce appreciable distortion. In Fig. 2 the applied grid signal 1-2-3-4-5 swings the plate current over the almost straight section A-B-C of the curve; plate current wave 6-7-8-9-10 has very nearly the same shape as the input signal voltage, and there is no appreciable distortion.

Overloading. Now suppose we have the same grid bias and plate voltage as for Fig. 2, but apply a larger signal to the grid so that the tube works on the upper and lower bends of its characteristic, as shown in Fig. 3. Here, the signal 1-2-3-4-5 swings the tube operation over range D-B-E, producing the output wave 6-7-8-9-10. The output wave is highly distorted; the peaks at 7 and 9 are flattened. This type of distortion is the result of overloading (too much signal voltage), and is very noticeable to the human ear.

Bias Changes. Now let us see what happens if instead of overloading the stage with too much signal, we apply a normal signal and allow the bias voltage to shift. Fig. 4A shows what happens if the bias is too low. The tube operating curve is the same as in Fig. 2, but the operating point is now at point F, near the upper bend of the curve. The bias voltage has been reduced, allowing a higher average plate current to flow.

Now when we apply grid signal 1-2-3-4-5, we will operate between G and H on the curve. The output wave

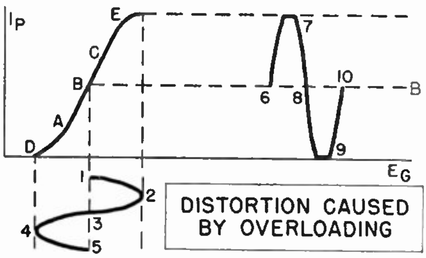

FIG. 3. The effect of too high an input signal.

6-7-8-9-10 is flat at 7, and the swing from 6 to 7 is much shorter than the swing from 8 to 9, so the upper half of this wave is quite distorted.

Similarly, if the bias is too high, we get distortion at the lower bend of the curve (Fig. 4B). Here, the bias voltage has been increased so that J is the operating point. The input signal swings over the operating region K-L, producing an output wave 6-7-8-9-10. The lower half of the wave is squared off and shorter than the upper half. This is the same effect as that in Fig. 4A, except that it is on the other half of the wave. Since the human ear can't recognize phase shifts of 180°, the two distortions will sound alike.

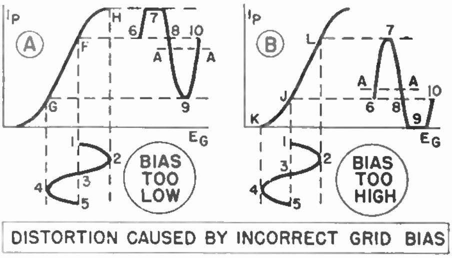

FIG. 4. The effect of too high or too low bias with normal input.

Plate Voltage Changes. Now let's see what happens if the grid bias remains fixed but the plate voltage changes. Again we will have distortion. Fig. 5 shows how. The three curves are for three different plate voltages with the same bias.

Suppose the plate voltage is 250 volts and the bias is adjusted to give class A amplification. Then, on curve 1 (the middle curve), the operating point will be B and the operating range A-C, so the output curve M is a duplicate of the grid signal.

With the same bias, suppose we increase the plate voltage to 300 volts. We will then operate in the G-H region on curve 2 and get output curve N. Notice that this is the same type of curve as that in Fig. 4A.

If we drop the plate voltage to 200 volts, we operate in the K-L region on the lower bend of curve 3, getting output curve P. This curve is like Fig. 4B.

Thus, overloading the tube, changing the grid bias, or changing the plate voltage may shift the operating point on the tube curve enough to cause distortion.

Self-Biased Stages. In a self-biased tube stage, any defect that changes either the grid voltage or the plate voltage usually changes both. Since these two changes tend to compensate for each other, distortion in a self-biased stage is not as great as shown in the curves we have studied. However, a self-biased stage cannot compensate fully for changes in operating voltages; some distortion occurs when any change is made, but it is considerably less than the same change produces in a fixed-bias stage.

Remember that changes in screen voltage have much the same effect as improper plate voltage. The distortion shown in Fig. 5 will occur if changes in the screen grid voltage make the tube operate over a curved part of its characteristic curve.

Low emission in a tube, caused by a wornout cathode or by low filament voltage, can change the shape of an Eg-Ip curve so that distortion occurs.

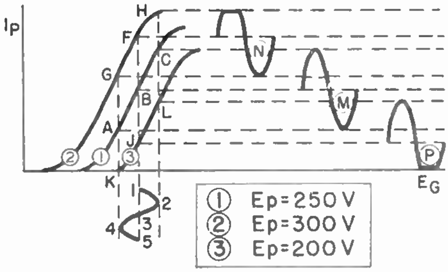

FIG. 5. The effect of incorrect plate voltage.

The effect of low emission is to lower the upper bend in the characteristic curve.

Plate Current Changes. Let us refer to Fig. 2 again. In this figure, the average of the plate current is the line B-B. When the signal is applied, the increase in plate current from 6 to 7 of Fig. 2 is equal to the decrease from

8 to 9, so there is no change in the *average* value of the plate current. Thus, you should notice no change in the average (dc) plate current when a signal voltage is applied to a properly operating class A stage.

In Fig. 3, the average plate current is the line B-B. Again the change from 6 to 7 is equal to the change from 8 to 9, so the average plate current will not change. Therefore, in the situation shown by Fig. 3, we cannot tell from the plate current when a stage is overloading.

However, in Fig. 4A we find something very interesting. The average normal plate current is represented by the line F. When we apply a signal, the plate current rise from 6 to 7 is not nearly as great as the plate current drop from 8 to 9. Therefore, the new average caused by this signal variation is somewhere near the point represented by the line A-A. When a signal voltage is applied, the plate current average drops from the F value to the A-A value. Thus, if the plate current drops when signals are applied, you know that the stage is operating at or near the upper bend in the tube characteristic.

In Fig. 4B, the plate current changes from the average value J to the value A-A—increasing when a signal voltage is applied. Therefore, an *increase in the plate current* when a signal is applied shows the stage is operating on the lower bend of the tube characteristic.

In Fig. 3, we chose an operating point exactly at the middle of the curve. If the actual operating point is higher or lower on the curve, an overloaded input will cause unequal half cycles and, again, the plate current will shift. The direction of the shift depends upon whether we are higher or lower on the curve, as in Fig. 4.

In general, there should be a steady plate current in a class A amplifier, whether or not a signal is applied. A plate current increase or decrease means there is some distortion in that stage. The direction of the change shows whether the stage is operating closer to the upper or to the lower bend of the tube characteristic. This test applies *only* to a class A amplifier, such as an rf stage with no avc, or an audio amplifier, not to a detector or to a class B amplifier, where a plate current change always occurs during normal operation when a signal is applied. As you will learn later, this gives you a highly useful test for distortion in a class A amplifier.

FREQUENCY DISTORTION

Whenever you have a combination of inductance and resistance, capacity and resistance, or inductance and capacity, frequency distortion will exist, although its amount can be limited by proper design. Therefore, there is always some frequency distortion in any audio amplifier, causing losses at both the low- and the high-frequency ends of the audible range.

Frequency distortion in high-fidelity receivers may be caused by a slight change in a part value or by misalignment. In ordinary receivers, defective parts are usually responsible.

Usually you will correct frequency distortion only when some defect has caused a radical change in the frequency response of the receiver. Let's see what defects there may be, starting with the rf stages.

Side-Band Cutting. Loss of high audio frequencies can be caused in the rf stages by side-band cutting, when the receiver has a narrow response. When the tuned circuits resonate sharply, the side bands are clipped and the side bands carrying the higher audio frequencies will not be passed. This condition may be caused by the receiver design or by too sharp peak alignment. The alignment can be quickly corrected with a frequency-modulated signal generator and an oscilloscope, by staggering the adjustments slightly so as to broaden the peak. This reduces both the gain and the selectivity of the receiver, but can

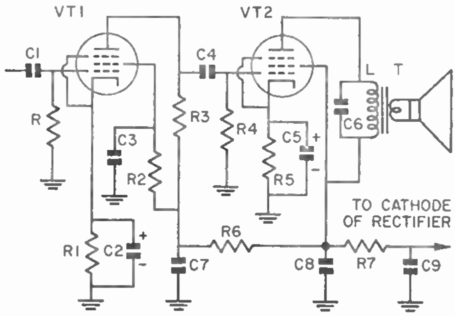

FIG. 6. A high-gain audio amplifier which might be found in some receivers and phono amplifiers.

be used in some cases to improve the frequency response.

Severe side-band cutting can also be caused by regeneration, although regeneration usually causes oscillation before a serviceman is called in. Treat regeneration just as you would oscillation complaints.

Defects in Audio Circuits. Fig. 6 shows a typical two-stage audio amplifier. Let's see how various troubles can cause frequency distortion in it.

If either of the coupling capacitors C1 or C4 opens, the reduction in capacity will cause severe frequency distortion. The volume will decrease tremendously, but there will be enough residual capacity in the wiring and between the broken ends of the capacitor leads to allow only the very high-frequency audio notes to pass. This defect can easily be distinguished by a great decrease in volume along with a "tinny" tone.

Capacitor C6 is used in the output circuit to prevent possible oscillation. If this capacitor opens, there will be no effect on low audio frequencies; but more high audio frequencies, which would be bypassed by C6, will be reproduced by the speaker.

An open in capacitor C2 or capacitor C5 will remove the bypassing across the bias resistors, allowing degeneration. This will reduce amplification somewhat, but will also flatten the frequency response and give better fidelity. However, if small amounts of capacity remain in these capacitors, the higher frequencies will be bypassed. There will then be less degeneration and a rising response at these higher frequencies.

C8 and C9 in this diagram are the filter capacitors. C8 provides the signal return path from the plate to the cathode of VT2. If C8 becomes open or loses capacity, the filtering action will be reduced, and R7 and C9 will then be in the signal return path. Adding R7 to the path reduces the signal current through L and reduces the volume. Loss of capacity at C8 puts R7 and C9 in the return path for low audio frequencies, but not for high audio frequencies. The lows will be reduced, but not the highs. However, the customer's complaint will probably be high hum rather than frequency distortion.

Since the most noticeable form of distortion in a radio is amplitude distortion, we will now take up the causes of it in detail.

Causes Of Amplitude Distortion In Radio Receivers

In servicing any electronic equipment for a given complaint, you must know the common causes of that complaint. Certain types of defects will produce the symptom in which you are interested; other types of defects, even in the same parts, will produce entirely different symptoms. Furthermore, you must know how to apply quick accurate tests that will show either that the part is at fault or that it is good.

This is not just a case of memorizing certain defects and their symptoms. There are too many parts in the various circuits for you to be able to remember all of them. Also, because of the slight differences in receivers made by different manufacturers, a particular defect may not produce the same symptom in every receiver.

For fast, accurate service work, you should have a schematic of the receiver you are working on. You can see from the schematic how the various stages and circuits work. All the parts are shown; and with them before you, it is possible to decide how a part might fail to cause the trouble. Looking at the schematic you can also decide what tests to make, and then proceed to make them.

Of course, some troubles are so common that you will recognize them easily, and won't need a schematic to help you think. For example, for distortion in the af system, you will always check the output tube and its coupling capacitor first of all. Then, you will look the set over and decide what other parts should logically be checked.

Only if you have not corrected the trouble and can think of no more logical tests should you bother with further localization procedures.

When you first start out, you won't have a great many ideas to try—this comes with experience—and you will have to depend upon localization procedures. With experience you will in many cases go right to the most likely cause of the trouble time after time.

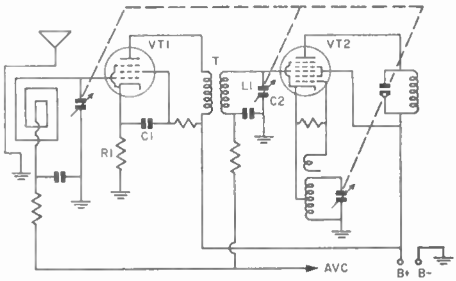

FIG. 7. A typical rf stage.

First, we will discuss defects in the rf stages that can produce distortion, then we will discuss defects in both single-ended and push-pull audio output stages. Both types of audio output stages are used in radio and TV sets, and in high-fidelity systems.

RF AND I-F STAGES

Generally, the stages ahead of the first af are free of amplitude distortion, so you can usually concentrate on the af stages, power supply, and speaker. However, this does not mean that amplitude distortion cannot be produced in the rf section of a receiver. Under certain circumstances, amplitude distortion does occur, as you will learn later. But first, let us see why it is not likely to.

During normal operation, tube VT1 in Fig. 7 has only a very small signal applied to its grid, and the bias produced by resistor R1 permits the tube to operate over the straight part of its characteristic curve. When a strong signal is received, however, the avc voltage causes the tube to operate near the lower bend of its characteristic curve. Since VT1 is of the remote cut-off type, the lower bend is very gradual. Some distortion results, but it is small.

Now, suppose excess bias caused by leakage in capacitor C1 is applied to the grid of tube VT1. This will cause the tube to operate on the curved part of its characteristic curve as shown in Fig. 8. Notice that the lower half of the plate current wave form is practically cut off. When the output signal is fed through coupling transformer T to the following resonant circuit, however, the restoring action of the circuit, called the flywheel effect, reconstructs the lower half of the signal. Let us see how this restoring action works.

When the rf signals in the form of pulses are fed into the resonant circuit formed by coil L1 and capacitor C2, the capacitor charges up on the positive pulses, and discharges through the coil between pulses. This stores energy in the coil, which in turn charges the capacitor with the opposite polarity. When the coil energy is used up, the capacitor again discharges, and the signal fed to the grid of the mixer stage from this resonant circuit contains both the positive and the negative halves of the carrier signal. Thus, the distortion produced by operating the tube on the curved portion of its characteristic is automatically corrected.

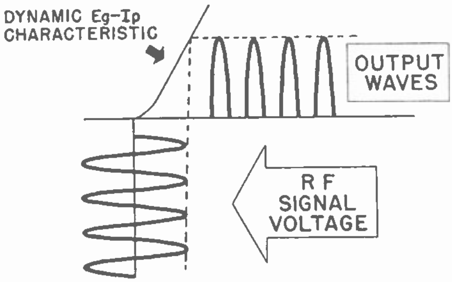

FIG. 8. When an rf stage is operated at cut-off, the output is a series of pulses. These are reconstructed by the following resonant circuit.

The important thing to note is that the tuned circuit can restore the wave shape of the carrier signal only. It cannot restore the wave shape of the modulation envelope. Although the rf output signal will not be distorted, the sensitivity of the set will be very low. Therefore, the customer will probably complain of low volume rather than distortion.

Similarly, the mixer is designed to operate at the plate current cut-off point just like any other detector. It must cut off half the wave, as shown in Fig. 8, to give the necessary mixing action. If a defect occurs, *the mixer may work on the straight part of its curve* and become more of an amplifier than a detector. There will still be some mixing of the incoming carrier and the locally generated oscillator signal, but the i-f output of the mixer will be low or there will be circuit noise. The customer will complain of weak reception or noise rather than distortion.

Incorrect electrode voltages in the oscillator circuit may make the oscillator block, and thus chop up reception. Again, the customer will not recognize this as distortion.

An i-f stage like that shown in Fig. 9 may cause distortion when it is overloaded. The i-f tube, like the rf tube we discussed, is a variable-mu tube with remote cut-off. Very little distortion of the modulation takes place at the lower bend. However, suppose that avc filter capacitor C breaks down, removing the avc voltage from the i-f tube and preceding tubes. Then, on strong signals, the sensitivity of the rf section of the receiver will not be reduced by the avc, so the signal voltage developed across the secondary of i-f transformer T will become considerably greater than the dc bias across resistor R. This will allow the tube to operate on both the bends of its characteristic (as in Fig. 3), and both positive and negative signal peaks will be distorted just as if a distorted af signal had been modulated on the carrier at the transmitter. This distorted signal will pass through the second i-f transformer T1, be rectified by the diode detector, and ultimately produce a distorted loudspeaker output. The following resonant circuits cannot correct for this because *both* halves of the wave have been affected instead of just one half.

Overloading can also be produced if VT1 or some other avc-controlled tube is gassy and draws grid current. This current will set up a voltage across R1 with polarity opposite to that of the avc voltage—that is, so the grid end of R1 is positive. As a result, the avc voltage is effectively decreased. Low avc voltage may allow the rf gain to increase enough to produce a signal that will overload VT1.

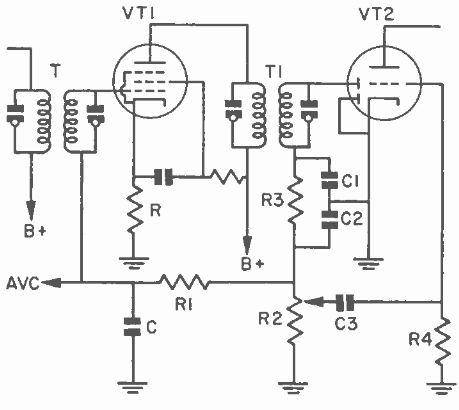

FIG. 9. An i-f amplifier stage.

Trouble in the second detector stage, VT2, can also cause distortion. For example, suppose the rf bypass capacitor C2 opens. This will allow so much rf energy to be fed into the first af stage that it may produce overloading and distortion.

If volume control R2 is incorrectly replaced with one whose resistance is too high, the diode detector may be cut off for short periods because of the excessively long time constant of R2 and C2. If the charge stored in C2 can't leak off rapidly enough, weak signal pulses will be cut off, thus producing a distorted output.

SINGLE-ENDED AUDIO STAGES

A typical single-ended audio amplifier is shown in Fig. 10. A defect in any of the shaded parts may cause amplitude distortion. The parts most likely to be at fault are coupling capacitor C6 and tube VT2, closely followed by C4.

Remember that, except for tubes, capacitors are the greatest troublemakers, especially those that have a large ac signal component applied across them in addition to the dc. Resistors seldom fail, but they do open or change in value at times. Therefore, you should consider them potential sources of trouble. When a resistor becomes defective, some other part is usually at fault, whereas capacitors themselves fail because of internal defects.

Let's take the shaded parts in Fig. 10 in order, to see how they can fail so as to produce distortion, and find out how to check them for the suspected failure. Since capacitors are the most frequent causes of distortion, we will discuss them first.

Capacitors. If capacitor C3 opens, i-f signals will be applied to the control grid of VT1 and may overload the tube, driving it off the straight portion of its characteristic curve, and thus producing amplitude distortion. To check C3 for an open, shunt it with another capacitor of about the same size.

If C4 becomes leaky, the dc voltage across the diode load resistor R3 will be applied to the control grid and this incorrect bias voltage will result in distortion. Check by connecting a vtvm across R4 and note if the voltage changes as you vary the volume control. If the voltage goes up to a high negative value when the volume is turned to maximum, this proves that C4 is leaky.

Leakage in C5 will reduce the plate voltage and cause distortion. An open in C5 can allow any rf that was amplified by the tube to be passed on to the output tube VT2, and may overload tube VT2. Check the capacitor by substitution if you suspect an open. Use an ohmmeter to check C5 if low dc plate voltage leads you to suspect leakage.

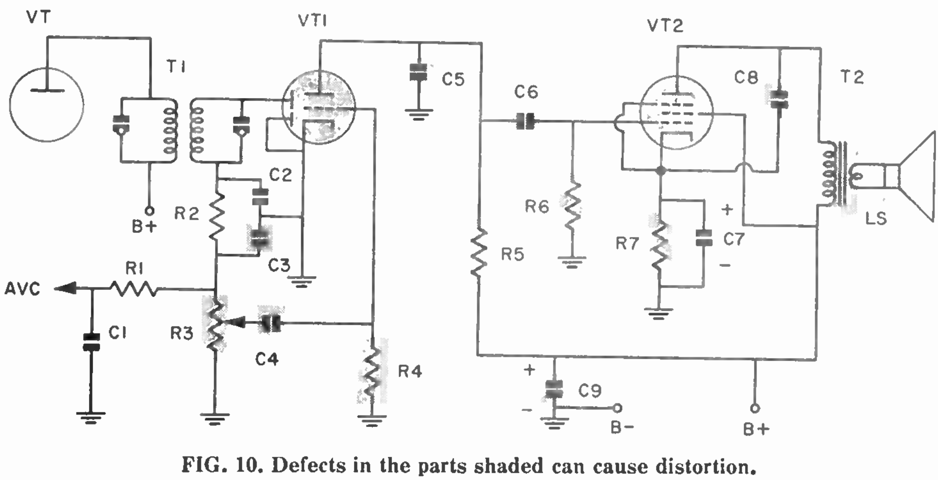

FIG. 10. Defects in the parts shaded can cause distortion.

If C6 develops leakage, a positive voltage will be applied to the control grid of VT2, and distortion will result. You can check on this by connecting a dc voltmeter across R6 with the positive terminal on the grid. You should not be able to get a voltage indication here. If there is a voltage drop across R6, C6 may be leaky or the tube may be gassy. In an ac set you can pull VT2 out of its socket. If the voltage remains, C6 is leaky. If it disappears entirely, VT2 is gassy. If the voltage drops but some voltage is still present, you have both leakage in C6 and gas in VT2. Either condition causes distortion. In an ac-dc set you cannot remove the output tube, so you just disconnect one lead of C6 and note the effect on any voltage across R6.

Leakage in C7 will reduce the bias on VT2 and cause distortion, because the tube will no longer operate on the straight portion of its curve. Capacitor C7 can be checked with an ohmmeter.

If capacitor C8 is connected from the plate to the cathode, as in Fig. 10, leakage in it will increase the positive voltage on the cathode. This will raise the negative bias to the point where distortion will occur. If you suspect C8, you can disconnect one lead and see if this clears up the distortion, or you can check the capacitor with an ohmmeter. An open in C8 can permit parasitic oscillation, which is inaudible, to occur in the output stage. Oscillation will develop a voltage across R6, making the grid end negative. There should never be a dc voltage across R6. As already mentioned, if you find voltage across R6 making its grid end positive, the defect is in C6 or in tube VT2. If there is a voltage drop that makes the grid end of R6 negative, the stage is oscillating.

Leakage in capacitor C9 will reduce the dc operating voltages. However, sometimes the voltage does not decrease enough to cause weak reception. You may find that the output will be distorted instead.

A high power factor or a partial open in C9 will usually cause hum or oscillation. In some cases the signal will not be as clear as it was previously, and the result will be distortion.

The capacitor may be checked for leakage with an ohmmeter if the B supply voltages are low, and by substitution if the symptoms indicate the capacitor is open or has a high power factor.

Resistors. An open in volume control R3 or a change in its value may keep the operation of the diode detector from being linear. Check the potentiometer with an ohmmeter.

If R4 becomes open, excess bias will be developed on the grid of VT1, and distortion and perhaps hum will result. Check the resistor with an ohmmeter. If the distortion and hum clear up when you connect a dc voltmeter across R4, this shows that the resistance between the grid and cathode is excessive.

If the value of R5 increases considerably, the plate voltage of the tube will drop, and the tube will no longer operate on the straight portion of its characteristic curve. This is a fairly common cause of distortion. If the plate voltage is low, be sure to check this resistor. An open in R6 gives the same results as an open in R4. Also, a large increase in the value of R6 may cause VT2 to become gassy, thus producing a distorted signal. The resistor should be checked with an ohmmeter if suspected.

An increase in value or an open in R7 will result in a large increase in bias. Thus, if you find that the cathode to B− voltage is abnormally high, you should, among other things, check the value of R7 with an ohmmeter.

Tubes. If tube VT1 becomes gassy, a positive voltage will be developed on its grid, and the sound will be distorted. You may not be able to measure the positive voltage, however, because it may decrease almost to zero when you connect the voltmeter between the grid and B−. If you suspect trouble in this tube, try a new tube.

We have already described, under the discussion of C6, the effect of gas in VT2. Cathode-to-heater leakage in VT2 can also cause distortion by reducing the bias. The tube may be checked for leakage in a tube tester, but the best check is to try another tube.

Output Transformer. Output transformer T2 can cause distortion if some of the turns on either the primary or secondary are shorted. It is almost impossible to identify such trouble with an ohmmeter. Here is a case where you must try a new part if everything else seems to be all right.

Loudspeaker. For the sound from a speaker to be free from distortion, the motion of the cone must be proportional to the signal current flowing in the voice coil. However, the voice coil motion may be non-linear because of a warped, torn, or loose cone, particles of dirt in the air gap, or an off center voice coil. The easiest way to check a loudspeaker is to substitute a good PM speaker in its place.

If you find that the distortion is originating in the af section of a receiver like the one shown in Fig. 10, check the parts as mentioned above, and you will find the cause of distortion in practically all cases. However, some defects cannot be found by looking at the diagram. Perhaps there is leakage through some wire to the chassis or perhaps some serviceman has previously worked on the set and made errors in wiring or in parts values. When this occurs, it is a good idea to try to localize the trouble to one stage so that you can devote all of your attention to that stage. Check the parts, and where necessary, try others. We will consider localization procedures a little later.

PUSH-PULL AUDIO STAGES

As you know, all even harmonics that are generated in a properly operating push-pull amplifier stage are removed by the stage. Also, the odd harmonics generated in the stage are usually not large enough to cause trouble. This relative freedom from distortion is one reason push-pull output stages, like that in Fig. 11, are so popular in high-fidelity receivers and amplifiers.

Second-harmonic distortion will be cancelled out in a push-pull stage only if the signal currents at the plates of the two tubes are just about equal. To obtain equal signal currents, two conditions must be met. The two tubes must have identical characteristics, and they must be fed the same amounts of signal voltage.

Your first step, therefore, in checking a push-pull stage is to test the emission of both tubes. The tubes should give readings within a few points of each other on a tube tester having a 0-100 scale to be satisfactorily balanced.

Such a test is not always conclusive, however. Tubes may seem satisfactory at the low voltages of the tube tester, but may not be matched under actual operating voltages. For this reason, you should try several tubes to find the best matched pair. High-power amplifiers often have terminals so that a meter can be connected to check the plate currents individually, and they often have separate bias sources so the biases can be adjusted to give equal plate currents.

Even if the tubes are perfectly matched, there will still be distortion if unequal signal voltages are fed to the grids. In Fig. 11, for example, signal voltages E1 and E2 must be equal to prevent distortion. Here the original signal E is applied to the input of tube VT1, amplified by this tube, and applied through coupling capacitor C3 and across R5 and R6 to the input of tube VT3 as E1. The portion of the signal across R6 (E3) is fed to the grid of the phase inverter tube VT2. The resulting amplified signal E2 across R7, which is 180° out of phase with signal E1, is fed to the other push-pull tube VT4. Thus, VT1 provides the signal for both output tubes, while VT2 drives only one of them. Pulling out VT2 will block only half of the push-pull stage.

Since VT1 and VT2 are used in similar circuits, they should provide the same gain. Therefore, if VT1 and VT2 are fed the same amount of signal, signal voltages E1 and E2 applied to VT3 and VT4 will be equal as well as being out of phase. By choosing the values of R5 and R6 properly, the voltage across R6 (E3) fed to VT2 can be made equal to the voltage E applied to the input of tube VT1. Then, with both tubes amplifying these signals the same amount, E1 will equal E2. Any distortion produced by even harmonics in output tubes VT3 and VT4 will be balanced out in the output transformer by the push-pull action.

Sometimes aging of VT2 will reduce the phase inverter gain, causing unbalance and distortion. If tubes VT1 and VT2 cannot be matched, R5 and R6 should be adjusted to produce equal E1 and E2 signals. This may be done by measuring voltages E1 and E2 with a vacuum tube voltmeter while you vary the value of R6. When E1 equals E2, R6 has the right ohmic value. A convenient way to make this adjustment is to substitute a 15,000-ohm linear-tapered rheostat for R6, adjust it until E1 equals E2, then measure the rheostat resistance with an ohmmeter and install a fixed resistor of the same value.

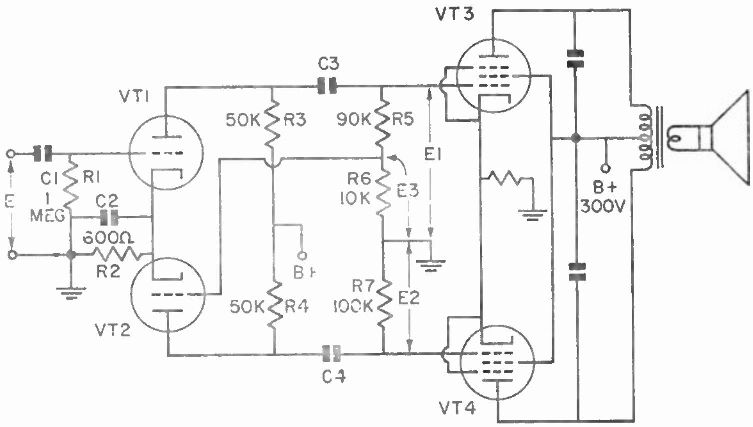

FIG. 11. Push-pull operation with VT2 as the phase inverter.

In very bad cases of distortion, disconnect coupling capacitor C4 and notice the effect on the tone quality. If there is no change, no signal is passing through VT4. You should then check tube VT2, tube VT4, resistor R4, coupling capacitor C4, and the supply voltages to VT4.

To check the output transformer, disconnect all leads, including the voice coil leads, and apply a low ac voltage (1 volt will do) to the *secondary*. The two primary voltages should be approximately equal. Since a large voltage step-up will occur, use the highest ac voltage range of your tester first, then switch to a lower range if necessary. Shorts or leakage in input and output transformer windings are not common, however. The usual transformer defect is an open winding.

SUMMARY

You have seen how incorrect voltages will make a tube non-linear in operation, and thus create distortion. Usually, defective parts (except for loudspeakers), do not cause distortion themselves; rather the distortion is produced by the changes these defective parts cause in the operating conditions of tubes or iron-core devices.

For example, a capacitor may become leaky or a resistor may change in ohmic value, yet signals may pass through them without excessive amplitude distortion. However, these defects may change the operating voltages of a tube enough to cause serious distortion, or may allow so much current flow through an af transformer primary winding that the core is saturated. This will decrease the reactance so that distortion occurs.

	Common Causes of Amplitude Distortion
RF	Gassy avc-controlled tube. Leaky avc filter capacitor.
Detector	Defective tube. Incorrect size diode load resistor. Defective germanium crystal used in place of i-f tube.
AF	Leaky coupling capacitor. Gassy tube. Low-emission tube. Shorted or leaky tube. Open volume control. Incorrect value plate and grid loads. Leaky bypass capacitor. Incorrect supply voltage.
Speaker	Voice coil rubs pole piece. Torn cone. Cone unglued. Dirt or metal particles in voice coil air gap.

Localizing Distortion

The cause of distortion can be found by using the same general procedures as for other defects. You must confirm the complaint, look for surface defects, use effect-to-cause reasoning when possible, and then localize the defect to a section, stage, circuit, and part.

When confirming the complaint, listen carefully to the receiver. Different defects produce somewhat different distortion sounds, and a little ear training will often help you go right to the trouble.

In the less obvious cases, particularly when dealing with a high-fidelity receiver, be sure to get all the clues the customer can give you. For example, find out whether the distortion is noticeable as soon as the set is turned on. Distortion that occurs only after the set has warmed up a half-hour or so is usually caused by gassy tubes or by heat warping the speaker frame. You can get many other worth-while clues like this by careful questioning.

Before going into the receiver, be sure the "distortion" is not produced by external causes. The customer will frequently confuse interference with distortion.

Perhaps one of the most annoying types of interference is chopped-up reception caused by picking up two or more stations at the same point on the dial. Sometimes a change in loop direction will favor one station more than the other and allow satisfactory reception of the favored station. This may even help when the stations are on the same frequency; but in general it is best for the customer to tune to another station when the interference does not occur. Interference of this type is more prevalent at night and during the winter months, because then better long-distance reception is possible. In the summer, reception may be entirely satisfactory, because then not as many distant interfering stations will be picked up.

Now, let us see what can be done about localizing a real case of distortion.

SURFACE DEFECTS

An inspection for surface defects is not very revealing, since few troubles causing distortion are visible to the eye.

Of course, you should first test all tubes and replace any bad ones. Examine the speaker cone to see if it is torn or crushed. You should also look for a blue glow *between* the electrodes of glass tubes, which indicates either the presence of gas or excessive plate current.

Sometimes the wrong tube will be placed in a stage. Always check the tube positions when a diagram or tube layout is available. With experience, you will usually be able to tell the correct tube locations without service information.

A worn volume control that makes a poor contact between the slider and the resistance element can chop up the signal. The customer may call this distortion. It can also cause intermittent reception, noise, or hum. If you notice any noise as you turn the control, replace the control.

After making the usual check for surface defects, you can then use effect-to-cause reasoning. However, there are many causes of distortion, and effect-to-cause reasoning may not be very helpful until you are able to distinguish between them by the effects they produce in the sound output. Since the most common sources of distortion in the average receiver are leaky coupling capacitors and gassy tubes, you should check these points before resorting to section and stage isolation procedures.

ISOLATING THE DEFECTIVE SECTION

For convenience, we divide the receiver into two sections: 1. The af section, which includes everything between the output of the second detector and the loudspeaker; and 2, the rf section, which includes everything between the antenna and the first af stage. There are two ways of isolating the defective section: the first is to clear one of them of any fault, and the second is to find the one that is at fault.

To check the rf section, tune in a signal from a broadcast station and listen at the output of the second detector with a signal tracer. You can check the audio amplifier by feeding an audio signal through it from another receiver. If the receiver is a phono-radio combination, try a *good* phonograph record. If the output from the record is undistorted, the trouble must be in the rf section. If the output from the record as well as that from the radio program is distorted, the trouble is in the audio amplifier.

You can also check the audio amplifier by using an af signal generator and a cathode-ray oscilloscope. A comparison of the input and output waveforms on the cro screen will show if there is distortion. Details of this test will be given later. Incidentally, an audio generator that produces a single tone cannot be used to localize frequency distortion; this type of distortion can be checked only by comparing the output at several different frequencies.

LOCALIZING A DEFECTIVE AF STAGE

Let us assume you have traced the trouble to the af section of the receiver, and see how you can localize the trouble to a particular stage. There are two methods: you can take voltage and current measurements, or you can use some form of signal tracing. Let's take up each method.

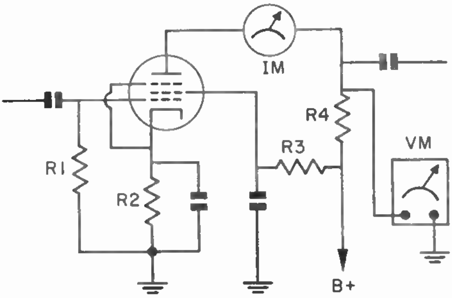

FIG. 12. Plate current can be measured directly by connecting a current meter in the plate circuit, or indirectly by measuring the voltage across the plate resistor.

Voltage and Current Measurements. As you have learned, amplitude distortion is usually caused by abnormal tube operating voltages. By taking voltage measurements and comparing them with those given by the manufacturer, you can find out if the grid bias, the plate voltage, or the screen voltage is not normal. After you have had some experience, you will probably be able to tell if the measurements are unusual without referring to the manufacturer's information.

Current measurements quickly spot distortion in Class A amplifier stages. You can connect a current meter in the plate circuit, as in Fig. 12, and notice whether the reading changes when signals are applied. You learned from Figs. 4 and 5 that if there is distortion in the stage, there will be a change in the average plate current when signals are applied to the input. (But not when equal positive and negative clipping take place, Fig. 3).

It is easier to make this check if you measure the plate current indirectly, instead of breaking the plate or cathode circuits for a direct measurement. Notice that the plate current of the tube in Fig. 12 flows through resistor R4. If the plate current changes, the voltage across this resistor will also change; so all you need to do is connect a voltmeter to the plate end of R4 and notice whether the reading changes when a signal is applied.

The direction in which the current changes is important. The table in Fig. 13 shows probable causes of either an increase or a decrease in the average plate current when a signal is applied to the input. An increase in voltage means a decrease in plate current; a decrease in voltage means an increase in plate current.

This method is practical when you have just one or two stages to work with, as in most modern receivers. If you are dealing with an amplifier having several stages, you will probably find the trouble fastest by using some means of further isolation. Let us now consider some of the signal-tracing methods.

VOLTMETER DEFLECTION	MILLIAMETER DEFLECTION	GRID BIAS	PLATE VOLTAGE	SCREEN VOLTAGE
DOWN	UP	TOO HIGH	TOO LOW	TOO LOW
UP	DOWN	TOO LOW	TOO HIGH	TOO HIGH

FIG. 13. Probable causes of changes in plate current as indicated on a voltmeter and on a milliammeter.

Signal Tracing. Fig. 14 shows a typical audio amplifier. To localize the stage producing the distortion, you can use a signal tracer with an audible output indicator, or an af signal generator and a cathode-ray oscilloscope.

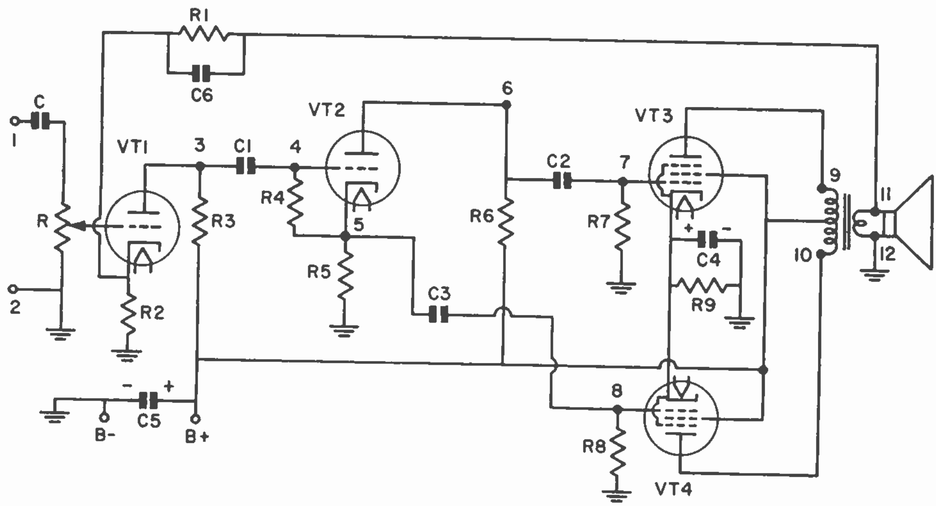

FIG. 14. Test points for localizing distortion with a signal tracer.

When using the signal tracer, you can use the output of the second detector as the audio signal source. First, tune in a station and notice the distortion level of the loudspeaker output. It is a good idea to mute the set loudspeaker while you are trying to listen to the audio output of your signal tracer. To do so, disconnect the voice coil of the speaker and connect a 4- to 6-ohm, 5-watt resistor in its place across the secondary of the output transformer.

Then, using the signal tracer, start at the input of the amplifier and move to the output, looking for the point where the distortion originates. Start by sampling the signal fed into the af system. To do so, clip one terminal of the test instrument to B−, and connect the hot probe to point 1 in Fig. 14. If the signal is clear and free from distortion at this point, you know that the rf section is OK, so it must be the af section at fault. Next, move the hot probe to point 3 to see if tube VT1 introduces distortion. If it does, you have isolated the trouble to that stage; check the tube and the operating voltages to find the exact cause. Check for voltage between the slider of the volume control and ground. This voltage may be due to a gassy VT1 or to failure of the rf filter in the second detector circuit or leaky capacitor C.

Trouble can occur between points 3 and 4 that will result in amplitude distortion at point 4. If coupling capacitor C1 is leaky, the signal at 4 may be distorted because the control grid of VT2 will draw current on the positive signal peaks. Also, the change in the grid voltage of VT2 will distort its output. An open coupling capacitor will cause weak reception and frequency distortion, not amplitude distortion.

The next points at which to sample the signal are 5 and then 6. If there is no distortion at either point, check the signal applied to output tubes VT3 and VT4 by connecting the hot probe first to point 7 and then to point 8. A signal tracer that indicates the signal level will show if the output tubes are receiving equal signals. The signal should then be checked at point 11. (If neither of the voice coil terminals is grounded, unclip the test lead from the chassis and connect it to point 12. Connect the hot probe at point 11). If the signal is clear at point 11 but the loudspeaker reproduces distortion when reconnected, the speaker itself is at fault.

Using a CRO. If a cro is used to sample the signal, the signal source should produce a single frequency, preferably having a sine-wave form. This means that you must feed the output of an af signal generator or the audio signal from an rf signal generator to the input of the amplifier. Then, you can compare the signal samples at the test points in the amplifier directly with the source signal. In this way you can accurately tell the nature of the distortion and the stage in which it originates.

Fig. 15 shows in block form how the af signal generator and cro are connected to the amplifier under test. The

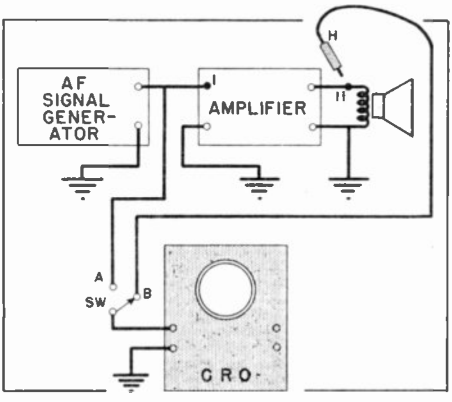

FIG. 15. How to connect a cro when tracing distortion.

hot lead of the signal generator is connected to the amplifier input (point 1 in Fig. 14). The *hot* vertical amplifier lead of the cro is connected to the point under test through a single-pole, double-throw switch, SW. When this switch is thrown to point A, you can see the signal that is being fed into the amplifier. When it is thrown to point B, you can see the signal being sampled and mentally compare it with the original signal. Of course, the *amplitude* of the sample signal will be greater than that of the original, but if the wave *shapes* of the two signals are the same, there is no distortion.

When you have the af signal generator and cro connected as described above, set the cro timing and synchronizing adjustments to produce 2 or 3 cycles of the input signal on the screen. You are then ready to compare signals. To do this in a circuit like that in Fig. 14, touch the hot cro test lead to points 1, 3, 4, 5, 6, 7, 8, 9, 10, and 11. When the pattern first changes shape, you have just passed through the defective stage; you can then find the actual defect with your voltmeter and ohmmeter.

As you move the cro probe from point 1 toward point 10, the signal strength will increase, so you should reduce the cro vertical gain to keep the pattern from becoming larger than the original. When moving from point 10 to point 11, however, there is a sharp reduction in signal voltage; here you must increase the vertical gain of the cro to bring the pattern up to normal size. Since the cro shows signal strength as well as wave-form, you can use it to tell whether the signals fed to the push-pull output tubes at points 7 and 8 are equal in amplitude.

Several typical cro patterns for different defects are shown in Fig. 16. The actual defects, of course, are found when the stage itself is analyzed. These patterns are for a cro with positive input polarity; if the input polarity of your cro is negative, the pattern will be inverted. This is one of the few times you will need to know the input polarity of your cro.

You can easily find the polarity of the oscilloscope input. To do so, turn off the horizontal amplifier so that only a spot of light is on the screen, and turn up the vertical amplifier gain. Now, connect leads to the terminals of a 1.5-volt flashlight battery, and touch the leads to the vertical input terminals of the cro. The spot will jump either up or down, and then return slowly to its original position. The spot jumps because of the momentary charging current through the input

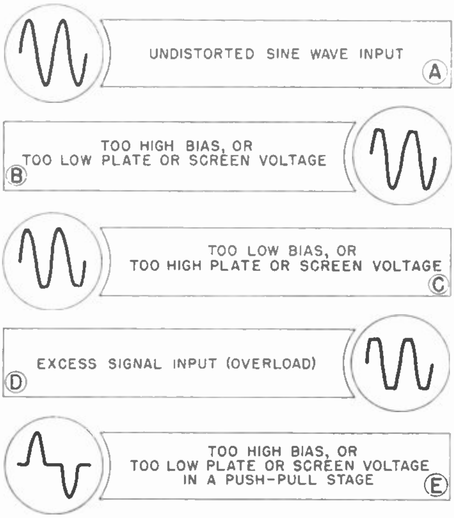

FIG. 16. CRO patterns for various conditions in an amplifier circuit.

blocking capacitor. If you reverse the battery connections, the spot will jump in the opposite direction. The direction of movement of the spot depends on the number of stages in the cro amplifier system and on the tube connections.

If the spot moves upward when the lead from the positive battery terminal is connected to the "hot" vertical input terminal, the cro has a positive input polarity. On the other hand, if the spot moves upward when the lead from the negative battery terminal is connected to the vertical input terminal, the cro has a negative input polarity.

If you get a cro, as you gain experience in using it, you will quickly learn to interpret distortion patterns in terms of the defect producing them.

A word of caution: Do not attempt to make a direct comparison between the waveforms in Figs. 16B and 16C with those in Figs. 4 and 5. The waves in Fig. 16 are *voltage* patterns as shown on an oscilloscope screen; those in Figs. 4 and 5 are *current* waveforms produced in the plate circuit of an amplifier stage. As you know, the voltage at the plate decreases when the current increases, and vice versa. Therefore, you would expect one to be the reverse of the other.

ISOLATING A DEFECTIVE RF STAGE

If your preliminary tests show the trouble is in the rf section, your first step should be to use effect-to-cause reasoning. Remember that distortion in rf stages may be caused by overloading or by a defect in the second detector circuit.

If effect-to-cause reasoning fails, you can isolate the defective stage with an rf signal tracer. To check an rf system like that in Fig. 7, tune in a station that causes the loudspeaker output to sound distorted. When you know what the distortion sounds like, substitute a resistor for the speaker as you did in checking the af system. Connect the ground lead of the signal tracer to B−. (Remember, if you are working on an ac-dc set, B− will probably not be the receiver chassis). Then, hold the signal tracer hot probe on the control grid of the first tube and tune the tracer to the signal. Sample the signal at the input and output of each stage, working toward the second detector. When going from the mixer input to the mixer output, the signal tracer, if it is the tuned type, must be retuned to the i-f frequency.

When you first hear distortion, you

have located the defective stage. If you find none, check at the second detector output with the audio section of the tracer to learn whether detection has introduced distortion.

The cro is not very satisfactory for sampling the signal in rf circuits, because its sweep frequency is not high enough to give a useful picture of the carrier wave shape. However, the cro may be used with a special rf probe which demodulates the signal before it is fed to the cro. When this is done, the receiver should be fed from a sine-wave modulated signal generator. Sample the signal with the tracer as just described, and watch the sine-wave modulation on the cro screen. When the wave shape becomes distorted, you have just passed the defective stage.

How To Service Noisy Receivers

If noise is heard along with a radio program, it may originate in the receiver or it may originate outside the receiver and be picked up by the antenna. If it is caused by atmospheric static or by man-made interference from oil burners, neon signs, fluorescent lamps, etc., no amount of work on the receiver will correct it. The elimination or reduction of man-made interference at its source is covered in another lesson.

In this lesson we are interested in the elimination of noise originating in the receiver circuits. This kind of noise is due to a supposedly good connection whose resistance varies instead of remaining constant, or to a short having a rapidly varying resistance.

Variations in resistance may occur in a joint, in a wire, or in a component with a partial open circuit. Either a partial short or a partial open, if in a voltage supply or a signal circuit, will result in a rapid variation in either the signal or the supply current. A similar noise voltage will be transferred to the following stages where the noise will be amplified.

For example, suppose you localize the defect to the rf section of a receiver. If the receiver is not tuned to a station, the sharp noise pulses originating in any rf stage will shock-excite the tuned circuits so they oscillate at their resonant frequency. The noise pulse will also modulate this rf signal, and the resultant signal will be amplified by the receiver just like a signal from a radio station.

If a station is tuned in, the same noise pulse will add to the station modulation, and the noise will be reproduced by the loudspeaker.

When confronted with a case of noise, you must first determine whether the trouble is in the set or is due to outside interference. If the noise disappears when the loop connections feeding the receiver are shorted, the trouble could be in the loop, but is probably due to external interference. If the receiver is noisy in two locations or in a location where another receiver gives normal reception, the set itself is defective.

In examining the receiver, look for loose connections; and if the set has previously been repaired, look for poorly soldered connections. Go over any such connection with a hot soldering iron, remove any excess solder, and burn up any unused rosin flux.

When there is a poor connection somewhere in the set, jarring the chassis will generally produce the noise. If there is no noise when the volume control is turned down, the noise originates in the rf-if section. If you cannot vary the noise with the volume control, it is originating in the af section. If you cannot find the trouble in the af section, but you can still hear the noise with the volume control turned down, it is probably in the power supply and is being fed to all stages.

If noise is heard when the volume control is moved, the control is bad. It should be either replaced or cleaned. A chemical solution made especially for cleaning noisy variable resistors is sold under various trade names at radio supply houses. This solution squirted into the control will often clean dirty contacts and prevent noise. This, however, is not always a permanent cure, and the control may have to be replaced in a short time. For this reason it is often better to replace the control than to clean it. However, if you are working on a small inexpensive receiver, and have already made extensive repairs, the customer might rather have you clean the old control than pay for a new one. Also, if you do not have a replacement for the particular control on hand, cleaning the old one may be satisfactory.

If noise is heard when the receiver is tuned, it indicates that the plates of the tuning capacitor gang are scraping against each other. Generally it is an easy matter to bend the plate slightly so this does not happen.

Once you have isolated the trouble to the rf section, the af section, or to the power supply, it is usually quickest to try to find the defective part without tracking it down to a stage or circuit.

It is a simple matter to do this. Just try moving parts, jarring parts, and pulling on leads while listening for the noise. If pulling on some lead, moving some part, or jarring some part causes the trouble to appear or to become worse, you have found the defective part or connection. Then, repair or replacement is simple. You can jar a part by tapping it lightly with the insulated handle of a screwdriver. Tap each tube with your finger, and wiggle paper capacitors back and forth by grasping them with a pair of pliers. Many servicemen prefer insulated pliers for this work to avoid the possibility of a shock.

Parts and shields such as i-f and af transformers cannot be readily checked by jarring the shield or by pulling on the leads. Other methods described later must be used to check them.

When partial shorts occur, arcing at a high voltage point is generally involved. Look for charred paths between the terminals of the tube sockets. If you hear an arcing sound, turn off the bench lights. This will often enable you to see the sparking.

If these methods do not lead you to the difficulty, further isolation is necessary.

STAGE ISOLATION

Let us discuss several of the most effective stage isolation procedures.

Stage Blocking. The volume control test already described is a form of stage blocking, since it prevents noise signals originating in the rf section from being passed on to the af amplifier through normal channels.

In using the following methods, always remember that the noise may radiate around stages or travel through supply leads, as well as along the normal signal paths. However, the noise will decrease as long as you are blocking between the noise source and the output, and will usually disappear entirely when you block the defective stage.

There are several ways of blocking stages, all of which make it impossible for the stage to pass a signal.

One of the most effective ways in ac sets is to pull out tubes, working from the output back toward the input. The noise will stop or greatly decrease each time you remove a tube, as long as the noise originates further back toward the input. (Both tubes must be pulled simultaneously to block a push-pull stage). When you pull out a tube and find the noise remains as loud as ever, the trouble is probably in the preceding stage interrupted (that is, the next stage toward the loudspeaker).

Of course, the tube-pulling technique cannot be used in ac-dc receivers where pulling out a tube will interrupt the entire filament circuit, nor in battery sets or three-way portables where removal of one tube might cause excessive filament voltage on the others. In these cases, you must short the signal input circuit, stage by stage, by shorting the resistor or transformer secondary across which the signal normally appears.

For example, to block the grid circuit of a stage, use a test lead with clips attached to each end, and hold it between the control grid terminal and B−. However, if the return end of the part connects to a bias source, you must hold the test lead right across the grid resistor leads. Block each grid input in turn, moving the test lead along from grid circuit to grid circuit toward the loop. The noise will be blocked altogether or reduced greatly as long as the source is farther back toward the antenna.

When you come to a grid circuit where blocking does not affect the noise, the noise is either in that tube, in the plate circuit of that stage, or in the coupling device to the next stage toward the loudspeaker. In other words, the defect is between the blocked grid circuit and the next grid circuit toward the loudspeaker.

It is possible to block the plate circuit also, if you are careful to avoid short-circuiting the plate supply. The test lead must be held *across the plate load* only. You can then use the same procedure as for grid blocking.

Examples of Blocking. Suppose you have the receiver shown in Fig. 17, in which a partial open in the primary of the first i-f transformer T1 is causing a variation of the mixer plate current, producing a rapid machine-gun like crackling in the loudspeaker. Here is how you could localize the trouble:

First, change the position of the receiver to see if the noise varies, indicating an external source. Turn the volume control all the way up, and ro-

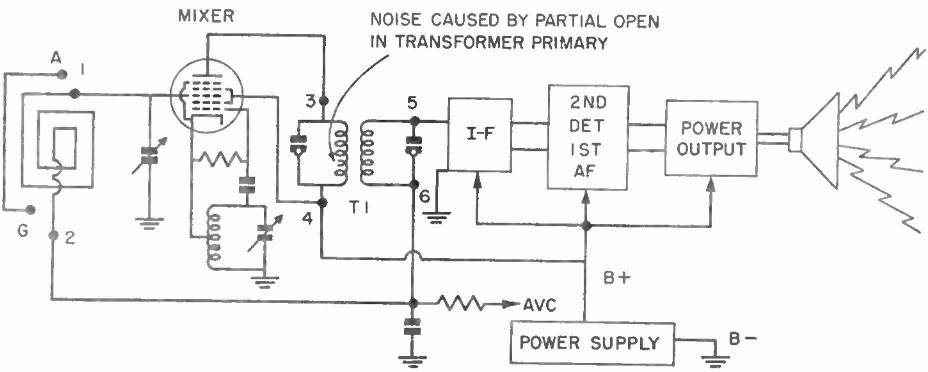

FIG. 17. A typical mixer stage with noise produced by a partial open in the i-f transformer primary.

tate the tuning capacitor gang. You find that the noise continues, so you know it is originating either in the receiver or is coming in over the power line. If you cannot eliminate the noise by installing a line filter between the receiver and the wall outlet or by plugging the set into a different wall outlet in a different location, you know it is in the set.

Next, rotate the volume control to zero volume. If this cuts out practically all the noise, you have localized the defect to the rf-if section of the receiver.

Turn the volume control back up again. If the radio is an ac set, pull out the second detector tube. This will block the noise or reduce it to a very low level. Replace the second detector in its socket; then pull out the i-f tube. This will also block the noise. Replace the i-f tube, and pull out the mixer tube. Again the noise will be blocked. Replace the mixer tube and short terminals 1 and 2 of the loop. The noise will continue when these terminals are shorted. This shows you that the noise source is in the mixer stage.

Now suppose the receiver is an ac-dc, a battery-operated set, or a three-way portable set instead of an ac set. The tubes in these receivers, of course, cannot be removed. However, you can localize the noise to the rf or af section as you did with an ac receiver by varying the volume control. You can then find the defective stage by blocking the stage input or output circuits (or both), one at a time, by moving from the output toward the input.

Since most of the receivers on which you work will be of this type—ac-dc sets, in which the tubes cannot be removed—let us go into the use of test leads for stage blocking more thoroughly.

Fig. 18 shows where to place a test lead to block each circuit in an audio amplifier. Notice the inverse feedback path from the secondary of the output transformer to the cathode of tube VT1. Before you carry out the blocking procedures, you should disconnect the feedback path at the cathode of VT1 or at the output transformer. Otherwise, noise originating in the feedback circuit or at the output transformer may make the stage-blocking method ineffective.

Positions 1 and 2 in Fig. 18 block

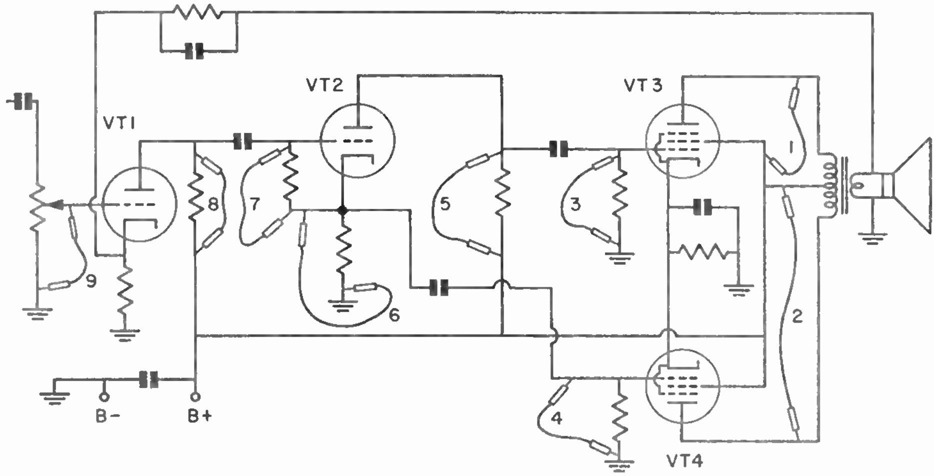

FIG. 18. Position for placing test leads for stage blocking.

the outputs of VT3 and VT4 and positions 3 and 4 block the inputs of tubes VT3 and VT4. You should connect the two test leads (use ones with a clip at each end) at 1 and 2 or 3 and 4 at the same time to block both push-pull tubes at once. If you connected only one test lead, only one of the push-pull tubes would be blocked, and noises originating near the set input would pass through the tube that was not blocked. This is all right if you are trying to tell which output stage is defective, but if you are looking for trouble that is originating nearer the input, both tubes in the push-pull circuit must be blocked at the same time. You can also do this by connecting one test lead from plate to plate to block the output or from grid to grid to block the input.

If the tests at positions 1 and 2 and at 3 and 4 block the noise, you can move back either to positions 5 and 6 at the output of tube VT2, or to position 7 at the input of tube VT2. Finally, move back to position 8 at the output of VT1, and then to position 9 at the grid circuit of VT1.

By blocking first the output of a stage and then the input, you can tell just which circuit in the stage contains the defect. For example, if the noise stops when you hold the test lead at position 8, but continues when you hold the lead at position 9, you know the noise must originate in the plate circuit of tube VT1.

One difficulty of shorting the output circuit of a stage is that you are working in the high-voltage circuit and must be very sure you connect the right points. *Never short from plate to B− or from plate to chassis.* This shorts the plate supply and may damage some parts in the plate circuit or burn out the rectifier.

This shorting procedure can be applied to the rf circuit shown in Fig. 17. Here, if the i-f transformer were faulty, shorting between terminals 3 and 4 or 5 and 6 would eliminate the noise, but shorting between terminals 1 and 2 would not. This shows that the trouble is in the mixer circuit.

Notice that you short directly across the input part, not from 5 to B− or from 1 to B−. There may possibly be a bias supply in the avc network somewhere; so going from 1 to B− or from 5 to B− would remove the bias and upset the circuit.

If you notice the noise is only *slightly* reduced as you block each stage, you can be fairly certain that the noise is occurring in the power supply or is being fed through it to all stages.

You may find that jarring any circuit in a receiver causes the noise to appear. Then, of course, you cannot use jarring alone to find the defect. In such a case, you must use stage blocking to localize the defect. You will find that as you block the stages, the points at which jarring the set produces the noise become fewer and fewer. When you find only one or two points which when jarred cause noise, the problem is greatly simplified.

Stage blocking is an extremely important service procedure that you should thoroughly understand. You will use it time and again in your service work.

Signal Tracing. Servicemen who have signal tracing equipment generally use it instead of signal blocking to localize noise. Remember that the noise is the signal, and in tracing to find its source, you may move the signal tracer in either direction through the receiver stages. If you move from the loudspeaker toward the antenna, the noise will decrease in intensity as you approach the source, because there are fewer stages of amplification between the noise source and the signal tracer. When you pass through the defective stage, the noise will disappear entirely or become very weak.

If you move the signal tracer from the antenna toward the loudspeaker, you will not hear the noise, or the noise will be at a very low level until you reach the defective stage, when it will suddenly increase to a much higher level.

A visual indicator on the signal tracer, such as a tuning eye or a meter, is not very satisfactory for noise tests. It is better either to listen to the audio output of the signal tracer, or to feed the output of the signal tracer to the vertical plates of a cro and look at the pattern on the screen.

In TV work, the only signal tracer that is satisfactory is a cro and rf probe, as you will learn later.

LOCATING THE DEFECTIVE CIRCUIT AND PART

After localizing the noise to a particular stage, first test the tube, by trying another one. If the noise continues, the tube is not at fault, so you must again use effect-to-cause reasoning. You will recall that noise produces erratic changes in current flow. Therefore, if there is no signal coming into the set, but you can hear the noise, you know that the operating current in one of the stages is changing. This means that the noise source is probably in a plate or screen grid supply circuit.

An intermittent open in the control grid circuit will also cause noise by removing bias and thus changing the plate current. However, this kind of trouble is far rarer than a defect in a current-carrying circuit. If it is in the control-grid circuit, it is probably caused by a defective connection that opens and closes rapidly when mechanically jarred. Arcing will not be the cause, because there is no current flow to form an arc.

If you hear the noise only when a signal is tuned in, the trouble may be in the speaker or may be caused by speaker vibration transmitted to some part or connection. When checking the speaker, push back and forth on the cone to check for loose voice coil connections.

A defect in an i-f transformer makes a different noise from that in a volume control. The first will cause sharp machine-gun like bursts of sound, the second a scraping sound when the shaft is rotated. The sound produced will be a valuable clue, when you have had enough practical experience to recognize the many different noises.

Carefully examine the parts in or near the suspected stage. Look for the characteristic green corrosion spots. Corrosion, by the way, is far more likely in a current-carrying circuit than in a signal circuit, which carries no direct current.

Meter Tests. Since noise means that the current in a receiver circuit is changing rapidly, there will also be a rapidly changing voltage somewhere in the set. If the noise occurs erratically or in bursts, try connecting the voltmeter between B− and the various tube electrodes; you should notice a quivering in the meter pointer each time there is a burst of noise if the voltmeter is connected in the defective circuit. Remember, however, that both the plate current and the screen grid current flow through the cathode resistor; also, sometimes a voltage change in one circuit will produce a change in another. Therefore, a voltage variation test may or may not indicate the defect. Furthermore, if the noise is continuous, the variations may be so rapid that the meter cannot follow them, so you may get no indication with a voltmeter.

To use a voltmeter when you suspect the plate circuit, first disconnect the plate lead at the tube socket in an ac-dc set, or remove the tube in an ac set. This will stop the noise. Now, connect the voltmeter between the plate lead and B− in an ac-dc set or the set chassis in an ac set. If you get an erratic meter reading, and you hear the noise when the meter is connected but not when the meter is disconnected, the noise source is either in the plate load or in the supply circuit. The reason you can hear the noise even with the plate lead disconnected is that the meter draws enough current through the defective part to start the noise again. This is more likely to occur if you are using a multimeter rather than a vtvm, because the resistance of the vtvm is so high. If you are using a vtvm, you can connect a resistor of about 50,000 ohms between the plate lead and B−. This will cause considerable current flow and a vtvm will register any variation in voltage.

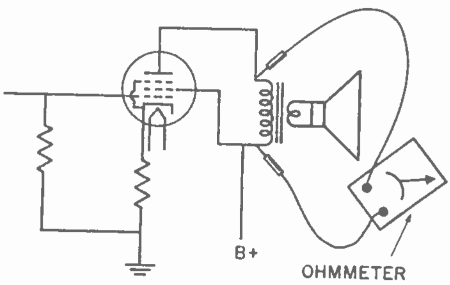

FIG. 19. How to connect an ohmmeter when looking for noise.

If you do not hear the noise, resolder the plate lead (or reinsert the tube into its socket), and connect the meter between the plate and cathode terminals of the tube socket. If you now hear the noise, and the meter reading varies erratically, the trouble is in the cathode circuit for that stage.

If the noise does not appear in either case, its source is in another circuit. The screen grid and control grid circuits are logical suspects.

With the set turned off, you can check with an ohmmeter directly across a suspected part as shown in Fig. 19. The ohmmeter will frequently provide the necessary current to cause the source of noise to act up. An erratic reading means the part is defective.

Using a Signal Generator. Noise that is heard all the time is easy to localize by making stage blocking, signal tracing, or meter tests. If the noise is heard only at times and only when a signal is being received, it is often difficult to find its exact location with ordinary procedures. Here a radio service type of signal generator with an unmodulated output can be very useful. Let us see how we would use it.

If the noise occurs only when a signal is being received, the noise source is usually in the rf section of the set. To find it, feed the maximum unmodulated output of your signal generator into the receiver between the mixer grid and B−. Tune the signal generator to the i-f value of the receiver, and either tune the receiver to a point where no interfering signal is heard, or short the local oscillator tuning capacitor. Nothing more than a rushing sound should come from the loudspeaker. Now tap the parts, one at a time, between the mixer grid and the second detector output with the insulated handle of a small screwdriver or with a wood, plastic, or Bakelite rod. If the noise appears when you tap a certain part, either the part or its soldered connections to the circuit are at fault.

If you do not hear the noise, tune the signal generator (its modulation still off) to the same frequency as the receiver, and if you shorted the tuning capacitor, remove the short. Tune the set to a quiet point on the dial. Now tap the various parts and push on connections in the local oscillator and mixer circuit to check them as possible noise sources.

If the receiver has an rf stage, it can be checked in the same way by feeding the signal generator output (still unmodulated and still tuned to the receiver dial setting) into the receiver outside antenna and ground connections.

By using your signal generator in this way, you can make a rapid check of the entire rf section. Any sudden noise variations will be modulated on the signal and you will hear it from the receiver loudspeaker.

The same test is effective in localizing intermittent defects in the rf section.

Servicing Intermittent Receivers

Noise and intermittent reception are basically caused by the same defects, the only difference is the rate at which the disturbance occurs. A change in the resistance of a conductor or a joint, in the value of a part, or in the insulation resistance between points at different potentials will result in either noise or intermittent reception. When the change recurs repeatedly at a rapid rate, noise is the result. On the other hand, if the change is repeated slowly —it may take a half minute or several hours—intermittent reception is the result. If the change becomes permanent, the resulting symptom may be hum, weak reception, no reception, oscillation, or distortion, depending on the type of defect and its location in the receiver.

The intermittent defect may produce hum, weak reception, squeals, distortion or a dead receiver during the time the defect exists. Generally, when servicemen say a set is intermittent they mean that it fades intermittently, because most intermittent defects reduce the signal strength. A good example is a defect in an af coupling capacitor that causes it to open and then reheal. An open coupling capacitor will either kill the reception or reduce the volume a great deal, depending on the strength of the station being received and on the design of the particular receiver.

Other intermittent symptoms are called intermittent hum, intermittent oscillation, or whatever the symptom may be. Actually such intermittents are not too difficult to find since the nature of the complaint is a clue as to its cause. You would check those components which if defective in a certain way would cause the complaint. In this section, we will be mainly concerned with intermittent reception—when the program stops coming through or becomes very weak.

The natural fading that sometimes occurs on distant stations must not be confused with intermittent reception; it is due to a change in the strength of the signal reaching the receiver rather than to a receiver defect. If there is fading on both local and distant stations, and particularly if you hear a pop or click when the loudspeaker volume changes, the difficulty is in the set.

The troublesome thing about all intermittent defects is that when the defect is not present, the set will work. Instead of waiting for the defect to appear, you will save time by trying to make it appear. Just as when looking for noise, you should wiggle parts, pull on leads, test joints, and jar parts by tapping them. In practically all cases you will quickly find the defective component or connection.

Tubes and shielded parts are another matter. Always try new tubes if you suspect the originals. If a part cannot

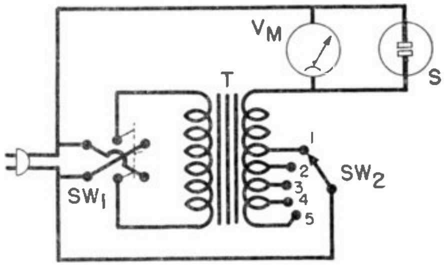

FIG. 20. How to connect a toy-train transformer to step up or step down the line voltage.

be jarred mechanically, you can wait for the defect to show up naturally, and then check the part, or substitute a good part. Of course, a localizing test is of value only while the operation is faulty. All too often, however, connecting the test probes into the circuit restores normal operation. In this case, leave the signal tracer connected into the circuit until the operation again becomes defective. Of course, if the periods between failures are too long, it is better to have your customer continue to use the receiver until the trouble becomes permanent or occurs more often.

You may also get receivers in which no amount of mechanical jarring will cause the trouble to appear. Often the defect is the result of thermal expansion due to heat, and the trouble will occur only when the receiver is in the cabinet. Placing a box over the chassis will speed up the heating of the chassis and the frequency with which the intermittent action occurs.

At other times, you can increase the power line voltage fed to the receiver by using a transformer like that shown in Fig. 20. The voltage applied to the receiver plugged into the receptacle "S" will increase as you turn switch SW2 from terminal 1 toward terminal 5. The higher voltage will sometimes cause the intermittent defect to become permanent. If you do this, there is danger that "good" parts may also be damaged. However, such parts often are slowly going bad, and if they break down under test, the customer is saved a later repair bill. Do not apply more than 130 volts to the receiver.

Before learning how to localize intermittent defects, let us study the intermittent troubles that may occur in typical parts.

INTERMITTENT DEFECTS

You already know the ways in which parts may become defective—how paper capacitors may open or short, how electrolytics may open, leak, or develop a high power factor, how interelectrode leakage may take place in tubes, etc. Now we will see how some of these defects can be intermittent.

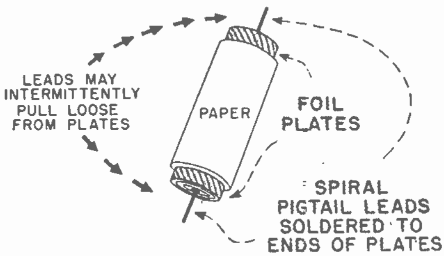

FIG. 21. Construction of a paper capacitor.

Paper Capacitors. The internal construction of a paper capacitor is shown in Fig. 21. The leads of the capacitor are ordinary bare wires whose ends have been curled into a loop. If tinfoil is used for the capacitor plates, the loop is soldered to the foil. With aluminum foil, the loop is filled with solder, making a solder disc, and then pressed into the soft face of the exposed foil to give an electrical contact. The foil may be crimped around the solder disc. The capacitor is then dipped in a wax, which, on hardening, holds the discs in contact with the foil plates. When we say that a capacitor has opened, we mean that one of the discs has pulled away from its foil plate. The effect is the same as if the capacitor lead were cut or a resistance were inserted between the disc and the capacitor plate.

Frequently, in examining the capacitors in a receiver you will find that some of the wax has puffed out of the ends. Such capacitors may become intermittent and should be replaced with others of about the same size and working voltage.

If one of the flat discs mentioned above is lightly in contact with the foil, instead of being completely pulled away from it, slight jars or electrical surges may make the connection open and close. For example, the disc may be in contact with the foil at a single

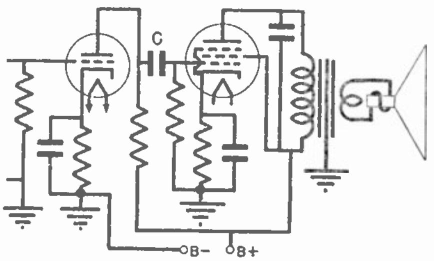

FIG. 22. A typical resistance-coupled audio stage.

point, and a signal surge may cause enough current to flow to burn out the connection. Another voltage surge may start an arc or may cause the disc to come in contact with the foil again, and the cycle of troublesome events may be repeated.

The condition just described would cause noise, rather than intermittent reception, if it occurred frequently enough. For example, if one of the connections to the coupling capacitor C in Fig. 22 were to open and then close again in a few seconds, the signal level would increase and decrease, and you would have intermittent reception. But if exactly the same effect occurred much more often—say several hundred times a second—the set would be noisy. For example, if the B-supply paper bypass opens and closes at relatively long intervals of time, the result is intermittent oscillation; if the same action occurs rapidly, the result is noise.

Electrolytic Capacitors. Dry electrolytics usually do not open or short intermittently—in them, such defects are permanent. However, sometimes a dry electrolytic is anchored to the chassis by a metal clamp around the capacitor housing; leakage sometimes develops between the capacitor and the chassis through the paper housing. The trouble may be intermittent and disappear when the paper dries out after several hours of operation. When the receiver has not operated for some time or when the air is very humid, the condition may appear again. Intermittent leakage between capacitor sections in a single container may produce intermittent hum or noise.

Volume controls. The carbon resistor strips in volume controls may become pitted, or the carbon may flake off so that only a small portion of the slider is in contact with the strip, and it is thrown out of contact by the slightest mechanical jar or by a current surge that burns out the section that the slider touches. Also, high resistance joints between the slider contact and its terminal on the case may intermittently open the slider arm circuit. Troubles caused by burned or pitted strips are most apt to appear in controls through which dc flows, as in the diode load circuit or in a grid circuit having grid currents.

Tubes. Defective tubes are one of the most common causes of intermittent reception. Quite often electrodes expand with heat and touch other electrodes, thus causing intermittent shorts. Also, the filament may expand and break. This interrupts the current flow. When the filament cools, the broken ends come together, and current flow resumes. This is sure to cause intermittent reception and is often found in ac-dc receivers. You will see the pilot lamp, if it is in the filament circuit, going out and coming on regularly. This is found by using a voltmeter, just as you would to find an open filament.

Gas in a tube often causes erratic operation; a faulty cathode may also do so.

The oscillator section of the mixer tube in a three-way portable frequently works intermittently. A reduction in line voltage will often stop the oscillator. This may happen in the evening when the load on the line is heavy or when an appliance, such as a deep freeze or an oil burner, comes on. Usually increasing the value of the oscillator grid resistor will clear up the trouble. The power company may be able to stabilize the line voltage. Do not call the power company, however, unless your measurements show that the line voltage definitely drops at times.

Resistors. Wire-wound resistors may have intermittent opens at their terminal connections, particularly metal-clad "Candohm" resistors. Heavy current through carbon resistors may cause resistance variations that in turn produce an erratic current flow. This may not happen until the receiver has been on for some time and the resistor has become thoroughly heated. The carbon rod in a resistor of this type sometimes breaks, causing an intermittent open.

Coils. Electrolysis in coil windings that carry dc, particularly the primary windings of i-f transformers, af transformers, and oscillator coils, may cause intermittent opens. Frequently the form on which an rf coil is wound will expand with heat, snap a lead from a coil to its terminal lug, and so produce an intermittent contact.

Connections. Connections sometimes are made to the chassis through rivets, which frequently work loose or corrode and so cause intermittent contacts. RF connections through rivets are particularly apt to do this. A poor contact may also develop between the chassis and the can of a grounded electrolytic capacitor. If the capacitor is insulated from the chassis or B− by a fiber washer, leakage may develop across the washer and allow the capacitor case (capacitor negative terminal) to short to the chassis intermittently.

Vibration. Vibration is very apt to cause intermittent reception, particularly in car and portable receivers. Many parts in these sets may be mounted on rubber to reduce mechanical shock; even so, leads to such parts may snap and the broken ends may make intermittent contact. Watch for intermittent voice coil connections where the connections are made to the cone.

General. We have given the most common intermittent defects. There are, of course, many more. There are also some defects that almost never contribute to intermittent difficulties. A bypass capacitor is more apt to open intermittently than it is to short intermittently; yet this last possibility should be kept in mind. An output transformer is not often intermittently defective, nor are properly soldered connections. However, servicemen frequently introduce intermittent troubles by poor soldering; hence you should examine all connections carefully if you find a wire loose in a radio after the set has been serviced by someone or if some of the joints have excess solder on them or unburned flux.

Now for some general rules: All intermittents respond to some stimulus —a voltage surge, a mechanical shock, or a thermostatic expansion or contraction that opens and closes a circuit.

Troubles due to heat are usually very regular; the radio goes on and off at rather definite time intervals, depending on the part or circuit that is defective. A short time interval usually indicates a defect in a tube or in a part carrying a high current. If the time period between cut-off intervals is rather long, the trouble is usually in a circuit carrying smaller currents or in which less heat develops. The trouble may also be in some large part that heats up slowly or in a part that absorbs heat from another nearby.

LOCALIZING INTERMITTENT DEFECTS WITH A VTVM

When is it necessary to localize the defect producing intermittent reception? As you have learned, localization is one of the first methods to use in servicing most complaints. However, when intermittent reception is the problem, this is not true; localization is used as a last resort. The serviceman will wiggle parts, pull on leads to parts, tap on the tubes with his fingers, and push on soldered connections with an insulated tool. In over 90% of the cases, this will disclose the cause of the trouble. If you cannot make the trouble appear by mechanical movement of the part leads and if heat will not make it show up long enough so that you can localize it, you will have to start replacing parts. This can be a time-consuming and expensive cure, but if the search area is narrowed down to a single stage, part substitution becomes practical.

If you find that you can take measurements during the intermittent defective operation, without shocking the receiver back into normal operation, you can just check the receiver while it is acting up. However, in most cases touching test leads to the receiver circuits will make reception snap back on. In such a case the test equipment must be left connected to the receiver and the set allowed to play until it cuts out. Then the indications given by the test equipment show whether or not the defect is in the stage or section under test.

The only practical way to localize an intermittent is to sample the signal in the various receiver stages, using a vtvm or a signal tracer. Signal injection is not practical because the signal generator may load the circuits to the point where the intermittent action will not occur. To sample the signal in the various sections or at the output of the various stages, you can use a vtvm capable of measuring af and rf signals, or you can use a signal tracer. Most servicemen prefer to use their signal tracers, because it leaves the vtvm available for other work.

Let us see first how to use a vtvm, in the circuits of the typical receiver shown in Fig. 23, then we will see how to use a signal tracer.

Before you can find the defective stage, you must find out if the trouble is in the rf or the af section. Let us see how to do this.

Localizing the Section. Connect the vtvm across R5 to measure the dc voltage across the diode load, and let the receiver play until the set cuts out. Then look at the meter reading. If it is unchanged, the trouble is in the af section between the volume control

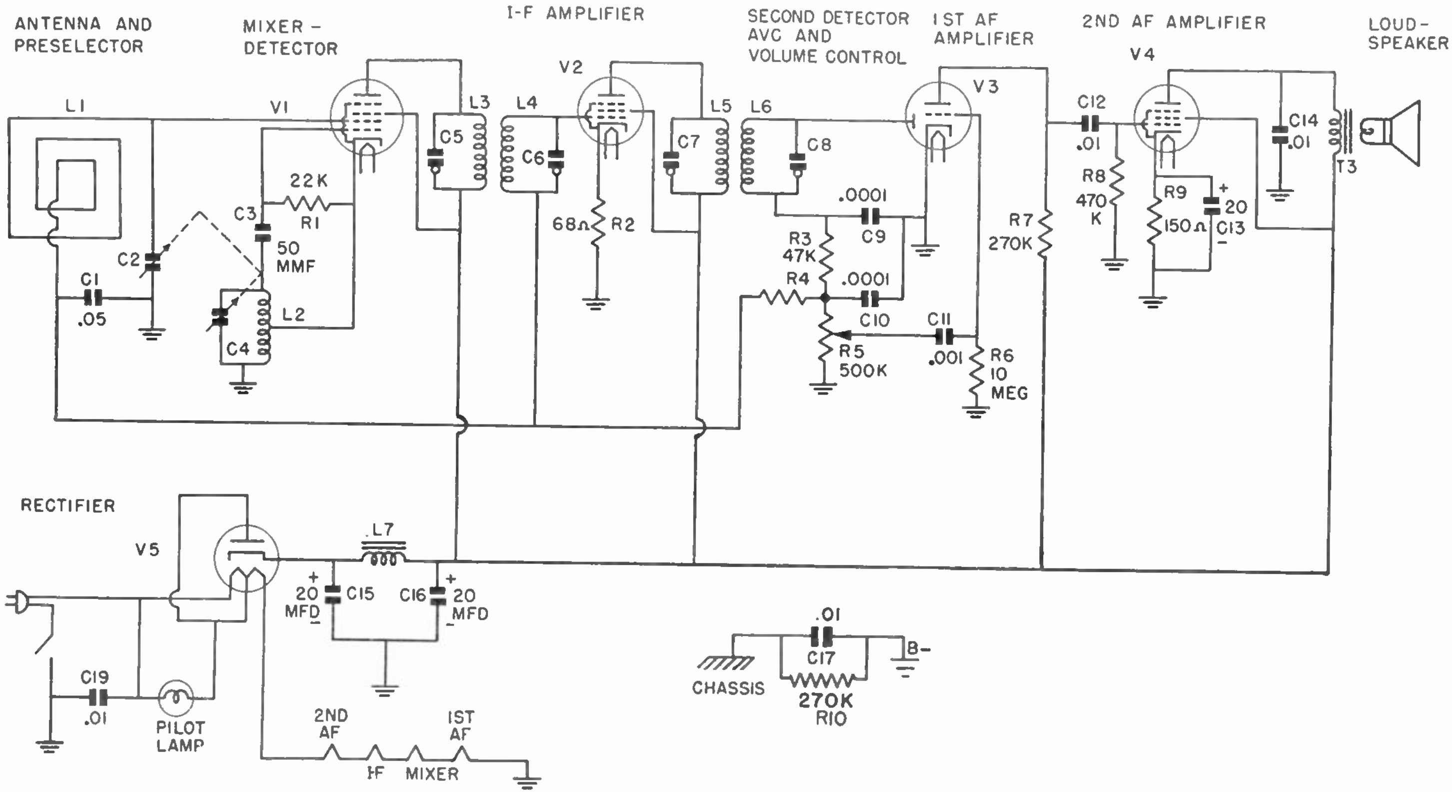

FIG. 23. A typical ac-dc receiver.

and the loudspeaker. On the other hand, if you find the voltage has dropped to a lower value, the trouble is in the rf section, which includes everything between the loop antenna and the second detector output.

Locating a Defective RF Stage. Let us suppose you have isolated the trouble to the rf section, and see how to go on from there. Leave the vtvm connected to measure the diode load voltage, and substitute good tubes for V1 and V2 one at a time. Replace one of the tubes, and let the receiver operate long enough for the intermittent to occur. If it does not occur when you replace one or the other of the tubes, that tube was the cause of the trouble. However, if the intermittent still occurs after you have replaced both tubes you will have to isolate it further.

To avoid confusion, remove the avc and replace it with a battery. To do this, disconnect R4 from the junction of R3 and R5 and solder the free end of R4 to the negative terminal of a 1.5 volt flashlight cell. Connect the positive terminal of the cell to B–.

Set up your vtvm for rf measurements and connect if from B– to the plate of tube V1. Tune in a strong station so you get a reasonable deflection on the meter. If the sound output from the receiver is too low, peak the primary trimmer of the first i-f transformer for maximum volume from the loudspeaker. This is necessary to compensate for the detuning caused by the vtvm in the circuit. Note the meter reading. Now temporarily disable the local oscillator by shorting C4 with your finger. Make a note of the reading on the vtvm. Now short the loop so the radio signal is not applied to the input of V1, and again write down the amount of the signal (from the local oscillator in this case) at the plate of V1. Let the set play until it cuts out. If there is a change in meter reading, compare this reading with the two that you took with the capacitor shorted and with the loop shorted. If it is the same as the first, the oscillator has stopped; if it is the same as the second, mixing is not occurring in V1.

If there is no change in the signal, the trouble is between the plate of V1 and the diode plate of V3.

A vtvm cannot be satisfactorily used to check the signal at the control grid of V2, but you may be able to get an indication at the plate of V2 or at the diode plate of V3. Remember to adjust the trimmers involved for maximum output when you connect the rf probe of the vtvm to the circuit and again when you remove the probe. When trying new parts, replace the ones that are easy to install, such as capacitors and resistors, first, and those more difficult to install, such as i-f transformers, last.

Locating a Defective AF Stage. A vtvm can be used in the af section, but it is not ideal because the signal modulation is constantly changing. This causes a fluctuation in the meter reading. However, any sudden drop in the meter reading when the symptom appears indicates the defect is between the ac vtvm probe and the last point at which a normal reading was obtained.

In the af system in Fig. 23, the signal should be sampled at the following points:

The control grid of V3.
The triode plate of V3.
The control grid of V4.
The plate of V4.
The voice coil.

A change in the average signal level at any test point indicates the trouble. For example, if the signal voltage drops at the control grid of V4, but is normal at the plate of V3, you would suspect an open in C12 or a short from the control grid of V4 to B–.

Remember that when there is no

modulation of the station signal, there will be no sound from the loudspeaker, and the af signal voltage will drop.

LOCATING THE DEFECTIVE STAGE WITH A SIGNAL TRACER

Section Localization. As with the vtvm, the first step when using a signal tracer is to determine whether the trouble is in the rf section or the af section. To do this, sample the signal at the diode load resistor (R5 in Fig. 23). If the signal fades, the trouble is in the rf section; otherwise it is in the af section.

Locating a Defective RF Stage. Again the avc circuit must be disabled while you check the rf stages. As before, disconnect the avc circuit at R4 and substitute a fixed bias, so a defect in the second detector will not change the signal level at preceding test points.

Connect the signal tracer at each control grid. If the tracer indicates a drop in signal level, the trouble is between the point of connection and that test point where the signal was normal. When the signal drops at the oscillator grid, you know that the oscillator has failed.

The signal tracer has three advantages over the vtvm in locating the cause of intermittent reception: (1) when using a signal tracer, you do not have to readjust the trimmers in the various stages because the signal tracer does not detune the rf-if resonance circuits; (2) the signal tracer has an audible output; and (3) the signal tracer sensitivity is high enough to permit signal sampling at any point in the rf system, even at the mixer grid.

Locating a Defective AF Stage. If fading does not occur at the diode load, connect the signal tracer at the grid and then the plate of each af tube, working toward the voice coil. Leave it connected at each point until the signal from the loudspeaker fades or cuts out. If, when the sound fades, the signal tracer does not indicate a change in signal strength, connect it to the next grid or plate. When the signal indicated on the signal tracer goes down at the same time that the sound fades from the loudspeaker, you have just included the defective stage or circuit in the set, and you should concentrate on that stage. Check the parts and finally try substitutes.

Servicing intermittents that involve stage localization takes a great deal of time and is seldom profitable. However, you cannot refuse to repair intermittent receivers or you will surely lose your customer's future business. The additional business he brings to you may in time more than compensate for your loss in time and money in repairing the intermittent set.

LOOKING AHEAD

In this series of lessons describing radio servicing techniques, we have given you information on how to identify, locate, and fix the most common receiver complaints. It is, of course, impossible to describe all the defects that can possibly produce any particular complaint. However, if you understand how the various receiver circuits operate, you will be able to locate and correct the more unusual defects.

We do not expect you to memorize all the information given in these lessons. Radio servicing, for the most part, should not be a memory process. While you are beginning your service work, you should use the servicing lessons as a guide. Try to apply effect-to-cause reasoning whenever possible, because it can save you much time in locating the defect.

For some complaints, we described several possible testing methods. Learn how to use all of them so that if one does not help you find the trouble, you can try another. After you have had some servicing experience, you will instinctively apply the correct test procedure to find the cause of a particular complaint. You will also know what parts defects can cause a particular complaint and check those possibilities first. The more experience you have in radio servicing, the faster you will be able to repair the receiver.

In the next lessons, you will study other types of receivers and electronic equipment such as auto receivers, high-fidelity systems, and TV sets; you will learn not only how they work but also how to service them. You will find that many of the procedures and tests you studied in the radio servicing lessons can be applied to other types of equipment in addition to radio receivers, because the same defects and complaints can occur in them. Of course, there are different testing methods and different component defects but you will find that the basic procedures are the same as those you have studied in these lessons.

Lesson Questions

Be sure to number your Answer Sheet 40B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. Which is the most noticeable type of distortion produced in radio receivers?

2. What can cause the magnetomative force to become so great that core saturation occurs in an audio output transformer?

3. Which TWO of the following voltage conditions will cause the tube to operate over the *lower bend* of its characteristic curve? 1, bias too low; 2, bias too high; 3, plate voltage low; 4, plate voltage high?

4. By taking plate current measurements how can you tell when the tube in a class A amplifier stage is operating on the non-linear portion of its characteristic curve?

5. What TWO effects would a large decrease in the value of coupling capacitor C4 in Fig. 6 have on the sound from the audio amplifier stage?

6. Suppose you have localized the cause of distortion to the af output stage; which components would you usually check first?

7. What TWO conditions must be present in a push-pull audio amplifier stage for the stage to be free from 2nd-harmonic distortion?

8. Suppose a receiver is noisy, but the noise disappears when you turn the volume control to the minimum volume position. Is the noise source: 1, in the *rf-if section;* or 2, in the *af section?*

9. What is the basic difference between the defects causing noisy reception and those causing intermittent reception?

10. Name TWO instruments that can be used to localize an intermittent defect in a radio receiver.

KEEPING PROMISES

To have the reputation for always meeting obligations and paying debts is a most valuable asset in social as well as professional life. If you owe money, pay promptly when payment is due. If you owe allegiance to a person or organization, grant it. If you have given your promise to someone, keep it. To hedge on any type of obligation is to start a moral disintegration which may eventually ruin your chances for enjoying life and its successes. Failure to keep an obligation is a sin which has resulted in many a failure in life itself.

J. E. Smith

INSTALLATION OF AUTOMOBILE RECEIVERS

41B

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL

NATIONAL RADIO INSTITUTE
WASHINGTON, D. C.
ESTABLISHED 1914

STUDY SCHEDULE NO. 41

For each study step, read the assigned pages first at your usual speed. Reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

1960 Edition

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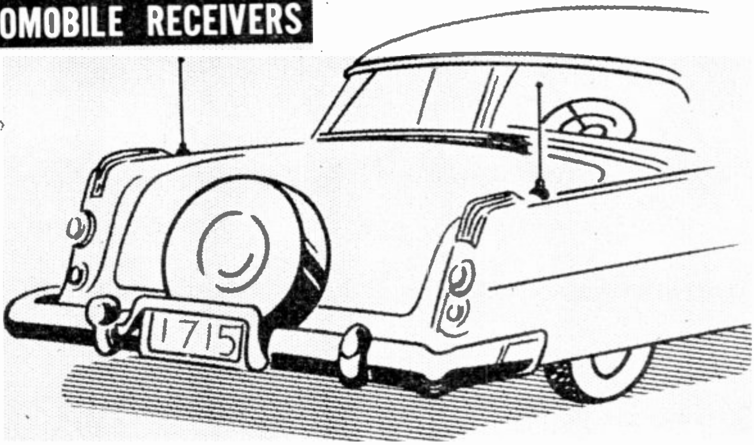
INSTALLATION OF AUTOMOBILE RECEIVERS



SINCE radios were first put into automobiles, they have been improved in three ways. Power and sensitivity have been increased, size has been decreased, and electrical noise pick-up has been reduced.

The first sets were made in two or even three large boxes; it was at least a two-day job to get even half of the noise out of the installation. Today's set comes in one small box, which can be installed, complete with antenna and noise-suppression devices, by a skilled technician in less than a half hour. Auto radio service and installation has developed since 1929 from a hobby into a business, one in which many electronics shops specialize.

The designer of automobile radios faces several problems that the designer of home radios does not have to face. He must make his sets work with a very small antenna in the presence of a very strong electrical noise field under continuous jarring and vibration, with a signal of constantly varying strength. Nevertheless, he has met these problems so successfully, that tube for tube, the average car radio will deliver better performance than a comparable home radio.

This can be attributed in part to the use of very high quality parts, high-gain tubes, high-Q coils and transformers, and highly efficient circuits. This, together with good design and workmanship, enables the car radio to give king-size performance in a very small package.

The basic circuits used in auto radios are identical with those used in any other radio. The big difference lies in the type of power supply. The only source of power for the auto radio is the car's battery. The battery can furnish only 6 or 12 volts. This is stepped up and rectified by a power transformer and a vibrator, and becomes the high-voltage supply for the receiver. Filaments are supplied, through appropriate filters, directly from the battery voltage.

High-gain tubes and high-gain transformers are used in practically all sets. It is interesting to note here that one stage using the common 6BA6 tube gives more gain than the whole set of type 24 tubes used in the first auto radio.

Auto radio cases are specially built to keep out electrical noise, by forming as nearly as possible, a continuous electrical shield. The necessary ventilation holes are made small so that the shielding will not be interrupted.

Various bolts and brackets are needed for mounting the set in the car and keeping it in place under severe vibration and jolting. These are usually made as part of the case.

Many of the features found in home sets are also found in auto radios—tone controls, dual speakers, and even short-wave bands in some special models. Some cars have provision for a speaker to be mounted on the shelf behind the rear seat. This feature can be added to any auto radio by using an external switch, and is built in on some sets.

For good performance from an auto radio, not only the design work, but also the installation and service work, must be of the best. Only the very best workmanship is good enough for successful auto radio work. Slipshod or careless workmanship will show up immediately, and the technician's most priceless asset, his reputation, will suffer. All solder joints must be clean and bright, all bolts well tightened, and all replacement parts well fastened into place to prevent future troubles. Many callbacks can be avoided by taking the pains necessary to do a good job the first time.

The Automobile's Electrical System

The auto-radio technician must work on the car's electrical system. Therefore, it might be a good idea to give a brief description of it here so that you will be familiar with its operation.

The wiring system of *all* cars is basically alike; there are only minor differences between different makes and models. The only source of the current used to operate all electrical equipment in the car is the car's storage battery. This may be either 6 or 12 volts, depending upon the car. Only equipment of the same voltage rating can be used.

The battery is kept charged by the generator; this is driven by the engine. A voltage regulator on later model cars, or a cutout on older models, regulates the charging rate and prevents the battery from being discharged by disconnecting it from the generator when the engine stops. All other equipment is connected to the battery through appropriate switches. Lights, heaters, radio, etc., are all supplied by the same battery.

Fig. 1 shows a diagram of a typical system. Only one wire is shown going to each appliance. The metal frame of the car is always used as the ground, and is the common return for *every* electrical appliance on the car. Therefore, only one wire, the "hot" wire, needs to be run to any appliance. Lights, for instance, have only one wire coming from the switch on the dash; the other filament terminal is grounded at the socket.

A storage battery has a definite polarity; some makers ground the negative side, some the positive side. As a rule, this will make very little difference unless you are installing quite an old set. Older sets with synchronous vibrators in their power supplies, were polarized, and had to be connected with the proper polarity to work. Practically all of the later sets have no polarity at all, and may be used in cars of either ground polarity. If in doubt, check the tube lineup; if there is a rectifier tube, the set has no polarity.

As we said before, the generator of the older cars had a device known as a "cutout." This is simply a relay, connected in shunt with the generator output lead, which automatically disconnects the generator when the engine stops or drops below the speed at which the generator charges. This is necessary to prevent the battery from being discharged through the generator, because any generator will run as a motor if a battery is connected to it.

The original generators using this circuit charged at full rate at all times. This often resulted in overcharged batteries on long runs. A far more efficient system came into use with the development of the voltage-regulated generator. This type has a separately wound field excited by the battery as in the older ones, the field terminal is brought outside of the generator, and used to regulate its output.

By inserting a resistance into this field circuit, the amount of charging current can be controlled. In the first models, this was done by means of a manual switch with "high-charge" and "low-charge" positions. In the voltage regulator, another relay accomplishes this automatically.

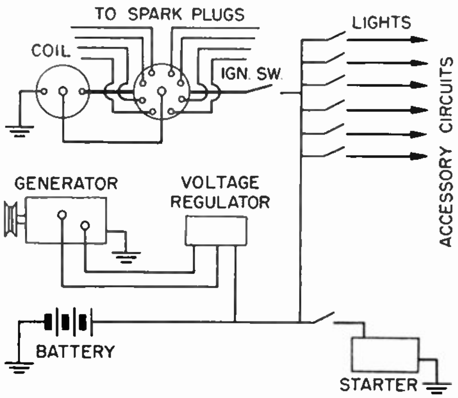


FIG. 1. The automobile electrical system.

The most commonly used voltage regulator on passenger cars today uses a total of three relays: 1, the cut-out relay, which disconnects the generator when the engine is idling; 2, a current relay, which opens automatically to prevent the generator from being overloaded; and 3, the voltage relay, which lowers the charging rate whenever the battery becomes fully charged.

As you remember, to charge a battery, the generator must have a voltage output *higher* than that of the battery in order to force the charging current through the battery. If the battery is low, its voltage is down; the relay allows the generator to put out its full rated current, charging the battery rapidly. If the battery is fully charged, its voltage is high; the regulator, being operated by the voltage across it, will open when the voltage reaches a preset level and cut off the generator. When enough current has been drawn from the battery to lower the voltage, the voltage relay closes again, permitting the generator to charge the battery once again.

The regulating action of this type of system is accomplished by varying or removing a resistance connected in series with the field windings of the generator. This raises or lowers the charging rate. If the system is in good working order, the battery will be kept fully charged at all times and the voltage will not be allowed to rise to excessive values.

To furnish the very high voltages needed to fire the fuel charge in the cylinders by making an arc across the electrodes of the spark plugs, a system consisting of a "coil," a set of "ignition points," and a "distributor" is used. These are the automotive names for them; we would call the coil a transformer, with a very high turns ratio, often as high as 100 to 1. The "ignition points" we would call a switch, and the distributor is merely a rotary switch. The circuit of an automobile ignition system is shown in Fig. 2.

In action, the primary of the coil is supplied with current from the battery through the ignition switch and points. When the points close, a surge of current flows through the primary; when the points open, the large magnetic field which was built up around the coil collapses. The collapse of this magnetic field generates a very high voltage across the secondary. This pulse of high voltage is applied through the rotor arm of the distributor to whatever spark plug is in firing position at that instant. This pulse can run as high as 25,000 volts. The wave shape of the pulse is in the form of a "damped oscillaton." The pulses produce familiar "plug noise," so-called although the noise actually originates at the breaker points and rotor arm of the distributor. This is the part of the circuit which causes the most noise trouble. Methods of dealing with this problem will be outlined later.

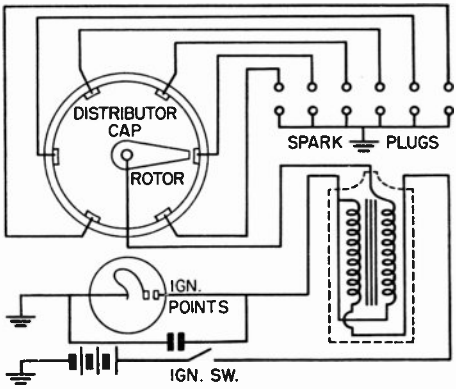


FIG. 2. The automobile ignition system.

Automobile Radio Antennas

Probably the most important part of the auto-radio receiving system is the antenna itself. Small as it is, this little brass "whip" is the heart of the system, and a great deal of the set's performance depends upon it and its conditions. It must be in absolutely first-class shape if any results at all are to be expected.

The antenna has two basic jobs: to intercept sufficient signals for the radio to deliver full volume, and to eliminate noise pick-up from the car's electrical system. The first is accomplished by the vertical, visible portion of the rod, the second and equally important part, by the base, mounting, and lead-in cable.

Fig. 3A shows a modern auto antenna. It does not represent any particular antenna, but is typical of the modern cowl-mounted type. Fig. 3B is a drawing of an obsolete type, which shows the great difference between the easily installed, highly efficient antennas made today, and the hard-to-mount, inefficient earlier models. The new antennas can be installed by one man using the proper tools and methods in less than five minutes; the old type often took two men over an hour.

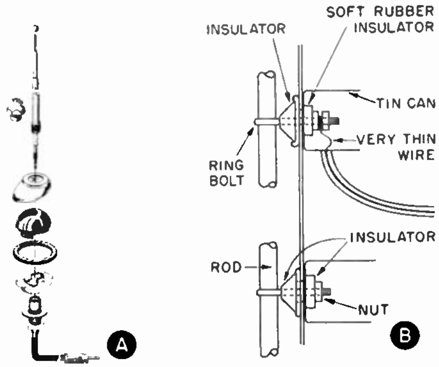


FIG. 3. A, modern one-hole mount antenna. B, old two-hole mount antenna.

The lead-in cables of the old antennas were made with an impregnated cotton braid which absorbed water quite readily. The new lead-ins are coaxial cables, using a thick polyethylene sheath, covered with a braided copper shield and an outer jacket of vinyl rubber. This solid plastic material, developed during World War II, is an excellent rf insulator, and entirely moisture-proof. The upper insulators of older antennas were made of hard rubber; constant exposure to sunlight caused deterioration and breakdown. The exposed insulators of new antennas are made of a harder grade of plastic material, which is practically immune to these troubles. Mounts are usually made in two pieces, one below the body surface and one above. Locking "dogs" on the base hold the two pieces in alignment. Teeth in the metal of the lower piece bite into the surface and make a good ground connection which is essential for the proper operation of the lead-in.

Most antennas used today are

variations of the "top-cowl-fender" type. This is one of the two major classes, the other being the "side-cowl" type. For convenience, we shall refer to them from now on as "cowl-mounts" and "side-mounts." The difference is merely in the mounting methods; each type has the same purpose. The cowl-mounts can be used on any horizontal or gently sloping surface; the side-mounts are used on vertical surfaces only. The cowl-mounts are often used on the flat tops of front or rear fenders, hence the name "top-cowl-fender" mount. The kind of surface available for mounting the antenna will determine the type to be used. Never attempt to install an antenna that is not right for the type of mount available. Trouble always follows.

Side-mount antennas are all much alike, varying only in length. All have two insulators for extra support. This type is mechanically stronger, so it is used most in installations requiring a rugged mounting, such as in trucks. A sketch of this antenna appears in Fig. 4A. The two-point support of the side-mount antenna has greater strength than the other types, naturally, and should be used when the antenna will be struck by tree branches as the vehicle runs through heavy brush, or in country use.

Cowl-mounts appear in several variations of the basic pattern: the standard cowl-mount (Fig. 4B), a three-section antenna, 55-60 inches long extended, 24 inches collapsed; and the "disappearing" type (Fig. 4C), which has a tube extending below the fender surface, so that the rod can be collapsed to a shorter length. These are generally mounted on fenders, although some are installed on the cowling. In 1955, some innovations in antennas appeared, for the first time in several years. The original cowl-fender antenna came out about 1946 or 1947, and was pretty well standardized by 1950. 1955, with its radical changes in automotive styling, also brought forth some new developments in auto antennas, such as the "rear-mount," consisting of

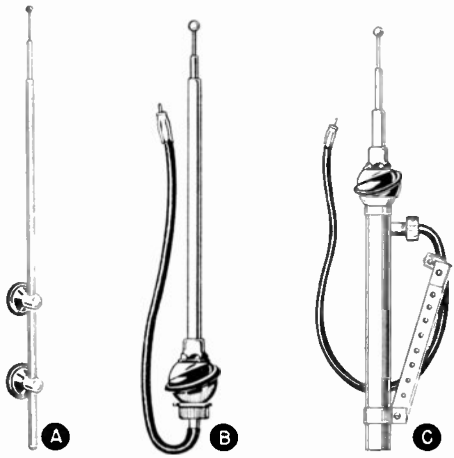


FIG. 4. A, modern side-mount antenna. B, cowl-mount antenna. C, "disappearing" antenna.

either one or two short "cowl-mounts" installed on the rear fenders. Earlier cars had lacked the space for installations of this kind. There were also other difficulties. Among these was the trouble caused by the excessive capacity of the 15 to 20-ft. lead-in needed in most cars.

This added capacity across the receiver input can detune the front end of the receiver enough to cause poor performance. To eliminate this, a capacitor is built into the lead-in at the set end, in series with the center conductor.

This capacitor is in series with the capacity between the center conductor and the shield. This series capacitor reduces the lead-in capacity across the receiver input and allows the input to be tuned.

When gay colored cars came out, matching antennas of Fiberglas were made. These are similar to glass fishing rods with metal conductors in the center. The glass antennas are like the regular cowl-mounts.

Another useful accessory appeared at this time. An antenna can be electrically lengthened by placing a coil in series with it. This was very useful on auto radios of the older types, which were designed to use much longer antennas than the later models. The antenna is cut off just above the base, and the coil inserted there, placing it in series with the rod and electrically lengthening it. Quite a bit of added volume may result by using this device on older sets. However, not as much improvement can be expected when using this with the newer sets which were designed to use short antennas.

Some novel variations on the cowl-mount antenna had appeared a few years before. These were cowl antennas, similar to the disappearing type, but with means for raising and lowering them from inside the car. Some used a purely mechanical lift operated by a knob inside the car, some used a small electric motor, while some used a pneumatic-lift arrangement, powered by the manifold vacuum of the engine. Troubles were quite frequent with these, however, and they have almost disappeared from the market.

Another different type of antenna made its bow along about 1936-37. This was the top antenna, which is a short rod mounted in the center of the top of the car, just above the windshield. It could be turned to various positions by a knob inside the car. Lead-in cables were brought down the side posts of the windshield and occasionally a matching transformer was used at the antenna base. This type of antenna has been seen on some comparatively late cars, although it almost disappeared for a while.

As we have said, the average car antenna is quite short. The longest commercial antenna is a 96-inch side-mount, which is quite a monster. The average antenna is from 55-60 inches extended, and is usually run with one section down, to give an average length of about four feet. By comparison with even a small broadcast antenna, this is very small, and one might wonder how the car radio gets enough signal to operate on the small amount of energy that this little rod can pick up. This problem has plagued designers for many years, and it was finally solved by making the whole front end, antenna, rf amplifier stage and lead-in, resonant within the band of frequencies which the set is designed to pick up. This increases its efficiency tremendously. Second, a very high-gain rf amplifier stage, using high-Q coils and high-mu tubes, is used on all auto radios to give the extra amplification necessary, and also to improve the selectivity. No car antenna will operate correctly until it has been tuned to match the set. This final adjustment is always made in the car, tuning the whole antenna stage to operate at peak efficiency.

The designer of an auto radio has the advantage of knowing within a very small range, exactly what he is going to have to work with. He knows the inductance and capacity of the antenna, the capacity of the lead-in, etc., and so can design the receiver front end to take advantage of it. Compared with the broadcast receiver designer, who must cope with a wide variation in antenna equipment and make the front end cover a much wider range, the auto radio designer has practically a fixed set of circuit constants to work with, and he can obtain much greater efficiency. The added gain and selectivity of the rf amplifier stage helps tremendously in obtaining the needed sensitivity. All tuning and adjustment is highly critical and great care should be used in making alignment adjustments.

The lead-in cable of the modern antenna is one of the most important parts. It is terminated in a standardized coaxial plug on the "set end," and in coaxial plugs of many varied shapes on the antenna end. It has low capacity, very low losses, and a high degree of weather resistance. It must be well shielded, with a closely woven braid of copper wire. Made up of four parts, it contains the inner conductor, which is a very fine wire to keep the impedance up; the "liner" of polyethylene, about 1/8 inch thick; a closely woven shielding of copper; and finally, an outer jacket of tough vinyl-plastic. Note the coaxial plug at the antenna end shown in Fig. 3A. Its threaded sleeve forms part of the antenna base mount, and is grounded. It is filled with a solid type of polyethylene. The end of the antenna rod comes through the top insulator to make contact directly with the female plug on the end of the lead-in conductor. Practically the only troubles encountered with these leads are breakage of the small center conductor, and loose joints at the plugs. If the break is at the set end, this plug may be removed and replaced. If it is at the antenna end, repairs are almost impossible because the plug is molded, so the antenna or at least the lead-in must be replaced.

The entire lead-in assembly is shielded, as shown in Fig. 5. This shield is grounded at the antenna end by the construction of the base, and at the set end by the antenna socket. This is absolutely essential; if either end becomes ungrounded, noise will be picked up. The continuous shielding around the center conductor causes the noise impulses to be picked up by the shield, and passed on to the ground on the body of the car itself. Thus, the noise is not picked up by the lead-in.

ANTENNA INSTALLATION

Antenna installations make up a large part, and one of the most critical parts of auto radio work. The performance of the set depends upon the successful installation of the antenna. The installation may be divided into two major parts: the selection of the location, which determines the type of antenna to be used, and the actual mounting of the antenna, which includes such things as drilling the hole and installing the antenna and lead-in. We will cover each of these in detail, to show you which methods are best, as determined by the actual experience of many antenna men over the years. There are several difficulties which you can easily get into in this work, but all of them can be avoided with sufficient care.

Selection of location depends to a great extent upon the type of car. Passenger cars have very few suitable vertical surfaces upon which a side-mount antenna can be used. Therefore, this type is used mostly on pickups and other trucks, unless a customer asks that it be used on his car. In this case, go ahead, but explain the difficulties to him, and if he insists, make the installation. Side-mounts can be used only on these places: vertical sides (skirts) of the front fenders, vertical surfaces of the side-cowling, and on the sides of truck cabs, above and behind the door. On some cars of 1954 or later, there is enough vertical surface on the sides of the rear fenders to permit mounting there, using a long extension on the lead-in, with a series capacitor.

The cowl-mount can be installed in a number of places, on the horizontal or gently sloping surfaces of the cowling just in front of the windshield, on the crown of the front fenders, or on the rear fenders. The "rear-mount" antennas mount on the crowns of the rear fenders, as explained, or, a pair of them can be mounted in front of the windshield. Remove the series capacitor from the lead-in when they are mounted in front.

One of the most important things is the location of the radio receiver itself. If it is in the center, as is the case with practically all custom-built sets, the lead-in cable will reach it with no trouble. If it happens to be off-center, the antenna must be installed on the side of the car nearer the set, so that the lead-in will reach. Extensions can be added if necessary, but it is much better and simpler to check the set's location first.

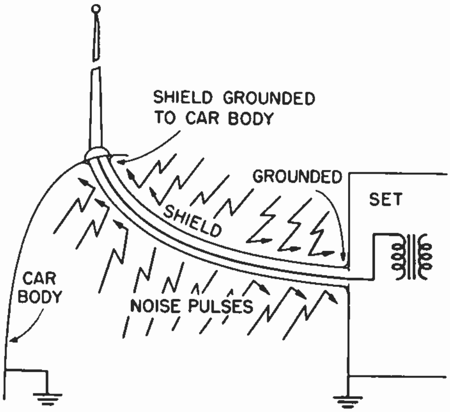


FIG. 5. Grounding the lead-in shield.

TOOLS FOR ANTENNA INSTALLATION

There are a great many special tools for antenna installation work. Most of these, although not primarily designed for this type of work, will make the job a great deal easier if correctly used. Speed is important in this as in any other kind of service work, and many otherwise difficult jobs can be made fast and easy by using the right tools for the job.

The basic tool kit for antenna installation work is shown in Fig. 6. It consists of several screwdrivers, common, "Cross-point," "Clutch," and the special hourglass-shaped points used on quite a few GM products; two pairs of "combination-pliers," large and small, the "bent-nose" type being preferred; one long and one short center-punch; 4-inch, 6-inch, and 8-inch adjustable wrenches; a heavy-duty electric extension cord at least fifty feet long, with a dual outlet on the end; a trouble light for work inside the car; a 1/4-inch electric drill, with an assortment of high-speed bits; a "fly-cutter"; a 1-inch Greenlee punch; a medium size mechanic's ball peen hammer; and last but by no means least, a 5-inch tapered reamer with a "T" handle, for enlarging holes.

FIG. 6. Tool kit for antenna installations.

The worst job in antenna work is cutting the hole for the antenna base. This runs from 7/8 inch to 1 inch for most antennas, and must be perfectly round and clean. To drill a hole this size, you need a heavy-duty electric drill, which is both heavy and expensive. However, several special tools have been developed for this task. One of these, which can be used in the smaller 1/4-inch electric drill, is the "fly-cutter," shown in Fig. 7. This consists of a 1/4-inch pilot drill and an adjustable cutter bar. This tool works the same as a boring tool used with a lathe; the point of the cutter bar, scribing a circle around the pilot drill, gradually cuts through the sheet metal, leaving a perfectly round, smooth hole.

One simple way of using this tool is to mark the location of the hole, center punch it well to keep the drill from skidding, and drill the pilot hole. Shut off the drill, and lower the cutter bar onto the surface. Turn it by hand until the tip of the cutter has marked a light circle. Compare this with the size needed, by measurement or using a template, and then adjust the size of the cutter either in or out as needed. It can be set to make any size hole from 5/8 inch to 1¼ inches. Tighten the cutter bar firmly, then proceed with the boring. To use this tool correctly, you must hold the drill *firmly* with both hands.

When the cutter is just about to break through the surface, hold it *very tightly*. This is the time when it may jam, causing the drill to jerk violently, possibly spraining your wrist, or gouging the car's finish. Hold it firmly, and the cutter will break out cleanly, leaving the drill spinning in the air.

A tool similar to this is the "hole-saw." The action is much the same, with a pilot drill to hold the cutter centered, and a circular hacksaw blade for cutting. This too will also do a good job if properly used. The main disadvantage of this is that it cannot be adjusted in size. However, different sizes of hole-saws can be used on the same arbor to give this tool more flexibility.

One more tool, which can be a little faster if correctly used, is the Greenlee punch. This is a two-part shear-type tool, with a punch and die drawn together by a large bolt. One of these tools in the 1-inch size, will do for many different makes of antennas, as most of them are within 1/16 inch of this size. Different sizes and shapes are available, round, square, "keyed" and "D" holes, and can be obtained at any radio supply house. This cutter is shown in use in Fig. 8.

The fastest way to use this is as follows: With the long center punch, mark the location of the hole. Drive the punch through the surface, until the taper of the punch has made a hole large enough to pass the bolt used in the punch. Take the punch apart and reassemble it with the bolt through the hole. The die should be on top, so the bolt head is accessible, and the punch on the bottom. Turn the bolt with an adjustable wrench until the punch has been forced through the metal and comes loose, leaving a nice clean hole.

Most side-mounted antennas require 1/2-inch holes for the insulator mounts. These can be made with a 1/2-inch Greenlee punch, or by drilling a 1/4-inch hole and reaming it to the required size. The fly-cutter will not make this size hole. Rotary files may be used in the electric drill to enlarge the 1/4-inch holes, if desired, or to touch them up where needed.

Antenna installations on new cars, using custom-built antennas designed for the car, are not difficult. Each antenna package contains a full set of detailed instructions, mounting templates, etc., and you should follow them to the letter for the first few times until you have memorized them. Even experienced antenna men will not make an installation of this kind for the first time without first carefully studying the instructions. The

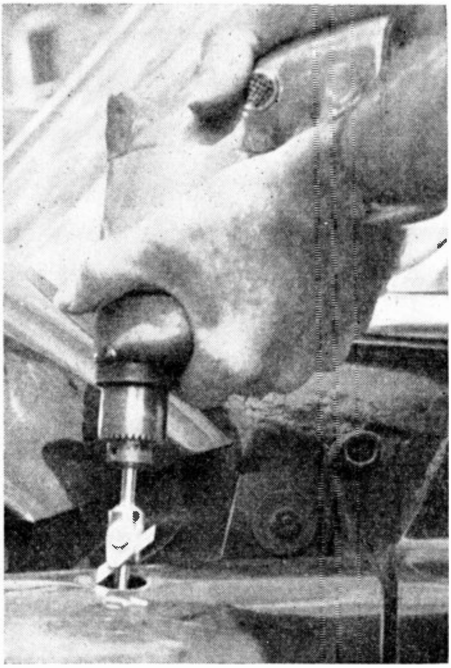


FIG. 7. Use of the "Bruno" fly-cutter.

templates enclosed should always be used when drilling the holes. This antenna is designed for this one car only! If it is of the disappearing type, holes have been made in the car frame and body to allow the mountings and the tube to pass. If the outside hole is not perfectly lined up with these holes, you're in trouble! If the upper hole is not lined up, the antenna will not be vertical, and the tube will not be in the proper position with respect to the mounting brackets. Extreme caution is necessary in all cases; be sure you're right before drilling.

The same general procedures are used for rear-mounted antennas. Follow the templates furnished, and you'll have no trouble. Lead-in cables must be run from the trunk space up to the front of the car. Raise the edge of the floormats or carpets from under the metal strips which hold them down at the sills. Most of these will be held in place by sheet-metal screws. Remove the moldings, raise the edge of the mats, and lay the lead-in down the side, replacing the mats and molding to hold it firmly in place. Inside the trunk itself, the lead-in cable and connecting harness, which joins the two antennas, should be firmly held in place with clips or small metal clamps so that it will not hang down inside the trunk space.

Installing one of the many types of antennas designed for mounting on any kind of car can be somewhat simpler. (These antennas can be used in place of the custom antennas, if desired.) When installing a cowl-mount type, use a place on the top of the cowling, just in front of the windshield corner post. Never put an antenna where it will be in the range of the driver's vision when looking straight ahead; always conceal it with the post if possible. Check the location carefully to see that it is not obstructed underneath by frame members or other parts of the car; then cut the hole using one of the methods just outlined. Slip the antenna into place, and tighten well. Incidentally, never tighten an antenna

FIG. 8. Using the Greenlee punch.

mount too much. This can cause more trouble than leaving it just a little too loose! Recommended tension is at the point where the rubber sealing washer just begins to show signs of "squashing out." This whole job can be done in less than five minutes by a skilled workman using the right tools.

If there is no cowling, with the hood going all the way back to the windshield, or if for any reason the antenna is not desired on the cowl, place it on top of one of the front fenders. The lead-in must be longer on account of the extra distance to the set; otherwise, the two installations are the same. The average cowl-mount antenna has a 36-inch lead-in, which will reach the set from any place on the cowling; fender mounts usually have 54-inch lead-in cables.

Quite a few cars provide holes in the body, under the hood, to allow the lead-in to be brought in from a fender mount. If there are none, select a spot where the lead-in will not be cut or pinched by hood hinges, springs, etc., and make one as shown in Fig. 9. The long center punch is best for this purpose, rather than a drill. Simply drive the punch through the sheet metal until the hole is large enough to allow the plug to pass. Seal around the lead-in with a rubber grommet or with a plastic sealing compound, to prevent the entry of dust and moisture into the car. The punch makes holes with rounded edges, instead of the sharp edges of a drilled hole; hence, the edges will not cut or damage the lead-in.

One word of caution right here—before making any holes, always check clearances from nearby parts of the car, both inside and outside! For instance, on the 1949-50 GMC and Chevrolet pickup trucks the hoods swung up and *back*, covering the entire cowling in the raised position. Unwary technicians often installed cowl-mount antennas in the ordinary place, toward the front of the cowling, only to see them snapped off when the hoods were raised. The correct location for the antenna on these cars is just as close to the windshield as possible. Even then, when the hood is raised, it will still just touch the rod. Always lock for problems like this before selecting a location.

Side-mounted antennas range from very easy to very hard to install, depending upon the type of car and its construction. Always check *very carefully* before drilling any holes in

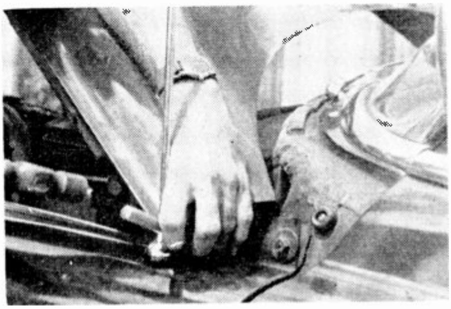


FIG. 9. Punching the hole for the lead-in.

the side cowling, to be sure that the inside is not blocked by door-hinge boxes, frame members, emergency-brake parts, and so on. For example, some GMC trucks, instead of the common fiberboard kickpads, had solid metal panels welded firmly in place, making it impossible to install side-mount antennas. In some cases, this situation was met by installing the entire antenna on the small vertical cowl ventilators, bringing the lead-in through the vent opening. This kind of job is strictly an emergency measure, and is not too highly recommended. (Note: cowl-mount antennas were standard on these trucks.) The best way is to remove the kickpad and make a careful inspection of the inside before drilling any holes. If it is difficult to transfer a measurement from inside to outside, take the long center punch and punch lightly from the inside. The punch marks will show up as dimples on the outside, and may be repunched from that side, to hold the drill. When installing side mounts, always drill the holes; never punch them, as some installers used to do. The punch leaves a hole with large ragged burrs on the inside, which would prevent the proper seating of the parts of the antenna insulators. A smooth-sided hole is absolutely essential. If the inside of the body is coated with a tarry compound, it will help to scrape this off for a distance of two or three inches around the holes to be sure that the antenna gets a good ground.

TESTING AND REPAIR OF ANTENNAS

Troubles actually originating in the antenna itself can be caused by only two things: electrical leakage or shorts, and open circuits. Electrical leakage is usually caused by moisture in the base assembly. This may be from a hygroscopic insulator (one which absorbs moisture) or from cracked insulators. Combinations of the two troubles are quite possible, as are intermittent conditions, the hardest of all radio troubles to locate.

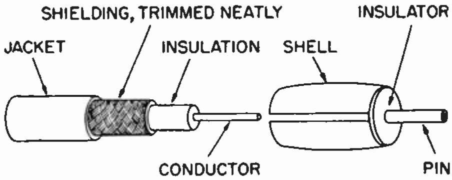


FIG. 10. Lead-in cable prepared for attaching the plug.

Measurements with an ohmmeter will usually catch the first two; the intermittent may be located by listening to the radio, while shaking the lead-in vigorously. Using the insulated handle of a screwdriver, move the antenna rod itself back and forth and listen for popping noises. This simulates the swaying and vibration which the antenna will get while the car is in motion. Best results will be had by tuning the set *off* a station, and turning the volume high.

If any of these tests produce a noise in the set, clean the antenna thoroughly. Take the base apart, scrape all grounding surfaces, clean the plugs and sockets, and check with your ohmmeter for leakage or shorts across the plug. Check the lead-in for continuity by connecting the ohmmeter to each end of the center conductor, and shaking the cable hard. Many times, the center conductor will be open at the set end. These plugs can be replaced or repaired, as we said before. Trouble at the antenna end usually makes replacement of the entire lead-in necessary. You'll usually be wasting time if you attempt to repair the antenna end.

To install or replace the plug on the set end, prepare the shielded cable as follows: With a sharp knife, "ring" the vinyl jacket about one inch from the end, and remove it. Carefully open the shielding braid and cut it off smoothly, leaving about 1/2 inch of the polyethylene exposed. Cut this off *very* carefully with a sharp knife, being careful not to nick the center conductor. Leave about 1/4 inch of the center conductor sticking out. The end should now look like Fig. 10. Clean and tin the end of the wire, and slip the end into the plug. See that the braid shield is tucked neatly into the shell, with no loose wires which might slip up into the plug and cause a short. Note from the cross-sectional view in Fig. 11 that the insulation is jammed tightly against the insulator of the plug itself, to prevent any shorts. Solder the wire to the center conductor of the plug. Make a neat joint, and wipe off any blobs of solder from the outside of the pin. Then very carefully tack the back end of the shell with solder, making a good joint, but being careful not to leave the soldering iron in contact with the cable for too long at a time. The polyethylene insulation used is sensitive to heat, and softens rapidly; if excessive heat is used, the insulation may be softened to the point where it will allow the shielding braid to cut through and short out the lead-in. Solder it a little at a time, allowing the plug to cool several times while making the joint.

If you discover electrical leakage in an antenna, take the antenna completely out. Wash it thoroughly with carbon tetrachloride to remove both dirt and moisture; dry it thoroughly and reassemble it. Recheck for leakage. If you find none, remount the antenna.

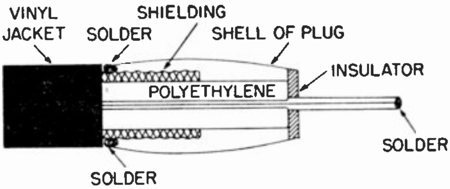


FIG. 11. Cross-section of lead-in cable and set-end plug.

There will be times when there is no apparent defect in an antenna, yet the set refuses to work. Substitute another antenna by plugging it into the set and holding it out the car window, holding it by the insulated base only. If this restores performance, replace the antenna and lead-in no matter how they test!

There are three basic tests which should be made with an ohmmeter on every antenna immediately after installation, and before connecting the antenna to the receiver. They are as follows:

1. Check from tip of antenna rod to pin tip of plug. This will usually be less than 3 or 4 ohms.

2. Check from the antenna rod to the body of the car, using the highest range of the ohmmeter. There should be an absolutely open circuit here; no reading at all.
3. Check from the car body to the shell of the plug at the set end. This should be an absolutely dead short; no resistance at all. Be sure to place the ground prod on a bare metal surface, as paint will cause a false reading.

Resistance between the tip of the rod and the pin of the plug may possibly be due to corrosion between the joints of the antenna, if it is old. Check to the bottom section to be sure. If it is corroded, pull the antenna out to full length and clean it thoroughly, using a scouring compound, until it is bright and shiny. Lubricate lightly with one of the silicone greases, such as Dow-Corning's "DC-4," to prevent re-entry of moisture.

Occasionally you will have to splice the coaxial lead-in cable to give it greater length. This is not difficult if the proper methods are used; but can be very hard if they are not. The correct method is shown by steps in Fig. 12. First, prepare the ends of the two cables, just as you did when getting ready to replace an antenna plug, except that you do not cut off the shielding braid. Strip the vinyl jacket from each cable for a distance of about 1-½ inches, exposing the shield. Fold the shield back over the jacket, exposing the polyethylene insulation. Carefully cut off this insulation about a half inch from the shield. Be very careful *not* to nick the little wire, as this can cause it to break later. Place the ends of the insulation about ¾ inch apart, and make either a good lap joint or a wrap joint in the center conductor. Be sure to make a very clean bright solder joint. Remove all excess solder to prevent making a lump in the conductor. Now, clip off the loose ends of the wire as closely as possible. Next, to make the best joint, go to the set-plug end of the cable, and melt the solder from the pin, permitting the center conductor to come out. Pull on this until the slack is taken up in the splice, and the ends of the insulation are "butted" to-

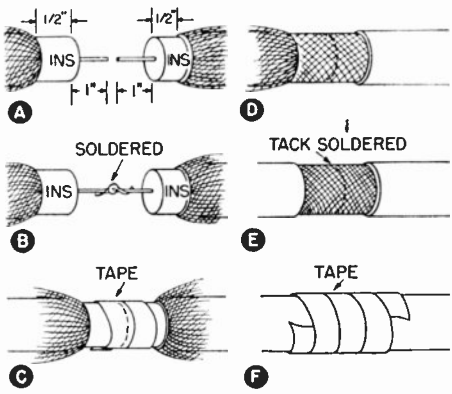


FIG. 12. The steps in splicing a lead-in cable.

gether. Resolder the plug to hold this tension. Do not pull the wire too tight as this will cause future breakage; pull just enough to take up the slack. Wrap one turn only of plastic tape snugly around the splice, over the insulation, fitting it neatly down to avoid a lump. Pull the shielding from one end of the cable down over the splice, laying it neatly and smoothly, then pull the other end over the first. Solder the two shields well; avoid excessive heating to keep from softening the plastic insulation. Clip off stray ends and make the outside shield as smooth as possible, then finish the splice with a double wrapping of plastic electrical tape. This tape will wrap very snugly if a piece of the right length is torn off, held over the soldering iron for a moment to soften it up, then quickly wrapped in place. If neatly done, this type of splice will be as strong as the original cable, and almost invisible.

The last step in any antenna installation is the tuning of the antenna to the set. As we said before, the automobile antenna is very short, and must be resonant for best results. This adjustment matches the antenna to the particular set *and car* in which it is being used. Every set has an antenna trimmer close to the antenna socket, accessible from the outside of the set. It will be labeled "Adjust ant," or "Adjust at 1400 kc." Although some of the very old sets used antenna "padders," capacitors which were adjusted at the low-frequency end of the dial, practically all sets now use "trimmers," capacitors which are adjusted at the high-frequency end of the dial. Tune in a weak station, never a strong local one, somewhere in the vicinity of 1300-1400 kc, and adjust the trimmer for maximum volume. The antenna should be pulled out to the length at which it will be used, and the trimmer adjusted to this height. Although these trimmers are not as "sharp" as some of the other alignment adjustments, still they should normally show a fairly sharp peak. If this antenna trimmer has no effect upon the set's volume, something is wrong. The antenna has a leakage or short, or there is trouble in the front end of the set itself. Substitute another antenna, temporarily, before removing the set from the car, as the trouble may well be here rather than in the set. If the trimmer shows a distinct peak on another antenna, then replace the old antenna.

For the final check, start the car engine and check to be sure there is not engine noise pickup, and the job is done.

Installing the Auto Receiver

Installing an automobile radio is a combination of mechanical and electrical work. Each step must be very carefully done if the set is to play well and the installation is to stand up under the jarring and jolting it must take. Unless this is done, you will have trouble later on. Thorough, careful workmanship is essential, and even the very smallest parts used must meet high standards of quality.

Auto radios receive pretty rough treatment, even in passenger cars, and sloppy workmanship in the installation will show up quickly. Take plenty of time when making any installation. Be sure that everything about the job is well done and well tightened up. Use bolts and screws that will stand up. If there is ever a doubt about which size bolt to use, choose the largest one! Better to have your safety factor a little too high than too low. If you'll follow the highest standards of mechanical work in every part of the installation, you'll never have trouble caused by parts working loose or falling off. Always use lockwashers wherever possible, and make sure all bolts are tight.

There are three basic types of car radio installation—in the dash itself, where all of the custom-built sets are mounted; under the dash, like the small universal sets; and the "firewall-mount" where the set is fastened to the firewall with a separate control head on the dash. These mounts are shown in Fig. 13. Right now, let's look at a few of the fundamentals of installation work.

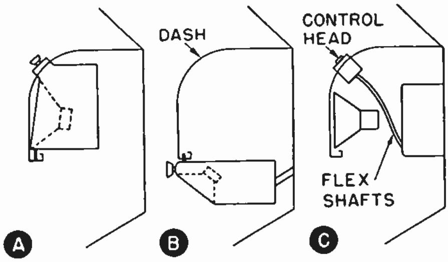


FIG. 13. Three types of receiver mountings. A, dash mounting; B, under-dash mounting; and C, firewall mounting.

The primary requirement of the car radio installation is sturdiness. The set must be mounted so that it will remain tightly in place through all the bumps and bangs it will get. It must be installed within easy reach of the driver so that he can operate the controls without leaning over too far from his position. Once this location is determined, then some way must be found to fasten the set in place so that it will stay there under any circumstances.

Every automobile radio must be supported in at least three places to give the installation sufficient mechanical strength. With the dash-mounted custom-built sets, two points are provided by the control shafts. Long threaded sleeves extend through the dash, and nuts are run down on these to hold the front end of the set. The back is usually supported by a brace fastened to the firewall. Fig.

14 shows a custom installation with three support points—the two control shafts and a brace. Some sets have the controls mounted high on top, with the bottom of the set fastened to the lower edge of the dash; some use long triangular brackets fastened to the back of the dash; some use other types, but the basic principle is the same. All of them provide some kind of three-point suspension. Three points are a minimum; if you can get four points, use them. The stronger, the better!

There are two main kinds of auto radios today. The first is the custom-built set designed to fit into one particular make or model of car, with controls, case design, and mounting made especially for that one model. The second is the universal set, which can be installed in any car, regardless of make or model. You may occasionally have to install a custom-built set in a car for which it was not designed.

Probably the majority of auto radios today are the custom-built sets. Basically, there are very much alike, with the variations for the particular make and model of car, type of dash, etc. All of them are mounted in a hole placed in the dash by the manufacturer. Some use separate speakers; some include the speaker in the case; some sets are made in three pieces, tuning unit, power supply and audio unit, and speaker. With the custom sets, space and mounting fittings are provided for each of these units.

The dial and controls are usually in the center of the dash; the volume and tuning controls are at each side of the dial scale. If push-button tuning is used, the buttons are mounted either above or below the dial scale.

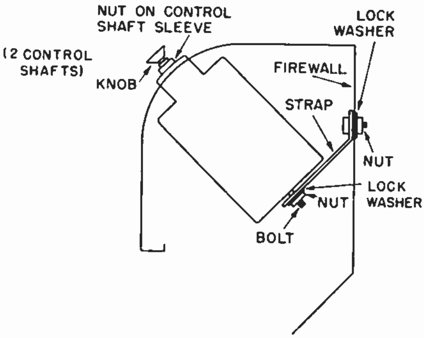


FIG. 14. Typical custom set mounting.

A speaker grille is provided in the dash, sometimes in the center, sometimes at the right side.

The space allotted to the auto radio is often very small, so that the designer has had to make the case in some very unusual shapes in order to get it in at all. Heaters, air-conditioning controls, and other equipment often almost fill up the space beneath the dash, so the car radio man has to take what's left. You will find that you will often have to remove glove compartments, heater controls, and many other parts to get at the radio set, either for installation or service. Unfortunately, there is no remedy for this; you will just have to go ahead and remove them.

This is a point, incidentally, which must be watched when making noncustom installations; always place the radio so that it will be accessible for service if it is at all possible. We'll deal with this in more detail later on.

INSTALLATIONS IN NEW CARS

Probably the easiest type of installation is that of the new custom-built radio in the car for which it was designed. All the holes are drilled, with the exception of the outside hole for the antenna, and a very complete set of instructions always accompanies each set. It is really unnecessary here to go into any great detail on this type of work, but we will give you a few basic hints which should be helpful.

Always follow the instruction sheets very closely; there are reasons for every move. The first thing to do in any job of this kind is to study this instruction sheet.

Unpack the radio, check to see that all parts are there, and then set it up on the bench. Allow it to play while you get the car ready. This is *always* a wise move. If there is any shipping damage or other trouble, it is much easier to find now than after you've finished installing it. Always jar the case heavily with your hand to see if there is any noise. This will show up any loose tubes, bad solder joints, or other defects. Leave the radio playing while you install the antenna.

Control holes in the dash, etc., will be covered with dummy plates. These must be removed first. They are usually fastened with Tinnerman nuts or clips. Often speaker grilles will be covered with heavy fiberboard or cloth, which must be removed before the set is installed. Remember to look for these; if you forget them, the set will have to be removed to get them out!

Quite often, installation work will be easier if you temporarily remove some other parts, such as the glove compartment, even though this is not specified in the instructions. These are almost always made of fiberboard, and are held in place only by small screws at the edges. If the glove compartment is taken out, it is sometimes easier to reach the mounting bolts and brackets. Note: Do not remove the screws holding the latches, as they may be difficult to adjust when replaced.

Let's deviate for just a moment here and talk about tools used in this kind of work. Your tool kit is about the most important thing around the job, except you. Using the proper tools can make a hard job seem easy; using the wrong tools can make even the easiest job seem difficult. The expense of the proper tools will be more than made up by the time saved on installations; the less time required to complete a given job, the more money the installer makes. If you run into a new type of screw or bolt, the best thing to do is to go and get the right tools immediately. If they are not available, make an order out right then for a set of them, so you will have them on hand next time!

In addition to the tools mentioned for antenna installation work, you will find the following tools almost invaluable:

A full set of "nut drivers," 3-inch, 5-inch, and stubby sizes; nut-holding "nut drivers;" screw-holding and right-angle screwdrivers for all types of screws; long-nose and locking-type pliers; heavy diagonal cutters; box and end wrenches (in at least 3/8, 7/16, 1/2, 9/16 and 5/8 inch sizes); Allen and Bristo set screw wrenches for inside hex head screws; a set of "fingers," a flexible tool for retrieving dropped parts and tools.

Now, let's get back to our new car installation. It is best to develop a routine for this kind of work in order to speed it up. For instance, on certain cars, you will remove the dummy plate over the control holes first, then remove the glove compartment, then pull the paper from the speaker grille, then remove the kickpad on the right side to mount the antenna and lead-in, put all bolts, screws, etc., removed, into the glove compartment and set it aside; next, install the antenna, and replace the kickpad; next, the speaker, if it is separate; then the set itself. In some cars, using the two-unit sets, the power supply and audio section, which includes the speaker, *must* be installed first, as the tuning unit blocks the only access to it. When removing these sets, the tuning unit must be removed before the audio unit can be removed.

Some sets use two leads for the "A" or hot lead. One is for the set, and the other is for the pilot light controlled by the set's switch, but connected to the dash-light terminal of the car's light switch. The power lead will always be the one with a fuse holder in it, and is usually connected to the ignition switch or to the fuse block. It may be connected to any terminal going straight back to the car battery, such as the hot wire on the ignition switch, the feed wire of the light switch, the ammeter, etc. New cars will specify which terminal the power lead is to be connected to, usually the accessory bolt of the ignition switch. This is a special terminal on the switch, used only to supply power to the instruments, heater, radio, and other accessories. It is always the longest bolt of the three visible on the back of the switch. It is best to detach the fuse holder lead from the set and connect it to the switch before placing the set in the dash. There is usually more room to work up there before the set is installed.

When the set and speaker are mounted and tightened down, be sure that all plugs and connections are firmly seated and then turn the set on for a test. At this time you should adjust the antenna trimmer for best reception. If the performance of the set is satisfactory, turn it off and proceed with the installation of the noise suppression devices. These will be furnished with the set in a small envelope of their own, and every one should be installed as shown in the instruction sheet. Each one is there for a good reason. If added bonding is specified, and the bonds are shipped with the set, install them exactly as directed. Some makers identify the capacitors by a special part number, because of difference in mounting brackets for different applications. These numbers are usually found on the end of the capacitor itself. Full instructions for their installation will be found in the instruction sheet. Follow these faithfully until you have installed enough sets to memorize them.

It will pay you to make a mental note of the peculiarities of the various cars, too. For instance, Chevrolets of a certain year used nothing but Phillips screws in the whole car, Kaiser used Allen set screws on the control knobs, and so on. If you remember these little things, it will save a lot of time. You'll take the right tools with you when you make the first trip out to the car.

INSTALLING UNIVERSAL SETS

Installing a universal set requires a little more thought, because you will actually have to design the installation instead of having it already done for you. Remember the two big points about this kind of installation and you'll have no trouble; it must be accessible, and it must be sturdy. The controls must be within easy reach of the driver, and the set and parts must be installed so that they will stay there under any circumstances. Both of these points are easily met if a little common sense is used in making the installation.

There are two types of universal sets. One is the small "underdash set" which is intended for installation at the lower edge of the dash, as shown in Fig. 15. Most of these are single-unit sets, with the speaker in the same case. The speaker can be removed, and a larger separate speaker used, if desired to improve the tone and volume.

Some underdash sets are built in a rectangular case so that they can be mounted, using adapter brackets, in the place in the dash provided for the custom set. These mounts are shown in Fig. 16.

The other type is the firewall mounted set. These, which may or may not use separate speakers, are fastened to the firewall, using "J" bolts fastened to the case or mounting plates, as pictured in Fig. 17. Bolts pass through the firewall into the engine compartment, and are held there with large nuts. Controls for these are in a separate control head, which includes the dial scale and pointer, pilot lights, volume and tuning controls, and on-off switch. These control heads are connected to the set itself by flexible shafts, similar to speedometer cables, although much heavier. Special fittings on the ends of these shafts couple them to mating fittings on the controls inside the set.

When selecting the location for the set, always install the control head and shafts *first;* the length of the shafts will then determine the location of the set, as it must be installed where the shafts will reach without too much stretching or bending. The shafts should never be bent with less than an 8-inch radius, and 12 inches is much better. Too sharp a bend will cause them to bind and break.

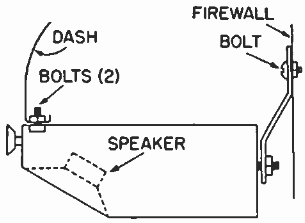


FIG. 15. Underdash mounting.

One simple way, if the underside of the dash is not too cluttered, is to install the control head, then slip the shafts temporarily into place in the set. Next, hold the set in various places on the firewall until a satisfactory location is found. Be sure that the shaft fittings are not obstructed by brake-rods or other parts of the car which will make it difficult to insert and remove them in the future.

To locate the mounting bolt holes, if a drilling template is not furnished with the set, make one from a piece of thin cardboard. Punch out the holes for the bolts. Hold the template in place on the firewall and mark the hole locations. Most cars use an insulating liner made of fiberboard; holes may be easily marked on this with an awl or ice-pick.

Some installers prefer to punch these holes instead of drilling them, punching from the inside of the car with the long center punch mentioned before. This leaves a burr on the outside which acts as a lock-washer. Before drilling or punching *any* holes in a firewall, look into the engine compartment to be sure that you are going to come in a clear space, and not behind, or worse, *through* some part of the car, such as the voltage regulator. The location of the holes may have to be shifted around in order to find a space that is clear both inside and outside.

Try to select a location where the set will be accessible for service and for making necessary connections. One well known make of set has a set of sockets on the side into which the battery, speaker, and pilot light leads are plugged. In some cars, these will be entirely inaccessible after the

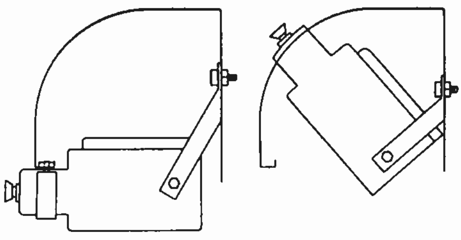


FIG. 16. Two ways of mounting universal sets.

set is installed. In cases like this, make the connections with the set as close as possible to its location, then set it into place and tighten it down.

Large lockwashers should be used on all firewall mounting bolts, and the paint scraped away under them to insure a good ground connection. This connection is usually all the

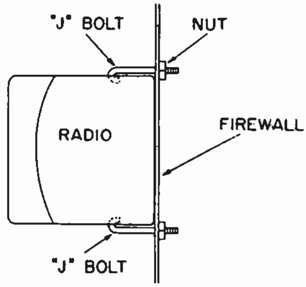


FIG. 17. "J"-bolt mounting to fire wall.

ground return that a car radio of any type has, and it must be a very good one to allow proper operation and freedom from noise.

If you are making an installation in a car different from the one for which the control head was built, try to get a control head which will fit the car. These are usually available for cars up to five or six years old. Older models may sometimes be found in the distributor's stock, but it will be more or less an accident.

The sets using the "J" bolts which hook into slots in the case, may be mounted in two ways: with the bolts on top and bottom, or with the bolts on the ends, so the installer has a choice of several positions which makes the job easier. Two opposite sides of the case must be used, of course. These sets are fairly easy to install. The "J" bolts are inserted in the holes, with the nuts on the outside, and the set hung on the hooks of the "J" 's until the installer can go around to the front and pull them up tight. The nuts should be run down fingertight, and the set then straightened into its final position before the last tightening is done.

The underdash sets may be just a little easier to mount, as they hang under the edge of the dash, and the mountings are a bit more accessible. Most of them have the same type of mounting. There is a heavy strap bracket across the top of the case at the front. This is fastened to the underside of the lower flange of the dash. Then there is a bolt on the back to hold the "back-strap" as shown in Fig. 18. To find the proper position, hold the set under the dash and check the clearance in the back and the accessibility to the driver. Be sure that the case does not interfere with the ventilator lifting handles and other controls. The usual place for these sets is just to the left of the center, with some very few being mounted on the left side of the steering column. This is possible in only a few cars because usually the hood latch and hand brake are in the way.

Hold the set temporarily in place, mark the holes for the front bracket by scratching the paint with an ice-pick, and then punch and drill them. Use No. 8 or No. 10 screws for this bracket, with lockwashers or stop nuts to keep them from loosening up. Next, hang the set up by the front bracket and measure the back-strap. If a new set is being installed, the strap will be quite long and have several holes so that it may be fastened at any convenient place. If the strap is too short, make a new one of heavy sheet metal at least an inch wide; drill holes at the proper places.

In most cases, a hole is drilled through the firewall, and a bolt used. However, if a heavy self-tapping screw is used, it may be inserted from the inside, saving some time. The set should be nearly level, with the controls extending out far enough to be easily reached by the driver.

When you have finished the mounting, grasp the set in both hands and shake it *as hard as you can.* If there is the slightest play or looseness, something needs tightening or changing. The set should be just as solid as the rest of the dash if the job is to stand up. Always use heavy brackets, bolts, and other hardware in order to give the installation enough strength.

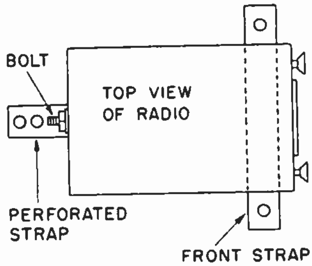


FIG. 18. Using shop-made mounting brackets.

This type of installation may be used with other sets if their shape permits, for example, the custom sets of different cars which are built in shallow boxes. Any of these can be installed under the dash if necessary. Make a flat strap of heavy sheet metal, bending it around the front end of the case. This type of bracket is sketched in Fig. 19. It should be set so that the controls come out far enough for easy access, and be long enough to permit mounting. Leave the two ends A—A just a bit short, so that the top of the case will be pulled up firmly against the bottom of the dash. Drill two holes in the ends and hang the set up in the usual place. For more stability fasten the strap to the case. To do this, remove at least two of the screws in the case which would be under the strap; drill holes in the strap to match, and replace the screws through the strap. If necessary, a piece of thick sheet rubber from an old inner tube can be cemented along the top of the case, between it and the underside of the dash to provide a little shock mounting.

These sets usually have bolts or fittings on the back for the back brace, but if not, the back brace can be fastened to the lids or sides of the case with self-tapping sheet metal screws. Use at least two screws. If no other way is available, the back brace can be fastened to the firewall, brought down to the back of the set, underneath it and up to the front strap, tucked under the front strap, bent over as shown in Fig. 20, and the bend hammered down flat. This should be done before the set is mounted.

Many new sets come equipped with an assortment of brackets, speaker mountings, angle irons, etc., so the radio can be installed in many different cars. Save those left over for future use; they are valuable. Long strips of heavy sheet metal can be found at tin shops. They also are useful and a good assortment of them is invaluable. They should be about an inch wide, and as heavy as possible.

SPEAKER MOUNTING

As we mentioned before, most cars have some sort of grille opening in the dash for a radio speaker. Quite a number of the custom-built sets use separate speakers, which are fastened in place behind this grille with bolts provided on the back of the dash, as in Fig. 21. Most of these speakers are the same size, a 6-inch by 9-inch oval PM, which simplifies stocking problems. We might repeat here that *any* auto-radio speaker can be removed from the case and installed in

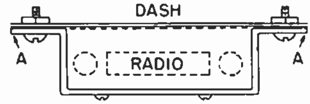


FIG. 19. Shop-made underdash bracket.

this grille. In fact, this is recommended for the firewall-mounted sets and the underdash sets, which often use very small speakers. The sound is much better in the dash grille. Practically all of the speakers used in auto radios are of the permanent magnet type which requires only two wires. Some of the older sets used the "6-volt dynamic" type with a field coil winding which drew about one ampere. If there is any trouble with the speaker, always replace it with a PM, as this saves the one-ampere field drain, and the performance is better.

If there are bolts behind the speaker grille, the job is simplified. The speaker can be fastened to at least two of these, and extension brackets used to reach the remaining bolts. Always get at least three points of suspension on any speaker; this

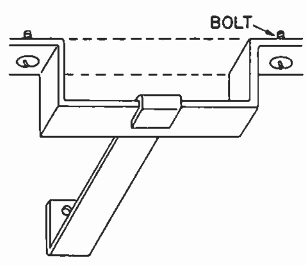


FIG. 20. How back bracket is fastened to front strap.

provides a sufficiently strong mounting to prevent rattling. Speaker mountings must be very tight, or loud sounds will cause vibrations and buzzes. Look out for thin pieces of metal around speaker mountings for the same reason.

Several different shapes of brackets can be used to mount speakers behind a grille. There are the "X" type, the "H" type, and the two vertical braces, to name but a few. This is best left up to your own ingenuity. If there are no bolts near the grille, fasten braces to the under side of the dash, with the top ends fastened to some nearby member.

If the car has no speaker grille in the dash, the speaker can be mounted in some other place with very good results. For instance, put it face downward on a horizontal brace so that the sound comes out from under the dash. Protect the cone with a piece of heavy screen wire such as hardware cloth to keep it from being kicked or otherwise damaged. The kickpads on the sides of the driver's compartment make handy places to mount small speakers. Remove the kickpad, and find a place with sufficient clearance behind it for the field and frame of the speaker. Cut out a hole of the right size and fasten the speaker directly to the heavy fiberboard, using "cup washers" under the screw heads to prevent tearing out. Use a heavy screen and a grille cloth in front of the speaker and it makes a good installation.

In pickup trucks and other heavier trucks, speakers may often be installed in the top of the cab, either over the windshield or even in the corner of the cab, behind the driver's head. Use the same methods of protecting the cone and also use a ring of soft rubber around the rim to protect the driver's head. These rings are furnished with many sets in dash mounting. Speakers may also be installed on the firewall in a suitable metal cabinet. Single mounting bolts are usually used with these, as they are light in weight.

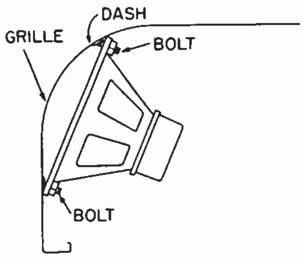


FIG. 21. Grille mounting of speaker.

Speaker wiring can be very simple in the average car. If one side of the speaker voice coil and one side of the output transformer secondary are grounded, only one wire is needed. There is one precaution that must be observed; if there are two wires from the speaker, be sure to connect them with the right polarity. If no sound at all is heard in the speaker, remove these wires from the set and reverse them. The grounded side may have been connected to the high side of the voice coil, grounding it out.

Now, we come to what *can* be the biggest headache of all—attempting to install a custom-built radio in a car for which it was not designed. Some of these jobs are possible, some are impossible. The sets used with the 1940-41 Chrysler-Plymouth, for example, were very long and narrow, with the dial and controls running vertically. The cabinet had a tapered back. Because of this shape, and the location of the controls and dial, it is almost impossible to install these sets in any kind of a car except the one for which they were built. This does not mean any slight to the radio, which was one of the best on the market. It simply means that you

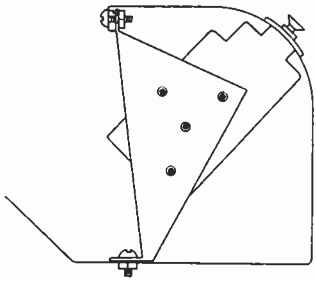


FIG. 22. Special brackets can be used to mount flat-type set in dash.

can't make a decent looking installation in any other kind of car.

On the other hand, many radios are built in such a shape that they are fairly easy to install in any car; they are flat and resemble the universal underdash sets. They can be installed as underdash sets, making a fairly nice looking installation.

One other possibility arises in this connection; the use of either an underdash set or a small universal as a "semi-custom" installation. This means mounting the universal radio in the space provided for the custom set. By using the dummy plate for a front panel, cutting out holes in it to allow the controls and dial to be seen, and remounting it, some very nice looking installations are made. This requires some very careful cutting and fitting, so that the finished installation will be neat, but with care it can be done. Several special brackets will also be needed to hold the set in place. One type of bracket is shown in Fig 22. This type of work will require a lot of extra time and should be charged for, over and above the regular installation fee.

Only experience and "cut-and-try" will determine whether a given set can be installed successfully in any given car. It is far better to refuse some installation jobs than to waste an entire day trying to make an impossible one, so don't be afraid to say "no" if it is necessary. The best way to find out is to try the set in different positions in the car to see whether a successful installation is possible.

In summary, it might be said that there is one tool in the auto radio man's kit which he can't get along without, and that is a large supply of plain horse sense. This, together with the right tool kit and a good share of ingenuity, will make any of these job fairly easy.

The Elimination of Electrical Noise

Radio manufacturers and engineers have made tremendous strides in the last twenty years in the elimination of noise picked up by auto radios. Careful shielding of the set and special filter circuits in the supply leads have reduced pickup by the set itself to almost nothing. The antenna is just about the only path by which noise can enter the set. Noise from the car can be kept from entering through the antenna only by suppressing the noise at its source.

Noise suppression devices have been improved tremendously both in efficiency and in ease of installation. Today, it is possible, by using the proper methods and devices, to eliminate almost all of the electrical noise originating in the automobile. A thorough knowledge of the car's electrical system and equipment, together with an understanding of the causes and remedies for noise, is essential.

There are two major steps in overcoming noise: recognizing it, and removing it. Before a noise can be taken out, it must be correctly identified. Unless this identification is correct, any work done will be fruitless. Therefore, we will go into the actual causes of electrical noise in as much detail as possible. We will also give the proper methods for reducing or eliminating this noise.

Every noise that originates in a car has its own peculiarities that will help you to identfy it. Although some noises sound similar, there are no two actually identical. The characteristic sound of a noise will give you clues as to its location. Noises heard only while the engine is running are obviously connected with the engine. Noise heard only while the car is in motion must be connected with the running gear, and so on.

If you have an automobile that is equipped with a radio, we strongly urge you to use it for practical training. Positive identification of noise is a matter of practical experience. You can gain a great deal of the needed experience by removing the noise suppression devices from your own car, one at a time. As each device is removed, one characteristic noise will be heard.

Many precautions are taken in the design of today's auto radios to make them noise-free. All car radio cases are designed so that the box is effectively a solid metal shield that keeps out noise. There are ventilation openings, but these are so small that they do not offer an entrance for noise. This is the reason for the numerous small screws and spring clips that hold lids on auto radio cases. Not for mechanical strength, but to make the edges of the lids a continous electrical ground. All of these screws and clips should be replaced whenever an auto radio is serviced.

Wires and leads through the case pass through special filters that eliminate noise pulses. The lead to the battery, called the "hot" lead or "A" lead, speaker leads, dial-light leads, and all other wiring must be filtered. The remote control shafts that are used on some sets must be well grounded at the case so that they won't feed noise into the set.

The antenna lead-in cable is a specially designed coaxial cable, shielded to eliminate pickup of noise. The lead-in is connected to the set through a special socket, designed to make a perfect ground for the shield. *Both* ends of this shield *must* be grounded to prevent noise pickup by the lead-in.

The tight case and the shielding or filtering of all leads to and from the receiver make the antenna the only point at which noise can enter the set. Most of the noise is generated by the car and radiated from its parts. The only way to keep the noise out of the antenna is to eliminate it at the source, or to suppress the radiation.

HOW NOISE IS REDUCED

Two types of units are used to reduce radiation. Which one to use depends upon where in the car the noise is originating. There are two types of electrical circuits in a car. One is the spark plug circuits that operate at high voltage but low current. The other is the rest of the electrical system which operates at low voltage and high current. Series resistors are used for suppression in the spark-plug circuits. Shunt capacitors are used on the low-voltage circuits.

Capacitors cannot be used across the high-voltage circuits because they would interfere with the ignition. Resistors cannot be used in series with the high-current circuits because of the large voltage drop that would result.

These series resistors are called "suppressors." The purpose of these resistors is to reduce the amplitude of the noise pulses on the wiring of the car. This action is shown in Fig. 23. Note particularly that the suppressor reduces but does not completely remove the noise pulses. This reduction in most cases is great enough to prevent radiation of noise strong enough to interfere with reception. The hood and metal sides of the car shield the antenna from these low-level noise pulses.

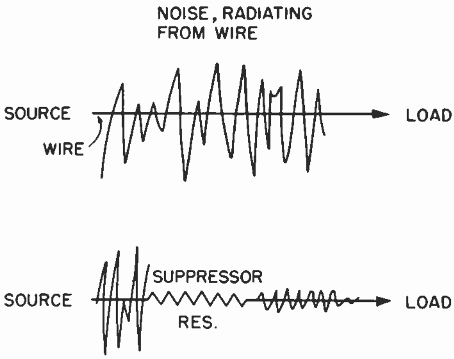


FIG. 23. The action of a resistor as a noise suppressor.

The capacitors used across the low-voltage circuit bypass the noise pulses directly to the car frame. These capacitors prevent radiation of noise pulses by keeping the noise pulses out of the electrical wires. They are generally .5-mfd units rated at 200 volts. They are specially made for this purpose and have strong metal cases with a single heavy lead ending in a spade lug. A second heavy spade lug mounted on the case itself serves the dual purpose of holding the unit in place and making the ground return connection. The case of these capacitors must always be connected to ground. The action of the bypass capacitor in removing noise peaks from the wiring is shown in Fig. 24.

Since every automobile has both high voltage and low voltage, it is almost always necessary to use both suppressors and bypass capacitors. Neither suppression in the high-voltage leads nor bypassing across low-voltage components alone is enough to prevent noise.

NOISE IDENTIFICATION

Let's take up the common noises, one at a time.

Plug Noise. Probably the commonest and most easily identified is "plug noise." This always makes a popping sound; one pop is heard every time a spark plug fires. Although most of this noise originates at the distributor and coil, it is always called "plug noise." Actually the spark at the plug points usually causes very little noise. The metal of the engine block forms a good shield. Cracked or dirty plugs can cause noise.

Plug noise will always vary with the speed of the engine, becoming slower and more distinct at lower speeds. Remember the high-voltage ignition system mentioned in the first part of this lesson, with the coil which built up a very high voltage whenever the points were broken? This causes a very high-voltage pulse to appear across the secondary and the distributor and spark plug wiring system. This voltage has a waveform like Fig. 25A. This is a damped oscillation that dies away because of coil and lead resistance. Actually, all we need to fire the plug is the first one or two peaks, the rest of the wave-train merely makes the noise worse. Therefore, we speed up the decay of this oscillation by inserting a resistor in series with the coil. The resistor dissipates the energy stored in the coil and reduces the length of time the pulse lasts. The resultant waveform looks like Fig. 25B. This reduction in the total time taken up by each wave-train reduces the noise generated, and makes it inaudible in the radio.

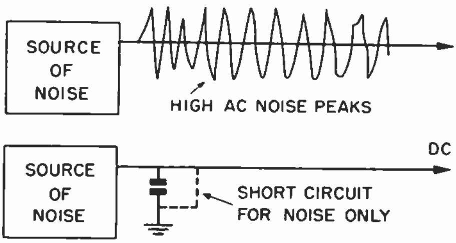


FIG. 24. Bypassing of noise by use of a capacitor.

The resistors used as suppressors are usually carbon units of around 10,000 ohms, although wire-wound or inductive suppressors are also used. These damp out the noise pulses by inductive reactance rather than by resistance, and allow the spark to be a little "hotter."

Although many automobile mechanics used to frown upon the use of ignition suppressors, claiming that it interfered with starting and cut gas mileage, experiments conducted by the U. S. Army several years ago completely disproved this. Vehicles

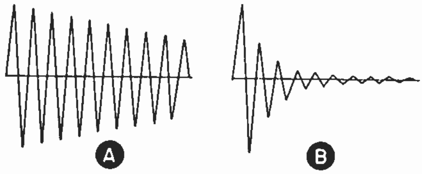


FIG. 25. Ignition waveform A, without a suppressor, B, with a suppressor.

equipped with suppressors were started and operated many times, in very cold weather, with no ill effects on either starting or gas mileage.

Special spark plugs equipped with built-in resistors are available at auto supply stores. In these, the resistor is part of the plug itself. Most common, however, are the separate units, which can be used on any car. The separate suppressors are built into Bakelite tubes, with fittings to accommodate the various connections used on spark plugs and spark-plug cables. One end of the suppressor fits on the spark-plug terminal in place of the cable. The cable fits on the other end of the suppressor.

There is another suppressor made to use at the distributor. A single unit is installed in the lead from the high side of the coil to the center terminal of the distributor cap. Some of these can be plugged directly into the socket in the cap and have a socket in the other end for the cable. There is also the "cable" type of suppressor, shown in Fig. 26. This has a socket on each end. The wire is cut, and the two cut ends are screwed into the sockets, where they are held in place by a threaded center post. Both types are simply series resistors.

All that is needed on most cars is a distributor suppressor, and this should be tried first. Then if the plug noise will respond to no other treatment, install a full set of suppressors.

When installing a special short-wave radio operating on the 19 and 25 meter bands, the use of spark plugs with built-in resistors will probably be necessary to get the engine quiet enough at these frequencies. The length of the spark plug leads makes them resonant at around 30 mc. Therefore the radiation is stronger around these frequencies than on the broadcast band.

To check and eliminate plug noise, first start the engine and turn on the radio. If the characteristic popping noise is heard, varying in speed with the speed of the engine, and stopping when the engine is stopped, it is plug noise. Install the suppressor in the center lead of the distributor, as in Fig. 26, close the hood, and recheck. If reduction in the noise is noted, good; if not, more measures must be taken. Always close the hood when

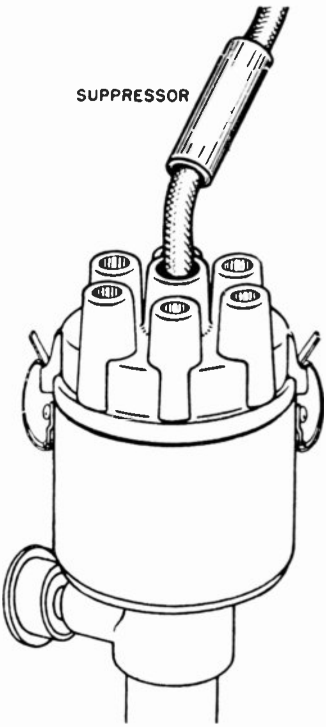


FIG. 26. Where a distributor suppressor is installed.

making noise checks. Otherwise, the shielding of the metal hood is not effective and it will be impossible to eliminate the noise completely.

If the plug noise is only partially removed by the distributor suppressor, install a full set of plug suppressors and retest. If the spark plug suppressors do not help, remove them.

Occasionally the distributor suppressor and the plug suppressors do not remove all the noise. In such a case, install a bypass capacitor at the battery terminal of the coil as shown in Fig. 27.

One good test at this point is to pull the antenna plug out of the set and recheck for plug noise. If you still hear it, it is entering the set through power leads or other leads. Install another bypass capacitor at the point where the power supply lead connects to the ignition switch or ammeter. Noise heard with the antenna out is known as "chassis pickup," and must be completely eliminated before any further work can be done. If there is still noise after you have taken these measures, you should have the ignition system gone over by a mechanic to see if the wiring is in good shape, point and plug clearances are correct, etc. If plugs are fairly old, replacing them with a set of resistor plugs will help immensely in stubborn cases. This, as with *all other* noise work, is just a matter of eliminating possibilities. If you suspect some part of being the source of the noise, check it, apply suppression devices if needed, then go on to another part. Do not be discouraged if the noise fails to respond to the first treatment; keep on working and you'll eventually get it.

Generator Noise. Noise coming from the generator has quite a different sound; it originates at the brushes on the commutator and therefore has the familiar "electric motor" sound. This is a high-pitched whine, which changes somewhat in pitch with the speed of the engine. The quickest test is to install a capacitor across the armature terminal of the generator. This should eliminate almost all of it. If the generator is old enough to have a cutout on it, install the capacitor on the battery side of the cutout; if it is the more familiar modern voltage-regulated generator, be sure to install the capacitor *only* on the lead going to the armature. You can easily identify this lead; it is always the larger wire of the two; the other goes to the field. The field terminal usually has a small paper collar around it, warning against connecting radio bypass capacitors to it. Doing so would upset the action

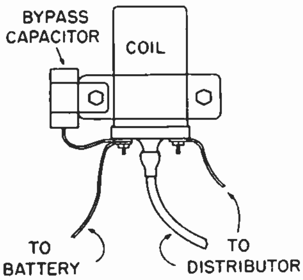


FIG. 27. A bypass capacitor is installed on the *battery* side of the coil.

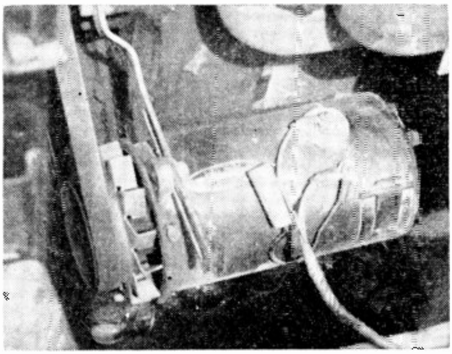


FIG. 28. A capacitor installed on a voltage-regulated generator.

of the voltage regulator. Install the capacitor as shown in Fig. 28. If generator noise persists after you have installed the capacitor, have the generator checked by a good mechanic. If the generator is in proper operating condition, one capacitor should eliminate all interference from this source.

Voltage Regulator Noise. A noise quite similar in sound to plug noise can originate in the voltage regulator. The three relays in this unit can cause a popping sound which, to the untrained ear, sounds like plug noise. However, it can be positively identified by two things: its irregularity and the fact that it is not heard at a slow idling speed, whereas plug noise is most apparent at this speed. Very gradually speed up the engine, watching the ammeter or charge indicator. If the noise appears at the same time that the ammeter begins to show a charge, you know it is originating in the voltage regulator. To correct this noise, connect a bypass capacitor across the "BATT" terminal of the regulator. There will be three terminals on the box; they are marked "BATT" for battery, "FLD" for field, and "GEN" or "ARM" for generator armature. A typical installation is shown in Fig. 29. The mounting lug of the capacitor can be fastened under one of the screws holding the regulator case, and the lead brought around to the "BATT" terminal. If the noise is reduced, but not eliminated, have the regulator checked by a good mechanic. Let us remind you once again, never connect a bypass capacitor to the field terminal.

Front-Wheel Noise. Some hard-to-find noises can originate in other parts of the car. One common trouble is "front-wheel" noise, which means just what it says. While the front wheels are rolling on pavement or asphalt, they will generate small static charges. If the grease in the front hub momentarily insulates the wheel from the rest of the car, then makes contact again, this static will discharge into the body of the car, causing a small pop in the radio. This is never heard on gravel or dirt roads, and seldom on wet roads.

The test for this is very simple. Take the car out to a smooth stretch of road with no traffic, and run it until the noise appears. This will be a sort of sharp "scratch, scratch" noise, varying with the speed of the *car*, not the engine. When the noise is heard, cut the ignition, and put the car out of gear, allowing it to coast

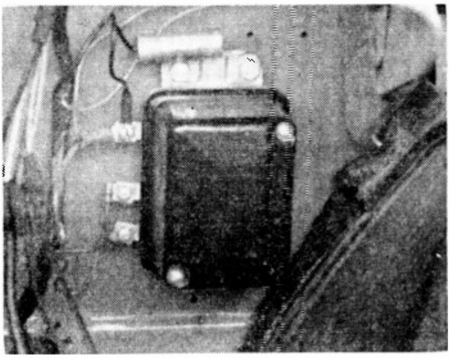


FIG. 29. A capacitor is connected to the "Batt" terminal of the voltage regulator.

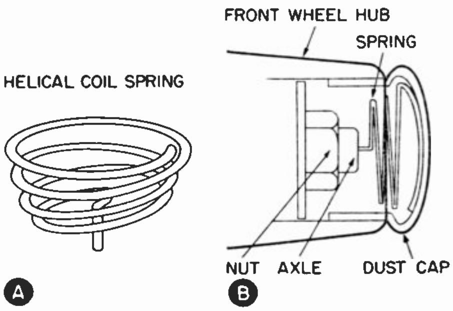


FIG. 30. Front-wheel noise eliminator and how it is installed.

to a stop. If the noise becomes slower and slower, vanishing entirely when the car stops, or if it stops when the brakes are applied, it is definitely front-wheel noise. (When the brake-shoes are applied, they ground the wheels.)

The cure for front-wheel noise is easy. Remove the front hub caps, and also the small grease caps over the ends of the front spindles. Inside the grease caps, install a set of grounding springs made for the purpose. These ground the front wheels at all times and prevent the build-up of the static charge. Be sure to put them so that the point of the spring is centered firmly in the "lathe center" of the front spindle. This is the small pit in the end. This is shown in Fig. 30.

A noise similar in nature to front wheel static is caused by static being built up in the front tires. If the grounding springs do not eliminate this noise, use a special applicator and blow a graphite powder into all the tires between the casing and the inner tube. The graphite spreads around the inside of the tires, and provides a leakage path for the static charges before they can build up.

Noise from Fuel Gauge. A noise with somewhat similiar characteristics is caused by the gasoline gauge. Although it gives a very similar "popping" sound when the car is in motion, it will also be heard if the body of the car is jarred with the ignition switch turned on, the car standing still, and the engine dead. If the "scratch" is heard whenever the body, and more especially the rear bumper, is jarred, suspect the gas gauge. To eliminate this, connect a bypass capacitor to the tank unit of the gauge; never to the meter on the dash. These are usually fairly accessible. They are under the trunk floor on most passenger cars, and under the front floor boards on pickup trucks. The unit itself will be a small round gadget, with a single wire running to an insulated terminal in the center Attach the pigtail lead of the capacitor to this terminal, grounding the case under one of the screws around the rim of the unit. This is shown in Fig. 31.

Clock Noise. Another instrument which can cause noise is a self-winding electric clock. One tiny pop every few seconds is the sound. This condition is corrected by connecting a bypass from the clock terminal to ground.

On some of the cars, electric oil-pressure gauges, temperature gauges, etc., feed noise into the radio by allowing it to travel up their wiring from the engine compartment. Connect bypass capacitors temporarily across the units in the engine com-

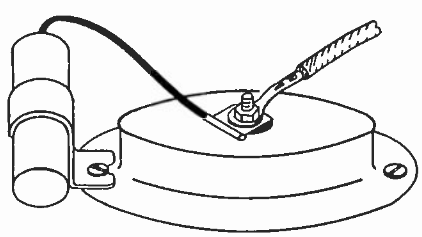


FIG. 31. Capacitor installed on a fuel gauge.

partment to check this. Control shafts, choke rods, etc., coming from the engine compartment, may also have to be bonded to the chassis, using small shield-braid, fastening it down well on each side. Wrap one or two turns of braid around each shaft.

Damaged Antenna. A somewhat unusual noise can originate from the antenna itself if it has been damaged. If the small metal ball or plastic bead has been lost, the anenna may have a "corona discharge," causing a very peculiar noise in the radio, ranging all the way from a low muttering noise to a loud, unearthly screech, like a dozen banshees. This varies at different speeds. If you hear this, check the antenna to see if the corona ball is missing. If it is, replace it with a common plastic bead or button about 3/8 inch in diameter. Make a hole in the bead, jam it onto the antenna tip and fasten it in place with plastic cement.

Checking for Noise. When hunting noise, be very careful when making diagnoses; it is quite possible for even the experienced technician to be fooled by similarities. One expert sat in a car for over a half hour, attempting to eliminate what was apparently a bad case of plug noise, a slow popping sound, perfectly synchronized with the speed of the slowly idling engine. After none of his remedies had any effect whatsoever, he shut off the engine in disgust, and then, to his surprise, heard the noise continue, unaffected! It was an outside electrical noise, being picked up by the sensitive receiver. He had neglected to make one vital check; he hadn't speeded the engine up. Had he done so, he would have noted that the noise was not affected by engine speed, and hence was *not* connected with the car! Moral: never overlook any test, no matter how simple, that will lead you toward making the correct diagnosis of any noise trouble.

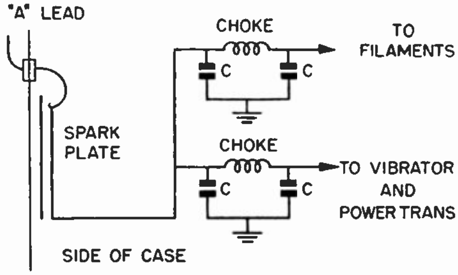


FIG. 32. "A" lead noise filters and spark plate.

This is like many other branches of electronics work, 90% diagnosis and 10% execution. Always check and recheck everything, then make your diagnosis. (Then check that, too!)

If all other remedies fail when applied to the car, and especially if the radio itself is fairly old, it would be wise to check the noise-elimination circuits in it, and possibly to add one or two. Most sets have these filters. If they are *not* there, then they should be added. It is not too difficult. Capacitors used are .5-mfd, 100-volt rating, and are made in a special oval shape which is easier to place in crowded chassis. Chokes may be wound of No. 14 enameled wire, tied with string and coated with plastic cement or coil dope. Spark plates may be purchased or made up out of sheet metal and "fish-paper" Teflon or mica. You will see how to connect these in Fig. 2. We recommend that at least one choke and two capacitors be used in both the vibrator and filament circuits, as shown in Fig. 32. Dial-light leads, speaker leads, etc., may have small mica or ceramic bypass capacitors connected at the point where they leave the case. These should be about 250 mmf in capacity, well grounded, and with leads kept as short as possible.

For a final check, see that all bolts holding the set are very tight, with the paint or insulating material scraped from under them. See that all parts of the car, such as hood, front fenders, instrument panel, etc., are well bonded; some unusual cases of noise have been traced to sources like this.

Noise elimination will be easy if you will take the time to become thoroughly familiar with both the causes and remedies of all types of noise, and never hesitate to check any diagnosis, even your own.

Lesson Questions

Be sure to number your Answer Sheet 41B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of lessons before new ones can reach you.

1. What part of the automobile ignition system causes the greatest amount of interference?

2. Where should the antenna lead-in shield be grounded?

3. What electrical change is made in the long lead-in for rear-fender antennas to prevent detuning the receiver front end?

4. What is the purpose of the antenna trimmer adjustment on an auto receiver?

5. Which type of antenna is stronger mechanically: cowl-mount or side-mount?

6. What is the smallest radius that should be used for bends in control cables?

7. What is the advantage of punching small mounting holes with a ½" diameter center punch? When should this method not be used?

8. When noise is found in an auto receiver, what must be done before the noise can be taken out?

9. How can "plug noise" be distinguished from other popping noises?

10. How can you determine whether noise is entering a set through the power leads?

DOING THE IMPOSSIBLE

To a vast number of human beings, the term "impossible" is like a closed gate, barring the path that leads to a more satisfying life. They turn away from the "impossible" without the slightest attempt to find out just *why* a particular accomplishment has this awful word attached to it.

"Impossible" is applied in the majority of cases simply because *nobody has done that particular thing before.* The history of science is full of thrilling examples of men doing the "impossible"—the steamboat, the airplane, the radio, and many, many more. Naturally, brilliant men were responsible for doing these things, but more important is the fact that they refused to believe in the "impossible." They were determined to find out *really* why it had not been done and *how* it might be done.

This is the approach to the "impossible" that works not only in science and invention, but in bringing to all of us the satisfactions we seek in life. When you believe the "impossible" is not a closed gate but a challenge to you to achieve and move forward into new fields, then you are a man marked for success.

J. E. Smith

SERVICING AUTOMOBILE RECEIVERS

42B

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

Study Schedule No. 42

For each step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. The Auto-Receiver Power Supply .... Pages 1-13

In the first part of this book you learn about vibrator power supplies and how to service them.

☐ 2. Part Replacement .... Pages 14-23

Auto radios are better made than home receivers. Here is a discussion of the best ways to maintain the best operation.

☐ 3. Preventive Maintenance .... Pages 24-27

This section tells you how to avoid "call-backs" on service jobs.

☐ 4. Testing the Radio in the Car .... Pages 28-31

Tests and repairs that can be made without removing the set from the car.

☐ 5. Removing the Radio .... Pages 32-33

Here are some hints to help you in this part of your work.

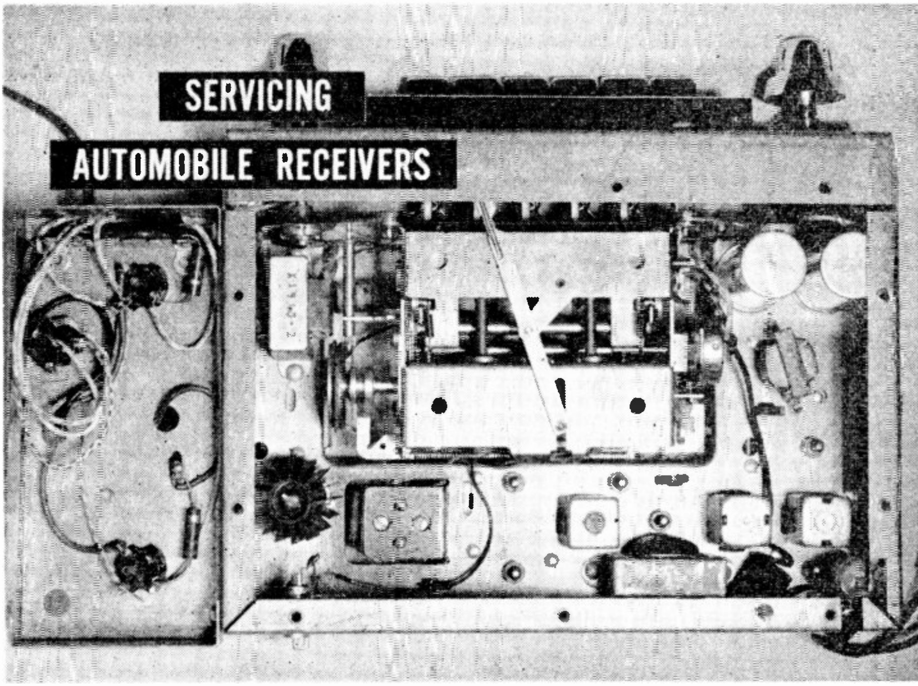
☐ 6. The Auto Radio Service Shop .... Pages 34-36

How to equip your shop and bench so you can do the fastest and best work the easy way.

☐ 7. Answer Lesson Questions.

☐ 8. Start Studying the Next Lesson.

FM5M1159 **1960 Edition** Printed in U.S.A.



The Auto-Receiver Power Supply

One of the main differences between automobile radios and home radios is in the power supply. All of the power used by the auto radio must come from the car's battery. Let us see what problems this brings up.

To operate a radio receiver, we must furnish two operating potentials, the filament voltage and the plate voltage. The filament voltage, and in transistor sets and some sets with specially designed tubes, the plate voltage, can come directly from the car's battery, but usually we need a plate voltage of 150 to 250 volts dc. Getting this high voltage from the low voltage of the battery offers the major problem in auto-radio design.

As you have learned, we step up voltage by using a transformer. However, the car's battery furnishes dc, and there is no such thing as a dc transformer; a transformer can operate only on ac. If we are to step up the low voltage, we must use a transformer, so we must furnish some kind of ac to make it operate. Some of the very earliest auto radios used a dynamotor, a small self-propelled dc generator, for this purpose. They were noisy, expensive, and hard to repair, and soon gave way to the system we are about to outline.

As you have learned, the *change* in magnetic flux linking the two windings

Courtesy Philco Corp.

of a transformer induces a voltage in the secondary. Therefore, if we can make the dc change in the primary, we will have the changing magnetic flux

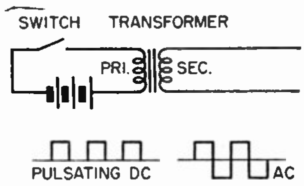


FIG. 1. Using a switch to give pulsating dc in a transformer primary.

that is necessary to induce a voltage in the secondary. All right, let's make it change. The simplest way is to make and break the circuit, causing the current to flow in pulses, as in Fig. 1. This is a changing current, building up to a maximum, then collapsing to zero, then building up again. Because of this changing flux, ac is induced in the secondary, with a voltage step-up determined by the turns ratio from primary to secondary. Thus we can get any voltage we need from this secondary, and it will be ac, which re-

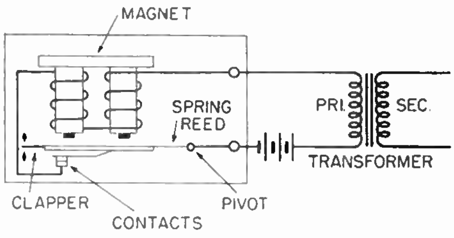


FIG. 2. A modified doorbell used with a transformer to produce ac in the secondary.

verses its direction of flow each half cycle.

We can take a doorbell and connect it in series with our primary winding, as shown in Fig. 2. When the circuit is closed, the arm will be drawn toward the magnet. This opens the contacts, or points, and breaks the circuit through the magnet coil and transformer primary. The loss of magnetism lets the clapper arm spring back and close the points again which causes the cycle to be repeated. We have made the primary current pulsating dc by interrupting its flow at a regular rate.

If we put the doorbell in a metal can, and installed a plug on the base, what we would have is a car radio "Vibrator." There are many different types and makes of vibrators, but no vibrator is anything but an automatic switch.

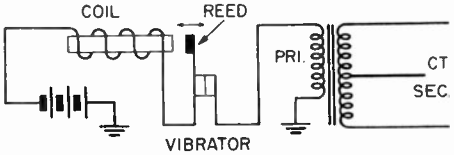


FIG. 3. Early interrupter-type vibrator power supply.

So far, we have followed in the footsteps of the designer of the first vibrator-type power supply. Now let's go into the improvements which were made, until we get to the types in use today. The first sets actually used a vibrator which was just what we described—a doorbell in a can. It had only one set of points, which merely interrupted the primary current as shown in Fig. 3. Current flowed in one direction through a single winding on the primary, although the secondary was center-tapped like the power transformers used in ac sets. This was not too efficient, so improvements were made.

Next came the "reversing" vibrator

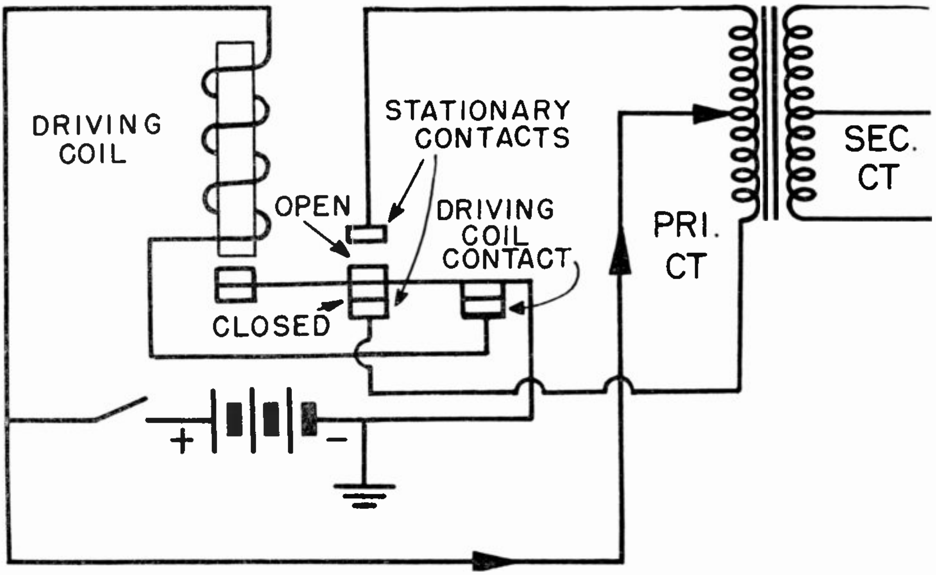


FIG. 4. Typical modern vibrator with center-tapped primary.

of Fig. 4, which was used with a center-tapped *primary* winding. The battery was connected to the *center* of the winding and the vibrator reed grounded first one end, then the other, of the primary winding, so that the current actually reversed direction in the primary. This added to the efficiency of the transformer. The collapsing magnetic field around one side of the primary was in phase with the increasing field around the other side. This permitted the design of smaller, more efficient transformers, with lower heat losses.

MODERN VIBRATORS

Let's pause here for a moment and take a look at the modern vibrator shown in Fig. 5. It is basically just like the one which we just described, but the appearance varies with different manufacturers. Each has the same parts: 1, the frame; 2, the driving coil and driving-coil contact; 3, the armature "reed", which carries the moving contacts; 4, the stationary contacts, on smaller reeds; 5, the "stack", which consists of insulators and plates bolted together to hold the whole assembly in rigid alignment; and 6, the base, which is the part that is plugged into the socket.

One full cycle of vibrator operation is something like this. When current is applied, it flows through the driving coil, through the "driving coil contact", and on through this to ground. The magnetic field set up in the coil pulls the flexible reed away from its resting position, toward the coil, as in Fig. 6A. The small bit of iron on the end of the reed is placed there to aid in this action, and also helps to set the speed of the vibrator. When the reed leaves its resting position it breaks contact with the driving coil contact, breaking the circuit to the coil. The magnetic field collapses, releasing the reed which springs back toward the resting position. When the reed is pulled toward the coil, it makes contact with the stationary contact on that side; when it is released, its momentum carries it back *past* the resting position,

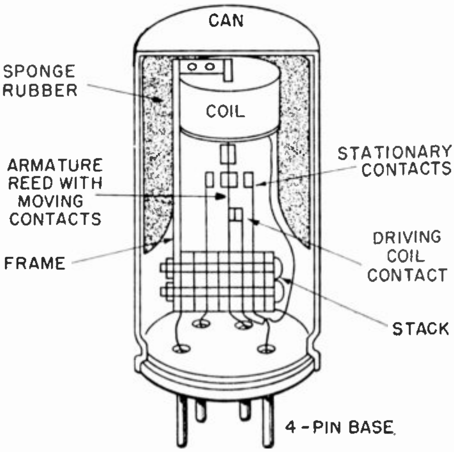


FIG. 5. A modern vibrator.

until it has made contact with the stationary contact on the other side, as in Fig. 6B. Thus, in one full swing, the reed has alternately grounded the two ends of the primary winding. The primary current has started to flow first in one direction from the center tap through one half of the primary winding to the grounded end, then been forced to reverse its direction by the action of the vibrating reed and flow from the center tap through the other half of the winding to ground. This cycle is carried on until the circuit is disconnected.

The original vibrators, as we said, had the battery "hot" wire going to the reed, which merely broke the current in the primary at regular intervals. The vibrator just described is typical of interrupter-type vibrators in use today. These will be found in almost all the commercial auto radios. A conventional full-wave rectifier tube and filter system is used with these, just as in the ac radios for home use. The complete high voltage supply circuit is shown in Fig. 7.

There is one other type of vibrator and power-supply system, rarely used in the auto radio today, but found quite often in the two-way FM radio receivers used for communications work. This is the "synchronous", or "self-rectifying" vibrator. Its characteristics and circuitry differ somewhat from the "non-synchronous" type we have just studied. We can get dc for our plate supply voltage by changing low-voltage dc to high-voltage ac and sending it through a full-wave rectifier and filter system. We can also make the vibrator do its own rectify-

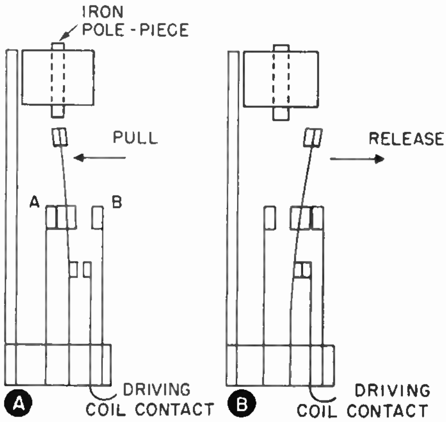


FIG. 6. Pull and release positions of a vibrator reed.

ing with the proper connections, hence the name "self-rectifying".

If we add an extra pair of contact points to the reed of our vibrator, which will connect alternately to the two ends of the secondary winding, we

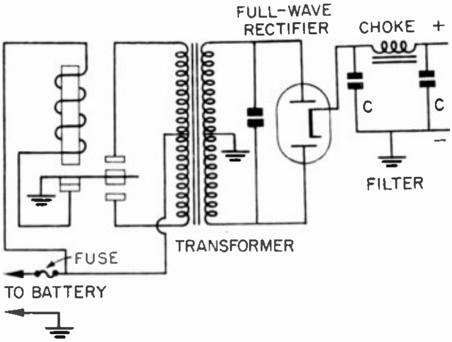


FIG. 7. Complete vibrator B+ supply.

can cause the current in the *secondary* circuit to flow in the same direction all the time. Because we reverse the secondary winding each time the reed moves, all the high-voltage pulses in the output will have the same polarity with respect to ground. This is shown in Fig. 8.

In the interrupter type of vibrator supply, the vibrating reed sets up an alternating magnetic flux around the primary of the transformer. This alternating flux induces the voltage in the center-tapped secondary. The alternating voltage in the secondary is rectified for use on the plates of the receiver tubes. The polarity of this rectified voltage is determined only by the polarity of the rectifier. The polarity of the battery voltage cannot affect the polarity of the output voltage.

In the self-rectifying vibrator supply, the reed position determines which half of the secondary is conducting. Remember that voltage is induced in both halves of the secondary at all times. Therefore, if one end of the secondary is connected to ground, the polarity of the center tap with respect to ground will be determined by the polarity of the induced voltage in that half of the coil. This polarity in turn is determined by the polarity of the current in the primary. If the battery polarity is reversed, the primary current will be reversed and the center tap polarity will also be reversed. If the center tap becomes negative, reverse polarity will be applied to the filter capacitors Since these are electrolytics, the reverse voltage will ruin them.

We want the center tap of the secondary winding to be positive with respect to ground. Some cars ground the positive battery terminal, others the negative. Since the battery polarity cannot be reversed, the vibrator wiring must be. If the secondary center tap is negative in any car, we can change its polarity by reversing *either* the primary or the secondary leads at the vibrator. This may be necessary when installing or testing this type set. Reversing both sets of leads will not change the polarity.

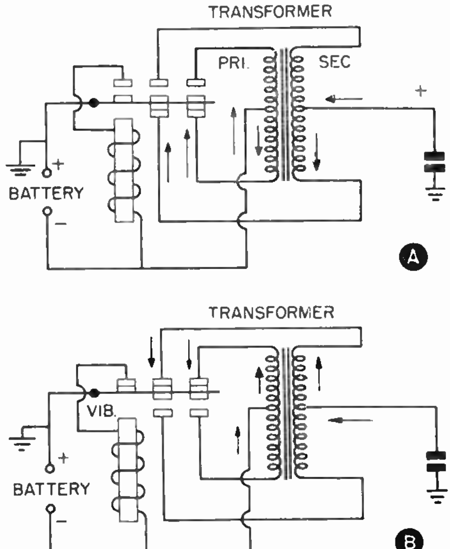


FIG. 8. Operation of a self-rectifying vibrator supply.

The names "synchronous" and "non-synchronous" are derived from the fact that the primary and secondary points of the synchronous type *must* open and close *exactly* in step ("in synchronism") with each other. One direct and positive clue to the type of vibrator used in any set is the presence of a rectifier tube such as a type 6X5, 6X4, OZ4, 84/6Z4, etc., in the tube lineup. If one of these tubes is used, the vibrator is a non-synchronous type, and the battery polarity is unimportant.

Vibrators, in auto radios today, all use the same base connections; in the early sets, there were as many different base connections as there were manufacturers, and vibrators made for one set would not work in another. Standardization has helped this problem tremendously, and all late model sets use the same type vibrator. The base of the 6-volt vibrator has four pins, two large and two small; the 12-volt vibrators use a three-pin base. Modern vibrators use a standard frequency, 115 cycles per second, although there are some few special types made for use in public address systems, and to run phonomotors and tape recorders, which have a 60-cycle frequency. The use of 115 cycles results in a ripple frequency of 230 cycles at the output of the rectifier. This higher pitched hum is fairly easy to identify, and comparatively easy to filter.

THE BUFFER CAPACITOR

One very special part, found only in vibrator-type power supplies, and responsible for a good deal of trouble, is called a "buffer capacitor". Whenever we break a circuit carrying a heavy current, we get a small arc across the contacts. This arc can cause burning of the contact points because of the high temperature it generates. Therefore, we must provide some means of getting rid of it. We can do this by connecting a capacitor

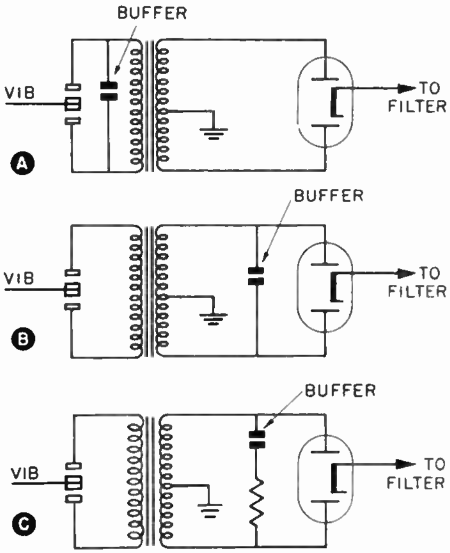


FIG. 9. Methods of connecting buffer capacitor.

across the primary of the transformer. This will absorb the surge produced by the collapsing field, thus eliminating the arc. The capacitor also aids in building up the efficiency of the circuit. It discharges through the primary, helping to build up the magnetic flux. This is shown in Fig. 9A. To keep the capacitor small, the circuit in Fig. 9B is usually used in 6 volt sets, and the circuit in Fig. 9C is most common in 12 volt sets.

From these circuits, you might ask,

"If that capacitor is supposed to be connected across the primary, what is it doing way over there in the secondary winding?" Well, there's a very good reason for it. Any transformer is an impedance-transforming device. It can make a small impedance appear large, or a large impedance appear small, depending on the turns ratio. The impedance transforming action of the transformer makes a comparatively small capacitor across the sec-

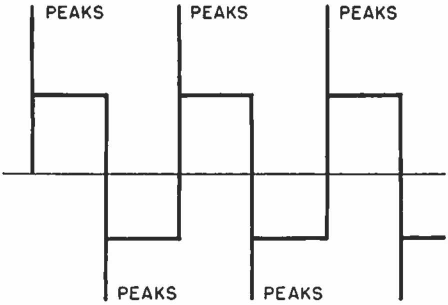


FIG. 10. Waveform across transformer secondary.

ondary look like a very large one to the primary. The secondary, primary, and the buffer capacitor form a resonant circuit for the frequency used in the power supply. Thus, the small buffer capacitor across the secondary can actually do the work of a very large one across the primary. The lone disadvantage of this type of circuit is the very high voltage requirement of the buffer capacitor. Because of the enormously high peak voltages found in the secondary circuit, capacitors with a voltage rating of at least 1600 volts *must* be used. The temporary peak values ("transients") of the waveforms shown in Fig. 10, will reach values as high as 1200 to 1500 volts. Special oil-filled capacitors are needed to withstand the high voltage. Always use this type for replacing buffers. More about these transients later on, when we get into the use of the oscilloscope.

The transformers themselves have become highly standardized in design; so much so, that they would be interchangeable if it were not for the physical dimensions of different sets. Many of them are "potted", that is, sealed up in a can filled with a tar-like compound, to increase their immunity to damage from moisture. Actual trouble with transformers is very rare; suspect them only after everything else has been tested.

We have gone into a good deal of detail about this part of the circuit because this is one place where you must be thoroughly familiar with the fundamentals. A very large percentage of the trouble encountered in auto-radio service work will be traced to the power supply, and a good understanding of it is very essential. The most common troubles will be bad vibrators, weak or dead rectifier tubes, leaky or shorted buffer capacitors, bad filter capacitors, and switch troubles.

Testing of vibrator and power supply performance is vital to good service work. You must familiarize yourself with the symptoms of proper and improper operation, so that you will be able to reach the correct diagnosis. Fortunately, most of these troubles will give you unmistakeable symptoms, and a little practice will enable you to recognize them immediately.

Testing for trouble in auto radios should follow a set pattern, and the tests should be made in a logical order.

The essential things must be checked first. If the power supply were defective, it would be of no use to test the tubes. A good sequence to follow would be something like this: Power supply, including the fuse, the vibrator, and rectifier tube; the tubes, speaker connections, volume control; then the speaker and antenna.

If the fuse is blown out, something has caused it to blow. Obviously, this is a short circuit, but it may have been momentary. This could have been caused by a vibrator stuck because of old age. The points can stick, blow the fuse, and then release, due to jarring of the car. To test for this, remove the vibrator, and turn the set on. If the pilot light and filaments light up, replace the vibrator with a new one. If this restores normal performance, the vibrator was at fault. If the new vibrator runs "roughly", and the set does not play, then there is something else wrong. These symptoms should immediately lead you to suspect a leaky or shorted buffer capacitor. Shut off the set and pull the rectifier tube, then take three readings at the tube socket with an ohmmeter. Read from ground to each plate, A to G and B to G in Fig. 11; these readings should be within 5% of each other and run about 300 ohms. Now read from plate to plate; this should give you the sum of the two previous readings, or around 600 ohms. If you read anything less than the sum of the first two readings, the buffer is shorted, and the set must be taken out of the car. This test will show up a shorted capacitor, but not a leaky capacitor. The only way to test for leakage is by substitution.

When replacing buffer capacitors, always use the same capacity as the original. As we mentioned before, this capacitor is chosen so as to be resonant with the transformer at the vibrator frequency. Never use a capacitor with less than a 1600-volt working rating. There is a certain amount of tolerance or variation allowable; however, it is pretty small. For instance, a buffer of .0075 mfd could be replaced with a .008, but not with a .006 or .009; these would be too far away from the original size. If you must miss, miss in an upward direction; use the nearest larger size available.

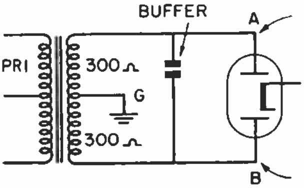


FIG. 11. Testing for a shorted buffer capacitor.

There is another complaint common to vibrator power supplies, with similar symptoms, but a different remedy. This is due strictly to old age. If a vibrator refuses to start buzzing until the set is jarred, but seems to run normally once it does start, it has aged to the point where it should be replaced. The points are dirty, and do not make contact until some mechanical jar causes them to. This vibrator is very likely to cause trouble with intermittent blowing of fuses as the dirty points may stick.

The sound of a normal vibrator is a smooth even buzz, and this is one of the sounds that a serviceman must learn to recognize. It will tell you more things in a few seconds than any other single test you could make. For instance, if the vibrator has a good smooth buzz, but the set remains dead, it is very likely that there is trouble somewhere else, such as a dead tube or bad speaker. The power supply is quite likely to be good, except for the possibility of a dead rectifier tube. However, this sound tells you immediately that the following parts are all right, and need no further checking: the fuse, the switch, the vibrator and probably the filter. All service work is a process of elimination; the normally operating circuits can be passed up, and the trouble sought elsewhere.

VOLTAGE AND CURRENT DRAIN TESTS

Voltage measurements in an auto radio receiver are exactly the same as in any other radio. All operating potentials should be checked as the very first step. Begin at the rectifier for the maximum high voltage. In the average auto radio, this will be from 150-250 volts. Next, the plate and screen voltages should be checked. Begin with the power output tube, and check all the way back to the rf stage. Any deviation or absence should be checked and corrected before proceeding. Many times this will reveal the trouble immediately, as most of the troubles, outside of dead tubes, lie in the loss of the proper operating voltages.

If the high voltage is more than 20% off at the rectifier cathode, try substituting a new rectifier tube. Many times a rectifier will test good in a tube tester, yet fail to deliver normal output in a set. This is not due to any fault of the tube tester, but to the fact that the tester does not load the tube down as heavily as the set. Replacement is the best test.

If this fails, test the buffer capacitor with an RC tester or by substitution. It may have a high-resistance leak, which is just enough to pull the high-voltage down. Your test ammeter will be invaluable here. Check the total current drawn by the set, and compare it with what you know to be normal, for a set with this number of tubes. For the average 5 or 6-tube set using a 6-volt battery, this should range from 6 to 7 amperes. A reading of 10 to 14 amperes would usually indicate a leaky buffer.

There are several other possible causes of high current drain, of course. Never make unwarranted assumptions as to the cause of any trouble until you have checked and found the assumption to be true! For instance, in the case just mentioned, low high-voltage, you could also have a leaky filter capacitor, leaky plate decoupling or screen bypass capacitor, a leaky "spark-plate" capacitor in the high-voltage, a short in one of the i-f transformers, a leaky audio coupling capacitor, or even a run-down battery.

The operating voltages should always be checked, and the first one in this type of trouble should be the input or battery voltage. Check your bench battery or power supply drain automatically in order to be sure. It takes only a moment, and much time may be saved. Develop the habit of making these tests as a matter of routine, and you will find yourself working much faster. Many a wasted hour on a service bench has been traced to overlooking something as simple as the input voltage!

Defective solder joints can also cause trouble in the power supply. Due to the high currents drawn, solder joints on the filter chokes in the input must be very good. A bad solder joint will cause the joint to heat up and cause a large voltage drop. This is

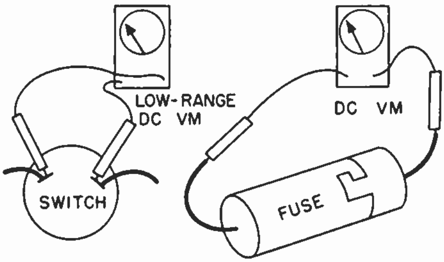


FIG. 12. Proper way to test for high resistance in the dc input circuit.

also true of fuses, switches, and any part in the input circuit. One quick and easy test for this is the measurement of the voltage drop *across* the suspected unit, using a very low range voltmeter as shown in Fig. 12. With this method, any loss in the contacts will show up immediately. If there is *any* reading at all, clean the contact very well, then recheck. In one case, a drop of 3 volts was discovered across a fuse holder. This left only 3 volts for the radio, with results in performance which can well be imagined. Always check all the way back to the battery when looking for trouble in the power input circuit. Remember, if a set draws 6 amperes, only ½-ohm resistance will give a 3-volt drop.

At this time it might be well to mention one source of considerable trouble in auto radios, the on-off switches. Because of the heavy current, these switches give quite a bit of trouble, and should be inspected each time the set is serviced. Fortunately, they will usually give positive indications of trouble. The switches themselves are rotary switches, similar to those used in home radios. Sometimes they are included in the volume/tone-control assembly; sometimes mounted on the pushbutton tuning assembly, operated by one of the push buttons. They have a small fiber disc that holds the elements of the switch in a round metal case. This fiber is usually a light tan or brownish color. Look out for a darkening of the fiber around the contacts; this indicates heating of the switch, which can only be caused by worn or dirty contacts. If this darkening is quite apparent, it would be a very good idea to replace the switch before it breaks down completely.

On the sets which have the switch on the push buttons, simply remove the wires and pry up the switch case; replace with a duplicate switch, then tack the case down to the pushbutton assembly with solder. Otherwise the entire pushbutton assembly must be removed—a long and tiresome job. If the switch is on the volume-tone control, quite often the entire assembly must be replaced, as separate replacement switches are sometimes unobtainable. A helpful hint here is to make a rough sketch of the control, on a piece of scratch paper, noting the color of wires and the parts that go to each terminal. This is much easier and quicker than tracing them out on the schematic, and just as accurate. This should be done when replacing any other part with several leads; it will save a lot of time.

When checking the B+ voltage distribution in the set, take ohmmeter readings through the circuit, watching out for low readings. The reading in any part of this circuit should never be less than 50,000 ohms, unless there is a bleeder resistor somewhere in the circuit. Watch out for charred or discolored resistors; check these carefully for change in the rated value. Heating or charring is always a sign of an overload, usually caused by a shorted bypass capacitor or tube. This heating may change the value of the resistor, upsetting the circuit in which it is used.

A stage-by-stage check of the entire set will show up most troubles. Begin with the output stage, and wind up at the antenna. If you have fixed all the troubles found between these two points, when you arrive at the antenna, the set should be working.

ALIGNMENT OF AUTO RADIOS

Because of the adverse conditions under which the auto radio must operate, careful alignment is absolutely essential. Proper peaking and tracking of all circuits is necessary if they are to deliver the performance for which they are designed. The actual alignment of the sets themselves is exactly the same as for a home receiver. One thing which must be checked carefully is the frequency used in the i-f amplifier stages. While most home sets today have settled on 455 kc, auto radios use 262, 370, *and* 455 kc. The correct i-f must be checked by reference to the service manual for the set, to be sure that the i-f's are aligned to their proper frequency.

You must exercise extreme care in making connections to the set, in order not to upset some of the sensitive circuits with the alignment equipment. This is not quite so important in the i-f amplifier stages, but is vital on the front end alignment.

Possibly the best method of making the front end adjustments is to connect the signal generator directly to the antenna socket, and rough-in the adjustments. Then, disconnect the signal generator, hook a short length of wire, not over three feet long, to the antenna socket. Placing the output lead of the signal generator near this wire will give enough pickup for an output indication. Now, touch up the antenna, rf, and oscillator adjustments to their final peak.

When making the final bench test, use this short piece of wire as an antenna. If the set will pick up several stations, it is probably all right. If it will not, then it is not sensitive enough to work properly in a car, and must be rechecked. Incidentally, during this alignment is a very good time to make final tests on any tubes which might be considered doubtful—i-f amplifiers, for instance. Align the stage concerned, make a note of the reading on the meter, then substitute a new tube for the suspected one. If the output reading increases over 20%, it would be a good idea to replace the tube. This test will work with oscillator-mixer tubes and rf amplifiers as well.

One way to do this is to connect

a vacuum tube voltmeter to the avc bus. The vtvm reads the developed avc voltage, which is directly proportional to the strength of the received signal. It is, in fact, the signal voltage itself, rectified by the second detector. Another way is to connect an output meter across the speaker. This measures the modulation of the received signal, amplified by the power output stage.

One peculiarity encountered in auto radios can cause trouble in alignment readings when the avc voltage is used as an indication of resonance. The standard auto-radio avc circuit takes the avc voltage from the top of the volume control, passes it through a filter network, and applies it to the grids of the controlled stages. This circuit is aligned normally; that is, each trimmer is adjusted for a peak reading. If the avc voltage is taken from a separate diode plate and the signal for this diode is taken from the last i-f amplifier plate circuit, the readings will be entirely different when tuning the last i-f transformer. The i-f trimmer which tunes the *secondary* winding, must be aligned for a *dip* instead of a peak. This is because the secondary winding is taking the maximum current from the primary at resonance, which is the condition we are striving to achieve. Our avc voltage is derived from the primary voltage; therefore, a *dip* in the avc will indicate correct tuning of the *last i-f trimmer* only. Needless to say, the schematic must be checked, to see whether or not this particular circuit is used. It is quite common in the 1945-1955 GM-Delco sets, and has been used in quite a few others. It has caused much confusion. Watch out for it. Fig. 13 shows this circuit.

One easy way to locate weak or defective stages in auto radios is to check the response of each tuned stage to its adjusting trimmers, whether they are capacitors or slugs. Each tuned stage should have a definite peak when tuned through its range. If this peak is not present, then the stage is defective or the wrong fre-

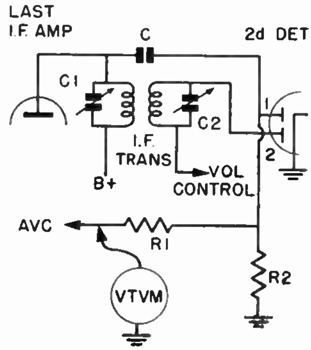


FIG. 13. Circuit in which avc is taken from plate of last i-f.

quency is being applied to it. Check by substituting tubes, and making resistance measurements of the windings of coils. I-F coils, for instance, should show very small resistance readings; about 11-15 ohms for the 455-kc coils, about 20-25 ohms for the 262-kc coils. Both windings should show the same resistance, except for the output winding of the last i-f, which is the diode coil. These often have filter resistors, of 47,000 ohms or so, inside the cans. Resistance readings of 15 ohms on one winding and about 1500 ohms on the other, together with a trimmer that shows no peak, indicate a bad i-f transformer, which must be replaced. Electrolysis of the fine wire is usually the cause of this condition. It is mainly caused by moisture which is a common source of trouble.

This is something which should be checked—see if the chassis shows any signs of having been wet. Many times water will blow into a set through open cowl ventilators, and can cause trouble. Dry sets out thoroughly, and coat any parts suspected of leakage with coil dope, such as the liquid polystyrene sold under several trade names. This will render them fairly moisture-proof and make the set last a lot longer. Washing thoroughly with carbon tetrachloride will also remove moisture from such parts as ceramic trimmer bases, after which they may be coated with the coil dope. Be sure to observe caution when using carbon tetrachloride, the fumes are very poisonous.

As a final note on alignment, it is not necessary to adjust the antenna trimmer on the bench; this should be adjusted *after* the set is installed in the car. Its purpose is to match the set to the antenna and car in order to make the antenna circuit as efficient as possible.

Parts Replacement

When you replace a part in an auto radio, you face a different problem from that in a home radio. You must realize that this part, and indeed the whole set, is going to get much rougher treatment than the average home radio. Therefore, you must take special pains to see that all parts are mounted in a way that will make them mechanically sturdy, and thus avoid troubles due to broken leads.

Bypass capacitors, for instance, should either be fastened to the chassis with small clips, or slipped under adjacent wiring to hold them firmly in place. They should never be installed so that they are supported only by their wire leads. A piece of spaghetti or insulating tubing should be slipped over all exposed wiring to prevent short circuits when parts are jolted or moved. If no other means is handy, large bypass or filter capacitors may be held in place by tying them to the chassis with a loop of insulated wire run through holes in the chassis.

When replacing filter capacitors of the can type, which are held in place by three or four small metal ears, extending through holes or slots in the chassis, be sure that these ears are well tightened, and that at least *two* of them are soldered down. Failure to do this will result in the capacitor working loose under vibration. These ears make the negative or ground connection, and a bad joint here means an intermittent filter capacitor. This trouble is quite common, even in brand new sets, through failure to make a good ground at this point.

If the tubular type of filters must be used for replacement, strap them down tightly; never leave them supported by their leads. Always leave a little slack in wire leads; the change in temperatures inside the auto radio can cause contraction and expansion strong enough to pull the leads out of bypass capacitors if they are too tightly stretched when installed.

When replacing output transformers, power transformers, chokes, or other heavy parts, be sure that they are well bolted down to the chassis, even if it means drilling one or two new holes. Always use lockwashers under all bolts or screws to prevent loosening. A small dab of paint, cement, or better still, nail polish, applied to the threads of a screw just before tightening, will hold it firmly.

VOLUME CONTROLS

Volume controls used in auto radios are practically all in the first audio grid. The signal is taken from the diode second detector and applied to the top of the control. The slider is connected to the first audio grid, sometimes through a coupling capacitors, sometimes directly. Values range from 250,000 ohms to 2 megohms, just as in home radios. Some of the early sets used different circuits, such as rf cathode bias controls, but these are rarely seen now.

Early sets using remote control shafts to operate volume and tuning controls, usually provided the control itself with a slip joint to prevent breakage of the control by turning the shaft too far. The single unit sets today use controls which are practically identical with those used in home radios. The main difference lies in the special physical shapes of the controls themselves, to accommodate the special needs of auto radios. The control bushing is very often one of the three points of support for the whole set.

Many different types of shafts are used on auto radio controls. These include the ¼-inch "quarter-flat", the ¼-inch "half-flat", the ¼-inch "round" shaft, and the ⅛-inch "split" shaft.

Tone control circuits are similar to those used in home sets. The most common is the "grid-losser" circuit, with a capacitor and variable resistor connected in series from the first audio grid to chassis. When rotated, the resistor alters the high-frequency response by bypassing the highs to ground through the capacitor.

For reasons of space-saving, dual controls are used in many sets; volume and tone controls are on coaxial shafts, with the on-off switch often on the back of the whole thing. If the switch fails, the whole unit must be replaced, unless a duplicate switch happens to be available. If so, the defective switch may be pried off, and the new switch installed, holding it in place by soldering the case to the body of the original control. Of course, this will work only if the switch is an exact duplicate of the original, as the "trip-dog" on the volume control will not operate an incorrectly matched switch.

In most cases, replacement controls for this type of unit must be obtained from the maker of the radio. Due to the use of special sizes, replacement controls must be exact duplicates of the originals if they are to work satisfactorily. Many of the larger control manufacturers offer "exact duplicate" replacement controls for the more popular sets, and, indeed, may make the ones used in the original sets themselves. These, of course, will work very well.

If the controls are noisy, they may be cleaned, using one of the special solvents made for this purpose. These are put up in bottles with a brush, and in pressurized spray cans, which are very handy in a crowded chassis. This solvent removes the dirt and corrosion and also leaves a slight film of lubricant on the surfaces of the control. It is a very good idea to give the volume control and switch a squirt each time the set is serviced; this will help to prolong the life of the switch.

Many auto radios use a dual switch, one set of contacts switching the vibrator and tube filaments, the other switching only the pilot or dial light, which has its own input lead. This pilot lead is usually connected to the car's light switch at the terminal that supplies current for the instrument panel lights. When replacing these switches, you may use a single-pole switch by simply tying the dial light lead to the power supply lead and using only one input lead.

If an exact-duplicate replacement switch assembly is not available, or if the customer objects to the price, you may use a separately mounted toggle switch instead. Tie the pilot and power-supply wires all together inside the set, soldering well, and install a switch of the type used for fog lights under the edge of the dash. Connect it into the hot lead from the radio to the car ignition switch.

REMOTE CONTROL HEADS

The remote control head as used on most of the older sets, especially the "universal" type, consists simply of a metal box which holds the dial scale and pointer, fittings for the tuning and volume control shafts, and a dial light. These are made in such shapes as to fit into the holes provided in the instrument panel for a custom-built radio set. One type is made for under-dash installation, being small and flat, and may be used in any kind of car.

These heads are connected to the set by means of flexible cables, similar in appearance and operation to speedometer cables. The ends of the inner shaft, which does the actual tuning, are provided with special fittings, known as splines, which engage matching fittings in the control head and inside the set.

FIG. 14. Construction of inner shaft remote control.

If repairs or alterations are necessary to these shafts, a few special precautions are needed. The inner shafts are made of spring wire, with at least three layers being wound in alternate directions to provide stiffness and eliminate backlash. This construction is shown in Fig. 14. These are kept under tension, and this tension must be maintained. If this shaft must be cut, it is necessary to keep this tension on it at all times. Mark the location of the cut on the shaft, clean it, then sweat solder into the strands until a space of at least an inch is covered. Cut in the center of this, using a very fine-toothed hacksaw, or better still, a fine-grit grinding wheel.

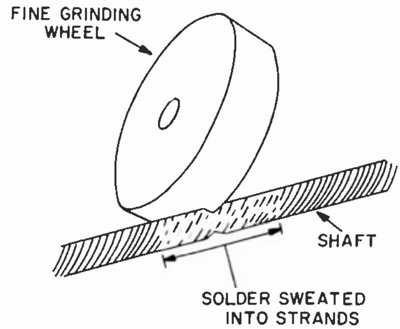


FIG. 15. Cutting a remote control shaft.

Using the corner of the grinding wheel, as shown in Fig. 15, grind a small notch on each side of the shaft, then bend it until it breaks. Touch up the end smoothly with the wheel. Don't allow the shaft to get too hot, as the solder might melt, releasing the tension of the wraps and ruining the shaft. The outer housing may be cut with the grinding wheel in the same way.

To remove and replace the fittings on the ends of the inner shaft, you will need to make a small holding jig. This is merely a block of metal, at least ½ inch thick, about one inch square. Drill a hole through the flat side the same size as the shaft, about ⅛ inch for most popular sizes. Now, using a hacksaw, cut a slot down into this hole. Your jig should look like the drawing in Fig. 16. To use this jig, slip it over the end of the shaft, then pinch it firmly in a vise. The slot allows the jig to hold the shaft firmly, preventing loss of tension. The old fitting may then be twisted off with pliers, if it is swaged on, as most are. Turn it in the direction of the twist of the outer strands of the shaft and it will unscrew easily, in most cases. The new fitting may then be installed, and sweated on with solder. Be sure to make a good tight clean joint, as it is under a good deal of strain.

Some remote control heads had the volume controls and switches mounted in the heads themselves, connected to the sets with shielded cables. These caused some difficulty in a few models,

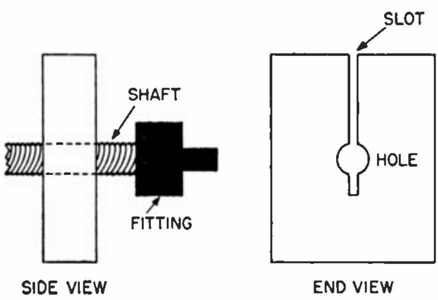


FIG. 16. Clamping jig for use when changing shaft fittings.

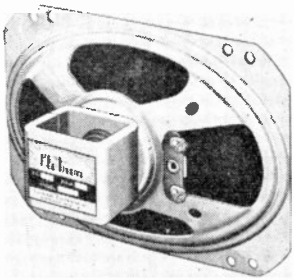
giving an extremely high buzz level. This was traced to the fact that the grounding of the control head and switch was not heavy enough. The current drawn by the set was traveling in the shielding braid covering the very sensitive volume control circuit. This caused a buzz voltage to be picked up by the volume control wiring. The cure for this was the addition of a very heavy grounding strap between the control head case and the set chassis. A battery ground strap, one inch wide, of very heavy wire braid, was used. This stopped the noise.

If the set has pushbutton tuning, the push buttons themselves are mounted in the control head, connected to the automatic tuner mechanism inside the set by a multi-conductor cable. The actual operation of tuning is done by this mechanism; only the push buttons are in the control head.

AUTO RADIO SPEAKERS

The speakers used in early auto radios were of many different sizes and shapes, but all of them were electrodynamic speakers with a 6-volt field coil. This field drew over one ampere of current. These have been replaced in all sets now by the permanent-magnet or PM dynamic, which has no field coil at all. A great number of sets today use the same speaker, a 6 inch by 9 inch oval PM, which simplifies the parts-stocking problem. Many of the cars using separate speakers have mountings for this oval speaker.

Some cars have a provision for a rear seat speaker. This is a PM unit, usually a 5-inch round speaker, located on the shelf behind the rear seat. The shelves are covered with a heavy fiberboard, usually supported underneath by a stamped metal framework. In this framework there will be found a cutout for the speaker, requiring only the cutting out of the fiber with a knife in order to install a speaker. Only two wires are required, and these are usually brought up to the set under the floor mats, on the left side of the car. Many sets have plugs and sockets for rear seat speakers incorporated in their design. Some even have special volume controls already mounted, to allow fading-in of the rear set speaker, play-



Courtesy Cleveland Electronics, Inc.
PM oval replacement speaker.

ing either the front speaker, the rear speaker, or both together. If there is no provision for it on the set, the extra speaker may be connected with a special switch made for the purpose, which is mounted under the dash. The voice coil lead from the set speaker is brought out of the case to this switch, and the rear speaker connected here also. The switch has three positions, "Front", "Rear", and "Both". Small resistors are generally used as pads across the switch to equalize the volume levels when speakers are switched into and out of the circuit. Otherwise, when only one speaker is used, there would be a sudden blare of sound.

The speaker itself accounts for a good bit of the trouble found in auto radios. Due to the difficult conditions under which it must work, it suffers from a lot of troubles, such as warped or dragging voice coils, open voice coils, and damaged cones. In cases where the vibrator is working, but there is no sound at all, the speaker should be checked first. Voice coil leads from the frame to the cone itself are made of very fine wire, just as in any speaker. Due to the high levels used in automobiles, these will often break. If the cone is all right, and the voice coil not dragging, these leads may be replaced by using leads taken from salvaged speakers or any other very flexible wire. They are fastened to the cone itself through a small metal grommet. The leads may be unsoldered here, using a very small iron, and replaced with new ones. Many intermittents may also be traced to these leads. They have a fiber core, with a very fine wire woven around it. If the wires break, the core will keep the wire in place, allowing it to make intermittent contact.

There are other problems that may be found in the older sets using 6-volt dynamic speakers that are not built into the set. In a set of this type, there must be three connections between the set and the speaker, as shown in Fig. 17. One of these is to the voice coil, one to the field coil, and one is a common ground return for both coils.

The ground return may be a wire lead, or it may be made through the

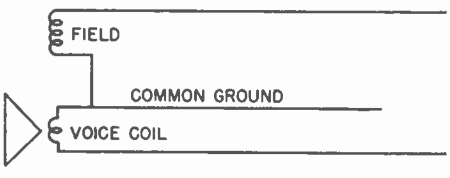


FIG. 17. Three-wire connection to a 6-volt dynamic speaker.

frame of the automobile. Therefore, if you see a speaker with three leads, you know immediately that it is a dynamic speaker; however, even if it has only two leads, it may still be a dynamic speaker with the ground through the car's frame.

If the car frame is used, the connections between the speaker frame and the car frame, and between the set and the car frame must be very good. If there is rust or dirt, it will raise the resistance of the connection and will cause the field current to flow through the voice coil. The leads of the voice coil are made of a very fine wire, which would soon be burned out by the field current. Of course, dirty connections will also cause noise. In a case like this, add a third lead for the ground connection. This will stop noise and protect the voice coil.

Be careful when you connect leads either to the speaker or to the set. Trace the wiring carefully. If the leads are color-coded, this will be easy. If not, use an ohmmeter to identify each one.

If you hear a loud buzz from the speaker as soon as the set is turned on, it indicates that the field current is passing through the voice coil. Shut the set off immediately, and trace the speaker wiring to find out why.

AUTOMATIC TUNERS

Quite a number of auto radios use some form of automatic tuning. These allow the driver to tune the set by merely pushing a button, without taking his eyes off the road. Some have even used foot switches like the familiar dimmer switch, to actuate the tuner. There are many variations in actual design, but only two or three in basic principles.

There are only three major groups of automatic tuners: the "manual" or semi-automatic, which moves the tuner to a preset location when a push button is depressed; the "fully automatic" tuner, which is started by the push button, and actually tunes itself; and finally, the "signal-seeking" tuner, which is both electrically-driven and electronically controlled.

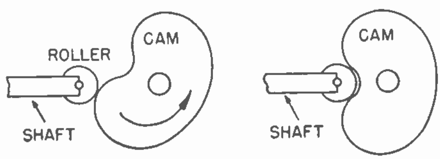


FIG. 18. The action of a simple cam-type tuner.

The simplest of these, of course, is the manual tuner. In this type, a variable capacitor is generally used, with an extension on the shaft. Mounted on this shaft are several cams; push buttons engage these cams and cause the cams to assume a preset position. The action of the shaft and cam are shown in Fig. 18. Because of the tremendous number of variations of tuners in use today, we shall not attempt to give you details on any one particular type. We can confine ourselves to the basic operating principles of each type, and let you look up the details in the instruction manuals for the set involved.

This would be necessary in any event.

The cams are fastened to the tuner shaft by a friction-fit set of spacers; a locknut on the end of the shaft is loosened for adjustment, then tightened to hold the cams in place. To set this type on the different stations, the locknut is loosened, and the set tuned to a station. Holding the tuning knob to prevent its moving, the first push button is depressed; this sets the first cam. This is repeated for each push button, retuning of course between push buttons, and the locknut is then tightened to hold the cams.

As we said, this is about the simplest of the automatic tuners and very little trouble is found in them. Most of this is mechanical, due to bent arms, lack of lubrication, etc., and can be easily remedied. Most automatic tuners, of whatever type, will consist, at first glance, of a bewildering array of arms, levers, pins and other gadgets. Each one is placed there for a definite purpose, and a little careful study will usually determine what that purpose is.

The biggest enemies of the automatic tuner are dirt and grease, which are plentiful in the auto radio. The very first step in any repair to an automatic tuner should be a thorough cleaning. Wash out all dirt and old grease, using carbon tetrachloride or other suitable solvent, and relubricate, very sparingly, using a cream lubricant, such as "Lubriplate" or a similar product. Check for binding or dragging between the various parts and most of them will work perfectly again. Remember, all tuners must be thoroughly clean before they can be expected to work properly. The tuning mechanism itself, whether a capacitor or a set of slugs, must move freely in its slides or bearings before decent results can be expected.

Many of the auto tuners use slug tuning. With this type, the motion of

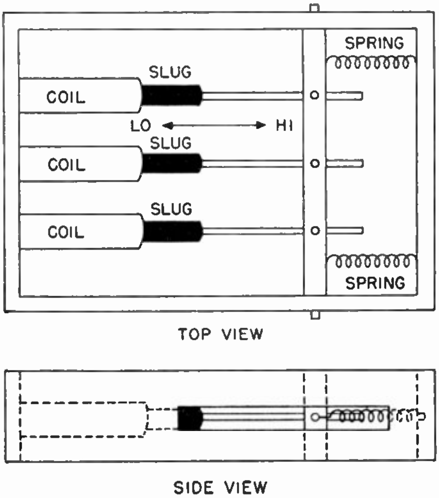


FIG. 19. Typical spring-driven slug tuner assembly.

the tuner is back and forth, as contrasted to the rotary motion of the capacitor tuner. The slugs themselves are mounted on a carriage, a strip of fiber with a small metal frame for added rigidity, which holds the ends of the adjusting screws. This carriage slides back and forth in guides or tracks along the sides of the tuner assembly, so that the position of the slugs with respect to the coils may be changed. The mechanical assembly of this type of tuner is shown in Fig. 19. This calls for a difference in the mechanism of the mechanical tuner drive, due to the difference in motion. Therefore, most slug tuners use the same system, or variations of it. The carriage is pulled all the way to one end of its travel by the push button, then released. It is pulled back toward the other end by a spring, until it strikes a preset stop, which halts the carriage in the right place to receive a given station.

Some tuners pull the carriage with a solenoid, actuated by the pushbutton switch; some do the same thing manually. The principle is exactly the same in either case. The push button moves the carriage to the end of its travel, at the same time setting a stop in its return path.

Some Ford and Motorola radios have used a novel variation of this type. The stops are mounted on a cylindrical frame, or "turret", which revolves 60 degrees every time the tuner is operated. The stops are mounted on long screws, running longitudinally on the turret. Five of these are for the automatic tuner, the sixth, with a much higher-pitched thread, is the manual tuning drive, which is moved by the tuning knob. In use, the carriage moves back and forth when the turret revolves, bringing a different stop into place each time it operates.

Many GM-Delco sets used another variation; the push buttons operated cams, similar to those described earlier. The mechanical drive was accomplished by a worm and gear, driven by the manual tuning knob. In addition to this, a clutch was installed between the manual drive and the main shaft to eliminate the drag by releasing the clutch every time the push buttons are operated. If this type shows signs of slippage with manual tuning, pry the clutch plates apart and wash out with carbon tetrachloride to remove the grease. If it still slips, loosen the screws holding one clutch plate and move it closer to the other. This will increase the tension. Never lubricate the clutch.

THE SIGNAL-SEEKING TUNER

A development of recent years, first appearing in Cadillac and other high priced cars, is the really "full automatic" tuner known as the "signal-seeking" tuner. This operates as follows: When the operating bar is depressed once, the tuner begins "seeking"; that is, moving from one end of the dial to the other. When the tuner crosses a station which is strong enough, it stops. During its travel, the audio output of the set has been muted by a pair of contacts on the tuner that short out the speaker voice coil. This eliminates the noise which would otherwise be heard while the tuner is operating. When it stops, this short is released, and the set plays.

In action, the cycle is as follows: When the button is pushed, the tuner carriage is pulled slowly to the high end of the dial by a spring. As it reaches the end of its travel, the tuner carriage is released and a solenoid pulls the tuner rapidly back to the low end of the band.

The drive spring works through a special gear train, which slows down the otherwise rapid travel to the speed necessary for stopping on a station. Also coupled to this gear train is a small plastic fan or paddle-wheel. This acts as an "air brake" while the tuner is traveling, preventing it from going too fast. Mounted near this paddle-wheel is a relay, with its coil connected in the plate circuit of a

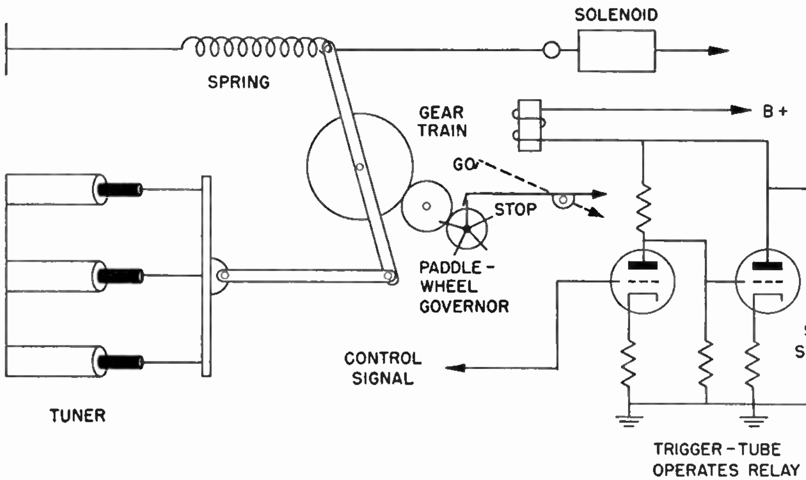


FIG. 20. Simplified diagram of a signal-seeking tuner.

tube. The armature or moving part of the relay has a small hook on the end that drops into the blades of the paddle-wheel, causing the tuner to stop when the relay is not energized. Fig. 20 is a simplified diagram showing the action of this type of tuner.

The coil of the relay is in the plate circuit of one section of the twin-triode tube. The first section of this tube has its plate direct-coupled to the grid of the second section. In this circuit the first section acts as an amplifier stage to insure sufficient current to operate the relay in the plate circuit to the second section.

To start the tuner running, the plate of the second section of the dual-triode is shorted to ground. This energizes the relay and lifts the hook on the armature out of the paddle-wheel which allows it to turn. At the same time a contact on the relay armature changes the bias on the first section of the dual triode so that the relay will be held closed. When the tuner crosses a station loud enough to be usable, a pulse of signal voltage developed by the i-f stages is applied to the grid of the first section of the dual triode. This pulse is positive-going and after amplification drives the second section to cut-off. Cutting off the plate current or the cut-off bias of the second section of the tube allows the relay to open, and drops the armature hook into the paddle-wheel so that the tuner stops on the station. If the tuner is not stopped by a signal before reaching the high end of the band, the solenoid is energized and the tuner assembly is drawn rapidly to the low end of the band, at which point the solenoid circuit is broken and the spring drive pulls the tuner back down through the band.

Troubles with this type of tuner, and with other types of signal-seeking tuners, may be found in either the set or the tuner. Obviously, mechanical trouble in the tuner itself will ruin its performance, but so will troubles in the set, such as power supply failure, a weak i-f amplifier tube, or antenna trouble. If the signal seeker does not receive a signal strong enough to actuate its circuits, the tuner is going to keep on "seeking" until one is found; or in case the set is bad, until it is turned off or repaired.

Inasmuch as there are on the market now at least three different types of these tuners, your best source of information is the schematic diagram of the tuner itself. Variations will be so wide that it would be impossible to give you any detailed information on it here.

Preventive Maintenance

The principles of preventive maintenance may save you a great deal cf trouble if properly applied. Briefly, this means the spotting of troubles *before* they happen. Whenever an auto radio is serviced, it should be checked very thoroughly before being reinstalled in the car. If the set is already out of the car and on the bench, many tests are practical which *can* spot troubles before they happen.

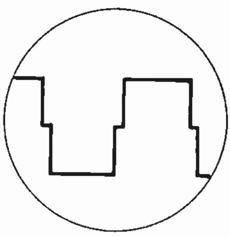


FIG. 21. Normal pattern for good vibrator. Note symmetry, square corners, and absence of high pips.

Test all tubes; make the test recommended in the discussion of alignment for doubtful ones. Tubes which test weak should be replaced, as the chances of their failure are great. Check the alignment, as outlined. Using the bench ammeter, check the current drawn by the set. If there is too much, test the filter capacitors, buffer, etc., for leakage. Leakage in filter capacitors will always become worse, causing trouble soon.

Give the whole chassis a thorough visual inspection, watching out for bad solder joints, burned resistors, defective tube socket contacts, frayed wiring, possible shorts, etc. Check volume and tone controls for freedom from noise; clean with cleaning compound. Check switches for cleanness and operation. If the set has an automatic tuner, check it very thoroughly for cleanness and good operation. Clean and relubricate if needed.

If an oscilloscope is available, you can make amazingly accurate predictions as to the future life and condition of the vibrator. Connect the vertical input of the scope across the primary winding of the transformer, which is easily accessible at the vibrator socket. Turn the set on, and adjust the scope to give a pattern with at least two cycles on the screen. Note the "square-cornered" shape of the pattern in Fig. 21. This is what you should see if the vibrator is *good*. If one of the points is dirty or burned, the pattern will be distorted and ragged, as in Fig. 22. If the pattern is one-sided, one point is not making contact at all; Fig. 23 shows excessive pips on the corners of the wave; the buffer is either open or too small. In fact, any deviation from the normal square-wave pattern may be reason for replacing the vibrator. Substitute another vibrator in good

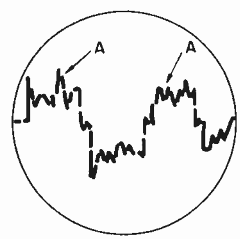


FIG. 22. Defective vibrator. Pattern is ragged showing that points are bouncing.

shape and note the difference. If the new vibrator brings the pattern back to normal, it should be left in. A vibrator which shows any of these abnormal patterns will fail within a short time, causing a call-back on the service job. As a last resort, you might explain this to the owner. If he disagrees with you, he will be much impressed when the vibrator fails, as it surely will.

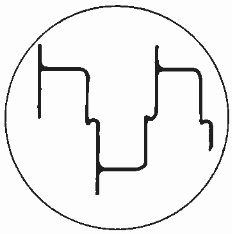


FIG. 23. Excessive peaks caused by open or too-small buffer capacitor.

If the buffer capacitor needs replacement, and the size of the old one cannot be made out, hook up the scope as described, and try different sizes of buffers, until you locate the size which gives the best shape to the pattern with the smallest pips and the least rounding off at the corners. Fig. 24 shows the effect of a buffer.

A long time ago, when vibrators were made much differently, it used to be possible to take them apart, clean and readjust them. The sealed construction of modern vibrators, together with superior materials used in their contacts, makes this job not only difficult but economically impractical. A new vibrator can be installed for far less cost than the time needed to disassemble, clean and reassemble a defective unit. The only time this would be practical would be in the case of a very special vibrator, such as the heavy-duty jobs used in some large mobile PA systems, and the 2-volt vibrators used in some portable equipment.

Getting a replacement is often difficult, so that cleaning and adjustment may be the only way to make a repair. Clean the vibrator and readjust it as nearly as possible, then turn it on. Use the oscilloscope and observe the pattern as you carefully adjust the points. If you can obtain a good square-wave pattern, the vibrator will probably work very well. The output voltage should be measured at the same time, and the vibrator adjusted for both highest output and best waveform. Be sure to use insulated tools if any adjustments are made while the vibrator is running; it is possible to get a very painful shock from one!

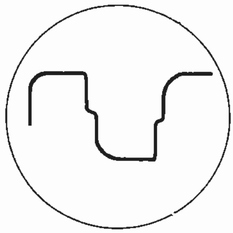


FIG. 24. Normal pattern except for rounding of corners due to a too-large buffer capacitor.

THE INTERMITTENT AUTO RADIO

While the intermittently-operating home radio can be very annoying to the serviceman, the intermittent auto radio can be much more so because of the difficulty involved in removing the set from the car. Therefore, it is highly advisable to take precautions to see that this condition does not exist in any set replaced in the car. This is not 100% possible of course, but you can and should put the radio through a series of severe tests designed to show up any intermittent condition, before returning it to the car.

There are several types of intermittent; the most common is the type which "suddenly stops playing". There is no sound in the speaker, although the vibrator is running, and the set apparently has power. This is always due to an interruption somewhere in the signal path, from the antenna through the speaker, and usually centers around the audio stages. Open coupling capacitors in audio stages, bad volume controls, broken wiring anywhere in that circuit, and, last but not least, a defective speaker, all can be the cause of this type of intermittent.

Another type does not cut out completely, but merely drops down in volume; the set loses all but a whisper of its output. Once again, this can be due to coupling capacitors, intermittent tubes, OZ4 rectifier tubes firing intermittently (a common cause), or old vibrators. The intermittent tubes will be either in the rf amplifier stage or in the phase-inverter stage if the set has push-pull audio output. The failure of any other tube, of course, will cause the set to stop entirely.

Intermittent operation may also be due to a defective vibrator. If one of the small flexible leads which connect the stack to the base plug is broken and making intermittent contact, it will cause this type of trouble.

Probably the best test for any tendency toward intermittent operation is the "drop test". The set, while still playing on the bench, is picked up and dropped onto the bench from a height of three or four inches. This will not damage a *normally operating* set. It will help in locating mechanical intermittents, however. If there is any noise, or if the set cut out, look for the cause. The set may also be jarred heavily with the heel of the hand, or with a small rubber mallet. Any noise caused by this treatment is *not normal* and must be fixed.

Intermittent oscillation can be traced to intermittent filter capacitors, especially those units which have poor ground connections. In the older sets, bypass capacitors were often connected to small lugs, riveted to the chassis. Corrosion may make a very bad connection at the ground point and cause intermittent oscillation. Spot-solder all such places well, first scraping the chassis and lug with a sharp tool to insure a good solder joint.

Electrolysis of coils was quite common in early sets, even including the primary of the output transformer. Resistance measurements of the suspected windings will usually show them up. There is another test, which is even quicker; merely short the load end of the winding to ground momentarily. The heavy current caused by this short will completely burn out a damaged winding, while a good winding will not be harmed.

A ¼-inch fiber rod, with slots sawed in the ends makes a very helpful tool for locating intermittents.

Slip the slot over the leads of coupling capacitors and twist them gently back and forth. If they are intermittent, this will cause them to break down. Wiring and other suspected parts may be punched, probed and twisted with this tool to check for possible shorts or opens. Tap tube sockets gently with the end to locate noisy socket contacts.

Only very careful attention to the smallest details can give you even partial freedom from intermittents. At best, there will be a certain amount of them. However, careful workmanship will help to reduce the number.

Testing the Radio in the Car

This is a very important part of your work, as the decision reached here can greatly affect your income. Time used in removing a set from a car, only to discover that the trouble was in the antenna, is time lost. Your efforts must be directed toward making a quick, accurate diagnosis of the trouble, to avoid wasting time and labor.

Checking in the car must be aimed entirely toward one thing, discovering the nature of the trouble so as to be able to determine whether or not it will be necessary to remove the radio from the car. Removal is always the biggest part of any car radio job, and should never be done unless it is absolutely necessary. There are many small jobs which can be done as well in the car as in the shop. Replacing tubes or vibrators, which furnish the majority of service jobs anyway; replacement of separate speakers, which are another large cause of trouble; minor tuning adjustments, such as touch-up adjustments of antenna and rf trimmers, and of course, all work on antennas and other parts which are part of the car itself rather than the radio set.

There will be many cars in which the design of the radio is such that no work of any kind can be done without removing it from the car. However, the majority of cars permit at least partial access to tubes and vibrators, by removing the lower lid of the radio case. Some radios have the power supply and audio stages built entirely outside the main case, so that these tubes and the vibrators are easily changed.

There is a certain order which in-the-car tests must follow. These tests are designed to determine as quickly as possible the condition of the radio. We will outline these for you.

First, turn the radio on. Many cars connect the radio through the ignition switch, so that this must also be on before the radio can be operated. If the car has a "two-way" switch, turn it to the left, to the "Accessory" position. Now, listen carefully to the set; you should be able to hear the mechanical noise of the vibrator and see the dial lights come on.

If the dial lights do not come on, and the vibrator does not start, check the fuse and fuse-holder. If the fuse is good, check to see if there is voltage at the "hot" end of the holder by measuring it with your voltmeter. The reading should be approximately the full battery voltage. If there is no voltage at the fuse-holder, see if the ignition switch is in the proper position. You're not going to get anywhere until you *do* get some voltage to the set. If you have voltage at the fuse holder, and the fuse is *apparently* good, but the set does not start, turn the radio switch on and hold the two ends of the fuse holder together; if the set starts to buzz, the fuse may have a loose end cap and be open, even though it appears to be good on a visual examination.

OK, the fuse is good, there is voltage at the fuse holder; the set won't start buzzing, *but* the tubes light up. Either the tube filaments or the dial lights are indications that voltage is getting into the set. No buzz: dead vibrator. Pull it, and put in a new one. It the set starts to play, the job is done.

Another similar case: good fuse, voltage to the set, *but* the set will neither light up nor buzz. The switch has a peculiar sound when it is turned on and off. Conclusion: defective on-off switch. The set must be removed for replacement of the switch.

Another case: fuse blown; shorting the ends of the fuse holder starts the set to buzzing, but the vibrator has an uneven, "ragged" sound. Conclusion: the vibrator is old, and has momentarily stuck, blowing the fuse. Replace with new vibrator, and check current drain; if the new vibrator has a smooth, even sound, and the current drain is normal, the vibrator was the only trouble. Note at this point—there will be a difference in the current drain between the 6-volt and the 12-volt sets. For a 6-volt set with 6 tubes, the normal drain will run from 6-7 amperes. The 12-volt sets, with double the voltage, will draw from 3-5 amperes. One possible trouble here might be a stuck solenoid in an automatic tuner; these normally consume as high as 20 amperes. This will not blow the fuse in normal operation because the short time the current is drawn is well inside the normal "time lag" of the fuse. However, if the switch sticks, this heavy current will blow the fuse. For the 12-volt sets, these solenoids pull from 10-12 amperes.

If the fuse is blown, and replacement of a new vibrator starts the set to buzzing, but even the new vibrator has a labored sound as if it were heavily overloaded, check the drain. If this runs over 12-14 amperes for a 6-volt set, or over 7-8 amperes for a 12-volt, turn the set off. This shows excess current drain. The most probable causes are leaky or shorted buffer, leaky filter, or shorted bypass capacitors. An ohmmeter check from the cathode terminal to ground will give an indication of shorted or leaky filter and decoupling capacitors. The set must also be removed from the car in this case.

Probably the final type of trouble centering in the power supply, where all of the troubles discussed so far have been found, is in the rectifier tube. The type OZ4, a full-wave gas rectifier tube, has become very popular in late years due to its lack of filament drain. However, the performance of these tubes can be somewhat erratic after they age a little. If the volume falls off very suddenly, or if it goes up and down erratically, replace the OZ4 tube and see if this doesn't bring the set back to life. In fact, if there *is* an OZ4 in a set that doesn't work, replace the tube *first*, just as a precautionary measure. They are very good tubes, but, as we said, they can be somewhat erratic at times.

Now, if the power supply seems to be all right and the fuse isn't blown, but the set is still dead, we must look further for the trouble. While this has taken up a good deal of time in discussion, you'll find that every one of these tests we've outlined up to this point can be done in much less than

60 seconds by an experienced man. Let's proceed with some more tests.

There is no sound at all in the speaker. This should lead us to suspect several things—the speaker itself, the audio tubes, or the power supply, mainly the rectifier tube. We can make one quick test which will check out all three at once: simply take the lid off the set, locate the power tube by consulting the little tube placement diagram which should be pasted on the lid, and pull the power tube out of the socket. Leave the set turned on, of course. If we hear a fairly loud "pop" in the speaker, this clears three things: the speaker, the power supply, and probably the power tube itself. If any one of the three were bad. we wouldn't have heard that "pop".

Now, if the set is still dead, let's look further. If it is equipped with glass tubes, a visual examination will spot a tube which has a burned out filament. If the tubes are metal, let the set run for a little while, then feel the tubes one at a time; if one of them is cold, it's dead. If none of the tubes are apparently dead, pull them out of their sockets, one at a time, beginning with the power tube and going toward the antenna. Replace each tube in its socket before going to the next one. Each one should produce a "pop" in the speaker, getting louder as we go toward the antenna. We're getting more gain each time we move one stage toward the antenna; hence the louder pops.

If one tube refuses to "pop", take it into the shop and check it; it may be internally shorted. Try replacing it with a new one. If we reach the antenna with no apparent bad tubes, and we cannot get a pop from the antenna terminal when the antenna plug is pulled out of its socket, there is probably something wrong with the set and it will have to be pulled. This is, of course, if there is *not* a normal rushing sound in the speaker. This sound should be present in any normally operating radio receiver when it is not on a station, or when there is no antenna connected to it. If you *do* hear this sound, but the set will not pick up any stations, first check the antenna, either by an ohmmeter test or by substituting a temporary antenna. If this produces noise, but no stations, replace the oscillator tube; the set is working but the local oscillator has failed. With no signal present to beat against, the rf signals will not come out as music, although local noise *will* come through, making the set sound as if it were between stations.

Incidentally, if the set has this sound, but the manual tuning will not bring in any stations, check to see that the push-button tuning is not set to one of the positions which would disable the manual control. If the set has "signal-seeking" tuning, make sure the sensitivity control is wide open. These symptoms could also be caused by failure of the tuning mechanism to move far enough, leaving the tuner between stations. This is probably a shop job anyhow, and the set will have to be removed.

If the set will work on a strong local station but will not receive any others, there are three possibilities. The rf amplifier stage may be dead or very weak, due to a bad tube, misalignment, or a defective component This symptom has also been noted on sets using push-pull output in the audio, with a triode phase-inverter tube. If the driver tube goes dead, enough signal will leak through the interelectrode capacity to partially excite the powerful output stage. The other possibility is a weak rectifier tube, especially the OZ4 just mentioned, or a very weak 6X4 or 6X5, if that type is used. This lowers the high voltage to such an extent that the gain of the set is reduced to the point where it will pick up only the powerful local signal. Other tubes in the set may also be weak, but the two mentioned are the most likely cause of the trouble.

It might be well to check all tubes before removing a set in cases like this. The fact that the set will play at all should tell you that it is in fairly good shape, lacking only some small thing to bring it back to full performance. The oscillator is working, as evidenced by the fact that it is getting the local station; the i-f's are fairly good, the speaker and other parts are at least partially working, so the chances are very much in favor of the trouble being something relatively simple, such as a bad tube. Of course, misalignment can cause this condition if the set has been tampered with, but correction of this is a shop job. If all other tests fail, remove the set and check the alignment. However, tampering is usually the only cause of misalignment of this serious a nature. A normally operating set *cannot* get that badly out of alignment by itself.

We must remember that tests made in the car are aimed mainly at one thing—discovering as quickly as possible the nature of the trouble, so that we can decide whether to remove the set or leave it in the car. Learn the symptoms of normal operation, those that indicate trouble inside the set and those which point toward trouble which can be remedied in the car, such as vibrators, fuses, etc., and you'll have very little trouble.

Removing the Radio

One of the hardest jobs you will encounter is the removal and replacement of the radio itself. This is strictly a mechanical job, and usually calls for several special tools. Unfortunately, there are so many different designs of auto radios, and of the cars themselves, that it would be impossible to discuss them all in detail. All we can do is give you a few general hints that should prove to be helpful.

After making sure that the radio must be removed from the car, the very first thing to do is make a careful survey of the situation, especially the type of mounting used. As we said in the section on installation, practically all auto radios use the three-point suspension system. The two bushings on the control shafts and a third point at the back support the set. There will be variations of this, as in some of the Oldsmobile and Buick sets, which use the control shafts and two side brackets, which engage two heavy bolts in the sides of the case.

Other exceptions include some of the Ford radios, which do not use the control shafts at all, but hold the set in place with two short heavy Phillips screws which pass through a flange on the front into the dash. The 1951 Plymouth mounted the receiver on a square, curved plate, held in place by four small Phillips screws through the corners. GM trucks hold the set by the control bushings and two short heavy bolts which go through the dash into the bottom of the case. A careful checkup on the exact method of mounting used is the only way to get one out.

Some of the two-piece sets, with the tuner and i-f stages in an enclosed case, and the power supply, speaker and audio stages on an exposed separate chassis, will offer special problems. In many designs, the tuner chassis must be removed before the power chassis can be taken out, due to interference under the dash from other parts such as heaters. Experience must be the only guide here. Never attempt to take a unit out by force. This will only result in damage to the radio. Even though it is a lot of work to get a given radio out properly, go ahead; the added time may be made up by increasing the service charge (with full justification).

Many of the cars from 1954 on, placed the radio in the center of the dash above the glove compartment. This makes it necessary to remove the glove compartment in order to get at the radio. These are usually made of a heavy fiberboard, held in place by 8 self-tapping screws, two on each of the four sides. Note: Take out *only* the 8 screws holding the pocket itself; don't touch the screws in the top center; these hold the latch, and if it is disturbed it must be readjusted, which is a time-consuming job. If the space in back is crowded, as usual, the pocket itself may have to be folded up slightly in order to get it out. In most cases, the radio will then come out easily.

Some sets will prove difficult to remove, even with all the bolts removed. As we said before, never force one out; you may break the delicate ⅛-inch control shafts or other parts, causing yourself an expensive and unpaid service job. There is always a way to get it out; it went in, didn't it? Although it may seem with many sets, that the car was built after the radio was installed, patient experimenting will always disclose the right way to remove a stubborn chassis. Try turning it into a vertical position so that it will be thinner; slide it up, down or sidewise, and sooner or later, it will come out! In many cases, other parts must be removed; in many Fords, Mercurys and Lincolns, for instance, a section of the heater duct had to be removed before the radio came out.

Many cars with accessories which were not built for the particular car will offer problems. It may even be necessary to remove the entire heater before the radio can be removed. In such cases, send the car to a garage; the average radio shop is not and should not be equipped for this type of work. There were some few cars actually built in this inconvenient fashion, such as the 1936 or 1937 Cadillac, but they are scarce now. Most of the later cars are somewhat better designed, fortunately for the patience of the practicing auto radio technician. The average set will prove to be fairly simple to remove and replace if you will take the time to study the installation, and take whatever steps are necessary to make the job easier. Certain extra material must be removed in some cars in order to make the job possible at all, and the only way to get the set out is to go ahead and do it!

There is only one universal procedure which will cover all makes and models, and that is, simply, "Remove all of the bolts and nuts, until the radio is obviously loose, then start turning it around until you find out how it went *in*—then, it'll come out!"

The Auto Radio Service Shop

The test bench used for testing automobile radios can be made into a very useful piece of test equipment with a few simple homemade gadgets. Proper test equipment can be used to speed up the testing and repair of automobile radios until they take little more time than home radios. On the other hand, unless proper equipment is used, auto radios can take up so much time that you will lose money on every job.

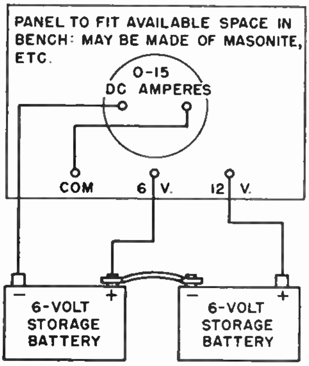


FIG. 25. Diagram of power supply for test bench use.

The test bench should provide the following features, as a minimum: A source of power for operating both 6- and 12-volt radios; Fig. 25 outlines a simple battery arrangement for providing it. A 0-20 dc ammeter of a good make, connected in series with one of the leads from the batteries or power supply to measure the current drawn by the set. A simple method of connecting radios under test; this can best be accomplished by gathering an assortment of the various types of fuse holders used with auto radios, and providing them with heavy leads, usually about 20 inches in length, with the fuse holder on one end, and a heavy spade lug on the other for connection to the terminal panel. An assortment of these leads is shown in Fig. 26.

The panel shown in Fig. 27 also includes a switch for a small trickle-charger, which keeps the batteries charged, and a charging-rate ammeter. This last is not necessary. One lead has a heavy battery-charging clip on one end; this is used for making ground connections to the chassis of the radio.

There are two ways of providing power. One, we have already mentioned, using automobile storage batteries with a small charger; the other,

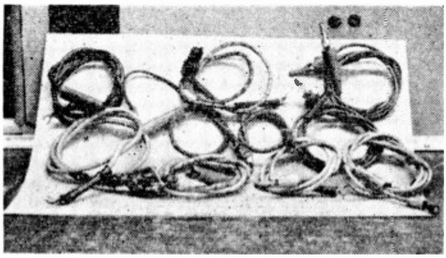


FIG. 26. Power leads for connecting set to test panel.

by means of one of the battery eliminators designed for this purpose. These will give you the needed 6 and 12 volts, dc, without the mess of batteries. The choice should depend upon the type of work being done. If the shop handles only common auto radios, the eliminators will serve the purpose very well. If much work is done on large mobile PA systems, or on two-way mobile radio transmitters, the batteries are best. Because of their higher capacity, batteries hold up under large current drains. The average eliminator's capacity is limited to about 10 amperes and will suffer from excessive voltage drop if more load than this is placed upon it. Select the type best suited to your own needs.

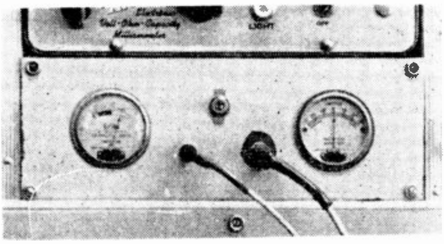


FIG. 27. **Test panel mounted on bench.**

Another very useful item is a separate test speaker, mounted in or near the test panel. The circuit diagram for a suggested set-up is shown in Fig. 28. The voice coil leads should be brought out to a pair of pin-jacks or a plug, and test leads made up to fit this. These may have alligator clips on the ends, or may have speaker plugs of the types used in the various auto radios. This saves the time needed to remove the speaker from the car, if it has been tested and found all right. There are not too many of these, and a set which will take care of all the car radios encountered in everyday work can be made up in a short time. They will save a lot of time.

A "bench antenna" will just about complete the picture. This is not complicated; merely a three-foot length of test lead wire, with a "pin type" antenna plug on one end and a "bayonet" plug on the other. Thus, it can be plugged into any car radio's antenna socket, and will furnish a good test for sensitivity. If the radio will pick up several stations on this small antenna, it is sensitive enough to work well in the car.

One more word on the connectors used to supply power to the sets. Some of the fuse holders used must have a fuse in place in order to make contact. Solder a short piece of wire across these fuses and then solder the fuses into the holders for maximum convenience. The piece of wire is to prevent blowing the fuse. While on the test bench, any short circuit will be shown up immediately on the bench ammeter, and the fuse is not necessary.

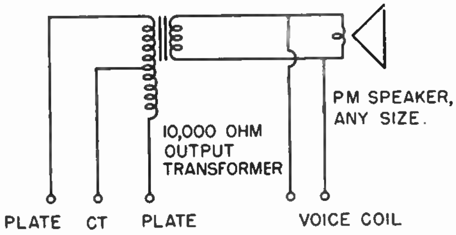


FIG. 28. **Diagram of test speaker.**

SPECIAL TOOLS NEEDED FOR AUTO RADIO

Because of the wide variety of special screws, nuts, bolts and fasteners used by automobile makers, you will need a pretty good sized set of assorted tools, mostly in the line of special screwdrivers and wrenches, before you can do many of the jobs necessary in this type of work.

A good rule to follow in the selection of your hand tools is this: If you find yourself *needing* some certain tool several times, go and get one! The proper tool at the right time can save you many hours of hard work. Never misuse tools; they are one of the most important things to your job, and they must be cared for properly. Never use a pair of pliers on a hex nut, for instance; this will only result in a "rounded-off" nut, which will be harder to remove the next time. The proper wrench, preferably a socket wrench, will remove the nut quickly and easily and leave it undamaged. This will show up in the quality of your workmanship, and be a very good reference for you.

While it might not be possible for the beginner in auto radio work to obtain a full set of tools immediately, we would recommend that you begin your set by purchasing such tools as are needed most, then adding to your collection, a little at a time, until the full set is on hand. Always buy the best quality tools available; cheap tools not only lower the standards of your work, but actually cost more in the long run. One good pair of long-nose pliers has been known to last over twenty years; several cheap pair would have been worn out and discarded in much less than that time.

There is an old saying, "the mechanic is no better than his tools," and there is a lot of truth in it. Get good tools, take good care of them and your job will be made much easier and more profitable. The faster you can work, the more money you will make, so there's a very practical angle there, too!

Lesson Questions

Be sure to number your Answer Sheet 42B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grades as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. In a vibrator type power supply, why is a transformer used between the vibrator and the rectifier?

2. Why is there no filament winding on a vibrator type power transformer?

3. A set using a synchronous vibrator will not work if the battery polarity is reversed. Will this reversed connection harm the set? Give a reason for your answer.

4. What hum frequency would you expect in the output of an auto radio if the filter capacitors are open or weak?

5. What voltage rating should a buffer capacitor have?

6. What is the proper way to check for resistance in switch contacts or fuses?

7. What are the three common intermediate frequencies used in auto radios?

8. What is an easy way of checking for defective i-f stages in a receiver?

9. What are the biggest enemies of automatic tuners on auto radios?

10. In the "signal-seeking" tuner circuit shown in Fig. 20, which polarity would you expect the control signal to have to stop the tuner?

HOW STRONG IS THE CHAIN?

Let's suppose you are running a construction job and need a chain to carry a heavy and very valuable load. You order your blacksmith to forge a chain; you want it made of the best steel—each link must be perfect. Such a strong chain will carry the valuable cargo safely. But if just one link parts—DISASTER!

Life is like that. It is like a chain composed of ambition, perseverance, character—and TRAINING. Until your link of Training has been forged there is nothing to tie the Success chain together. And you need a strong link to hold it together.

You are using good, strong, time-tested material now. But don't skimp on material. Don't think you know a subject — KNOW THAT YOU KNOW IT! Don't try to cover a subject or a lesson in a day when common sense tells you it should require a week. Don't ruin your steel by allowing flaws to creep in which may eventually weaken your chain.

Put all of your N.R.I. Training into your success chain—make it as big and as powerful as possible.

J. E. Smith

PUBLIC ADDRESS EQUIPMENT

REFERENCE TEXT 42BX

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL

NRI

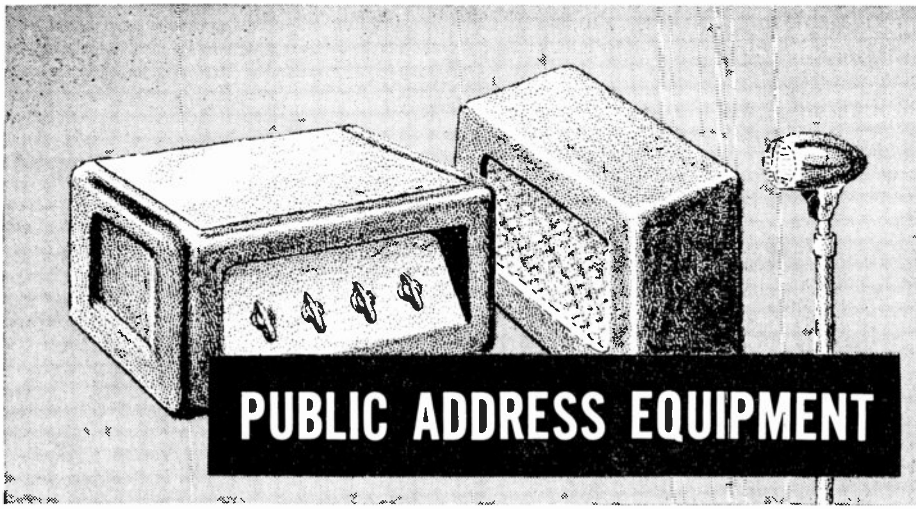
NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE

FM4M1159 **1960 Edition** Printed in U.S.A.



PUBLIC ADDRESS EQUIPMENT

OPERATING, installing, and maintaining public address systems can be a profitable business for you. You can do this as full-time work or as a money-making side-line for an already established service business. It is a logical side-line, because PA systems include the same electronic components and circuits that you find in your everyday service work. Of course, you will need some additional knowledge on impedance-matching and acoustics, and more experience in working with microphones, transmission lines, etc. You will be able to get this information easily if you have a good fundamental knowledge of electronics and radio.

You should not hesitate to take on public address work. Even though there may not seem to be many opportunities in your locality, if you look into the matter, you will probably find that the public is not aware that such services are available, and that no effort has ever been made to create a demand for public address equipment. If so, you should first find out where PA systems are needed. Contact the prospective customers, and point out how a PA system will benefit them. The effort you make in creating a demand for PA installations will be well worth it.

In public address work, you are not restricted to servicing the equipment. You can make additional income by renting PA equipment or by selling and installing PA systems.

TYPES OF INSTALLATIONS

There are three major types of public address installations—permanent, semi-permanent, and temporary. Permanent installations are made in places that are used frequently, such as large auditoriums, churches, factories, hospitals, public buildings, office buildings, schools, and large stadiums. Semi-permanent installations can be made in dance halls, auditoriums, small athletic fields, and other public meeting places that are not used frequently enough to warrant a permanent installation. You can rent out public address systems for such installations. The mounting positions for the amplifiers and speakers and the actual wiring between the mountings are permanent. Then amplifiers, microphones, and speakers are added just before the event, and removed after it is over. In some semi-permanent installations, the speakers are installed permanently, and only the microphones and amplifiers are brought in when they are needed.

There are also many uses for small, temporary PA systems. Such a system is made up of an 8- to 12-watt amplifier, one or two microphones, and one or two speakers. The complete system is lightweight and can be easily moved. This type is used for small gatherings as in small meeting rooms or at parties.

Small, portable, battery-operated PA systems using transistor amplifiers have been developed. These can be used where there is no source of electric power. If more audio power is required in areas where there is no available power, such as at political rallies or charity drives, mobile PA systems installed in trucks or cars can be used.

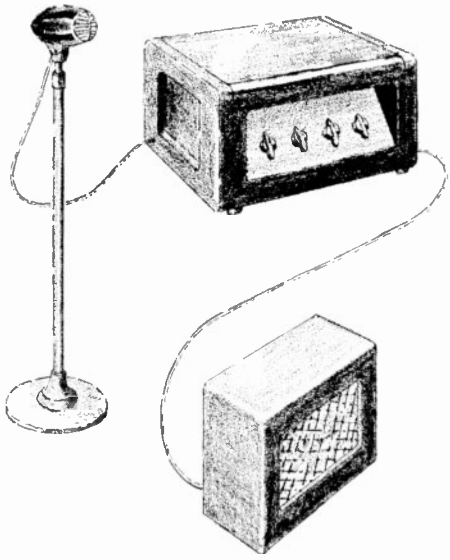


FIG. 1. This is the basic PA system—a microphone, an amplifier that builds up the signal from the microphone, and a loudspeaker that converts the electrical signal into sound.

UNITS OF A PA SYSTEM

The basic units of a PA system, shown in Fig. 1, are a microphone, an amplifier, and a loudspeaker. The simplest PA system consists of one each of these major units. More elaborate systems use a number of microphones and loudspeakers with a single, though perhaps more complex, amplifier. A record player or tape recorder is often a part of a PA system, depending upon the needs of the installation. The record player can be used before and after programs and during intermissions to provide background music. Tape recorders are used for reproducing recorded information or for recording parts of the program for future use.

This book is the first of two reference lessons on PA fundamentals and PA equipment. In this introduction to PA, we will cover the basic parts of a PA system. You will learn how a microphone works, the various types of microphones that are available, and the circuits in the PA amplifier that are not usually found in other audio amplifiers. You will study the various types of loudspeakers used in PA work. These loudspeakers operate in the same way as those used in high-fidelity equipment or in radio and TV sets; the main difference is in their physical construction. We will also discuss the transmission lines that connect the microphones to the amplifier and the amplifier to the loudspeaker. Finally, we will take up the two methods of connecting loudspeakers to the output terminals of the amplifier; the constant impedance method, and the constant voltage method.

Audio Signal Sources

The microphone is the most common audio signal source for public address systems. Other possible sources are the pickup head of a record player, the head of a tape recorder, and an audio line. Since these devices often give a stronger output than a microphone does, their outputs are generally fed into a higher level stage of the amplifier than signals from the microphone. Most amplifiers have mixing circuits so that signals from the various signal sources can be intermixed and reproduced simultaneously.

The microphones used in public address are of the crystal, dynamic, velocity or reluctance type. We will not take up carbon, condenser, and other types of microphones, because they are not now often used in PA work.

TYPES OF MICROPHONES

Crystal. The crystal microphone is perhaps the most common public address type because of its ruggedness, low cost, high output, and adequate frequency response. A diagram of the basic unit is shown in Fig. 2.

The crystal microphone operates in much the same way as the crystal phonograph cartridge and crystal

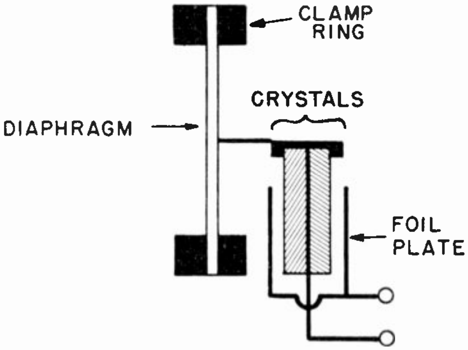


FIG. 2. How a crystal microphone is connected to produce an output signal.

loudspeaker. The crystals are connected back to back; the tinfoil plate between the two crystals acts as one terminal of the microphone cartridge

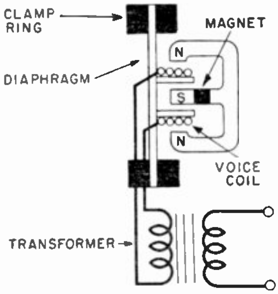


FIG. 3. How a dynamic microphone is connected to produce an output signal.

unit. The plates on the outside of each crystal are joined to form the second output terminal.

Three corners of the crystal are clamped tightly to the case, and the remaining corner is mechanically linked to the diaphragm. As the diaphragm moves back and forth, it bends or twists the crystals, causing them to generate an output voltage. This output voltage is proportional to the amount of mechanical stress. The louder the sound, the greater the mechanical stress, and the higher the output voltage of the crystal microphone.

Dynamic. The operation of the dynamic microphone is similar to the operation of a moving-coil loudspeaker, as you will see by studying the diagram in Fig. 3.

The voice coil is attached to the diaphragm and is in the air gap of a strong magnetic field. Any motion of the diaphragm by the sound waves causes the voice coil to move in and out through the magnetic field, which induces a voltage in the coil. The output voltage is passed on through a transformer, which is a part of the microphone; the secondary of the transformer connects to the output cable.

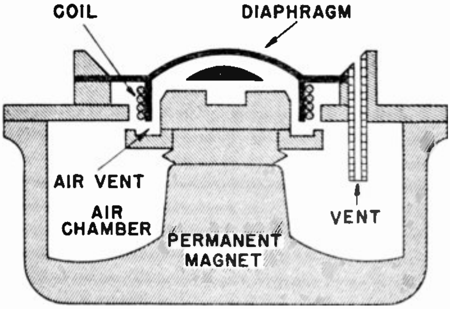


FIG. 4. Cut-away view showing the resonance chamber and vent in a dynamic microphone.

The dynamic microphone is rugged and can be used where temperature and humidity conditions make the crystal type unsuitable. It is a popular type for public address work.

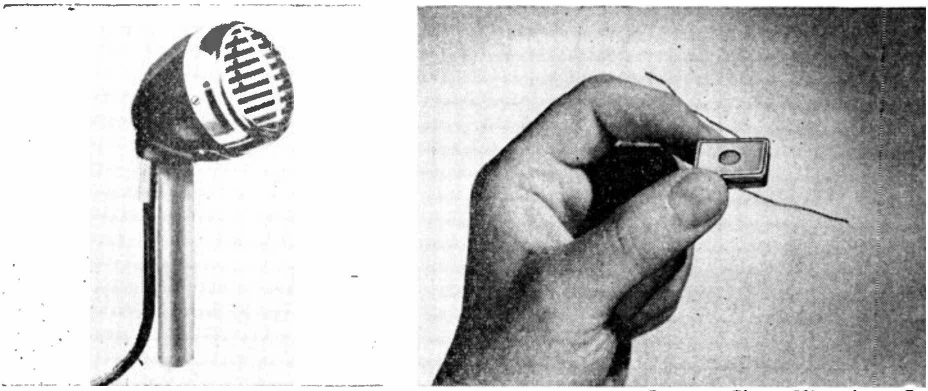
Fig. 4 shows a cut-away view of a dynamic microphone. The diaphragm and its assembly have a certain mass and springiness, so the assembly has a certain resonant frequency at which it will vibrate most readily. This resonant point would probably occur in the audio range and cause an undesirable peak in the microphone response.

To prevent this, the microphone contains an air chamber at the rear of the diaphragm and a vent which connects the air chamber to the outside air. The very small vent, of course, does not pass air readily. When the diaphragm in the microphone moves inward, part of its energy is absorbed in forcing air out the small vent. Thus, the air chamber and vent offer resistance to the motion of the diaphragm. They do not prevent motion of the diaphragm, but just reduce excessive motion at the mechanical resonant point.

The air-chamber principle can be used with any pressure-operated microphone where the voltages that are generated are proportional to the pressures of the sound waves striking the diaphragm. By designing the air chamber and vent properly, it is possible to eliminate resonant effects almost completely.

Reluctance. The controlled-reluctance microphone has become increasingly popular because of its high output and ruggedness. It can be built as a very small unit (down to one inch in size) and is ideal for small compact vacuum tube and transistor devices. Two typical reluctance microphones are shown in Fig. 5. The desk or floor stand version is available with high or medium impedance, and the tiny reluctance unit has an impedance of approximately 1000 ohms.

In a controlled reluctance microphone, the sound waves striking the diaphragm change the reluctance of a magnetic path. The changing flux



Courtesy Shure Microphone Co.

FIG. 5. Controlled-reluctance microphones.

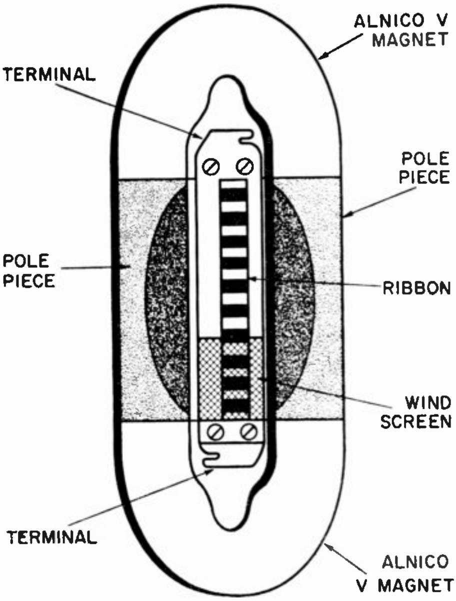


FIG. 6. Internal structure of a velocity microphone.

lines induce voltages in balanced coils connected to the output terminals.

Velocity. The operation of a velocity or ribbon microphone is different from the types already discussed. Instead of having a diaphragm, it has a very thin ribbon of an aluminum alloy suspended between the poles of a powerful magnet as shown in Fig. 6. The ribbon is clamped at its ends, and wires from a matching transformer are connected to the terminals. The ribbon itself completes the primary of the transformer, and thus acts as a one-turn coil. As the ribbon moves in the magnetic field, a voltage is induced in it. A varying signal voltage appears at the output of the matching transformer.

When sound waves strike the ribbon, it moves back and forth in step with the motion of the air particles. It has very little springiness and very little mass. Thus, it practically floats in the air and is able to follow air particle motion faithfully. The ribbon is crimped or accordian-pleated to give easy movement and to help prevent resonant vibrations.

Since the ribbon is able to move almost as though it were an additional air particle, it is said to respond to the velocity of the air particle movement rather than to the pressure of the sound wave. This is why it is called a velocity microphone.

The velocity microphone is capable of giving a very high-fidelity reproduction. It is, however, more delicate than the crystal and dynamic types. Gusts of wind or sharp puffs of air from a person speaking too close to the microphone can damage the ribbon. When using a velocity microphone shield it from the wind, and make certain that the person using the microphone speaks across its face instead of directly into it.

The ribbon can also be damaged by rough handling. It is mounted vertically or nearly vertically, and it must be kept in that position. Velocity microphones must also be kept away from the alternating current fields of power lines and power transformers to reduce hum pickup.

A combination ribbon and pressure type of microphone can be built by

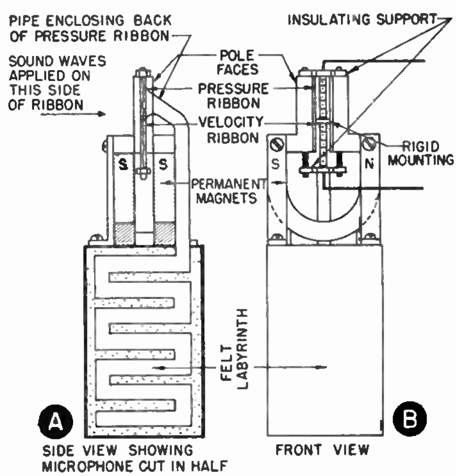


FIG. 7. Front view (A) and side view (B) of the internal appearance of a pressure-operated ribbon microphone.

enclosing the back of the ribbon in an air chamber as shown in Fig. 7. There is a pipe-like piece enclosing the back of the ribbon, which leads to an air chamber at the bottom of the microphone. The ribbon itself acts as a diaphragm and becomes pressure-operated. The part of the ribbon below the rigid mounting is still velocity-operated.

MICROPHONE CHARACTERISTICS

A number of factors must be considered in choosing a microphone for a specific public address application. These factors are impedance, frequency response, sensitivity, pickup or directional pattern, and physical features.

Impedance. In general, microphones are classed as being low impedance or high impedance. The velocity microphone has a very low impedance and almost always contains a built-in impedance-matching transformer that is designed to match the microphone either to a 200-500 ohm audio line or directly to the high-impedance grid input of an amplifier stage. Dynamic microphones also are low-impedance types and have output impedances that range between 8 and 50 ohms. Generally, a transformer is used to raise the output impedance of the microphone assembly to match 200-500 ohm lines or high-impedance inputs.

The crystal microphone is a high impedance type. Therefore, it can be used to supply signal directly to the high-impedance input of a public address amplifier.

A high-impedance circuit is more subject to hum and interference pickup than a low-impedance circuit. For this reason, the cable between the microphone and the amplifier must be kept short. If you use a low-impedance microphone and connect it to the low-impedance input of an amplifier, the cable can be considerably longer. However, as you will learn later, the impedance of the microphone is not too important. You can always use impedance-matching transformers to match high-impedance microphones to low-impedance lines, and low-impedance lines to high-impedance inputs.

Frequency Response. The frequency response of the microphone you choose for a particular PA system depends on the needs of that installation. Almost any style of microphone is satisfactory for voice pickup. Some microphones are designed so that their frequency response is limited to the voice range between 100 cycles and 6000 cycles. These microphones can be used to produce clear, understandable speech even in noisy locations. If the microphone is to be used to pick up music, it should have a wider frequency response.

The modern microphone, regardless of the type, can be made to have a wide frequency response with careful design. Frequency response often depends on cost; the more expensive the microphone, the wider the frequency response. For example, it is possible to obtain crystal microphones with an audio frequency range extended from 30 cycles to more than 10,000 cycles. Dynamic microphones are available with frequency responses up to 12,000 cycles, and the very high-grade velocity types have ranges extending beyond 15,000 cycles.

A well-made high-quality microphone will also have a more uniform response over the audio frequency range. In this respect, the velocity microphone has the smoother response, although any high-quality microphone, regardless of type, will be more uniform than an inexpensive one.

A high-fidelity microphone, however, is costly and is often rather delicate. In most PA installations, it is best to use as rugged a microphone as possible. Make sure its frequency response meets the requirements of the installation, but does not exceed them too much. This will keep microphone costs at a minimum.

Physical Features. The physical features also should be considered in choosing a microphone for a particular application. The delicate velocity microphone should be used only for high-quality public address installations in large auditoriums and in orchestral work where there is the least opportunity for rough handling and damage. It is perhaps the least used of the basic types because of the limited number of high-fidelity public-address installations.

Dynamic microphones are popular for permanent and semi-permanent installations. Their frequency response is good, and long lengths of cable can link the microphone and amplifier because of their low impedance outputs. The crystal microphone is most common for portable and small semi-permanent installations.

For outdoor installations, use a rugged crystal or dynamic microphone. Make certain it is able to withstand temperature and humidity changes, and that it is wind-blast proofed. Such a microphone contains baffles and special mountings to make it least susceptible to wind gusts.

Output. Microphone output is an important consideration in planning a public address installation. The old obsolete carbon microphone had the greatest output for a fixed sound level, but a very limited frequency response. The crystal microphone has the next greatest output. This is one of the reasons that the crystal microphone is popular for small portable public address systems. The dynamic microphone output level depends on its frequency response and physical dimensions. The output ranges from about the level of the crystal microphone down to that of the velocity microphone, which has the least output.

Of course, you can make up for the low microphone output by using additional amplifier gain. The larger semi-permanent and permanent amplifier systems have the additional gain required for full output from a better, but less sensitive microphone.

Naturally, if you are to drive an amplifier to its full output, the microphone used must supply at least the minimum input voltage for which the amplifier was designed. For a given amplifier, it is best to use the type of microphone recommended by the amplifier manufacturer if any such recommendation is made, or choose a microphone that supplies the recommended input level and impedance.

There is some lack of uniformity in microphone ratings. The microphone rating is its output in relation to the sound pressure applied to it. The unit of measure of sound pressure is called a "dyne." Sound pressure is generally given in dynes per square centimeter. The term "microbar" is also sometimes used. One microbar equals one dyne per square centimeter. The peak sound pressure per square centimeter of microphone surface of a man speaking into it in a conversational tone is about 10 dynes.

Microphones are usually rated in terms of decibels down from a certain reference voltage or reference power. The reference voltage is usually 1 volt. The reference power is usually 1 or 6 milliwatts.

To be certain what the output of a given microphone is, you must know the reference standard. Standard references are given in Table 1. The first is the most common.

You may find the rating of a microphone given as "—50 db below 1

TABLE I
1 volt/1 dyne/cm² (1 volt/1 microbar)
1 volt/10 dynes/cm²
1 volt/100 dynes/cm²
.001 watt/1 dyne/cm²
.001 watt/10 dynes/cm²
.006 watt/10 dynes/cm²

volt/dyne/cm² into a load of 1 megohm." When the complete rating is given in this way, you know at least what reference level was used. In comparing two microphones having the same reference level—for example one rated at —50 db below 1 volt/1 dyne/cm² and another at —60 db below 1 volt/1 dyne/cm²—you know that the microphone with a —50 db rating will have the highest voltage output.

On the other hand, if the rating is given as just "—50 db," as it frequently is in supply house catalogs, you do not know what reference level was used; and you may be badly misled if you compare the output rating of this particular microphone with that of another that is rated on a different reference.

For example, three different pressure levels are given in Table 1, each 10 times the pressure of the one preceding. A 10 times difference in pressure on a microphone increases its output by 20 db. Therefore, the same microphone could be rated as —70 db below 1 volt/1 dyne/cm², or —50 db below 1 volt/10 dynes/cm², or —30 db below 1 volt/100 dynes/cm².

Similarly, a power rating in terms of 1 milliwatt is 8 db higher than it would be if the microphone were rated on the basis of a 6-milliwatt reference level. In other words, a microphone rated at —50 db for the 1-milliwatt level would have to be rated at —58 db if the 6-milliwatt level were used as the reference.

All this means that you must be careful to choose a microphone whose db output level is high enough to get full rated output from the amplifier used. Then, when you compare microphones made by different manufacturers, always make sure that their ratings are in terms of the same reference; otherwise you may get the wrong idea of the relative outputs. If you cannot tell what standard was used from the information given, write both the manufacturer of the microphone and the manufacturer of the amplifier. One or the other will be able to tell you whether the particular microphone and amplifier you are interested in will work properly together.

Of course, once you have had experience with particular brands of microphones, you won't have to worry about the reference standards used, because you will know what their ratings are.

Pick-up Patterns. The response pattern of a microphone shows how well it responds to sounds coming from different directions. The three most common microphone response patterns are shown in Fig. 8.

The pressure microphone response shows that the microphone will respond equally well to sounds picked up from all directions. This is the pattern that is usually obtained from a dynamic microphone, a crystal microphone, or some other type of pressure-(diaphragm) operated microphone. The figure 8 velocity pattern shows

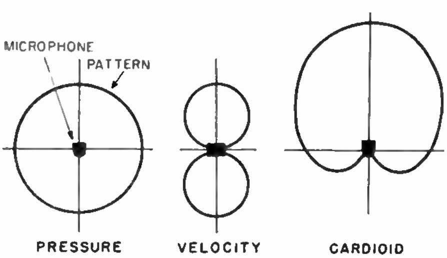


FIG. 8. The cardioid response is produced by combining the responses of a velocity and a pressure unit.

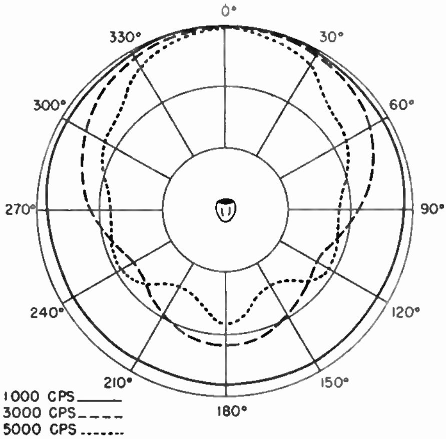


FIG. 9. This graph shows how a nondirectional microphone picks up sound coming from various directions. The response at three different frequencies is shown. The front of the microphone faces the 0° line.

that the microphone will pick up sound equally well from the front and rear, but there is practically no pick-up from the sides. This is the pattern that is usually obtained from a velocity (ribbon) microphone. When the two operating principles are combined in the same microphone, as is the pressure-operated ribbon microphone, the response pattern has the cardioid (heart) shape shown in Fig. 8. Notice that there is a very broad pick-up from the front, but very little from the back.

The directivity patterns of a microphone also depend on the frequency of the sound being picked up. For example, a pressure microphone is usually classified as non-directional or omni-directional because it responds equally well to sound waves coming from all directions. This is true, however, for sounds below 1000 cycles. At higher frequencies, around 3000 to 5000 cycles, the response is more directional; there is more pick-up from the front than from the rear. The diagram in Fig. 9 shows the pick-up characteristics of a pressure-operated microphone at different frequencies. From this, you can see that you can get a better over-all pick-up of all frequencies when the sound waves arrive straight toward the front of the diaphragm.

Pressure-operated microphones of this type can be made more non-directional by directing them upward, as shown in Fig. 10B. In this position, the microphone has the maximum sensitivity overhead, but will pick up equally well in all horizontal directions. A metal shield placed above the microphone will minimize the sound sensitivity from overhead and will improve the side pick-up.

A standard velocity ribbon microphone with two sides open has a figure 8 directivity pattern, as you saw in Fig. 8. Sound is blocked on the sides by the microphone structure and the wind shield. In PA work, you can use the bi-directional response when two different sound sources are to be picked up simultaneously. Suppose you want to pick up the music of an orchestra. The orchestra can be divided into two sections with the microphone placed in the middle. Because of its directivity pattern, the microphone will have maximum sensitivity from the orchestra, but minimum pick-up toward the audience. Therefore, there will be good orches-

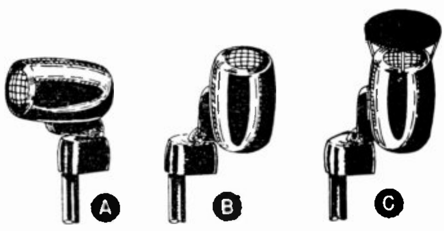


FIG. 10. A microphone that is relatively nondirectional in its normal position (A) becomes even more so if it is turned to face upward (B). The response can be further improved by putting a shield above the microphone (C).

tra pick-up, but minimum noise pick-up. If the rear of the ribbon microphone is enclosed by a baffle, the microphone will operate the same as a pressure microphone as far as its directivity is concerned.

It is possible to obtain a cardioid response pattern from any microphone that contains both dynamic and velocity units, crystal and velocity units, or one that contains special air chambers and baffles. For example, in a pressure-operated velocity microphone, half of the ribbon operates as a pressure unit, while the other half operates as a velocity unit. It is also possible to use a single crystal or dynamic microphone with special acoustic chambers in the microphone housing to get a cardioid pattern. Most microphones of these types contain a three-position switch that can be used to change the response pattern to any of those shown in Fig. 8. Thus, you can choose the pattern to suit the pick-up conditions.

Shield plates for various types of non-directional microphones are included as accessory items. These can be attached to the microphone to sharpen its response. They can be removed whenever a non-directional pick-up is desired.

OTHER SIGNAL SOURCES

Audio signals picked up by a microphone are not the only ones that can be reproduced by a PA system. Most PA amplifiers include separate inputs for record players, tape recorders, and tuners. Also, both microphone and recorded signals can usually be sent at the same time because separate gain controls are included in the amplifier for each input.

When choosing a phonograph or tape recorder for the PA system, make sure that the impedance of the phono cartridge or the play-back head matches the amplifier input impedance. Phono cartridges and play-back heads having either high or low impedances can be obtained.

In some installations, the signal source for a public address system is an AM or FM radio tuner. Generally, this type of installation is one that supplies a continuous musical program for factories, department stores, large food stores, etc. Since the tuner will have to operate for long periods of time, it must have good stability so that it will need little or no adjustment. This type of performance is obtained only with the more expensive tuners.

Many of the better PA amplifiers also have an audio line input. This input permits the telephone line or other signal distribution lines to be a source of signal for the public address system. Signal distribution lines are often used in large auditorium and arena installations and for conveying the sound of special events. Also, if the event is to be broadcast or telecast, the station or network microphones may be the only ones permitted. For such an installation, the public address system can receive its signal from telephone lines through special cable from the station remote amplifier system. Thus, the regular public address microphone need not be used, making the stage or announcing area less cluttered with pick-up equipment.

SUMMARY

In this section, you learned that the microphone and other signal sources you choose depend on the needs of the particular PA installation.

In choosing a microphone, its frequency response, ruggedness of construction, and output level should be considered. The type of installation and the type of program material to be sent will determine the requirements.

If the system is to be used for speech only, the frequency response can be restricted to the voice range. For music it should be wider. For noisy locations, shields can be added to prevent noise pick-up.

For most installations, especially outdoor ones, the rugged crystal, dynamic, or reluctance microphones are best.

Remember when choosing a microphone that the outputs are rated in different ways by different manufacturers.

PA Amplifier Specifications and Circuits

The audio amplifiers used in public address systems contain the same basic circuits as those found in hi-fi amplifiers and the audio sections of radio and TV sets. In some PA installations, it may be necessary to amplify the audio signals from more than one signal source at the same time. This is rarely if ever done in other types of audio systems. The signals must be fed to different amplifier inputs, and then mixed in the amplifier circuits. The circuits used to mix the signals are described in this section.

Before we discuss any of the amplifier circuits, let us briefly describe the ratings and characteristics of PA amplifiers.

AMPLIFIER SPECIFICATIONS

There are many types and sizes of PA amplifiers. They differ in power output, in fidelity, in power supply requirements, in the numbers and types of microphones or other signal sources they will operate from, and in input and output impedance characteristics All these factors must be considered in choosing an amplifier for a specific job. The manufacturer's catalogs give information on these characteristics to help you in making your choice. The following is a list of the specifications you will probably find with the amplifier.

Power Output. Amplifiers intended for public address use can be grouped into low-power, medium-power, and high-power classes. In general, any amplifier under 15 watts is considered a low-power type; those between 15 and 50 watts are considered medium power, and those over 50 watts are considered high power.

Amplifier Gain. With a specific signal voltage level applied to the input, the amplifier in a PA system should increase the signal until it is high enough to drive the amplifier to full output. The manufacturer usually gives the over-all gain of his amplifier, from the input jacks to the output, in db. Two gain measurements are usually given: one for phonograph pick-up and the other for microphone input. The output of a record player, of course, is much higher than that of the microphone. Therefore, less gain is required by the phono channel. A value, such as 100 db, is usually given for the microphone inputs, and perhaps 40 to 60 db for the phono inputs.

For example, if the amplifier is rated at 60 watts and has a 100-db gain for the microphone channel, you can determine from a db chart that the 60-watt output represents +40 db, when based on a 6-milliwatt reference level. Since the output of the amplifier is +40 db and the gain is 100 db, the amplifier will be capable of delivering full output if the input signal is —60 db. This is the rating that the microphone should have. In making a db approximation of this type, be certain that the same reference level is used for both amplifier output and microphone sensitivities.

The manufacturer will usually recommend types of microphones or phonographs that are suitable to use with the amplifier. If the information is not given, you will have to make the simple calculation described above to decide whether a specific signal source can drive the amplifier to full output.

Frequency Response. As mentioned earlier, the frequency response is important. If the system is to be used for voice alone, there is no need for very low notes or very high notes, above 6000 cycles. High fidelity requires a very broad frequency response for true reproduction of the much wider musical range. The frequency response of an amplifier is usually shown in the form of a chart like that in Fig. 11, or is given in a statement of db above and below a reference level between a specific low frequency and a specific high frequency.

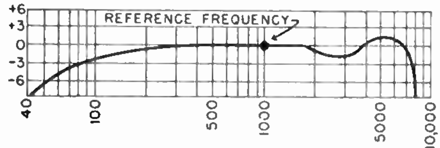


FIG. 11. This frequency-response curve shows how many db up or down the amplifier output is at various frequencies.

For example, a certain amplifier may be said to have a response that is flat within ±3 db from 40 to 10,000 cycles. This means that the output will vary slightly, but will always remain within 3 db above and below the output level at a reference frequency over this frequency range. In most cases, the output at 1000 cycles is referred to as the 0 db reference level for indicating the frequency response.

Tone Controls. The manufacturer sometimes indicates in db the influence of the various settings of the tone controls on the frequency response.

Distortion. In public address work, a total harmonic distortion of 5% is considered tolerable. The rated power output of the amplifier is not the peak power output, but the maximum power at which the output is no more than 5% distorted. Sometimes the rated power output is for 2% distortion. The distortion, of course, increases as the output power increases.

Hum Level. The output hum and noise level of a public address amplifier should be as low as possible. Noise level is in general far below that of the amplifier hum. Most manufacturers indicate that the hum level is so many db below the rated power output. A value of 50 to 80 db down is considered acceptable for general purpose public address amplifiers. The noise level is also given in terms of db down with respect to the amplifier's rated output.

INPUT TERMINATIONS AND MIXING CIRCUITS

The input circuits of the amplifier are important because they must correctly match whatever signal source or sources are to be used. At the same time, a gain control must be included so that the amplifier output can be adjusted to meet the requirements of the installation. Individual gain controls for each amplifier input are helpful so that the signals from two or more sources can be mixed and adjusted to the proper relative levels. Finally, the voltage amplifier section must amplify the input signal to a high enough amplitude for driving the power output stage of the amplifier.

In almost all modern public address amplifiers, the voltage amplifier stages are resistance-coupled. Triodes are more common than pentodes. The voltage amplifier stages are conventional except for a few features, such as input coupling and mixing circuits.

When the amplitude range or response of an amplifier is given by the manufacturer, it is assumed that the input and output impedances are matched to get the proper transfer of power. The impedance values of the input channels are important amplifier ratings. Many amplifiers provide only high impedance inputs; so some means of matching low-impedance signal sources to the amplifier input circuit must be provided. This is usually done with input-matching transformers.

Let us now consider the various types of input arrangements.

Input Coupling Circuits. It is standard practice to use coaxial jacks as the input connections between the various signal sources and the grid of the first tube. A number of basic input arrangements are shown in Fig. 12.

A high impedance input, Fig. 12A, is intended for operation from a high-impedance device such as a crystal or ceramic pick-up or a crystal microphone. When a low-impedance signal source is used, it must be transformer-coupled to the input stage, as shown in Fig. 12B. Transformer T1 then functions as an impedance transformer and matches the low impedance of the signal source to the high impedance of the input grid. This

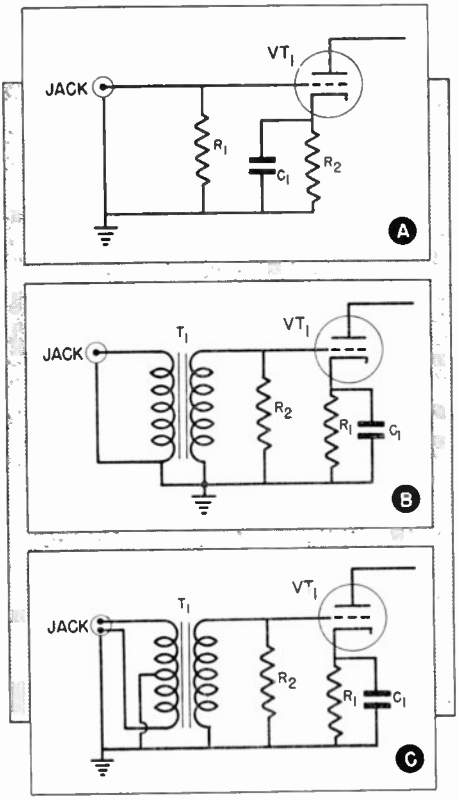


FIG. 12 Three kinds of input circuits. A high-impedance circuit is shown in A, an unbalanced low-impedance circuit in B, and a balanced low-impedance circuit in C.

type of connection is called an unbalanced input because one side of the line between the input and the microphone is at ground potential.

The arrangement of Fig. 12C is referred to as a balanced input and requires the use of a two-wire cable between the signal source and the amplifier input. The braided shield serves as the ground return. The advantage of the balanced system is that both conductors pick up equal amounts of noise or hum voltage and, in feeding them in opposite directions across the primary, the hum and noise will be cancelled. Thus, balanced inputs can have higher signal-to-noise ratios. This is particularly helpful in noisy or high-hum level locations when a long length of line must run between the signal source and the amplifier.

Input Mixing Circuits. Not only must each signal source be terminated correctly, but also there must be some arrangement so that more than one signal source can be used at the same time. Also, there should be a provision for a smooth changeover from one signal source to another. This can be done by resistance networks or by vacuum tube stages.

Resistance Mixing. Even the simplest small portable PA system has at least two inputs, one for a microphone and one for a record player. The amplifier is arranged so that both microphone and record player can be used at the same time, and a gradual fading, if required, can be made between the two signal sources.

In elaborate systems there may be three to six microphones and perhaps one or more record players connected at one time. Also, a group of two or three microphones may have to be used to pick up an orchestra. The level of each microphone must be adjusted individually to get the proper balance between various sections of the orchestra at the input circuits. Thus, true flexibility can be obtained only if it is possible to turn one microphone off and another one on smoothly without having to disconnect one microphone and plug in a second one. For this reason, PA systems have a number of input terminals each with its own separate controls.

Some typical input circuit and resistance mixing networks are shown in Fig. 13. In Fig. 13A, two microphone channels are used, each with its own level control, R1 and R2. By adjusting the controls, you can cut one channel "off" and the other "on", or

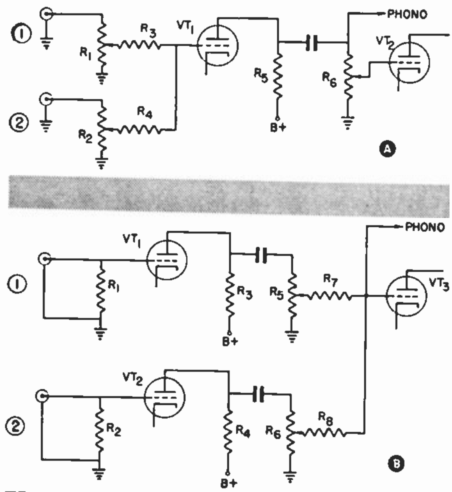


FIG. 13. Two kinds of resistance mixing circuits.

fade from one to the other. If desired they can both supply signals at the same time.

The signal or signals are amplified by the preamplifier stage, tube VT1, and are then passed through a master gain control to the second voltage amplifier. The master gain control permits adjustment of the over-all gain of the amplifier. It regulates the over-all amplification of both signals, but at the same time it does not disturb their relative levels. In other words, you can pre-set the mixer controls R1 and R2 to some desired level, and then use the master control to vary the over-all volume as required.

Notice that the phonograph pick-up is fed into the amplifier at the master gain control. Since the crystal or ceramic phono cartridge has a higher output than the microphone, the additional gain provided by tube VT1 is not needed.

Resistors R3 and R4 are used as isolation resistors to minimize the interaction between the two level controls. When potentiometer R1 is adjusted for minimum signal from input 1, the arm of the potentiometer is at ground potential. If resistor R3 were not in the circuit, the grid of the tube would be connected to ground; no signal could be supplied from the input of channel 2. In effect, resistors R3 and R4 prevent any shunting of the input grid but at the same time permit individual adjustment of the input signal levels.

The disadvantage of this simple input arrangement is that there is some interaction between the channels. Also the signal-to-noise ratio of the system varies with the setting of the controls. Remember that very weak signal levels are being supplied, and since resistors R3 and R4 act as voltage dividers to the input signals, there will always be some signal loss. If the signals are attenuated before they are introduced to the grid of the first amplifier tube, there is a reduction in the signal-to-noise ratio. Noise often develops after potentiometers R1 and R2 have been used for some time. It is especially noticeable when controlling the gain at very weak signal levels.

A better mixing arrangement is shown in Fig. 13B. In this system, both input signals are amplified before they are applied to a mixing network. Thus, the input signal-to-noise ratios are fixed and the signals are amplified to a higher level before being introduced to the mixing action. Therefore, mixing has much less of an influence on the signal-to-noise ratios.

At the outputs of VT1 and VT2 in Fig. 13B, the signals are applied to separate volume controls which regulate the relative gains of the two input channels. The master volume control is at the input of the next amplifier stage to regulate the overall gain of the system.

Electronic Mixing. The electronic mixing circuits in Fig. 14 have additional advantages and are used in the more expensive public address amplifiers. In electronic mixing, the signals are applied through separate volume controls to separate channel amplifiers. Both signals are then developed across a common plate resistor, such as resistor R3 in Fig. 14A. Isolation between the channels is obtained by the vacuum tubes and resistors R5 and R6.

The signal-to-noise ratio of this circuit is poor at low input levels because the gain of each channel is controlled at the input circuit. In the arrangement of Fig. 14B, however, electronic mixing is accomplished by tubes VT3 and VT4. The input tubes, VT1 and VT2, amplify their corresponding input signals before they are applied to the gain controls and mixing circuits. Thus, signals with a higher signal-to-noise ratio are available across resistors R2 and R5 before they are introduced to the channel gain controls R3 and R6. The two signals are mixed across the common plate load resistor R7 and are applied to the following voltage amplifier stages. A master volume control is

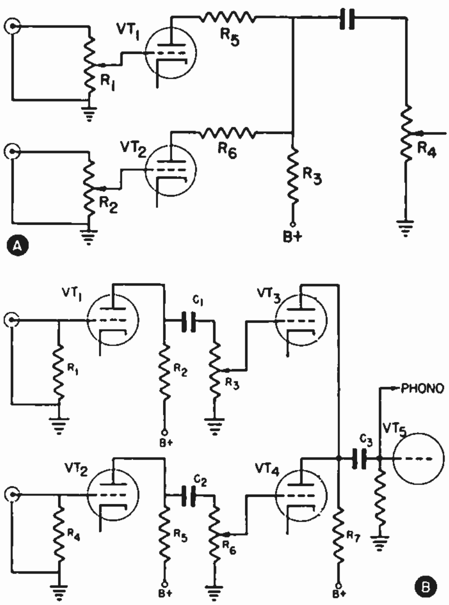


FIG. 14. Two examples of electronic mixing.

generally included in the next amplifier stage.

Phonograph Channels. In most PA installations, the output levels of one or more record players must be regulated in addition to the microphone gains. A typical arrangement

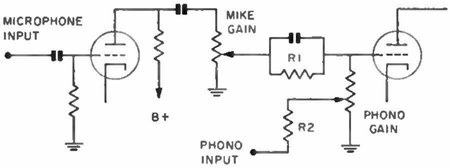


FIG. 15. Mixing of single microphone and single phono inputs.

for a small portable amplifier containing single microphone and phono channels is shown in Fig. 15.

The microphone signal is applied directly to an amplifier stage, and the output is coupled through a microphone gain-control circuit to the grid of the second voltage amplifier. The phono input also supplies signal to the second amplifier grid through a separate volume control. Since the lower-level microphone signal is amplified by the first stage, both the microphone and phono signals are at about the same level at the grid of the second stage. Isolation resistors R1 and R2 minimize interaction between the microphone and phono channels. With this arrangement, the microphone and phono levels can be adjusted separately, so recorded music can be used as background for voice and there can be a smooth changeover.

When there is more than one phono channel, resistive networks such as those shown in Fig. 16 may be used. In the first example, Fig. 16A, individual volume controls are used for the two phono inputs. This circuit is similar to Fig. 13A. Again resistors R3 and R4 minimize interaction between the two phono channels.

Occasionally the PA amplifier contains a special fader control as shown in Fig. 16B. This control has a grounded center tap. The output of each channel is applied across one half of the control. Hence, there is zero output when the potentiometer arm is set at the center tap. When the arm is moved toward one end of the control, the output of the channel connected to that half rises, while the second channel remains cut off. When the arm is moved in the other direction, the second channel output is increased and that of the first is cut off.

Such an arrangement is referred to as a "fader control" because it is possible to move from maximum volume for one channel down to zero for both and then gradually up to maximum for the second. It represents a simple single control method of fading from

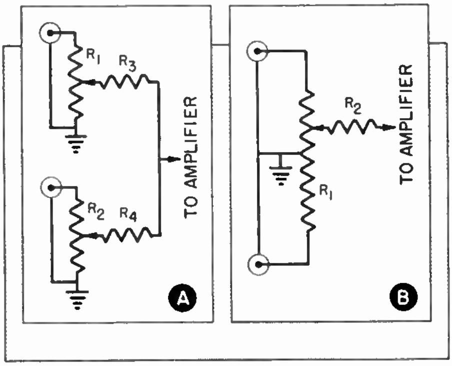


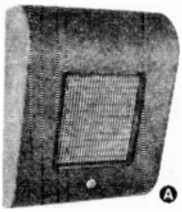
FIG. 16. Two kinds of circuits for phono inputs: a mixing circuit (A) and a fader circuit (B).

one recording to a second. Resistor R2 functions as an isolating resistor and prevents shunting the grid of the input tube to ground as the arm is moved toward the center tap position.

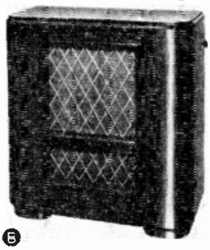
The controls in Fig. 16A also can be used as faders. However, the operator must adjust both controls at the same time to get fading action.

Loudspeakers Used in Public Address

Permanent magnet loudspeakers are used almost universally for public address work. Rugged versions of the cone-type speakers discussed in previous lessons are used for many indoor public address installations. For portable and semi-permanent installations, the speakers are generally enclosed in a small baffle for wall mounting purposes as shown in Fig. 17A. The base reflex cabinet shown in Fig. 17B is also popular because of its superior performance and the fact that the back is completely enclosed. Since the sound comes out from only one side of the speaker system, there is less trouble with microphone placement and feedback howl.



Courtesy RCA



Courtesy Jensen Mfg. Co.

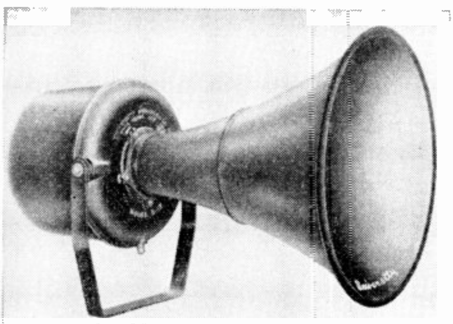
FIG. 17A. A typical wall baffle.
FIG. 17B. A typical bass reflex loudspeaker baffle.

The type of loudspeaker baffle to use depends on the installation. A large baffle gives better tone quality, but a small simple baffle can be carried and mounted easily.

In outdoor public address installations, speakers with metal diaphragms instead of paper cones are used in weather-proofed horn enclosures. They have a much higher efficiency than paper-cone types, and thus convert audio power output to sound power more efficiently. The paper cone deteriorates with age, particularly if it is subjected to high humidity and other temperature and weather variables.

A typical driver and horn is shown in Fig. 18. In this arrangement, the driver with its vibrating diaphragm excites a long horn. A horn type speaker is quite directional as well as highly efficient. For example, a long narrow horn with a small mouth tends to project the sound directly from the mouth of the horn without allowing it to spread. To cover a larger area, the horn surface should flare outward so that the sound is distributed over a wider angle.

To reproduce low-frequency sounds, a horn must be very long. The fidelity of the horn depends on the regularity of its flare, or increase in cross-sectional area. Therefore, the horn must start with a very small throat so the mouth will not have to be too large. Horns that carry speech only, and thus handle a limited frequency range can be rather short. However, if music is to be carried, the horn must be so long and large, that the space required becomes a problem.


Courtesy University Loudspeakers, Inc.
FIG. 18. Driver and horn speaker.

Courtesy University Loudspeakers, Inc.

FIG. 19. A typical reflex trumpet, much used for outdoor installations.

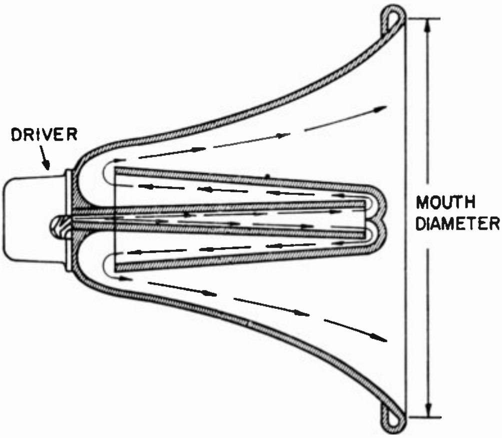
One way to get better frequency response from a horn type speaker without making it unduly long, is shown in Fig. 19. This type of speaker is known as a re-entrant or reflex trumpet. The sound travels down an inside horn and is then forced back toward the rear before it reaches the horn mouth. This is shown by arrows in Fig. 20. With this internal folding, it is possible to make the overall dimensions of the horn rather short and still have a long air column.

The chart in Fig. 20 shows that the low-frequency response depends on the physical dimensions of the horn. The better the low-frequency response required, the longer the length of the air column must be, and the wider the mouth diameter.

A particular advantage of this type of construction is that the loudspeaker can be made weatherproof. The moving parts of the speaker assembly are completely enclosed, and the horn and driver enclosure are made of metal, and painted inside and out.

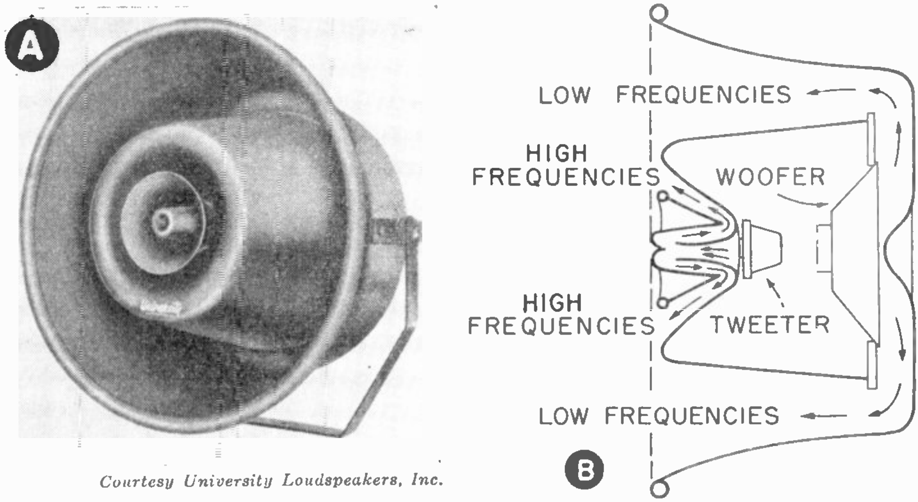
It is possible to use the reflex horn principle with paper-cone type drivers because they too can be completely enclosed by the folded horn construction. An example of this type is shown in Fig. 21.

The coaxial type of reflex loudspeaker is used for all-weather high-fidelity reproduction of speech and music, and has a frequency-response range extending from 50 cycles to 15,000 cycles. You can see in Fig. 21B that the speaker consists of a cone-type woofer mounted in a rear baffle chamber that matches to a large



AIR COLUMN LENGTH	MOUTH DIAMETER	LOW-FREQUENCY CUT-OFF
2½ FT	16 INCHES	200 CPS
3½ FT	20 INCHES	150 CPS
4½ FT	26 INCHES	120 CPS
6½ FT	31 INCHES	85 CPS

FIG. 20. Cross-sectional view of a reflex trumpet and chart showing the response in relation to the physical dimensions of the horn.



Courtesy University Loudspeakers, Inc.

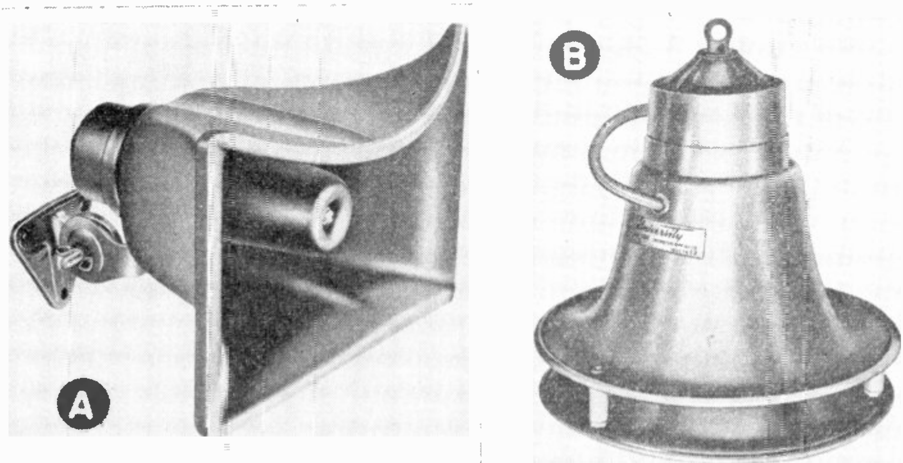
FIG. 21. Coaxial reflex speaker.

folded horn. A heavy duty tweeter driver unit is coaxially mounted and radiates the high frequency energy by its own smaller folded horn assembly.

The unit shown in Fig. 21 has a mouth diameter of 33½ inches and a depth of 20 inches. It is able to handle 30 watts of audio power.

There are versions of the coaxial reflex speaker that have smaller physical dimensions, more limited frequency response, and smaller power rating. The smaller speakers can be used for voice paging. Most of them are under 10 inches in diameter, and their frequency response extends from a few hundred cycles up to better than 10,000 cycles. The absence of bass permits clear, crisp speech even in areas where there is high background noise.

The speakers shown in Fig. 22 use the horn principle and are weatherproofed so that they can be used out-



Courtesy University Loudspeakers, Inc.

FIG. 22. Paging speakers.

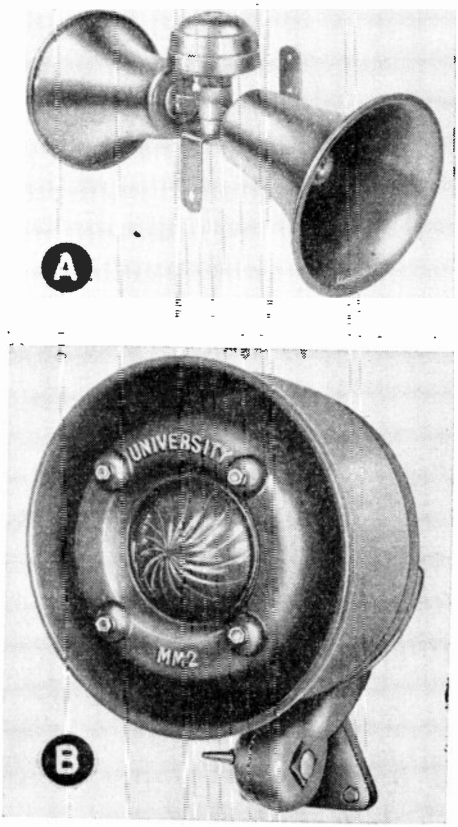


FIG. 23. Special speaker types.

doors and in dusty or wet locations indoors. The type shown in Fig. 22A is able to radiate sound over a wide angle. The wide-angle dispersion directs the sound into the areas to be covered and minimizes the dispersion of sound above and below. The paging speaker in Fig. 22B is a radial type for ceiling mounting. It radiates sound uniformly through 360 degrees and, at the same time, minimizes the useless vertical dispersion of sound.

In addition to the speaker just described, many other types are available to meet specific needs. For example, two special speaker types are shown in Fig. 23. The dual paging unit in Fig. 23A can be used to cover two areas with a single speaker. The same driver supplies energy through a coupling arrangement to both horns.

The second speaker is a submerge-proof type that is especially rugged and is immune to salt spray, gases, live steam, and harmful dust and fungus. It will continue to operate even when under water, and will drain automatically when withdrawn. This type of speaker is ideal for laundries, boiler rooms, fire or police department vehicles, docks, bridges, etc.

Explosion-proof speakers are also available for locations where combustible particles in the air could become ignited by a spark from an ordinary speaker mechanism. This type should be used in dusty locations, such as grain elevators, flour mills, starch plants, and other pulverizing plants, and in dry-cleaning, dyeing and paint-manufacturing plants.

Blast-proof speakers are also available that will withstand tremendous instantaneous peak air pressures which would destroy the voice coil and diaphragm assembly of an ordinary speaker. Such a speaker can be used close to sharp noises, such as blasting operations, artillery sites, and other sources of sharp impulse noises or vibrations.

If you are called upon to make an unusual installation, remember that these special speakers are available for many specialized services.

Transmission Systems

Transmission lines have two important functions in public address systems: They connect the microphone to the amplifier, and they connect the amplifier to the loudspeaker system.

Although lines containing two parallel conductors are occasionally used for audio frequency work, such a line is not desirable because it will pick up hum, noise, and interference. Stray pickup can be reduced by twisting the wires so that they are separated only by their insulation. Close spacing and twisting causes stray pickup of one wire to be cancelled by the pick-up of the second. Regular twisted wire is often used as an audio line where the power levels are high enough to make losses unimportant, and where the line will not be subjected to wearing by excessive motion or weather deterioration.

Both low and high priced lines designed specifically for audio work can be obtained from any radio supply house. Typical examples of audio lines are shown in Fig. 24.

The line in Fig. 24A consists of a twisted pair of wires enclosed in cotton insulation or in shielded braid. You can also get water-proofed wire of this type for outdoor use. These lines are used to connect loudspeakers to the amplifier output terminals. Since the lines must transfer audio power, they should have a reasonably large cross-sectional area to carry the current.

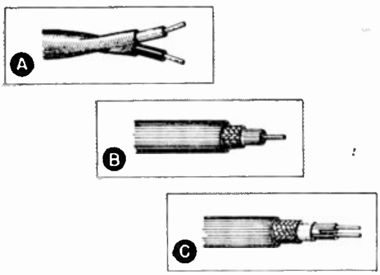


FIG. 24. The three most common kinds of audio lines: A, twisted-pair line; B, unbalanced coaxial line; C, balanced coaxial line.

If the PA system is installed temporarily, the wires may be strung around the room; in a permanent installation, they are frequently placed behind the walls, preferably in conduit. Likewise, for a permanent outdoor installation, the cables are enclosed in conduit and often buried in the ground.

In making a permanent installation, you will have to comply with the local electrical codes. Most electrical codes require that you use special conduits or special wire markings. In some cases, the installation must be made by a licensed electrician.

Twisted-pair lines cannot be used for high-impedance microphone lines, because they will pick up hum and noise. Instead, some form of shielded cable is used for a high-impedance link between the microphone and the amplifier. This type of line, shown in Fig. 24B, consists of a center conductor surrounded by insulation that in turn is surrounded by a shield that acts as a second conductor. The shield serves as the ground conductor and completely surrounds the hot or "high" side conductor. Thus, hum and noise fields are grounded by the outer surface of the shield and do not set up large signal variations between the inner and outer conductors. The outer shield is made of braided fine wires so that it is flexible and can be used conveniently for public address work.

The best shielding can be obtained by using three-conductor cable like that in Fig. 24C. This is the type that is used to connect a low-impedance microphone to the low-impedance input of the amplifier. The two active wires are enclosed in a braided shield. The shield functions as a third conductor and serves as the ground lead between the microphone transformer and the amplifier. Most high-fidelity microphones have cable plugs to fit this type of line.

Now that you know the types of lines that are used in public address work, let us study some of the important electrical characteristics of the lines that must be considered in making a PA installation.

MICROPHONE TRANSMISSION LINES

When we refer to high and low impedance lines in public address work, we are not referring to the surge or characteristic impedance concept used in television and high-frequency work. The characteristic impedance of a line is determined by its inductance, capacitance, and resistance. However, for low-frequency audio operations where the line length is very short in comparison to the audio signal wavelength, we need not consider the surge or characteristic impedance of the line. The terms high and low impedance when used to describe audio lines refer to the impedances of the terminating devices; that is, the source and load that the line connects to and not the actual impedance of the line itself.

High - Impedance Microphone Lines. Microphone lines are considered to be high impedance if they link impedance values above 10,000 ohms. Crystal and ceramic microphones have impedances higher than 20,000 ohms. Therefore, these microphones can be connected directly to the high-impedance grid circuit of a tube through a connecting line. The power loss in the resistance of a high-impedance line is negligible. If the impedances of both the microphone and the amplifier input are around 10,000 ohms, a line having a resistance of 10 ohms will have such a small effect on the signal current that it will not matter. Frequency response and noise pick-up sensitivity, however, are definite problems with high-impedance lines.

Stray noise and hum fields are troublesome whenever the impedance to ground is high, because even a small interference field can develop an appreciable voltage across a high impedance. The high input impedance to the control grid of a tube makes the grid sensitive to interference. Furthermore, the desired signal level at the grid of the first preamplifier tube is always low, and even a low hum or noise voltage will be reproduced by the loudspeakers. You can decrease the interference by keeping the connection between the amplifier input jack and the grid short, and by shielding all portions of the high-impedance circuit so that it will pick up less interference. This latter method is used in high-impedance microphone cables. The shielding is always carried inside the amplifier to the grid of the tube, and sometimes even encloses the input resistor. Although the line is shielded, it always has a certain amount of pickup per unit length. Thus, it is best to keep the high-impedance line as short as possible.

The shunting capacity of a microphone line can decrease the high-frequency response. The influence that the capacity has on the signal level at high frequencies depends on the type of line (its capacity per foot) and the length of the line. The higher the capacity of a line, the more severe will be its influence on the high-frequency response (a high capacity has a much lower shunting reactance at high frequencies). Likewise, the longer the line, the higher the total capacity, and therefore, the more severe its influence on high-frequency response.

For example, if we have a particular audio cable with a capacity of 50 mmf per foot, the total capacity of a 10-foot line will be 500 mmf. If we increase the line length to 20 feet, the total capacity will be 1000 mmf. The longer line will attenuate the high audio frequencies more.

However, if we use a cable whose capacity is only 25 mmf per foot, we can use 20 feet of line and have the same amount of high-frequency attenuation as 10 feet of the 50-mmf line.

The higher the source and load impedances, the more severe the shunting influence of the line capacity. For example, a fixed amount of capacity shunted across a 20,000-ohm line will attenuate the high frequencies more than if it were shunted across a 5000-ohm microphone line. Thus, the high-impedance microphone is capable of giving a good frequency response only if a reasonably short low-capacity line is used between it and the amplifier input.

Fortunately, ceramic and crystal microphones are capacitive themselves, so that their impedances decrease as the frequency increases. If the microphone cable is chosen properly, the impedance of the microphone can be made to function with the line capacity as a voltage divider to produce an essentially constant frequency response over a good part of the audio range. In other words, the microphone impedance and the cable reactance decrease progressively at higher and higher frequencies. Thus, the input voltage at the grid of the amplifier is practically constant over a wide range of frequencies.

This effect occurs only if the microphone cable has the proper characteristics. Therefore, you should not shorten or lengthen the cable that is supplied with a crystal microphone. If you do, the output will not vary uniformly with frequency. High-impedance microphone cables are generally 10 to 15 feet long; some shielded cable can be 25 feet or more.

Low - Impedance Microphone Lines. Whenever a microphone is to be far from the amplifier, you should use a low-impedance line. Low-impedance lines are also used even for short distances with low-impedance microphones.

A low-impedance line will not pick up very much noise and interference. The very low-impedance terminations also reduce the influence of line capacity on the frequency response. Hence, it is possible to use a very long line between the microphone and the amplifier before the line capacity has any effect on the high-frequency response.

The impedance of a low-impedance line has been standardized at approximately 500 ohms, although some manufacturers use 200 ohms. Two connection methods are shown in Fig. 25. If a high-impedance microphone is used, as in Fig. 25A, a microphone transformer steps down the impedance to match the 500-ohm line. The transformer can be connected either at the microphone output terminals or in the line near the microphone. At the amplifier, a second transformer transforms the 500-ohm line impedance to the high impedance of the grid. If the microphone is a low-impedance type, it can be connected directly to the low-impedance line through its internal transformer. Then, a transformer is used at the amplifier to match the low-impedance line to the high-impedance input, as shown in Fig. 25B.

Remember that a line is referred to as a 500-ohm line only because it

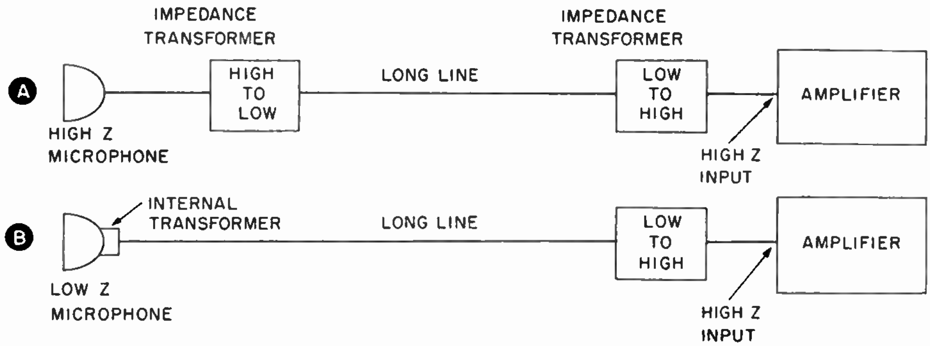


FIG. 25. How long lengths of transmission line can be used to feed the high-impedance input of the amplifier.

serves as a link between 500-ohm impedances. The actual resistance of the line is determined by the length and size of the wire. Its capacity is also determined by the size of the wire as well as the spacing between wires and the length of the line. The same type of cable can be used as a high-impedance line or as a low-impedance line; whether it is high or low depends on the terminating impedances. A low-impedance microphone does not have to be shielded cable. When the impedance is low, hum and noise pickup is not usually a problem. However, if there are ac power lines near the microphone cable, it may be advisable to use either one-wire or two-wire shielded cable.

LOUDSPEAKER TRANSMISSION LINES

At the output of the PA system, we have the problem of connecting one or more loudspeakers to the amplifier. Here, we are working from plate circuits rather than into grid circuits. Also, we are dealing with low-impedance loudspeaker voice coils. In fact, the impedances are so low that a loudspeaker line is not considered to be low-impedance unless it is below 50 ohms. In most instances, such lines terminate in values approximating voice-coil impedances from 2 ohms to 16 ohms. High-impedance lines also can be used between the amplifier output terminals and the loudspeaker. We will discuss these later.

Low - Impedance Loudspeaker Lines. Since the signal power levels at the amplifier output are high, you need not worry about hum and noise pickup on a low-impedance loudspeaker line. A twisted-pair line that is protected from weather and from mechanical damage is satisfactory. Also, since the terminating impedances on such a line are very low (under 50 ohms) the capacity across the line will not be troublesome. The resistance of the line itself is important, however.

The line resistance is distributed in both sides of the line, one half in each as indicated by R1 and R2 in Fig. 26. Although we ordinarily think of copper wire as having practically no resistance, actually long lengths of

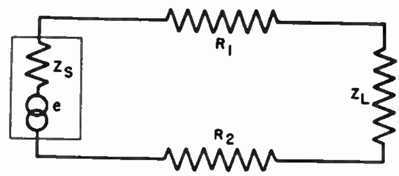


FIG. 26. The resistance of the wire in a low-impedance loudspeaker line acts as a voltage divider with the load impedance.

wire have enough resistance to cause trouble when used to connect low-impedance voice coils. These resistances act as voltage dividers with the voice coil impedance ZL. If they are relatively high in comparison with ZL, there will be a considerable amount of power lost in the line that will not be delivered to the speakers.

Tables like that shown in Fig. 27 can be used to find the "resistance per loop foot" for various sizes of wire. A loop foot actually represents two feet of wire, because it is the amount of wire needed to connect an amplifier to a loudspeaker when the two are one foot apart. You can find the total resistance of a loudspeaker cable with the aid of such a table by multiplying the resistance per loop foot by the number of feet of cable used between the amplifier and the loudspeaker.

For example, let's suppose you are using No. 18 wire, which is a common lamp cord size. Its resistance as shown in Fig. 27 is .0128 ohm per loop foot. A 100-foot run of this wire would, therefore, have a resistance of 1.28 ohms. If you tried to run a wire of this size and length from an output transformer to a 4-ohm loudspeaker voice coil, a considerable amount of power would be lost in the line itself, because the line resistance is high

B & S GAUGE	D C RESISTANCE IN OHMS
10	0.0020
12	0.0032
14	0.0051
16	0.0080
18	0.0128
19	0.0161
20	0.0204
21	0.0256
22	0.0330
23	0.0407
24	0.0513
26	0.0816

FIG. 27. This table shows the resistance per loop foot of various gauges of wire.

WIRE SIZE (B & S)	LOAD IMPEDANCE 4 OHMS	8 OHMS	16 OHMS
14	125′	250′	450′
16	75′	150′	300′
18	50′	100′	200′
20	25′	50′	100′

FIG. 28. Maximum loop lengths that can be used with various load impedances to keep line loss no more than 15% for audio frequencies below 1000 cycles.

with respect to the load impedance.

In general, engineers consider a line loss of 15% in the 400-to-1000-cycle range to be reasonable. Tables like that in Fig. 28 give the maximum length of line of any one size that can be used for various low-impedance values, assuming a maximum loss of 15%. In the example, the 100-foot run of No. 18 wire is too long for a 4-ohm load; if you were using this load value, the maximum length of line that you should use is 50 feet to keep the line loss at 15% or less.

Of course, using a larger size wire reduces the resistance and permits a longer run for the same load impedance, as you can see in Fig. 28. However, large wire sizes cost considerably more money. Furthermore, if the load consists of a group of loudspeakers, its net impedance will be so low that the permissible length of the line will be severely limited. Hence, you ordinarily will not find a low-impedance loudspeaker line longer than about 200 feet, and seldom one that is over 50 feet.

High-Impedance Lines. The problem of power loss on the transmission line can be solved easily by operating the line at a higher impedance. You can do this by using impedance matching transformers at each end of the line, one to match the source to the line and a second to match the line to the load. For power transfer to loudspeakers, terminating line im-

WIRE SIZE (B & S)	LOAD IMPEDANCE 100 OHMS	250 OHMS	500 OHMS
14	1000′	2500′	5000′
16	750′	1500′	3000′
18	400′	1000′	2000′
20	250′	750′	1500′

FIG. 29. Maximum loop lengths for high-impedance loudspeaker lines if 5% power loss at the middle frequencies is allowed.

pedance values ranging between 100 and 600 ohms are called high impedances. Notice that these are what we call low impedances for microphone lines.

The line loss is negligible when the termination is 500 ohms. Effectively, of course, going to a higher impedance termination means that for the same power, we have a higher voltage and lower current. The reduced current causes less drop to occur in the resistance of the line.

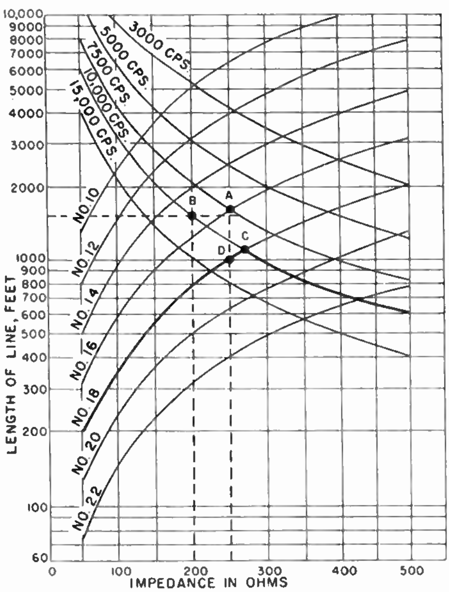
Fig. 29 gives line lengths that provide 5% power loss at the middle frequencies. Compare these with Fig. 28. Incidentally, the loss should not be more than 5%, because the impedance-matching transformers have some loss. The total loss including line and transformer losses will be about 15% if the line loss is kept down to 5%.

Obviously, you can run much longer lines if you terminate them in high impedances. Also, you can use smaller wire, thus saving on the cost of the line; this saving is often worth while if a long line is used. Of course, you must use transformers at each end of such a line. The transformers may be desirable anyway to give the proper impedance matching and power transfer, as we shall show later.

Although using a high-impedance line does solve the loss problem, it reintroduces the problem of the shunting capacity. The average capacity of a twisted-pair electric cord is about 50 mmf per foot, so the line length must be kept down if the high-frequency response is not to be seriously reduced.

Line Lengths. Fig. 30 shows a chart prepared by one loudspeaker manufacturer from which you can find either the length of line that can be used for a particular frequency response and a fixed impedance, or the impedance that is needed at the end of the line when a certain length must be used.

For example, let's assume that the line is to be 1500 feet long, and that the response is to go to 7500 cycles before the power drops to half its normal value (3 db loss). We find 1500 feet on the vertical scale (where the dotted line is drawn in), and fol-



Courtesy Jensen Mfg. Co.

FIG. 30. Transmission line design chart prepared by Jensen Radio Mfg. Co. It is based on a 5% power loss in line and a 3-db loss at the upper limiting frequency due to a line capacity of 50 mmf per foot across a typical moving-coil loudspeaker load.

low across to the 7500-cycle curve, point A. Reading downward along the dotted line to the bottom, you find that the load impedance must be 250 ohms. To find the wire size necessary, find the curve that comes closest to point A; it is for No. 16 wire.

If you have a fixed impedance, you can determine the line length for a particular frequency response. For example, suppose you have an impedance value of 200 ohms. Read upward until you strike, let us say, the 10,000-cycle curve at point B. Again you can use a 1500-ft line. Notice that changing the impedance from 250 ohms to 200 ohms will allow you to go from a 7500-cycle to a 10,000-cycle response for the same line length. If you go the other way—toward a higher load impedance—the fidelity, using the same 1500-ft length, will fall off. For example, at 500 ohms, the response is something under 5000 cycles.

This same chart can be used to determine the maximum line length for a particular size of wire and frequency response. Let's suppose you want to use No. 18 wire. If the frequency response is to be within 3 db up to 10,000 cycles, follow the No. 18 wire size line to where it crosses the 10,000-cycle line. This is at point C. Reading now to the line length scale, you will find that you can use a line length of about 1050 feet, and reading downwards you will find that the impedance should be about 270 ohms. If you used the more practical impedance value of 250 ohms, which crosses the No. 18 wire size at D, you could use a line 1000 feet long of No. 18 wire and have a frequency response that would be somewhat less than 3 db down at 10,000 cycles.

Of course, the response will always be improved if any length less than these maximums is used. For example, returning again to the 250-ohm impedance value, point A shows a length of about 1500 feet and a frequency response to 7500 cycles. Point D at 1000 feet and the same impedance gives a frequency response flat beyond 10,000 cycles. If the length is only 800 feet, the frequency response goes to 15,000 cycles.

SUMMARY

In this section you learned that high impedance microphone lines are subject to hum pickup. Therefore, the cable must be shielded and kept as short as possible. Low-impedance microphone lines can be considerably longer. Impedance matching between the microphone, line, and amplifier input circuits can be obtained by using transformers.

You also learned that if you terminate power transmission lines with high impedances, the line losses will in general be negligible, but the frequency response may suffer. On the other hand, the frequency response is good if you use lower impedances as line terminations, but you will run into line loss difficulties. Therefore, it is the usual practice to choose some compromise impedance value that gives the desired frequency response without excessive line loss at the line length necessary.

Loudspeaker Connections

In the preceding section you learned something of the basic characteristics of transmission lines. Now, let us find out how to connect one or more loudspeakers to the amplifier. In the average job, usually at most only three or four loudspeakers must be connected together. More elaborate installations may require the use of a great many more, however, particularly when several rooms are to be covered.

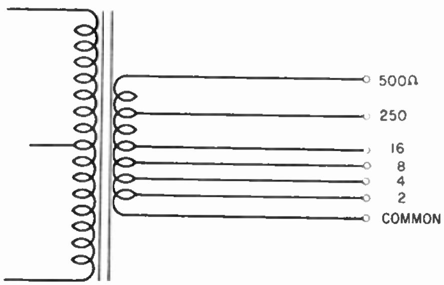


FIG. 31. The taps on a typical output transformer.

Very often you will find that you can choose any of several different voice-coil impedances for a given loudspeaker. One that is usually equipped with an 8-ohm coil can be purchased with a 4- or 16-ohm coil. It is particularly helpful to be able to make such a choice when you have to connect together a group of loudspeakers and must arrive at some reasonable combined impedance that can be matched by available transformers. The impedance values usually provided at the secondary of a universal output transformer are shown in Fig. 31.

The same 4, 8, and 16-ohm values are almost standard today for driver units, although some that have a higher impedance (about 45 ohms) are also offered. High-impedance voice coils are useful when several loudspeakers are to be connected in parallel; the total net impedance of the parallel combination will be very low unless the voice-coil impedances are fairly high to begin with.

Impedance matching is only one of the methods that can be used to connect loudspeakers to the amplifier output. The other method, in which the loudspeaker connections are made according to the needs at a particular location, will be discussed later.

Now let's study several practical examples of the problems you will meet in matching loudspeaker and amplifier impedances, and learn how they can be solved.

LOW-IMPEDANCE CONNECTIONS

You learned that when the distance from the amplifier to the loudspeakers is small, you can connect the transmission line directly to the voice coil terminals. If you have more than one loudspeaker, you can connect the voice coils either in series or in parallel. The parallel connection is the most common because if one of the voice coils becomes open, the remaining loudspeakers will continue to operate. This is important in PA installations.

You can calculate the net impedance of voice coils connected in parallel in the same way as parallel re-

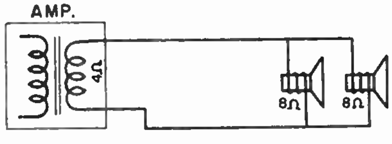


FIG. 32. Matching impedances of parallel voice coils.

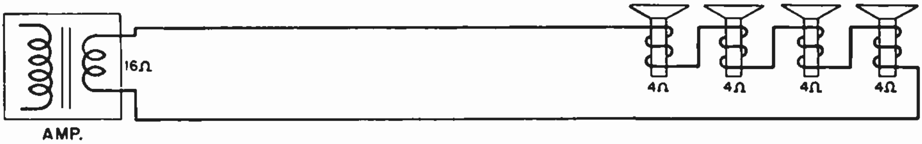


FIG. 33. Matching impedances of series-connected voice coils.

sistors. If all the voice coils have the *same impedance*, the net impedance will be equal to the impedance of any one divided by the number of loudspeakers. For example, the net impedance of the two 8-ohm voice coils in parallel in Fig. 32 is 4 ohms. You can use a low-impedance line to connect these two voice coils to the 4-ohm tap on the amplifier output transformer. In figuring the line loss, you must use the net impedance; in Fig. 32 it is 4 ohms, so the maximum line length is figured on this basis. If you used two 16-ohm loudspeakers, the net impedance would be 8 ohms; this would make it possible to use a longer line for the same wire size.

If two or more loudspeakers are connected in series, and all have the same impedance, the load will be the sum of the voice-coil impedances. Fig. 33 shows an example.

It is also possible to connect the loudspeakers in series-parallel, as shown in Fig. 34. The impedance of this combination is the same as that of an individual voice coil as long as all the voice coil impedances are the same and are connected as shown.

As long as the loudspeakers in each of these cases have the same voice-coil impedances, the power will divide equally between them. Thus, if two loudspeakers are connected either in series or in parallel and their voice-coil impedances are equal, each will receive half the power. If there are three loudspeakers, each gets one-third of the power; if there are four, each gets one-quarter of the power; and so on. Therefore, to make sure none of the loudspeakers in such a combination will be overloaded, all you need do is to see that each has a power rating that is greater than its fractional portion of the amplifier output rating. If the amplifier is rated at 50 watts, for example, and you have two loudspeakers, each will get 25 watts of power. The loudspeakers, of course, must be rated at 25 watts to handle it.

Unequal Impedances. If the loudspeaker voice-coil impedances are unequal, the power distribution will also be unequal. For example, when two unequal loudspeakers are connected in parallel, the resulting impedance is

$$Z=\frac{Z_1Z_2}{Z_1+Z_2}$$

For example, if you have an 8-ohm speaker voice coil in parallel with a 16-ohm speaker, the result will be

$$\frac{8\times16}{8+16}=\frac{128}{24}=5.33 \text{ ohms}$$

There probably won't be a tap rated at 5.33 ohms on the output transformer of an amplifier; 4 ohms is about the closest. Connecting this group to the 4-ohm tap will result in a certain loss of power. This cannot be avoided.

There will also be an unequal power distribution; the loudspeaker

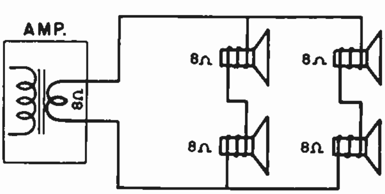


FIG. 34. Matching impedances of voice coils connected in series-parallel.

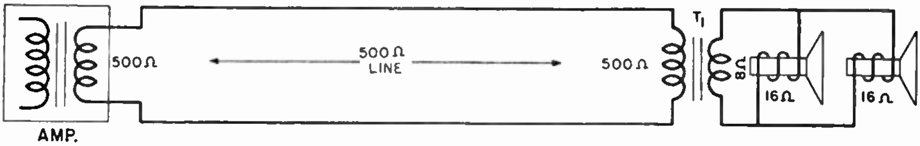


FIG. 35. Use of high-impedance line with grouped loudspeakers.

having the lower impedance will receive the greater amount of power when they are in parallel. In this case, the 8-ohm loudspeaker will get twice the power of the 16-ohm loudspeaker. (The same voltage is across both, and the power in each is $P = E^2 \div Z$; hence, the lower the impedance, the higher the power.)

You should keep this fact in mind if you are connecting loudspeakers of unequal impedance in parallel, because otherwise you may accidentally overload one of the loudspeakers. If a 50-watt amplifier were connected to the 8-ohm and 16-ohm combination just described, 33⅓ watts would be applied to the 8-ohm loudspeaker, and 16⅔ watts to the 16-ohm one. Thus, if both loudspeakers were rated at 25 watts, the 8-ohm loudspeaker would be overloaded.

If these two loudspeakers were connected in series, the net impedance would be the sum of the two impedance values or $8+16=24$ ohms. In a series connection, the loudspeaker with the higher impedance would get the most power. In our example, the 16-ohm loudspeaker would get twice as much power as the 8-ohm loudspeaker.

You can see that it is desirable to have voice coils of equal impedances when low-impedance lines are used, unless you want to apply more power to some loudspeakers than to others. When a high-impedance line is used, the loudspeakers are matched to the line with transformers. In this case, it is not necessary to use loudspeakers having equal voice-coil impedances to get equal power distribution, nor does the use of equal impedances mean that the power will necessarily be equally divided. Let's take up high-impedance lines now.

HIGH-IMPEDANCE CONNECTIONS

Fig. 35 shows how a high-impedance line can be used to match two loudspeakers located some distance from the amplifier. An impedance-matching transformer near the loudspeaker matches the loudspeaker impedance to the 500-ohm line. The line is then terminated at the proper 500-ohm value at the amplifier output transformer.

By using a high-impedance line, there is less line loss, and the loudspeakers can be placed much farther from the amplifier. Because of shunting capacities, however, the total length of the 500-ohm line that can be used depends on the frequency range wanted. If the line has to be so long that a 500-ohm terminating impedance will not permit you to get the frequency response you want, lower impedances must be used. Hence, in the example shown in Fig. 35, it may be necessary to use 250 ohms instead of 500 ohms at each end of the line. Transformer T1 must be able to match the impedance of the loudspeaker group to a 250-ohm line. If the amplifier transformer does not have a 250-ohm tap, replace it with one that does. This replacement will, of course, have to be designed to handle the power output of the amplifier.

Obviously the arrangement shown

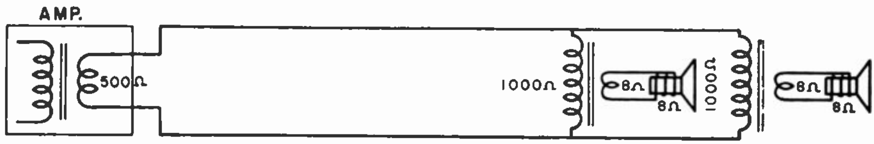


FIG. 36. Use of high-impedance line with separated loudspeakers.

in Fig. 35 can be used for practically any number of loudspeakers, provided the loudspeakers can be connected in the proper series or parallel arrangement to give a terminating impedance that can be matched by transformer T1.

The statements made before about power distribution hold here; in fact, you can consider transformer T1 to be the same as the amplifier output transformer. Therefore, if you use loudspeakers of equal voice-coil impedances, they will divide the power equally. If their impedances are unequal, they will divide the power according to their respective impedances and to whether they are connected in series or in parallel.

In some PA installations, the loudspeakers may not be grouped closely enough together to make it practical to run a low-impedance line between the secondary of the matching transformer and the voice coils. In such cases, the loudspeakers must be located wherever they are wanted, and then a high-impedance line must be run to each location. Each location, of course, must have its own matching transformer.

Fig. 36 shows an example. Here each loudspeaker has a matching transformer; the transformers are chosen so that the net impedance of all the primary windings will equal the proper terminating impedance—500 ohms in this case. Since we have two matching transformers and their reflected primary impedances are 1000 ohms, the net impedance of the two in parallel equals 500 ohms. If we had four loudspeakers, each primary would have to have a 2000-ohm reflected impedance so that the net impedance of all of them would still be 500 ohms.

In cases like this, where each loudspeaker is to get the same power, you can find the primary impedance each must have by multiplying the terminating line impedance by the number of loudspeakers wanted. Thus, if there are six loudspeakers and the terminating impedance is 500 ohms, the primary impedance that each matching transformer must have is 6 x 500 or 3000 ohms. Each transformer must then be able to match this impedance to that of the voice coil that is to be connected to its secondary. If each transformer meets this requirement, the power will be evenly distributed among the loudspeakers no matter what their voice-coil impedances may be. The transformers effectively make them all equal as far as the amplifier is concerned.

Unequal Power. In many installations, we do not want equal power at each loudspeaker. One example is an installation in which high-powered loudspeakers are used in an auditorium and one or more smaller loudspeakers are used in side rooms to handle an overflow crowd. Obviously, an equal distribution of power would overload the smaller loudspeakers or underdrive the large ones, or perhaps do both.

To see how to create an uneven power distribution, let's suppose we have a circuit like that shown in Fig. 37, in which LS1 and LS2 are each rated at 25 watts, LS3 is rated at 10 watts, and the amplifier has an output impedance of 500 ohms. Our problem is to find the primary impedance values for each transformer that will provide the proper power distribution.

To find these primary impedances, we must take these steps:

1. Find the total power.
2. Find the ratio between the total power and that needed for each individual loudspeaker.
3. Multiply the line or amplifier output impedance by the power ratio to get the primary impedance each transformer must have.

The total power needed (Step 1) for our example is the sum of the powers of the individual loudspeakers. This is 25 + 25 + 10, or 60 watts. Therefore, a 60-watt amplifier must be used in this installation.

The ratio of the power (Step 2) of each of the 25-watt units to the total power is 60 ÷ 25 or 2.4. The power ratio for the 10-watt speaker is 60 ÷ 10, or 6.

The line impedance is 500 ohms. Therefore (Step 3), we must multiply 500 by 2.4 to find the impedance that the primaries of T1 and T2 must have. This turns out to be 1200 ohms. Multiplying 500 by 6 gives us 3000 ohms as the impedance of the primary for T3.

We can prove that we have found the correct ratios by computing the net impedance of these three primary impedances in parallel. The net impedance of the two 1200-ohm primaries in parallel is 600 ohms; this 600-ohm value in parallel with the 3000 ohms of T3 makes a net impedance of 500 ohms for the whole combination. Since this is equal to the amplifier output impedance, the loudspeakers are correctly matched to the line.

Therefore, if we use transformers that have reflected primary impedances equal to those we have calculated, the power will be divided so that each speaker will receive the proper amount. Again, it doesn't matter whether the voice coils connected to the transformer secondaries all have the same impedance or different impedances as long as the transformers match them properly to the calculated primary impedances.

As another and somewhat more difficult example, let's compute the primary impedance needed for the transformers in the circuit shown in Fig. 38. This is a small hotel installation in which two 25-watt loudspeakers are used in a ballroom, four 5-watt loudspeakers are used in a dining room, and fifteen 2-watt loudspeakers are used in individual rooms. The loudspeaker groups therefore take respectively:

$$2 \times 25 = 50 \text{ watts}$$
$$4 \times 5 = 20 \text{ watts}$$
$$15 \times 2 = 30 \text{ watts}$$

making a total power of 100 watts to be supplied by the amplifier. The

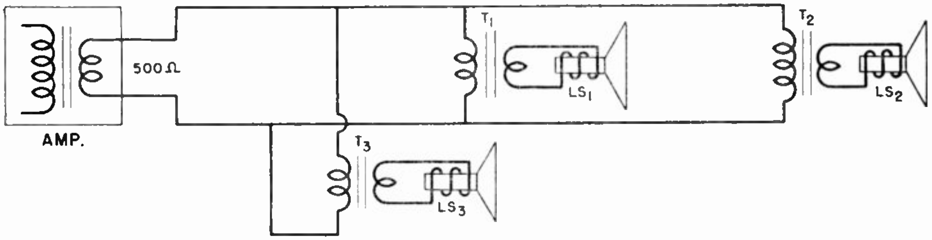


FIG. 37. Unequal powers can be supplied to the various loudspeakers by choosing the proper impedances for the transformer primaries.

power ratio for the 25-watt loudspeakers is 4 (100 ÷ 25). For the 5-watt loudspeakers, it is 20 (100 ÷ 5), and for the 2-watt loudspeakers, it is 50 (100 ÷ 2).

With an amplifier termination of 500 ohms, the primary impedance for the 25-watt loudspeakers should be 2000 ohms (500 x 4); for the 5-watt loudspeakers it should be 10,000 ohms (500 x 20); and for the 2-watt loudspeakers it should be 25,000 ohms (500 x 50).

If you tried to locate the parts for this installation, you would find it difficult or impossible to obtain transformers for the 2-watt loudspeakers. Power-handling transformers rarely have turns ratios that would cause a loudspeaker voice coil to appear as a primary impedance of more than 10,000 to 15,000 ohms at the most. Therefore, it would be wiser to use some lower value of source impedance so that you can get the turns ratio for the 2-watt loudspeakers down to a reasonable value.

If you use a source impedance of 125 ohms, the 25-watt loudspeakers will require primary impedance values of 500 ohms (125 x 4), the 5-watt loudspeakers will require 2500 ohms

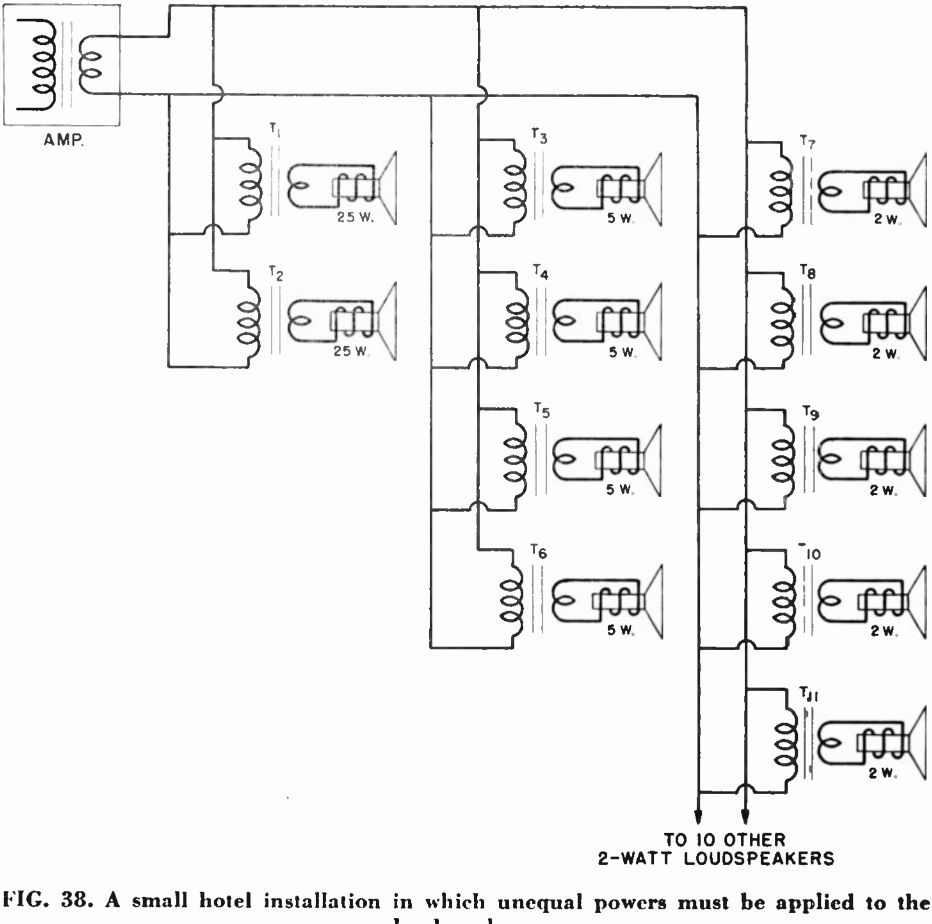


FIG. 38. A small hotel installation in which unequal powers must be applied to the loudspeakers.

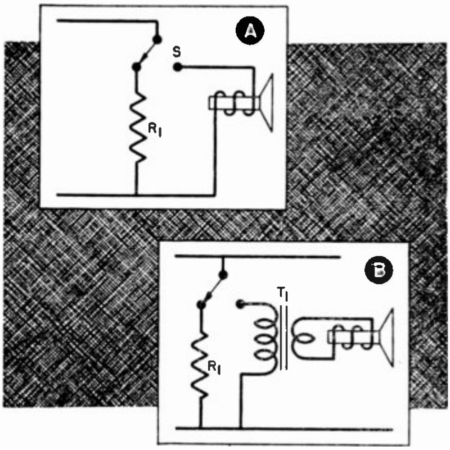


FIG. 39. Two ways of keeping the impedance of a line constant whether loudspeakers are switched in or out.

(125 x 20), and the 2-watt loudspeakers will require 6250 ohms (125 x 50). Transformers having the necessary turns ratios to produce these impedances can be obtained easily.

Incidentally, while we are on the subject of transformers and the values that are available, there is one fact you should keep in mind when you are looking for transformers. A transformer rated to match two specific impedances can often be used for other impedances that are in the same proportion. For instance, a transformer listed to match 4000 ohms to an 8-ohm loudspeaker can also be used to match 2000 ohms to a 4-ohm loudspeaker, and can be used to match 8000 ohms to a 16-ohm loudspeaker with only a slight loss in fidelity. Line-to-loudspeaker transformers can be used this way because the source impedance is always less than the actual primary reactance of the transformer, so there is little frequency distortion.

In many multi-speaker installations, it may be necessary to switch individual speakers on and off, or to regulate the output volume of each speaker. This must be done so that the impedance match and volume levels are not disturbed along the transmission line. Typical switching and attenuator circuits are shown in Figs. 39 and 40.

In Fig. 39A, a single-pole double-throw switch is used. When the speaker is switched off, a resistor is inserted into the line. The resistor is the same value as the voice coil impedance and, consequently, line matching and volume levels are not disturbed along the rest of the line. In the arrangement of Fig. 39B, the speaker is transformer-coupled to the line. Switching takes place on the primary side. Here the resistor has the same value as the reflected primary impedance of the transformer.

Attenuator L and T pads like those shown in Fig. 40 can be used to adjust speaker volume levels individually. These matched attenuators present a constant impedance to the source and loudspeaker load regardless of attenuator volume setting. Hence, volume levels can be set comfortably at each speaker without disturbing levels along the multi-speaker line.

CONSTANT-VOLTAGE LINES

The loudspeaker matching method

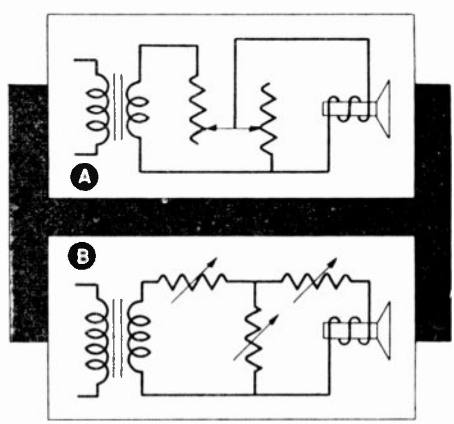


FIG. 40. Typical L pad (part A) and T pad (part B).

Courtesy University Loudspeakers, Inc.

FIG. 41. A driver unit that can be used with either a 70-volt constant-voltage system or a constant-impedance system.

just discussed can be called constant-impedance matching because the impedances of the voice coils and transformers were matched to a particular constant output impedance. The voltage applied to the loudspeakers depended on the amplifier output rating. In the constant voltage distribution method, it is the voltage that is held constant. The loudspeaker impedances are chosen according to the power you want the speaker to deliver.

The constant-voltage system is similar to the 110-volt power distribution system in your home. Here the voltage is constant at 110 volts; each electrical device, such as an appliance or light, is rated in watts, and draws current according to its needs. In the constant-voltage sound system, the voltage on the distribution line is held constant at 70.7 volts or 141.4 volts, usually labeled 70 volts and 140 volts. The loudspeakers draw current according to their wattage ratings. The amplifier is designed to produce 70 volts or 140 volts across its output transformer secondary when operated at full power output.

An example of a driving unit that can be used with either a 70-volt constant voltage system or a constant-impedance system is shown in Fig. 41. Notice in the cut-away view shown in the illustration that a transformer is used between the loudspeaker input terminals and the voice coil. The primary connections are brought out at the bottom of the driving unit; a drawing of the terminal board showing the wattage and impedance values is shown in Fig. 42. The terminal marked "C" is the common terminal. Connections can be made directly to the voice coil by using terminals VC1 and VC2.

If the loudspeaker is used on a constant-impedance system, you have a choice of impedances from 165 ohms to 2000 ohms. On a 70-volt constant-voltage line, the power output from the loudspeaker can be either 2.5, 5, 10, 20, or 30 watts. The connections to make depend on the power needs at the location.

The constant voltage system is easier to use because you do not have to make complicated calculations as in the constant-impedance system. Suppose you are making a factory

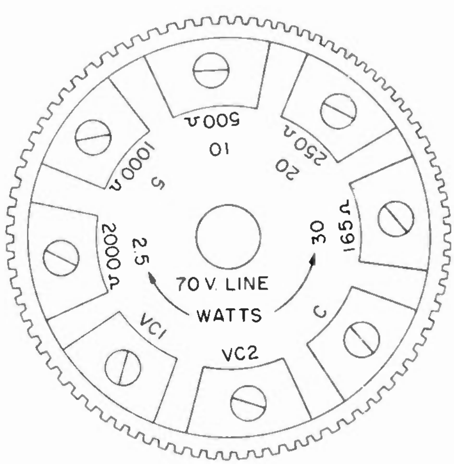


FIG. 42. Terminal board shown in the cut-away view in Fig. 41.

installation in which you need 2.5 watts for the main office, 10 watts for the stock room, and 30 watts for the assembly line. Instead of computing the impedance ratios to meet these requirements, all you have to do is connect the distribution line to the proper terminals on the loudspeaker driving unit. When the connections are made, the impedance will be matched automatically, and the loudspeaker will produce the correct amount of sound power. Of course, the amplifier must be able to deliver the total amount of power required by all the loudspeakers.

Another advantage of the constant-voltage system is that it can be easily changed to meet the changing needs of the installation. Suppose after a period of time two 30-watt loudspeakers are needed in the production area instead of the single 30-watt speaker. If the amplifier rating is high enough to deliver the extra power, all you need do is connect another loudspeaker to the distribution line. Thus, you do not have to rearrange the circuit impedances to include the additional loudspeaker impedance. Each loudspeaker receives the correct amount of power regardless of whether other loudspeakers are added or removed from the system.

In a constant voltage system, power is not wasted in attenuators used to adjust the power requirements at a location. Connections are made at the loudspeaker according to the power output desired. Also, if you want to turn a loudspeaker off, you can disconnect it completely from the distribution line without upsetting the rest of the circuit.

The constant voltage method is becoming very popular, especially in high-power, multi-speaker systems. In the next PA lesson, you will study amplifiers that can be used in this system.

YOU HAVE TO WORK

Here is another one of my favorite quotations—this one by Bob Burdette:

"My son, remember you have to work. Whether you are handling pick or wheelbarrow or a set of books, digging ditches or editing a newspaper, ringing an auction bell or writing funny things, you must work. Don't be afraid of killing yourself by overworking. Men die sometimes, but it is because they quit at five p.m. and don't go home until two a.m. It's the intervals that kill, my son. The work gives you appetite for your meals; it lends solidity to your slumber; it gives you a perfect appreciation of a holiday. There are men who do not work, but the country is not proud of them. It does not even know their names; it only speaks of them as old So-and-So's boys. Nobody likes them; the great, busy world doesn't know they are here. So find out what you want to be and do. Take off your coat and make dust in the world. The busier you are, the less harm you are apt to get into, the sweeter will be your sleep, the brighter your holidays, and the better satisfied the whole world will be with you."

J. E. Smith

SERVICING

PORTABLE RECEIVERS

43B

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WASHINGTON, D. C.

ESTABLISHED 1914

Study Schedule No. 43

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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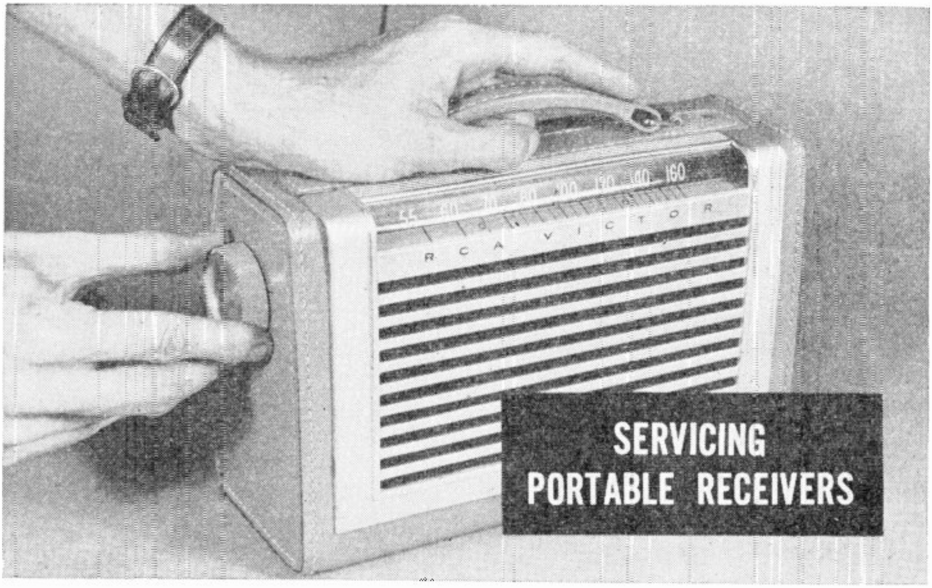


THE battery-operated radio is the simplest form of radio receiver, using the simplest possible power supply—dry batteries. For this reason, battery sets will provide you with your easiest service problems, and at times, some of your hardest, too! However, if the basic circuits are well understood, there will be very few troubles that you cannot locate and repair quickly. Fortunately, the circuits used in most of these sets are basically simple.

Battery-operated radios can be divided into three classes: the home receiver, which is usually large enough to hold the 1000-hour battery pack; the battery-operated portable, powered only by dry batteries; and the three-way portable, which works on batteries, ac or dc power. The ac-dc power supply used is almost the same as in home ac-dc sets. There are differences mainly in the filament circuits.

Most of the sets built up to 1954 used tubes of a special series, designed for battery operation. Introduced in 1939 and known as the "GT" series, such types as 1A7GT, 1H5GT, 1Q5, 3Q5, etc., were included. Another series, which saw only limited use, is the "loctal" group of tubes, interchangeable electrically, but having different bases: 1LA6, 1LC6, 1LN5, 1LH4, 3LF4, etc. Later on came the miniature types, 1R5, 1U4, 1U5, 3Q4, etc., which are electrically the same as both of the preceding series, but use the miniature size envelope. Most miniature and loctal-base tubes, except for a few power amplifiers, use a filament voltage of 1.4 volts, and a filament current of 50 milliamperes. The "3" tubes, 3Q4, 3Q5, etc., use center-tapped filaments, 3 volts at 50 ma, or 1.4 volts at 100 ma.

A word here about the characteristics of a dry-cell battery would be in order. These familiar batteries come in combinations of many voltages, from the single "pen-light" cell up to the 300-volt batteries used with Geiger counters. The basic unit is the single dry-cell. It consists of a carbon rod, which is the positive electrode, surrounded by a "mix" of manganese dioxide and graphite saturated with a solution of sal ammoniac, all enclosed in a case of zinc. The cross section of a dry cell is shown in Fig. 1. The sal ammoniac reacts with the zinc, releasing electrons by chemical action. These electrons flow out of the battery from the case. Electrons from the outside circuit flow back into the battery through the positive carbon electrode.

As the cell is used, hydrogen forms around the carbon electrode, and tends to block the flow of current through the cell. The manganese dioxide in the mix provides oxygen which combines with the hydrogen to form water. This process is called depolarization. If a very large current is drawn from the cell, hydrogen is formed faster than it can be removed. This raises the internal resistance of the cell and reduces the voltage under load. This is the reason an apparently dead dry battery, whose voltage has dropped below its normal value, will be able to furnish more current if allowed to stand unused for a few hours.

When battery sets were first built, names were given to the different batteries and are very convenient when talking about them. We will use these terms throughout the remainder of this lesson. The filament battery is called the "A" battery. The plate or high-voltage battery is called the "B"

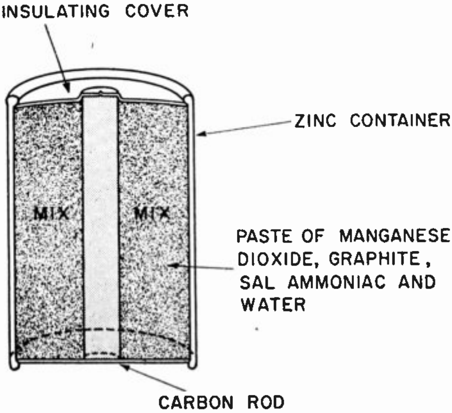


FIG. 1. Construction of a round dry cell.

battery. For this reason, the plate voltage is still known as the B voltage; the positive as B-plus and the negative as B-minus. Bias voltages, for the grids, were furnished by small batteries, 4.5, 7.5 or 22.5 volts, and called "C" batteries. Present practice eliminates all but the A and B batteries, however, which are the only two we'll have to work with. Remember those letters, though; you'll be hearing a lot about them.

The open-circuit voltage of a new cell is 1.6 volts. This is the no-load voltage that would be measured by a vtvm. After about three or four hours of use, this voltage will drop, under load, to below 1.5 volts, and remain there until the active materials of the cell are almost used up. Then there will be a gradual decline in the voltage under load, until the cell reaches the cut-off voltage of 1.1 volts. At this point, the active materials in the cell may be considered to be completely used up.

Tube designers took note of this decline in voltage in designing the new battery tubes. The tubes were designed to operate on a normal filament voltage of 1.4 volts, with a cut-off at 1.1 volts. (Cut-off is the point where the efficiency of the tube falls below a usable level, due to the lowered temperature of the filament.) Thus, the characteristics of both tube and battery were matched. Incidentally, always make measurements in battery circuits with the set turned on so that the batteries will be operating under full load. Never test a battery without a load, because even an almost totally discharged cell, after a little rest, will read full voltage without a load.

To make high voltage supplies, small cells are connected in series until the desired voltage is reached. A 90-volt battery requires 60 cells (1.5 x 60 = 90). To make an A battery, with a low voltage and high current capacity, larger cells connected in parallel are used.

Battery packs for use with either portable or home radios are made by putting both A and B batteries into a single box, with the connections brought out to a special plug. This arrangement is shown in Fig. 2. Several years ago the RETMA (Radio-Electronics-Television Manufacturer's Association) brought out a set of standard sockets and plugs to avoid confusion and eliminate the danger of tube burnouts. These make it impossible for a battery radio to be plugged into the wrong battery. Unless the right voltages are there, the plug will not fit. Most of the manufacturers have held to these standards although a few, unfortunately, have kept on using special plugs and sockets so that only their own make of battery could be used.

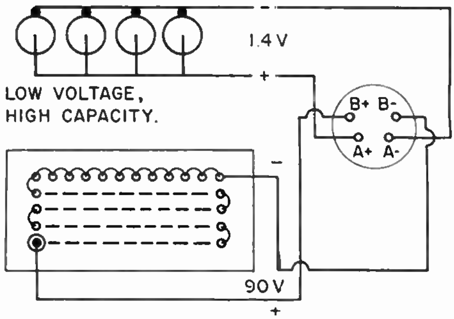


FIG. 2. Connections of a typical A-B battery pack.

The Battery Set

As we said, the battery set is probably the simplest radio receiver that can be built. These sets are very much standardized and servicing them is easy, once the basic circuit is mastered.

Practically all home sets use this circuit: a mixer-oscillator, a pentode i-f amplifier, a diode-triode 2nd detector-1st af amplifier, and a pentode power amplifier stage. The schematic diagram is shown in Fig. 3. PM dynamic speakers are used in all sets. Some sets use one stage of tuned rf amplification ahead of the mixer. A few designers use an additional i-f stage for added gain, but generally the circuit consists of the four tubes

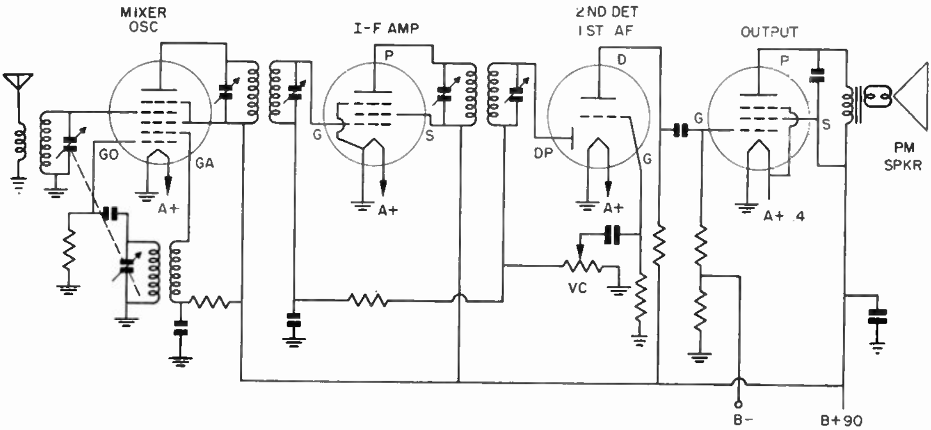


FIG. 3. Basic circuit used in battery receivers.

shown. Portables often have five tubes, including an rf stage for added gain.

In the four-tube circuit used in home sets, there is an A drain of 200 ma at 1.4 volts, and a B current drain of 8-10 ma at 90 volts. These standard current drains make it possible for battery makers to build the 1000-hour battery packs by balancing the capacities of the A and B batteries so that both give about 1000 hours of intermittent operation. In the ideal battery pack, both A and B batteries would be exhausted at the same time; in use, there is a small difference. Most portable radios use a separate A battery, so that it can be replaced independently of the B battery. This is done to make the set smaller and lighter. In sets using a flashlight cell for the A battery, the B battery will usually last through several sets of A batteries.

The larger portables use small versions of the pack battery; the batteries are balanced for current demand, and usually run down together. For this reason, special attention should be paid to the condition of the batteries in relation to each other. If one battery is good and the other is down, the set should be checked carefully to find out why. The battery itself may be defective, or there may be trouble in the set.

Due to the small amount of space in portable cases, special compact cells have been developed by battery manufacturers. Batteries must fit into odd corners of the cases, and are usually special types for portables only. Exact physical duplicates must be used for replacement. In special cases where portables are used in the home, extension battery cables may be provided and the larger, less expensive home-type batteries used. Due to manufacturing costs, the small portable packs, with a life of only 200-300

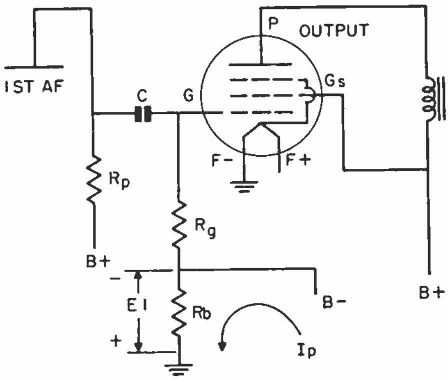


FIG. 4. Standard bias supply circuit used in battery radios.

hours, cost almost as much as the 1000 or more hour home-type packs.

SPECIAL BATTERY RADIO CIRCUITS

There are a few unusual features common in battery sets but not often found in ac sets. Among these are the bias circuits, filament circuits, and filter circuits.

In the battery set, the power output stage is the only one requiring applied bias voltage. The rf, i-f and mixer stages are usually biased by a circuit which combines avc with contact bias, the small voltage developed by random electron flow in tubes. Since the power output stage consumes almost 80% of the total current drawn by the set, its bias voltage is very important to the battery life, and should be checked every time the set is serviced.

To obtain this voltage without using a C battery, a special circuit shown in Fig. 4, is used. It has several advantages over the C battery. The bias voltage developed is always directly proportional to the amount of B voltage applied, making the circuit self-adjusting as the B battery runs down. A C battery would *not* go down in step with the B battery.

Hence, when the B battery was partially discharged, the bias would still be at maximum, and the stage gain would be reduced or there would be distortion. Some sets even include a special resistor in the circuit, whose only purpose is to deliberately discharge the C battery. In such circuits, the bias goes down as the B voltage goes down, and the output of the set does not change very fast.

The negative connection of the B battery goes to ground through a small resistor, Rb, ranging from 300 to 1000 ohms, depending upon the bias voltage needed. The grid resistor of the power tube is returned to B—. Thus, the grid is made negative with respect to ground by the amount of voltage developed across this bias resistor. This bias sets the plate current drawn by the output tube, making it work at the proper point on the curve. Since the plate current of this tube has a tremendous effect on the battery life, this resistor and circuit are very important.

Filter circuits are unusual, too. In place of the numerous bypass capacitors used in other types of radio receivers, the battery set has only one major bypass, usually an electrolytic capacitor of about 10 mfd at 150 volts. The location of this capacitor in the circuit is shown in Fig. 5. Because of its position in the circuit, it bypasses both the audio stage returns and the radio-frequency stages. This prevents any common coupling in the battery circuit, which could cause oscillation as you tune in each station. Actually, this unit should be called the common bypass capacitor, but it is better known as a filter, and we shall refer to it by that name from now on.

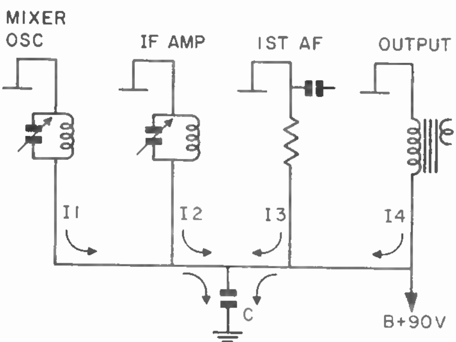


FIG. 5. The single filter capacitor, "C", provides a low impedance path back to ground for the return *currents* of signals from all stages in the battery set.

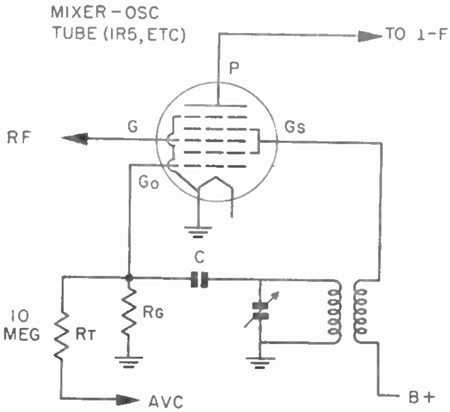


FIG. 6. Use of tilt resistor.

In some sets a tilt resistor will be found in the oscillator circuit. This is a large resistor, usually around 10 megohms, between the oscillator grid and the avc circuit. This circuit is shown in Fig. 6. Its purpose is to equalize the gain of the set across the entire broadcast band by changing the gain of the i-f stages as the set is tuned across the dial. The oscillator is self-biased. Both the gain of the mixer and the bias change as the oscillator is tuned across the band. The gain is highest when the oscillator bias is greatest. Part of this bias is fed to the avc circuit, so that the gain of the i-f depends on the oscillator bias. A strong oscillator reduces the gain of the i-f stage. In this way the gain of the receiver as a whole remains constant as the oscillator is tuned across the band.

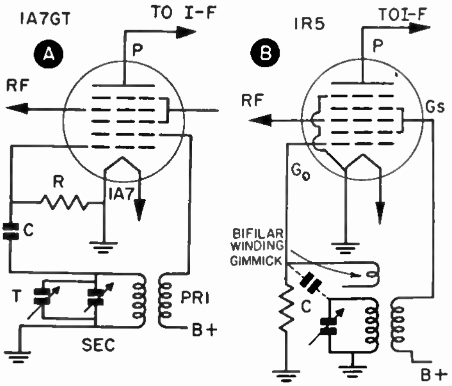


FIG. 7. These common oscillator-mixer circuits are used in most battery sets and portables.

Be careful when checking this circuit; if this resistor has dropped in value, permitting too much voltage to be fed into the avc, the over-all gain of the set will be reduced to an unusable level. Where the set is being operated in remote areas, and maximum gain is needed, this circuit can be disabled by removing the tilt resistor entirely.

TESTING BATTERY RECEIVERS

One of the main causes of trouble is the oscillator circuit. Most sets use a pentagrid converter tube, with the second grid serving as the oscillator plate. The circuits in Fig. 7 show two common oscillator circuits. Both oscillators use feedback windings. The method of coupling the oscillator grid to the tuned circuit and the tube types are the only differences between them. Either tube will work with either circuit.

The conversion gain of these tubes is quite low, hence the need for good tubes and correct voltages. Conversion transconductance of a 1A7, for instance is only 250 micromhos, as compared with almost 500 for a 6BE6. The filament voltage is the most critical of all the applied voltages in this circuit. If the tube becomes weak, through aging or overloading, the transconductance will fall off and the tube will not sustain oscillation. The same thing happens when the filament voltage falls below cut-off (1.1 volts in most of these types).

To check this section, first check the filament voltage at the battery, then at the tube itself. Substitution of a new tube is the best way to check the tube. If neither of these tests shows why the oscillator does not work, test the oscillator circuit components. Most circuits use two-winding coils, with the oscillator plate voltage applied through the tickler winding. Electrolysis of the fine wire in this coil will stop oscillation, due to the lack of voltage on the oscillator plate. Incidentally, this winding usually consists of fifteen or twenty turns, always wound on the outside of the coil. It can be rewound with little trouble, noting the number of turns and direction of winding. If the set does not work when the winding has been replaced, reverse the leads on the tickler winding. A few circuits use a single tapped coil. This type of coil should be replaced rather than rewound.

To test the oscillator, always use a vtvm. This is a very high impedance circuit, and a low-resistance voltmeter will load the oscillator so much that it will not work. An oscillator works like a class C amplifier; the tube is driven into grid current on part of each cycle. This current through the grid leak resistor will develop a dc voltage across the resistor, which can be measured with a sensitive voltmeter as an indication of the circuit's performance. The more voltage developed here, the better the circuit is working. Actual values will run from 15-18 volts dc with the set tuned to the high-frequency end of the dial, and 7-8 volts at the low end. This variation is normal. Battery-set oscillators usually show up trouble by weakness at the low end of the dial. Therefore, measure the oscillator grid voltage at the low end; if sufficient voltage is developed here, the tube is working all right.

It is quite possible for a set with a weak oscillator to work over the upper half of the dial, and not play at the low end. This is always oscillator trouble, if the cut-off is gradual. If the set cuts off with a loud "pop" in the middle of the dial, one of the plates of the tuning capacitor is shorting.

Although oscillator circuits may appear to be quite complicated, they are really simple. If the circuit fails to operate, start trouble shooting by checking the tube. The operating voltages are next, then the remainder of the parts in the circuit. Check all parts for proper value, and for shorts or leakage to ground. One common source of trouble is a short or leakage across the tuning capacitor, caused by metal particles or dirt. This section, in a two-gang capacitor, is usually the one with the smallest plates. Remove all wiring and check to ground for shorts. Wash all trimmer capacitors with a solvent and check carefully for leakage. Even a 1-megohm leak will cause trouble. Dirt or moisture in the plates of a mica compression-type trimmer will often cause leakage. Replace the mica, if necessary.

Watch out for the special compensating fixed capacitors used in some circuits. These are units with a special temperature coefficient which compensate for oscillator drift caused by changes in the temperature. Replace with exact duplicates, if defective. When checking coils, check not only for correct resistance of the windings (usually 3 to 5 ohms for secondary, 1 to 3 ohms for plate or tickler), but also for a high-resistance leakage between them. Some oscillator coils use a small open-ended winding, shown in Fig. 7B, which has only one end connected; this is called a "gimmick", and is actually used as a capacitor. They occasionally open up, or short over to other windings. Used in place of the grid capacitor, a gimmick can be easily checked by temporarily connecting a small capacitor (about 100 mmf) in its place. Connect it from the oscillator grid to the "hot" end of the tuned winding of the coil.

One positive test for the oscillator circuit is the "voltage-cutoff" check. This is easily done by lowering the filament voltage and noting the point at which the oscillator stops working. We will go into detail on how this is done later. If the oscillator cuts out at some point well above the normal cut-off voltage of 1.1 volts, it will cause trouble. Battery life will be short, since the set will not use up all the available power in the battery. Check by replacing tubes, because this is the major cause of trouble. A good tube will sustain oscillation well down into the 1.1-volt region, and some have been checked as low as .9 volt! However, if the tube will still oscillate at 1.1 volts, it will give satisfactory performance and full battery life.

There is a simple check for filament continuity which can be used on almost all tubes in the battery series, especially the GT tubes. The filaments of these tubes are of very fine wire, almost invisible to the naked eye. They are mounted in the tube structure in the center of the elements, pass-

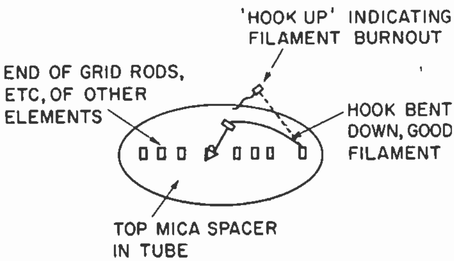


FIG. 8. Top mica spacer of battery-type tube.

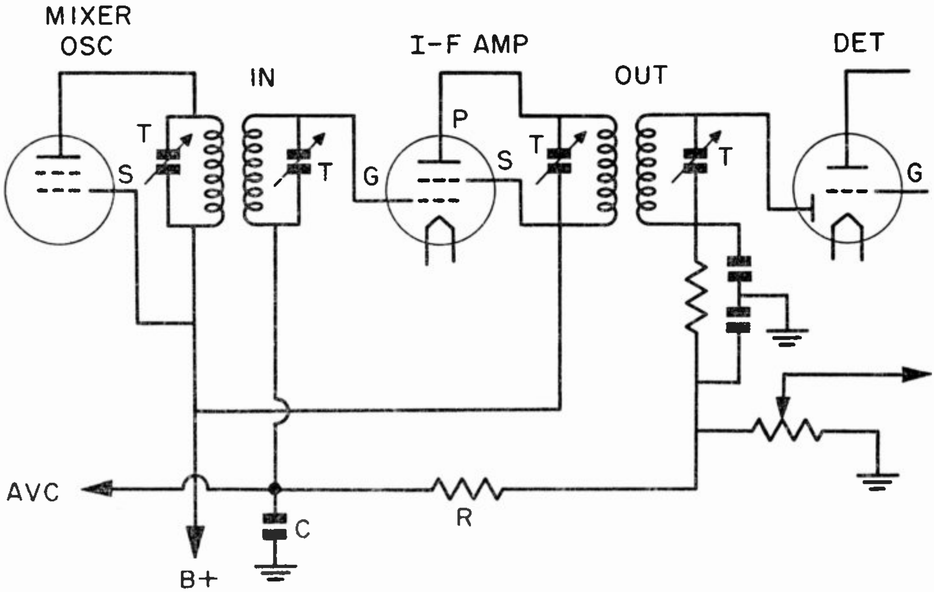


FIG. 9. Typical i-f amplifier stage in portable or battery radios.

ing through a triangular hole in the upper mica spacer. The upper ends are held under tension by a tiny spring, called the "hook", one end of which is tied to the mount; the other end is welded to the filament. Fig. 8 shows this hook in a tube of this type. Normally, this is under tension and shows a decided bow; if the filament is broken or burned out, the tension is released and the hook flies up into the top of the bulb. This can easily be seen by a visual examination. If the hook is up, the filament is open, and no further tests need be made. Make a quick check on each tube, before any other tests are made. If all tubes are burned out (a common occurrence in battery sets), this will save much time.

If you have a set like this, always check very carefully to see what caused it! Remember, there is absolutely *no circuit* in a standard battery set which can cause this! In other words, something external caused it. At times, the insulation will go bad on a battery cable, causing a short between filament and plate voltages in the battery cable. Watch for this condition, and never replace any tubes in a set until the trouble has been found and cured. Otherwise, all the new tubes may burn out.

The i-f amplifier stages follow the oscillator stage. The i-f usually has just one pentode stage. Nearly all sets use the circuit of Fig. 9. Troubles in this section are mostly found in the transformers themselves—open or high-resistance windings caused by electrolysis, just as in the case of the oscillator coils. Check the windings with an ohmmeter; each winding should have the same resistance. It will vary from 12-18 ohms for a 456-kc i-f stage, and from 25-30 ohms for the 262-kc sets.

Older sets used large i-f transformers, while the newer, more compact sets use powdered-iron core "K-Tran's" and similar transformers which have much more gain and selectivity yet are much smaller. Schematically, the circuit for both is the same. One word of caution here—when adjusting the iron-core transformers, always use the special tools made for them. Common screwdrivers will damage the cores.

One exception to the ohmmeter test would be the output i-f transformer, if it includes a tweet-filter inside the can, such as shown in Fig. 10. In this case, a resistance reading of 47,000 ohms would be obtained, due to the filter resistor, and only a completely open coil could be spotted by this test.

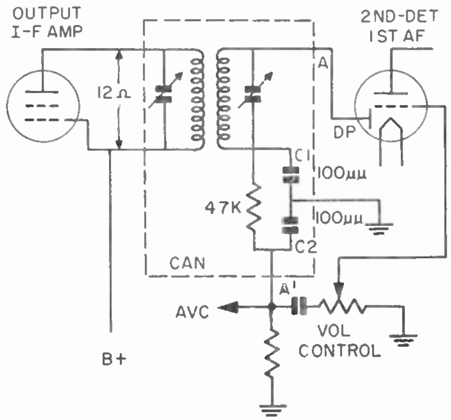


FIG. 10. Tweet-filter inside can (dashed line) of output i-f transformer.

A quick check of the alignment will show up troubles in the i-f stage. Connect a vtvm to the avc line. It should read 3 to 4 volts on a medium to strong signal. Vary each trimmer adjustment slightly, and see if each one has a good response. If any trimmer adjustment shows no response, the stage or coil associated with it is defective. Substitute another tube, and check the coil if the tube is OK. Any stage that is operating properly will show a definite peak in its response; the reading will drop off sharply on either side of the peak.

Three-Way Portable Radios

Three-way portable radios differ from straight battery sets mainly in the filament circuits. Signal circuits, etc., are practically the same, especially in the basic circuit. Although some of the earlier models used a parallel filament circuit, the complicated switch needed to make the changeover from battery to ac-dc operation made it much simpler to design the sets with a series filament string. This made a change in the battery hookup necessary. Instead of connecting the cells of the A battery in parallel, they were connected in series. This still gave the same battery life. Battery life depends on the total *wattage* drawn from the battery (product of the voltage and current). 1.4 volts at 200 ma gives the same number of watts as 5.6 volts at 50 ma.

If the tubes in a series filament string do not draw the same current, shunt resistors must be used across the low-current tubes. The battery voltage must be the sum of the filament voltages. For instance, a string consisting of three 1.4-volt tubes and one 3-volt tube adds up to 7.5 volts; a 7.5-volt battery must be used. (Although the filament voltage is rated at 1.4 volts, common practice is to call it 1.5 to simplify calculations, and this will be done in this text.)

Common design practice in these sets will always place the tubes in the same order in the filament string as shown in Fig. 11. The first audio, which is the most sensitive to hum, is closest to ground. Due to shock hazard the chassis is not used as a ground. Instead a floating ground or

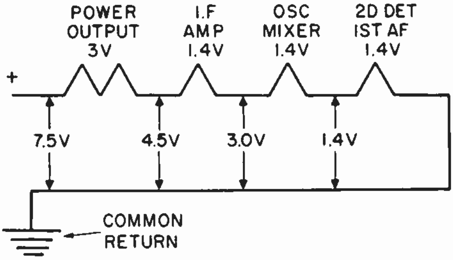


FIG. 11. Usual order of tubes in connecting series filament strings.

B-minus is used. This same practice is followed in designing the standard ac-dc sets for use on 120 volts ac-dc in homes.

The *plate* current of each tube must also flow through the filament string. This is because the filaments of the tubes are also the cathodes. While this 8 or 10 ma is not so important as far as actual current is concerned, it is considerable percentage-wise, as the filaments draw only a very low current. Therefore, the careful designer will allow for this, and provide shunt resistors across some tube filaments, especially the power tubes, as in Fig. 12. They provide a path for the excess plate current to ground around the small filaments, to avoid overloading them.

POWER SUPPLIES

The power supplies for three-way portables are similar in over-all design to the half-wave rectifiers used in the common ac-dc sets. One big difference lies in the closer tolerances required in the output voltages. This type of power supply must furnish not only the plate voltage, but also the filament voltage and current. A dropping resistor is used to reduce the output voltage of the supply to the 7.5 or 9 volts needed by the filaments. Obviously, there is room for only a small variation in the output of the power supply if troubles are to be avoided. Hence, voltage regulation (the variation in the voltage output under varying loads) must be better, and all parts must be in perfect condition.

Because the filaments are also the cathodes, almost pure dc must be used on them to avoid excessive hum. For this reason, a large filter capacitor is placed across the filament circuit. One thing must be remembered: always replace parts in this circuit with *exact duplicates*. The filter capacitors are not too critical but resistors must always be duplicated exactly. If a filament dropping resistor were lowered only 10%, it would result in increased voltage on all the tubes, shortening their life tremendously. The total voltage across the filament string must be checked carefully with an accurate meter when a set is serviced.

There are two fundamental precautions that *must* be observed when doing *any* kind of service work on any kind of battery set. First, be very careful when probing the circuits and making voltage measurements not to short the high voltage to the delicate filaments of the tubes! Even a momentary short, by a test prod or screwdriver, can completely destroy a *full set* of tubes. Second, never remove any tubes while the set is operating or plug the set in while one or more tubes are miss-

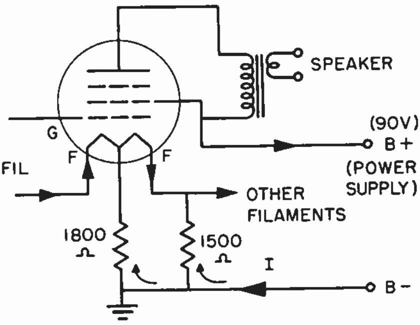


FIG. 12. Shunt resistors used on filament of power output tube.

ing. Always check battery connections, cables, plugs, etc. to make sure that there are no loose connections or exposed wires due to bad insulation. If you want to make resistance measurements in a suspected chassis, be sure that all batteries are disconnected, the power plug pulled, and to be perfectly safe, take all the tubes out of their sockets. When a set is brought in for service, always test *all* tubes before making any other tests. In this way, if all the tubes *are* burned out, you will be sure that *you* didn't do it accidentally. This may sound like a lot of unnecessary precautions, but it is based on the sad experience of many technicians, so take heed!

As we just said, you should first test the tubes themselves. They are easily damaged by a momentary overload, quite common in the three-way portables where a line surge (or small lightning stroke in the power lines) can cause the tubes to be overloaded and weakened. All tubes in these sets must be in perfect condition for best performance. The portables must work with a loop antenna, and the low rf pickup in remote areas makes it imperative that the set be in absolutely top condition.

There is one more rather unusual circuit, not often seen, but which should be mentioned. This set uses a battery-type output tube, such as a 3Q5, during battery operation, but switches an ac-type pentode into the power stage when working on ac. This circuit is not too common today, but should be remembered. If a combination rectifier-pentode, such as a 117L7, is used, or even if a 50L6 is used, the filament string (less the 3Q5 filament) is often supplied from the voltage drop across the *cathode bias resistor* of the pentode when on ac. This voltage normally runs from 6 to 8 volts in ac-dc home sets and is deliberately set at 4.5 or 6 volts in the portable, depending upon whether three or four tubes are to be fed from it.

A very common trouble found in this circuit is the development of leakage in the input coupling capacitor or gas in the tube. Either of these conditions will cause the tube to draw excessive plate current by reducing the grid bias. This added plate current causes the voltage drop across the cathode resistor to rise and results in an increased voltage on the battery tube filaments. Check the filament voltage very carefully when this circuit is used; also check coupling capacitors for leakage. Check for voltage across the grid resistor with a vtvm. Any voltage indicates a leaky capacitor or a gassy tube.

TESTING THREE-WAY PORTABLES

The power supply used in the three-way portables is almost identical with the circuit used in the ac-dc home sets using ac type tubes. However, due to the much closer tolerances necessary in the portables, parts must be kept in better condition.

The rectifier itself may be either a tube or selenium rectifier. Types such as 35Z5, 50Y6, or even 117Z3 or 117Z6 are used. The heater voltage of the rectifier tube must be supplied by the ac line. Therefore, we must provide a resistor to drop the remainder of the line voltage. This used to be a long flexible resistor wound around the line cord. Later models use fixed resistors mounted on the chassis. One of the benefits derived from replacing the tube with the selenium rectifier was the elimination of this resistor whose high heat dissipation made a "hot-spot" on the chassis. The dry rectifier, of course, has no filament so needs no dropping resistor. Incidentally, a tube rectifier may be replaced with a selenium rectifier by connecting the positive side of the rectifier to the cathode connection of the tube, and the negative side to the plate connection. They may be wired into the tube socket from the top, if necessary.

The only precaution needed here is the selection of a rectifier that will have enough capacity to supply the current. The filament circuit needs 50 ma, while the plate circuits use a total of perhaps 15-20 ma maximum. It is necessary to use a rectifier of at least 100-ma capacity to give the unit a large enough margin of safety. While many set designers use 75-ma rectifiers in the original design, the safety factor is not large enough and the life is usually short. The 100-ma size is about the largest that can be mounted in the limited space of the cabinets. Often, when attempting to replace a 75-ma rectifier with a 100-ma unit, the space will be too small. In this case, one of the "encapsulated" rectifiers must be used. These are 100-ma selenium rectifiers sealed in an insulating tube which look a great deal like a large paper capacitor. With their insulation, you can mount them almost any place in the chassis, as long as you don't short circuit the leads.

The small resistor marked R1 in Fig. 13 is known as a "surge resistor". It limits the current flow through the rectifier and into the filter capacitor. This resistor is usually between 27-47 ohms with a tube rectifier, and from 47 to 75 ohms with a selenium rectifier. It is more important with the instant-heating selenium rectifiers than with tubes. Selenium rectifiers begin to conduct current the moment voltage is applied, while the tube rectifiers require a warm-up period. This instantaneous conduction will cause the full voltage to be applied to the input filter capacitor, C1. A large uncharged capacitor appears as a dead short when voltage is first applied, so

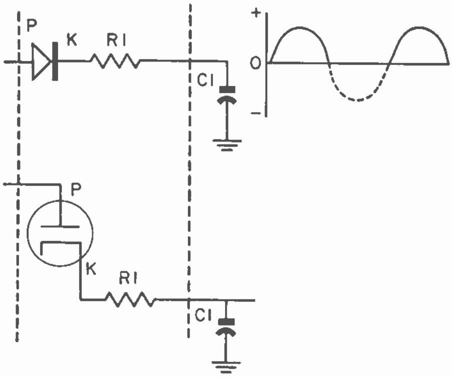


FIG. 13. **Selenium and tube rectifiers.**

the current is limited only by the external circuit resistance. Since the rectifier will be damaged by excessive current, a surge resistor is used to limit the current.

The capacitor itself can also be damaged by the sudden application of voltage. Even though an electrolytic capacitor is "formed" during manufacture, part of its dielectric layer is lost when it is not in use. The dielectric layer is re-formed when voltage is applied gradually. Therefore, an uncharged capacitor may break down when a large voltage is applied suddenly. The flow of the high initial charging current through the surge resistor keeps the initial voltage across the capacitor low. As the capacitor charges, the current is reduced and the voltage across the capacitor gradually builds up to the full value.

If the tube is replaced by a selenium rectifier, the surge resistor should be doubled in ohmic value. A 1/2-watt resistor should always be used here, so this resistor can act as a fuse. A sudden current overload will cause the little resistor to explode, sometimes quite violently, which saves the rectifier itself from damage. If this resistor is found burned or discolored, always investigate to see what caused it.

One of the best clues to the condition of a power supply of this type, with either type of rectifier, is the output voltage under full load. If it is not within very narrow limits, then something must be done. When checking the power supply, this is the first thing that should be measured. If the voltage is there, and of the proper value, we can pass the rectifier as being all right; if it is not less than 120 volts, with an input of 110 volts, OK. If this voltage is down to 100 volts, with 110 volts input, we can expect trouble because it will cause low filament voltage. This is an indication of one of two troubles: a rectifier with low emission, or an input filter capacitor with too low capacity. This is assuming that the surge resistor does not show signs of burning. A burnt resistor might indicate an overload, causing the power supply to have too much voltage drop.

First, test the rectifier by substitution. Plug in a new tube or unhook one wire from a selenium rectifier and substitute a known good one. If this fails, try bridging a good filter capacitor of sufficient capacity across the input filter. If the input filter *is* open, the voltage at the rectifier cathode will drop to between 40-50 volts. With one of lowered capacity, the drop will be less. In any case, if shunting with a good capacitor raises the voltage more than 10 volts, replace the old one.

The filter capacitors used in most sets of this type will have an average value of 30-40 mfd, at 150 volts, for input filters, and from 50-80 mfd as output filters. They are not critical.

If you need a 30-mfd, and have only 40-mfd units, go right ahead and replace it. If you do not have the exact replacements, use more capacity than the original, not less. Usually, the filtering will be somewhat better with the larger capacitor.

The filter resistor is more common than the choke because it costs less and is smaller. Its value is ordinarily between 1000 and 1500 ohms and must be at least 2 watts in rating. The filament dropping resistor used to lower the high voltage to that required for the filaments will run 2000 ohms for a 7.5-volt string and about 2150 ohms for a 6-volt string. Once again, always use an exact replacement for this dropping resistor. It determines the voltage applied to the filament string and its value must be exactly right.

If a set is weak, although all tubes are good, suspect the power supply. If the voltage at the output of the filter is at least 90 volts, measure the filament voltage next. While it is possible to measure each tube individually, it is generally sufficient to measure the total voltage at the low end of the filament resistor. This is ordinarily the largest resistor in the set, and will be either a metal clad resistor or a ceramic-cased type. The voltage from the low end of this resistor to the common negative point should equal the sum of the tube filament voltages. Four 1.4-volt tubes and one 3-volt tube equal 9 volts. To make allowance for line surges, a voltage around 8 volts is generally used on a string like this to prolong tube life. If the voltage across the filament string is less than 7 volts for a 9-volt string, trouble can be expected.

Very little trouble is found in the filament resistors themselves, aside from opening entirely which is easily spotted. They are wire-wound and do not change in value, as do composition resistors. Therefore, most of the low voltage trouble in filament circuits can be traced to the supply voltage.

Never change the value of one of the filament dropping resistors to raise the filament voltage; instead, find out why the power supply does not feed proper voltage to the filament resistor. Some inexperienced technicians shunt the filament resistor so as to raise the filament voltage, when the trouble lies in a weak rectifier tube. Then, when the rectifier tube is finally replaced, the filament string is severely overloaded and tubes will be burned out. Never shunt filament resistors; see that they have the proper supply, and the tubes will work.

One other trouble, which might be baffling, lies in the tubes themselves. As a final test, if the right voltage is applied to the whole string and there is still trouble, check the voltage across *each tube*. Remembering the laws of series circuits, you will see that each tube must have the same resistance to get its proper share of the voltage; they are, in effect, just a number of resistors in series. If the filament resistance of one tube goes *up*, due to a defective filament, this tube will promptly take more than its share of voltage, causing others to be too low. One case was found where a 1N5 in the i-f socket had a voltage drop of 3.4 volts across it; the oscillator had only .8 volt and refused to work. The 1N5 checked out fairly good in a tube tester but obviously had a high resistance filament.

Accidental shorts in the middle of the string, caused by drops of solder, bits of wire, etc. can cause a similar effect; the total voltage will read nearly right but some of the stages will be dead. Remember, any of these mysteries can be solved by simply checking the filament voltage of all tubes in the string; one will be found with something out of order!

An elaborate system of shunting resistors, such as the one shown in Fig. 14, can also cause confusion, unless their existence is remembered. If some of the filaments are shunted, usually by quite small resistors, the tube filament can burn out, and the circuit continuity will be maintained by the shunt resistors. Of course, the resistance and voltage measurements

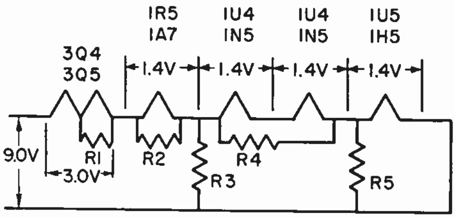


FIG. 14. Typical filament series circuit, with shunt resistors.

will be upset, but the over-all continuity will not be affected too much. Always look out for these resistors when checking this kind of trouble. For instance, if the half of the filament shunted by the resistor on a 3Q5 or similar tube went out, the gain of the stage would drop, but the tubes would still light and the set would still work. It would be very weak but it would still be operating.

While discussing this circuit, it might be well to mention the changeover switch, which transfers the circuit from the battery position to the ac-dc position. Most of these switches in the newer sets are actuated by inserting the ac line plug into a slot in the back of the chassis. This does not mean that the metal prongs of the plug itself are used to complete a circuit. The prongs merely serve to actuate a multi-position switch, mounted below the chassis deck. It is operated by the line plug so that the set cannot be used on battery and line power at the same time. Some of the older sets had a separate switch knob on the front panel, sometimes combined with the on-off switch to make this transfer.

The transfer switch has several jobs. It must disconnect the power line from the circuit; transfer the high voltage B circuits from the B battery plug to the output of the filter system; transfer the filament circuit from the A battery plug to the end of the filament dropping resistor. Some of these switches can be rather complicated in appearance, but the circuit is quite simple. Fig. 15 shows the circuit of a typical switch. Very little trouble is found in these switches, but it will pay to check the contact resistance of switch points in case of trouble.

Checking the Audio Circuits. The audio stage or stages, as outlined earlier in this lesson, are comparatively simple. They usually consist of the triode section of the 2nd detector and a pentode output tube with a PM dynamic speaker. While the circuit we are about to discuss is one used in straight battery sets, everything said about it is applicable to the ac-dc portable radios as well, with the exception of the bias circuit.

The triode section of the 2nd detector serves as a resistance-coupled amplifier. Plate load resistors run from 250,000 ohms to 1 megohm for the usual tubes, with a coupling capacitor of about .01 mfd. The small pentodes such as the 1U5, used in some sets, must have a screen dropping resistor and bypass capacitor too. Plate load resistors for these tubes are around 1 megohm, with the screen resistor between 1.5 and 4.7 meg. Screen bypass capacitors are about .02-.05 mfd. Check these resistors very carefully, especially in the portables, because many designers use very small (matchstick) resistors in these low-current circuits, and they cause trouble by changing value. Check screen-grid and plate voltages carefully. Grid resistors may be very large (up to 10 megohms in some circuits). This is done to make the tube furnish its own bias by means of the contact current discussed earlier.

The grid resistor of the power tube is usually .25 megohms. This must return to the bias resistor B— junction to provide the bias voltage for the output tube. This is a good place to check voltages. Measure the voltage developed at the bias resistor and then on the grid itself, always using a vtvm, because of the high resistances in the circuit. A common low-resistance voltmeter would draw so much current that the readings would be useless.

For instance, if the correct bias

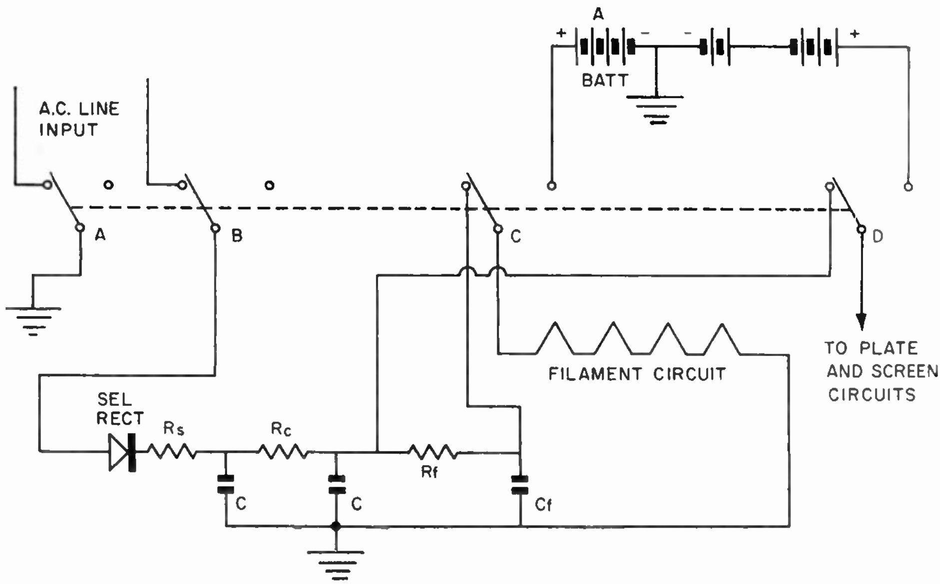


FIG. 15. Transfer switch.

needed were 4.5 volts for a 1A5 tube, this amount should be read at the bias resistor (negative with respect to chassis, of course). Almost the same voltage should also be read at the grid itself. If it is not less than 4 volts, the circuit is in good shape. If the voltage on the grid is less than 4 volts, trouble can be expected. Leakage in the coupling capacitor is the most likely cause. This leakage causes a very small positive voltage to be impressed upon the grid, bucking out part of the bias voltage. The tube then works on the wrong portion of its curve, drawing too much current, and introducing distortion. Of course, if the leakage is high enough, the entire bias voltage may be bucked out, and the grid will read several volts positive!

Unhook one end of the coupling capacitor, and re-measure the grid voltage. If it has returned to normal, replace the capacitor. Always use one with a 600-volt rating to give it the highest insulation resistance possible. If the voltage does not go back to normal, replace the tube itself. Gas currents in the tube or a small interelectrode leakage will cause the same symptoms.

This is one test that can be quickly made, and should be made on every battery set that is serviced. Upon this bias voltage depends the amount of current drawn by the set, and hence the battery life.

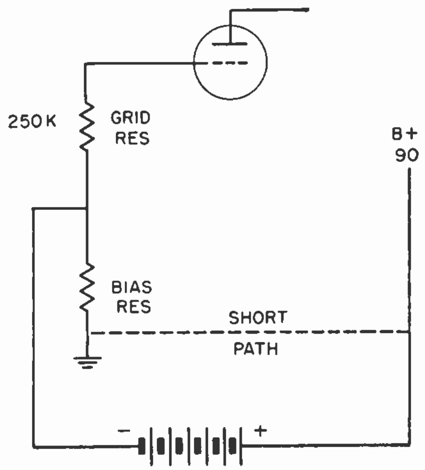


FIG. 16, Shorting the B+ to ground.

Due to its peculiar position in the circuit, the bias resistor will be destroyed instantly if there is a short in the plate circuit. A glance at the circuit in Fig. 16 will show you why. If a dead short is placed from the B+ to ground, the small bias resistor is, in effect, shorted directly across the 90-volt battery. This resistor must always be checked for signs of discoloration or charring. Overheating will cause it to change in value, upsetting the bias voltage. Replace it with one of the proper value. Never use anything over a half-watt resistor here; a small resistor will explode if overloaded, opening the circuit and preventing the B battery from being totally discharged through the short circuit.

If you do not have a schematic of the set you're working on, and the bias resistor is burned beyond recognition, look up the bias voltage of the tube in any tube manual. Connect a 1K-ohm rheostat in place of the bias resistor. Vary the rheostat until the bias voltage is correct. Measure the resistance that gives the right bias and use the closest standard resistor as a replacement.

A variation of this bias circuit is used in the portables. In the home battery set, the filament is grounded; the grid then must be negative with respect to ground (in this case the chassis). The chassis is *never* grounded in the portables, but all returns are made to a floating ground or B—, and the filament of the output tube, due to its position in the series string, is always above ground potential, too. We can't make the grid negative, but we can make the filament positive with respect to the grid. Since the grid voltage must be referred to the negative side of its own filament, we return the grid resistor to a point in the circuit which is more negative than the tube filament.

If we have a 9-volt filament string and the negative side of the filament is 6.0 volts positive with respect to the grid, and we need 6.0 volts bias on the grid, we simply return the grid resistor to the common B—. If we need less than this voltage, say 3 volts, we return the grid resistor to a point along the filament string which is 3.0 volts positive (6.0 — 3 = 3 volts). This circuit is shown in Fig. 17. The voltages along the filament string are indicated. While some sets use this circuit on ac-dc and switch to a conventional bias supply on batteries, it is not necessary; the circuit will work on either batteries or ac-dc.

We come now to another very common trouble, open filter capacitors. As we said before, the filter capacitor is actually a common bypass capacitor. As shown in Fig. 18, it furnishes a low-impedance path to ground for the signal circuits of the audio, i-f and mixer stages. If this capacitor becomes open, or if its capacity falls off too much, the impedance of this return path rises. This impedance is common to several stages and provides coupling between two or more stages. The result is oscillation.

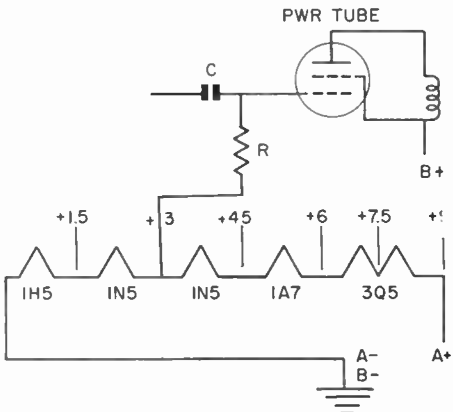


FIG. 17. Grid-resistor returns for series filament strings.

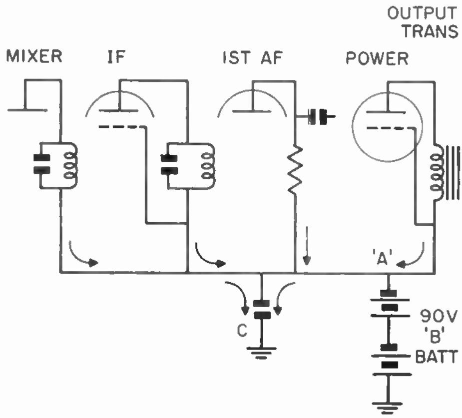


FIG. 18. Filter capacitor circuit of a battery radio.

One easy way to find this trouble is to try aligning a set in this condition. You will find that the i-f's will peak up nicely until you reach the last one. Then it will break into oscillation or "squeal" when tuning between stations. This is due to feedback between the i-f and mixer stages. If the sound is more of a continuous howl at a lower pitch, it is feedback between the two audio stages. In either case, the trouble is probably due to a defective filter capacitor. It can be checked very easily. Simply bridge a good capacitor across the suspected unit; the trouble will clear up immediately if the capacitor is poor. Never leave a good capacitor shunted across a defective one. Always cut the bad one completely out of the circuit; it might develop leakage later on and cause trouble.

This same precaution also applies to the portables, although we have been talking principally about home battery sets. If an output filter goes down in one of these sets, the same symptoms will be found: oscillation, howl, and probably a severe hum, caused by the failure of the capacitor to remove the remaining ripple from the power supply. Never replace a single section of a multiple filter capacitor. Always replace the entire unit if one section is found defective. A multiple unit is composed of several sections in the same can. The sections have about the same life. If one has failed the others will fail soon, too. Therefore, to avoid trouble, replace the whole unit.

Testing Battery Sets and Portables For Performance

A handy piece of equipment in the service shop is one which will enable you to accurately test battery radios and portables for performance under conditions of varying line voltage. Varying line voltage is the cause of such complaints as: "When the refrigerator starts, the radio stops". All that is needed for this test is some means of varying the voltage to the set while observing the performance of the radio under test.

This can be done in two ways: by means of a small auto-transformer, or by a large variable resistor, such as an old power rheostat, rated for at least 15 watts. The average portable radio will draw only 10 or 12 watts and this size would prove ample.

When using these preliminary tests on portables, the radio is plugged into the auto-transformer outlet, and the line voltage adjusted to normal. Then the voltage is run down to about 105 volts and up to 120 volts. If the portable still plays at either end of this range, it can be considered satisfactory. If it will not play on a line voltage lower than 110 volts, there is trouble either in the power supply or in the oscillator stage. The easiest test is replacement of the oscillator tube. If the set then operates at 105 volts, fine; if not, check the power supply. If a tube rectifier is used, replace it; if it uses a selenium rectifier, you must remove the chassis for further voltage measurements. Exceptionally good sets will still play down to 100 volts. However, if the set plays between 105 and 120 volts, it will give satisfactory performance in practically any home; the line voltages should never vary more than that.

For testing battery sets, another piece of equipment is needed. This is one of the small battery eliminators for electrifying battery sets. They simply consist of a small transformer and a pair of selenium rectifiers which furnish 1.4 volts A supply and 90 volts B supply. For use on the bench testing battery sets, they are ideal. Plug the eliminator into the auto-transformer, and hook the set to the eliminator. This time, instead of measuring the line voltage, connect a low-range voltmeter across the A battery terminals of the plug, so as to read the actual A battery voltage applied to the set. Using normal line voltages, check the set for performance. After it has been made to play, run the line voltage down gradually, watching the A voltage. If the set is still playing on the low end of the dial at a voltage of 1.1 volts, you can pass it as good.

This form of test is particularly desirable because it exactly simulates the running down of a battery. Because we are reducing the primary voltage, the B voltage also goes down, exactly in step with the A voltage. Incidentally, it is a good idea to allow the customer to witness this test, explaining to him just what you are doing, and why. If the oscillator tube cuts out halfway down, at about 1.3 volts, you can show him that a new tube will make the set go on down to 1.1 or below, and tell him what that means in terms of battery life. He will be highly interested. It's money in his pocket!

You can use the auto-transformer to make checks of power supplies, using either tube or selenium rectifiers. Apply normal line voltage to the set, then measure the rectifier output. The voltages given earlier in this lesson as typical were based on an input voltage of exactly 115 volts. For instance, if the power supply had an output voltage of 110 volts, with an input of 115, that would probably indicate the beginning of trouble. If the output voltage were 110, with an input of only 95 volts, the power supply would be OK. Always measure the input voltage. Then you will know if the trouble is in the power supply.

Servicing Portable Radios

There are some peculiarities common to both portable and home-type sets, and others found only in the portables. Here are a few of them, with their cures.

If oscillation is encountered at the low end of the dial, and the set has a standard flat loop mounted on a bracket on the rear apron of the chassis, try installing a half-shield of aluminum foil or thin sheet-metal close to the chassis and extending half-way up the loop. This should extend the full length of the chassis. Apparently, a feedback occurs between the loop and the i-f stages at low frequencies. This shield must extend at least as far up as the tops of the tubes. Be sure that it is well grounded to the chassis. Realign the loop after installing this shield.

If a popping noise is heard when the set is jarred, indicating a loose connection, and no loose wires are found in the circuits, look for a noisy 35Z5GT rectifier tube. This trouble appears to show up mostly in this one type. While it does not affect the operation of the tube, it is unpleasant. Replacement of the tube is the best cure, but if this is not possible, an open-topped shield may be placed over the offending tube. The top must be left open to allow heat to dissipate and the shield must be well grounded. This can be done by tacking a short pigtail of flexible wire to the shield and soldering it to the chassis nearby. Leave enough slack to permit removal of the tube when necessary.

If the fine wires of a cabinet-mounted loop break off close to the wood, drive two common insulated staples into the wood, as near to the break as possible. Wind the end of each wire around one leg of a staple, and solder in place. Make the connections from the loop to the set by soldering larger pieces of wire to the other legs of the staples.

If a set comes in with a special battery plug, and you have only a standard battery in stock, remove the special plug and install a standard RETMA plug. This takes only a few minutes, and standard batteries can be used from then on. However, be sure that the battery you have will fit inside the cabinet.

Some of the early portables used the loctal series of tubes. There was some difficulty with microphonics in the second detector circuit in sets using a diode-pentode type 1LD5. Replace this tube with a type 1LH4, even though it is a diode-triode. Leave the screen grid resistor and capacitor in the circuit; they come out on an unused pin of the 1LH4. The circuit will work just as well as before, with much less trouble from microphonics.

Very low volume and considerable distortion in some portables, especially those using the diode-pentode types in the first audio-second detector stage, may be traced to open screen-grid resistors. Many sets used small matchstick resistors; these gave quite a bit of trouble by increasing in value or opening entirely. Check this very carefully, using a high-impedance voltmeter, or vtvm, as the indicated voltage will be only 15-20 volts. These resistors are usually 3.9 megohms.

PORTABLE RADIO ALIGNMENT

With few exceptions, everything in this section about portable radios will also apply to the home-type battery radios. Their alignment is just as critical as that of the portable. No battery set is as powerful as the average ac set, because of the need for economy in operation. Hence, careful alignment work is important.

The i-f stages must be carefully peaked on the proper frequency. Consult the service data for the set you're working on to find the location of trimmers, alignment frequencies, etc., before attempting any over-all alignment work.

I-F transformers are divided into two major types; the older large type using mica compression trimmers, and the smaller iron-core type with a higher Q and more gain. The two are easily recognized by their size, as the iron-core types are usually not over ¾ inch square, and about 1-½ inches high.

We repeat a warning given before; never use a screwdriver to align the cores of these transformers. Always use the special tool made for the purpose. Some have a bit similar to a screwdriver but it has a much broader nib and is made to fit exactly into the slots in the cores. A small screwdriver will cause chipping of the corners of the slots in the soft powdered iron cores, breaking them out in a few turns, so that they cannot be adjusted at all. If the cores are touched with a metal screwdriver, it will usually detune the transformer, making it impossible to get an accurate adjustment of the stage.

To make an over-all alignment, first be sure that the entire set is in good shape: tubes good, power supply up to normal, etc. Set up your signal generator to the correct intermediate frequency, and connect an indicator to the set to show the value of the output signal. This can be an output meter connected across the voice coil of the speaker, or a vtvm connected to the avc line. The last method is almost standard for service shop work because of its simplicity. The vtvm is always there and it takes no time at all to clip its voltage probe to one of the grids or to the tuning capacitor. AVC voltage is often fed to the first stage grid through the loop itself and the vtvm can be connected to the bottom of the loop. Maximum avc voltage indicates a maximum of signal being passed through the stage being aligned. It will always be negative to ground and the maximum value will be about 5-6 volts.

Connect the signal generator to the mixer grid. This connection may be made to the stator plates of the large section of the tuning capacitor, if one is used, or to the hot end of the loop, if the set is slug-tuned. If the signal generator seems to upset the tuning, merely place the end of the lead on or near the loop. Enough signal will be picked up for the purpose. To prevent the lead from moving and changing the reading, it can be clipped to the insulation around the loop.

Set the signal generator to the intermediate frequency, and disable the local oscillator or tune the receiver so no beat is heard. If you are using the avc as an output indicator, turn the generator's attenuator up until a reading is noted on the vtvm; now back it down until it is just a half volt or so above its minimum. For instance, if the "no-signal" reading on the meter is 1.2 volts, set the generator to give a reading of about 1.5 or 1.7 volts. Now, align the i-f stages. As the reading increases with alignment, back the signal generator's gain down, keeping the reading near the starting value. This must be done to prevent the high avc voltage from flattening the peaks of the i-f stages.

Begin at the last or output i-f transformer and work toward the antenna, with this or any kind of alignment. After peaking all trimmers or adjustments, go back and retouch them. If oscillation is found when the alignment reaches its peak, check the output filters. Bridge a good capacitor across them as a test. If this clears the oscillation, replace the filters.

The next step should be the calibration of the dial scale. This means that the set must be adjusted so that the dial scale will indicate the correct frequency. A 1000-kc station will come in at 1000 kc or at 100 as the dial is usually marked.

First, locate the oscillator trimmer capacitor. This is the trimmer on the smallest section of the tuning capacitor; if a slug tuner is used it is visible through a hole in the chassis. It can usually be reached without removing the chassis. If the service data is not available, and there are two trimmers, one is the rf or antenna, the other the oscillator. To tell them apart, tune in a station or a signal from the generator, and move each just a little. The rf trimmer will be quite broad; a full turn will not have much effect on the signal. The oscillator trimmer will cause the signal to disappear with a very small movement and it can be tuned in again by moving the dial of the set or generator. Mark it "osc" with a pencil and proceed with the alignment.

Turn the tuning capacitors wide open or run the slug tuner to the high end of the dial, slugs as far *out* of the coils as possible. If the service data is on hand, note the high-frequency adjustment point recommended; 1500 kc, 1720 kc, etc. If it is not, look at the dial of the set. If the largest figure is 1700 or 170, set the generator at 1720 kc. If the figure is 1500, set the generator at 1520 kc. Leave the signal generator output clipped to the insulation of the loop. If you want to, you can set the dial exactly on the 1500 mark and the generator at 1500 kc. With the type of dial used on practically all modern home radios, and especially on portables, you can't make the calibration *exact*. Just set it so that the stations come in somewhere in the vicinity of the corresponding dial markings. That is the best you can do with the broad calibration marks.

With the dial set at the high end and the signal generator at the corresponding frequency, tune the oscillator trimmer only, until the maximum output is reached. Next, tune the signal generator to a frequency around 1400 kc, and tune this in on the radio. Now, peak the antenna and rf trimmers at this frequency. One important point about this adjustment; it *must* be made with the loop antenna in exactly the position it will occupy when the set is replaced in the cabinet! This is necessary because a change in the position of the loop with respect to the large mass of metal on the chassis will cause a slight detuning effect. You need every bit of gain you can get!

Some of the older sets with the loop wound around the case itself have holes in the top of the case, with small snap buttons filling them, to allow tuning of the antenna after the set had been replaced. On others, it is necessary to cut off the handle and blade of a very small screwdriver, making it only an inch long. With this screwdriver the trimmer can be adjusted after the set is back in the case. Of course, if the loop is mounted on a bracket on the back of the chassis, it is only necessary to see that the loop is fastened to the bracket in the right position.

A small amount of adjustment is possible if the antenna tuning capacitor has slotted outside sections on the rotor plates. The set may be made to track better over the dial by bending each section individually to provide best response. However, this is a slow and tiresome procedure and does not always give enough improvement to justify the time. If the response appears to be off badly at some of the low frequencies, it's worth a try. Use a signal generator and output meter for best results. The plates may be bent out in sections to make the loop track as well as possible. If necessary, the setting of the oscillator tuning trimmer may be varied slightly, throwing the calibration off somewhat at the high end of the dial, but giving much better results in the middle section. This adjustment depends somewhat upon the location of the major stations. If they are all near the higher end of the dial, say around 1100-1200 kc, concentrate on making that section as "hot" as possible for best results in use.

On the old sets, with the loop on the case, better results may be had by replacing the loop with one of the small iron-core loopsticks. One can be installed in any convenient place, using the bracket that comes with the loopstick. Place it as close to the mixer-oscillator tube and tuning capacitor as possible for best results. Because they can be adjusted, these little loops will give better results than the conventional loop.

To adjust it, connect the loopstick in place of the old loop; one lead to the stator of the antenna section of the tuning capacitor, and the other to ground or the avc connection, whichever is used. Do not disturb the setting of the trimmer capacitor. Tune in a signal at around 1400 kc, from the generator, and adjust the rf trimmer for maximum; next, tune the set and generator to about 600 kc. Adjust the iron core of the loopstick for maximum volume at this frequency. Now, go back to 1400 kc and readjust the rf trimmer. It will be necessary to repeat this process at least four or five times, as each adjustment will throw the other one off a little. Continue until each adjustment has reached its maximum and very little adjustment is needed when changing from the high to the low end of the dial. Now, try the set and see if it does not have quite a bit more gain all over the dial.

REPLACING THE TUBE RECTIFIER WITH A SELENIUM

If the set has a tube rectifier, and it is burned out, a selenium rectifier may be substituted. If the rectifier used was a straight rectifier type, such as 35Z5, 50Y6, 117Z6, or 117Z3, the rectifier may be directly replaced, connecting the plus or output side to the old cathode connection, and the input side to the old plate connection. If the tube required a resistor cord or filament dropping resistor, they can be either ignored or removed entirely.

If the tube used an octal socket, the new rectifier can be wired into the circuit by soldering two short pieces of stiff wire to the lugs, covering with braided sleeving and slipping these wires down through the holes in the socket. Pull them tightly into place and wrap around the lugs of the socket. This will make the rectifier almost self-supporting. If desired, the base of the old tube may be used, and the selenium rectifier plugged in. Break the glass, and remove all of the old lead wires from the base. With a 35Z5, for instance, clean out pin 8 for the cathode and pin 5 for the plate. Connect the new surge resistor to either lug of the rectifier, slip a large piece of sleeving over it, and wire the rectifier into the tube base, as outlined above; positive to pin 8 or cathode and input or plate to pin 5. The rectifier may be pulled tightly down until the bottom of the plates rests on the top of the tube base, making a sturdy mount. This may then be plugged directly into the old tube socket. A big advantage is that it can be removed and checked in a tube checker. Set the tester up for a 35Z5, and check for output.

If the old tube uses a miniature base, such as a 117Z3, bolt the rectifier firmly to the chassis at any convenient place. Run two leads from the rectifier lugs down through the center hole of the miniature socket, connecting the positive lead to pin 6, and the other lead to pin 5. Be sure that the wire used is braid-insulated, not solid plastic, because of the possibility of heat softening the plastic and causing a short circuit.

When making replacements of this kind, always use a rectifier of at least 100-ma rating; the 75-ma rectifiers do not have sufficient reserve capacity.

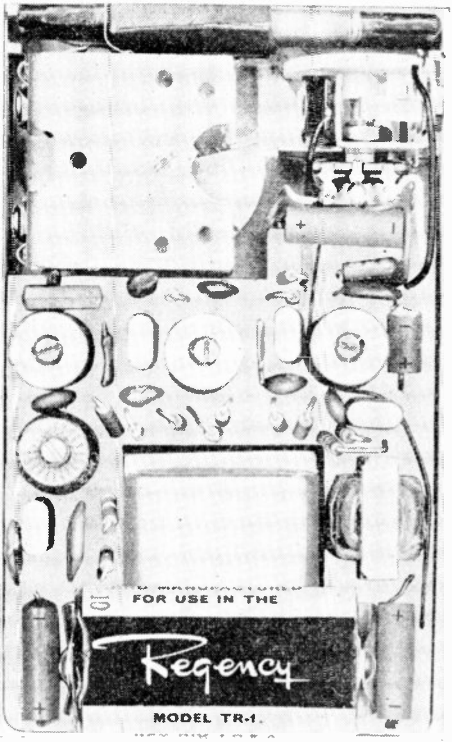
The Transistor Portable

Late in 1954 the first transistorized radio made its appearance on the market. This was the Regency portable built by I.D.E.A., Inc., of Indianapolis, Ind. During 1955, several manufacturers ventured into this field and by now there are quite a number of different makes available. We will discuss the Regency set here, but all principles apply to the others as well.

The average portable of this type uses four or five transistors, usually of the junction type. Some use power transistors in the output stage, some use a vacuum tube, while some of the smaller sets use low-power transistors. A germanium crystal diode is used as a second detector in many circuits.

These transistor receivers are all superheterodynes. Although the triode oscillator mixer is not too common in tube receivers, it is used with transistors. Printed circuit wiring is used in most models, as they are largely of the "pocket" type and made as small and handy as possible. The Regency, for instance, will slip comfortably into a man's shirt pocket, batteries and all. Complete with batteries, the receiver weighs only 12 ounces. Cases are made of polystyrene plastic, in several colors.

The parts of the tiny set are mounted on the printed-circuit wiring board. All are soldered at once, by dipping one side of the board in mol-



Courtesy I.D.E.A., Inc.

FIG. 19. Transistorized receiver.

ten solder. The antenna is an iron-core loop, visible above the tuning capacitor in Fig. 19. It is flat and non-directional, a decided advantage in a portable of this type. At the left is the tuning capacitor, a miniature two-gang type. Next to it is the volume control and switch and an earphone jack. Below, in a row across the chassis, are the i-f coils and oscillator coil, and the i-f transistors. The output transformer is visible at the lower right side next to the magnet of the speaker, which is only 2-¾ inches in diameter. At the bottom of the chassis is the battery clip with the connections at each end. On either side of this are the two high-capacity, low-voltage electrolytic filter and bypass capacitors. Other circuit components, such as resistors and capacitors, are visible over the rest of the chassis.

This is a four-transistor circuit, using germanium junction transistors of the N-P-N type. The circuit of this receiver is shown in Fig. 20. A grounded-emitter circuit is used in all stages. Generally, the circuits used are very similiar to those in the tube type of radio receiver, especially as to signal path.

The signal is picked up by the loop antenna, and fed into the base of the mixer transistor, X1. This also serves as the oscillator. The oscillator injection voltage is derived from the tuned circuit, L3, C3, and C5, which is inductively coupled to coil L4 in the collector circuit. The mixer is coupled through T1 to the base of the i-f transistor, X2. X3 is another i-f amplifier, feeding the output i-f transformer which is coupled to the crystal diode second detector. The output of this diode is developed across the load resistor, R11, and fed through the gain control, to the base of the audio transistor, X4. The output of X4 is transformer-coupled to the speaker.

In the all-transistor radio, there is no filament drain. The small operating currents of the collector and emitter circuits of the transistors themselves are all that are used. These are very small; they run between 3.5 and 4.8 ma for this particular set. This current, together with the very low voltage required, makes possible the use of very small, compact batteries, which give astonishingly long life compared with the tube type radios. Only 22.5 volts is used here; others vary according to design, but as a general rule, very small voltages, compared to those we have been working with, are used.

SERVICING AND REPLACING PARTS IN TRANSISTOR SETS

Service work on these ultra-compact sets will be quite different from the

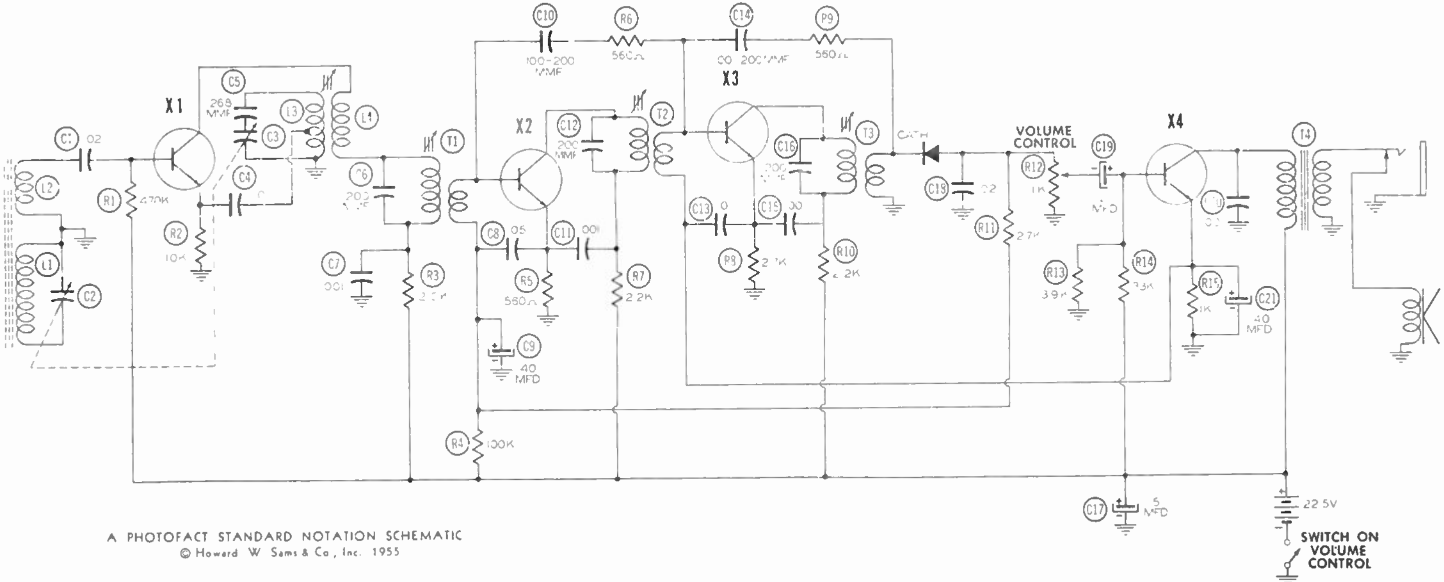


FIG. 20. Schematic of Regency Model TR-1.

Courtesy Howard W. Sams

other types. You may wonder, upon opening the case of one of these tiny sets, just how are you going to make any voltage measurements or tests at all! A closer inspection, however, will reveal that it is not too difficult. In this set, *all* components are visible from the back of the chassis. Resistors, capacitors, etc. are all accessible since their leads go through the printed-wiring board and are soldered underneath. However, they are accessible from the back, if a small test prod is used. If the regular test prod is too large, wind a short piece of stiff wire around the tip, and slip a piece of spaghetti over it, leaving only the end exposed. This may then be bent so as to reach into tight places, even underneath the transistors themselves, if necessary.

Since the transistors are all triodes, some form of neutralization must be provided to eliminate oscillation and feedback if they are to work as rf amplifiers. Feedback RC networks are used for neutralization in this set. Note C10 and R6 in the first i-f stage, and C14 and R9 in the second. These RC networks feed back a portion of the output voltage of each stage into the input for greater stability. These networks are matched to the transistors used. If a transistor is replaced, the capacitor must be changed also.

Some very low voltage electrolytic capacitors are used in this type of circuit for filtering and bypassing. These may run up to 40-50 mfd. at a working voltage ranging from 3 volts to 25 volts, depending upon whether they are used in the collector return circuit or in the emitter circuit. They must be checked very carefully. The application of too much voltage, even from the ohmmeter, could break them down. Always check the polarity of the ohmmeter battery before testing any capacitors or transistors.

Do not use an ohmmeter with a battery greater than 3 volts for any transistor set tests. It might not do any damage to the set, but due to the nature of the circuits, all readings would be misleading. Some of the older ohmmeters used as high as 45 volts. If even 3 volts were applied to a transistor with the wrong polarity, it could be ruined.

As in all other battery-operated equipment, the batteries themselves should be the very first item to be tested. With this particular set, using a 22.5-volt battery, an under load voltage reading of around 15 volts would indicate that the battery was too low and should be replaced. A low battery can cause weak operation and also oscillation. Oscillation may result from low battery voltage, since the neutralization of the i-f stages is dependent upon the operating voltage.

When a low or dead battery is discovered, the first test that must be made is for normal battery current drain. There is no means of knowing whether the battery was run down normally or whether it was discharged by a short or leakage in the high-voltage circuit. Measure across the battery clips with a low-range ohmmeter, placing the positive lead of the ohmmeter on the positive terminal. The reading in this set should be between 6000 and 15,000 ohms. Readings in other sets will vary according to their circuitry. Check the schematic diagram and you will usually be able to make a very close estimate of resistance to be expected. In this set, you will note that there are several paths to ground: R14-R13 in series, total 37,000 ohms; R4, R11, and the volume control, total 128,000 ohms; the leakage resistance of C17, together with the normal paths through the transistors. The total will come out around the figure given. If this resistance is too *small* (less than 6000 ohms), there is a short or leakage somewhere in the circuit which must be checked out.

A quick way to determine whether the resistance is within tolerance is to connect a milliammeter in series with the battery and measure the current drawn. Normal current, as stated earlier, is between 3.5 and 4.8 ma. If it is more than that, check the electrolytic capacitors for high leakage. The quickest way would be to temporarily open one end of a suspected capacitor and remeasure the current. Any large electrolytic capacitor may be used to shunt a suspected electrolytic to prevent oscillation while this test is being made.

A novel avc circuit is used in this set. The control voltage is developed from the output of the diode detector, filtered, and then applied to the *base* of the first i-f transistor. This works just like any other standard avc circuit. The received signal, increasing in strength, causes an increase in the rectifier dc voltage developed across the diode load resistor, and is fed back to the grid (input element) of the controlled stage, decreasing its gain, to maintain a steady output.

Base bias for the second i-f transistor is developed across the emitter of the output or audio transistor. The bias resistor in the emitter lead is bypassed by a very large capacitor to stabilize the voltage, further bypassed by a .05 capacitor, C13, and fed to the base of the i-f transistor through the secondary winding of the second i-f transformer. .

One more very important warning—with the small batteries used in these sets, it is usually possible to reverse the battery when installing it. This can cause damage not only to the electrolytics but also to the transistors. Take extreme care that this does not happen and warn the user, too.

The transistors themselves are very stable, long-life devices, and little trouble has been found with them in the field. There have been many cases of mistaken diagnosis, where the blame was placed on the transistor when actually a bypass capacitor or resistor was at fault.

The printed wiring boards require a little different technique in making part replacements. Only a few components, such as the two large electrolytic capacitors, can be replaced in a standard fashion.

To replace a resistor or capacitor located in the central part of the circuit, the following procedure is recommended. Using a pair of sharp-nose pliers, crush the defective part, leaving the wire leads. Of course, if the leads are long enough, they can be cut off with a pair of thin diagonal cutters. In any case, leave at least a half inch of wire above the board. Cut the leads of the new part short, and make a very small loop in each lead. Slide these loops over the leads of the old part and solder, taking care that heat does not travel far enough to cause the lead to break loose from the board. This can be helped by using long-nose pliers; grasp the lead between the solder joint and the board with the pliers, then solder. The tips of the pliers will absorb some of the heat, preventing it from melting the joint at the board itself. Always use a very small soldering iron with a fine tip and keep the solder joint as small as possible.

Alignment of these sets is more or less conventional. This set uses a 262-kc i-f; others will vary from this. The i-f transformers used here are of the single-tuned variety. There is only one tuning adjustment per stage, a movable powdered-iron slug in the primary coil. To check alignment, if necessary (which is seldom, due to the construction of the transformers) inductively couple the signal generator to the loop antenna by making a loop with three or four turns and connecting it across the output cable of the signal generator. Never make a direct connection between an ac-operated signal generator and a transistorized receiver. Always use inductive coupling.

Due to the construction of some sets, the avc line is not accessible for alignment work. Therefore, we will have to fall back on the standard output meter connected across the output transformer secondary. On this set, or any using a phone jack, the high side of the voice coil is easily accessible at the spring of the phone jack. Use a very low signal generator output.

To align rf and oscillator circuits, set the generator to 535 kc, close the tuning capacitors completely, and adjust the core of the oscillator coil for maximum output. Tune set and signal generator to 1630 kc, and adjust the oscillator trimmer on the tuning capacitor for maximum. Tune set and signal generator to 1500 kc, and tune the antenna trimmer. Couple the signal into the loop by placing the end of the generator lead close to the loop and using just enough signal to obtain a readable deflection on the meter.

These receivers, although quite compact, can be treated exactly like any others. The signal circuits operate in exactly the same way as in tube sets. Remember what each stage *does*. If it is supposed to amplify an i-f signal, check to see if it is actually doing that; if it is supposed to amplify an audio signal, check for audio gain. If all voltages are correct, a signal fed into the input of the stage should produce an output. If it does *not*, there is something wrong in that stage.

By starting at the speaker and checking back to the antenna, repairing each trouble as it is located, the set should be working when you get to the antenna. If it isn't, you have overlooked something; go back and repeat the process!

Remember, no matter how complicated *any* set may appear, it is made up of a group of small, simple circuits. These simple circuits connected together make up a complicated circuit. Learn what each of the small circuits does, learn to test them individually, and you will never have any trouble.

Lesson Questions

Be sure to number your Answer Sheet 43B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. The customer brings in the battery pack for his portable receiver for testing. He does not bring in the receiver. The battery is rated at 1½ volts and 90 volts. The voltage test of this battery without load shows the output voltages to be 1.35 and 80. Would you expect these batteries to operate satisfactorily in the receiver?

2. What stages are found in all battery-operated home receivers?

3. Which stage in a battery receiver has the greatest effect on B battery life?

4. What is the purpose of the resistors connected in shunt with the filaments of the tubes in a three-way portable?

5. Are the tube filaments in a three-way portable heated by alternating current or direct current?

6. What is an advantage of replacing a vacuum tube rectifier in a three-way portable with a selenium rectifier?

7. What is the purpose of the surge resistor?

8. Suppose you intend to replace a tube rectifier with a selenium rectifier. What should you do about the surge resistor: (a) remove it entirely (b) leave it unchanged or (c) increase its resistance?

9. What part in a battery set should be checked first if the set squeals in tuning at every station?

10. What part of a transistor radio should be checked first when the set does not operate properly?

HOW AND WHY

There is an exceptionally fine quotation I want to pass on to you. I do not recall the name of the author, but the truth in the quotation makes it unforgettable. Here it is:

> *"The man who knows HOW to will always have a job—the man who knows WHY will be his boss."*

Your NRI training fits this thought perfectly. You are being taught HOW to service receivers, so you can be sure of plenty of work in this, your chosen field. Also, your fundamental training gives you the background of WHY receivers function as they do, WHY they break down, and WHY the particular servicing methods we recommend lead directly to the source of trouble.

We not only want you to be a successful serviceman—we want you to have an assured future, with every opportunity to advance to the top. You will need only the touchstone of a little practice experience to weld your "HOW and WHY" training into a single, compact unit of knowledge that can lead you wherever you wish to go.

SERVICING HIGH FIDELITY SYSTEMS

44B

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WASHINGTON, D. C.

ESTABLISHED 1914

Study Schedule No. 44

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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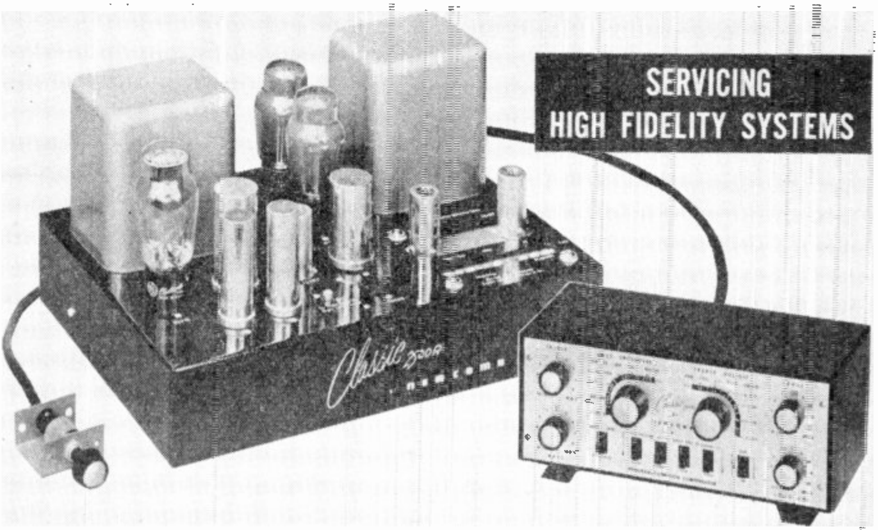


IN EARLIER lessons you learned about the component units that make up a high fidelity system. A typical arrangement is shown in Fig. 1. When there is a complete failure, a decided weakness, or a very apparent distortion, the defective section can generally be isolated quickly. For example, a defect in the amplifier would cause poor reproduction of signals from player as well as tuner. A defect in the phono-pickup section of the preamplifier generally permits a normal reproduction of any signal taken from the tuner. A tuner defect, when present, would not interfere with the normal phono reproduction.

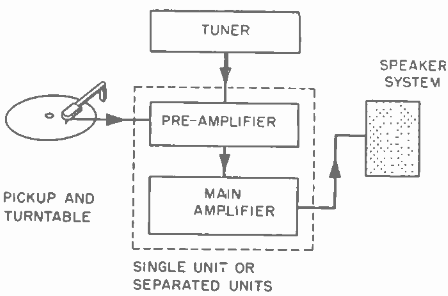


FIG. 1. Block diagram of a Hi-Fi system.

A signal source and an output meter can be used to localize defects. A defective major unit can be located by checking output levels of the preamplifier, tuner, and main amplifier with signals of known strengths applied to the input circuits. A signal generator or a test record can be employed as a signal source. The usual signal-tracing methods used in radio servicing are also used here.

The more obscure defects which produce annoying disturbances in the quality of reproduction are harder to track down. The human ear, test records, and a few special test instruments are all that are needed to find the simple as well as the obscure defects in hi-fi systems. The good technician has a critical ear that is able to interpret performance by listening to test records or hi-fi selections.

As its name states, a hi-fi system is one that can reproduce the audio information exactly as it was picked up or recorded. If it cannot, it either distorts the tones it is to amplify, or adds spurious signals that never existed at the pickup point. Some of these disturbances are quite difficult to hear and identify, and you can learn to recognize them only by experience. Even so, these disturbances can be quite annoying to the ardent hi-fi fan.

Types of Trouble in Hi-Fi Systems

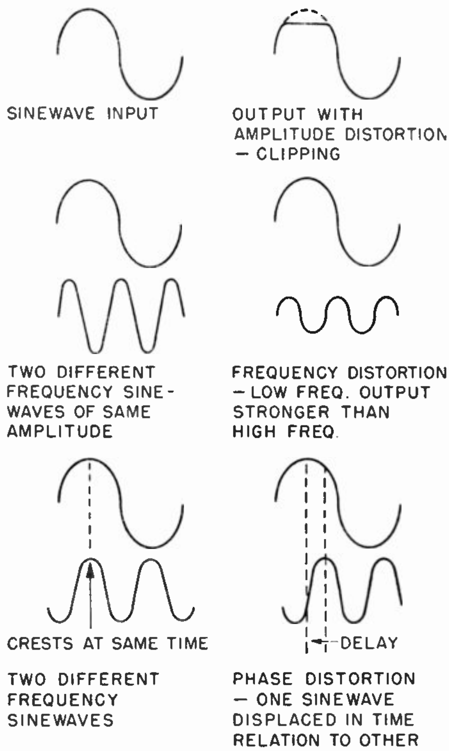


FIG. 2. Waveform distortions.

WAVEFORM DISTORTION

Three of the fundamental types of distortion are amplitude, frequency, and phase. Amplitude distortion refers to the misshaping of a wave because of the inability of the amplifier to pass the high amplitude portions of the audio signal. For example, when a strong sine wave note is passed through the amplifier, the top or bottom portion of that waveform may be rounded off or clipped as shown in Fig. 2. If we assume the original design of the amplifier was correct, this type of distortion can be caused by an aging tube, a decline or change in the supply voltages, or a defective component part that is changing the operating point of one of the stages. This type of defect is easy to find with an oscilloscope.

Frequency distortion has to do with the inability of the hi-fi system to evenly amplify the entire range of audio frequencies. A hi-fi system should amplify all frequency components with the same gain, from 20 cycles up to a high frequency limit somewhere between 15,000 and 20,000 cycles. In other words, a 100-cycle tone and a 10,000-cycle tone which originated at the pickup point with the same amplitude should also be radiated from the loudspeakers with equal amplitude. If one of the tones is lower in amplitude, there is frequency distortion in the reproduction system.

Phase distortion, although it is not as common or as noticeable as the previous types, can also prevent true rendering of the audio information. When phase distortion is present, different frequencies take different lengths of time to pass through the system. If we assume that two different frequency notes are picked up at the same instant, they should also be radiated from the loudspeaker system at the same time. If one of the notes is delayed a trifle with respect to the other, there is phase distortion present in the audio system.

Usually the time displacement is not so great that it actually can be heard as a time delay of one note with respect to another. Rather, the tones to be reproduced run together and a crisp and lifelike reproduction is not attained.

The wave shapes of frequency and phase distorted signals are also shown in Fig. 2. Notice that with amplitude distortion the shape of the applied sine wave signal is altered; with frequency distortion, the final amplitude of two different frequency signals is not the same, although they both had the same amplitude originally. In an exaggerated example of phase distortion we notice that the high frequency signal follows after the lower frequency one in time, although peaks of both occurred simultaneously at the pickup point.

A musical note is made up of the fundamental and many harmonics. It is the number and strength of these harmonics that give each instrument its characteristic sound. Phase distortion changes the time relationship of these harmonics and the instrument no longer "sounds right."

SPURIOUS SIGNALS

Probably the most common form of spurious signal distortion is called "harmonic distortion." When harmonic distortion is present, harmonics of the fundamental tones are produced as the audio signal passes through the amplifier system. For example, if a 1000-cycle pure tone is fed to the input of an amplifier, there can also be 2000-cycle, 3000-cycle, etc., tones in the output. The harmonic signals are, of course, weaker than the fundamental tone, but the same action repeated for all of the other audio tones passing through an amplifier can cause a severely distorted and unrealistic output. Thus, as shown in Fig. 3A, the presence of harmonic distortion in the amplifier develops spurious signal tones at frequencies that are multiples of the signal frequency to be passed through the amplifier. Harmonic distortion always accompanies amplitude distortion.

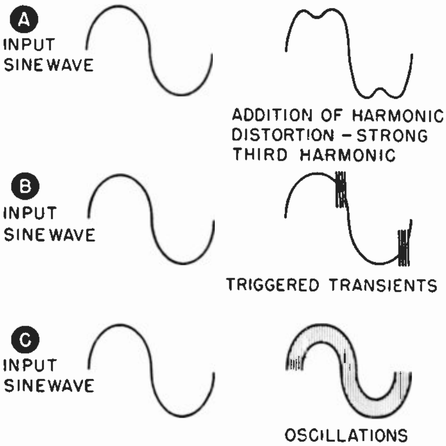


FIG. 3. Addition of spurious signals.

When an amplifier has intermodulation, or IM, distortion, it produces spurious signals when two or more different audio frequencies are fed into the amplifier. The spurious frequencies that result from intermodulation distortion are formed by a "beating" or nonlinear mixing in the amplifier. For example, if a 100-cycle and a 1000-cycle pure tone are introduced at the input of an amplifier, this type of distortion would cause beat notes to be produced at the sum and difference frequencies, or at 900 cycles and 1100 cycles. In fact, with serious IM distortion a whole series of spurious beats are produced. In severe cases of IM distortion, harmonic distortion will also be present. Every harmonic will beat with every other tone to produce two more tones.

In summary, intermodulation distortion is produced when two of the desired audio tones beat together to produce sum and difference frequencies plus harmonics of the sum and difference frequencies. With the many tones of a musical selection passing through such an amplifier, the introduction of tones that were not in the original music results in very unrealistic sounds from the loudspeaker.

The tones of speech and music are composed of a fundamental and many harmonics. The presence of these harmonics on the fundamental, changes the shape of the wave from the sine wave of the fundamental. The wave frequently takes on a very steep front, rising almost as fast as a square wave. When a steep-fronted wave of this type passes through a circuit which is resonant in or near the audio frequencies, damped oscillations occur. These oscillations take place at the resonant frequency of the component parts. This damped sine wave adds to the signal which was fed into the amplifier, and in some cases will cause a very definite ringing sound in the output. These short-lived oscillations are called transient oscillations. Transient oscillations may be caused by feedback loops acting as RC oscillators, or by self-resonant transformer windings. Another form of transient can occur in the loudspeaker system. A good amplifier must be capable of passing a steep-fronted wave without the formation of these transient oscillations.

In some amplifiers there are continuous oscillations at a frequency above the audible range. These oscillations are not noticeable in the output. However, when an audio signal is passed through the amplifier, these waves will add to the signal, overload the tubes and cause amplitude distortion of the desired signal. In cases where IM distortion is present these parasitic oscillations will beat against the desired tones and produce spurious audible tones in the output. Oscillations of this type are usually caused by faulty operation of feedback networks, or by insufficient decoupling between the individual amplifier stages and the power supply. This lack of decoupling allows signals from the output to be fed back into the input through the power supply wiring. At some frequency, the signal fed back will be in phase with the signal at the low level tube, and oscillation will take place at that frequency. When the signal fed back is not strong enough for continuous oscillation, it is still possible for transient oscillations to be generated on strong signals.

Hum is another spurious signal that can be introduced into a hi-fi system. To obtain faithful reproduction of music it is necessary that the amplifier system pass frequencies below 60 cycles. Consequently, the amplifier system will amplify any 60-cycle hum components that leak into the system. 60-cycle hum from the turntable motor often finds its way into the system through the pickup and tone arm to produce a rather high hum level.

Filter and bypass capacitor failures

also introduce 120-cycle ripple into the amplifier stages. The filaments of preamplifiers are often supplied with dc power to minimize the hum level in the early stages. If ac filament voltage is used, the filament lines must be balanced and components mounted carefully to reduce hum pickup by the amplifier stages.

Occasionally the hiss or tube noise level in the amplifier system rises. This is often the result of an aging tube or overheated components in the first stages of the preamplifier. Noise level from the tuner also rises with aging of tuner tubes, alignment drift, or limiter-demodulator defects.

Spurious noises can also be introduced at the pickup and phono motor. Such disturbances can be high level record scratch, turntable "wow," or motor "rumble." The motor assembly should be shock-mounted and have a minimum of motion horizontally and vertically. Of course it should be quiet in operation so as not to directly excite the pickup cartridge with noise. The turntable should rotate smoothly and not produce any uneven wear on the records. A smooth motion of the record at a constant speed prevents the introduction of untrue tones into the system due to erratic motion of the record on the turntable.

Record scratch can be the result of any of a number of defects or an accumulation of defects. Some records have a high scratch level when new. Scratch level is increased by improper care and storage. Dust may accumulate or the records may become scratched in handling and storage. Improper mounting of the cartridge, a worn stylus, improper tone arm pressure or position can all increase scratch levels.

It is apparent that a hi-fi system can be afflicted with quite a few defects that prevent lifelike reproduction of audio information. You should familiarize yourself with all these disturbances and learn to recognize them.

Test Equipment for Audio Servicing

Hi-fi systems can be serviced effectively with test records, a few test instruments, and a critical ear. Test records are very helpful in checking the over-all performance of a hi-fi system from pickup to loudspeaker. The ear is the final judge, in most cases, in evaluating the reproduction of the test record.

Test instruments can be attached to the amplifier output to permit critical measurement of the test record signals at the output of the system. Various types of test records and their uses will be discussed in a later section.

Performance is measured and defects are localized to specific stages and circuits by the use of test instruments. Test instruments are particularly useful in showing certain defects in the system to the quality-conscious hi-fi fan. If he can be shown readings or oscilloscope patterns of what should or should not occur in the amplifier, he will have more confidence in your adjustments and the quality of your work. It is sometimes difficult to convince a customer that an improvement or change is necessary by simple listening tests. Often his ideas of good reproduction do not agree with yours. For example, many new hi-fi fans assume a booming bass is a good thing because they have been accustomed to hearing the overemphasized bass of juke boxes for many years. At the same time a visual presentation of results is helpful in overcoming some of the mistaken notions of the hypercritical high fidelity fan.

THE OSCILLOSCOPE

The oscilloscope is the most useful test instrument for hi-fi work. It has a number of applications. It can be connected to the amplifier output to permit visual observation of the signal fed to the input from an audio generator or test record. Also it can be used to make an audio sweep observation of the system response using one of the audio sweep test recordings now available.

Most modern service oscilloscopes, because they have been designed for TV work, have an adequate high frequency response. Inasmuch as the low frequency audio components of music are quite strong and, in addition, are emphasized to permit truer loudspeaker reproduction, the performance of an audio system at low frequencies is very important. Thus it is advisable that the oscilloscope be able to pass a 60-cycle square wave with a minimum of distortion. For making critical low frequency observations and measurements, a direct-coupled vertical amplifier is best.

With an audio signal or a square-wave signal applied to the amplifier input, an oscilloscope can be used for signal tracing. In this way you can locate the point where distortion occurs. Used with a voltage calibrator, the scope can measure individual stage gains or the over-all gain of the system. Likewise it is employed to check relative gains in various frequency ranges. The presence of parasitic oscillations is easily determined by using the oscilloscope with no signal applied to the input. Transient oscillations will show up on the flat top portion of a square wave.

AC VACUUM TUBE VOLTMETER

The ac vacuum tube voltmeter is a small portable type instrument that can be used to tell much about the operation of a hi-fi system. It can be used to check gain and frequency response and do work similar to that of an oscilloscope. It is not as effective in locating waveform distortions in the system since it does not present a picture of the waveform.

The vtvm is excellent for signal tracing and measuring gain, stage by stage, through the system. If the instrument is flat from about 20 cycles to better than 20,000 cycles, it can be used to make frequency response measurements. In this way tests can be made for frequency distortion and the source of distortion localized. The meter can also be used to detect parasitic oscillations.

A good sensitive vtvm is desirable since it can be used to check signals in the weak signal stages of the preamplifier and even measure the output of the pickup cartridge directly.

The ac vtvm can be used to check the power output of an amplifier by measuring the voltage across a terminating resistor. This resistor should equal the rated load resistance for the amplifier. From the voltage readings, the power output can be calculated using Ohm's law.

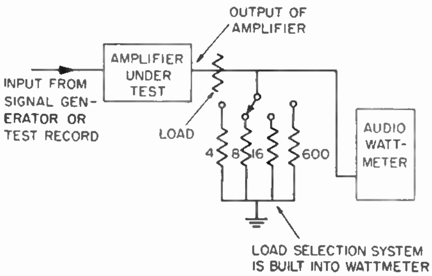


FIG. 4. Plan of an audio wattmeter.

AUDIO WATTMETER

The audio wattmeter is used to measure, directly in watts, the output of an audio amplifier. As shown in Fig. 4, the wattmeter loads the amplifier correctly when it is set to the impedance position corresponding to the output impedance of the amplifier. The meter is calibrated to measure the power delivered to the matched load by the amplifier.

DISTORTION METERS AND AUDIO ANALYZERS

Distortion meters are available that read the percentage of distortion at the output of an audio amplifier directly. When a pure tone is applied to the input of an amplifier, the distortion meter separates the harmonics from the fundamental in the output and measures the strength of these harmonics. The meter reading indicates the percentage of harmonic distortion as compared to the fundamental signal level output.

Analyzers which measure IM distortion are also available. These analyzers are of two types. The first type measures the strength of the difference frequency formed when two signals beat together in the amplifier; the second type measures the percentage modulation of a low frequency signal on a high frequency signal.

The difference frequency IM tester which is shown in block form in Fig. 5 is rarely used for service work. This type of tester requires much more complicated equipment and more set-up time, and is therefore used primarily in laboratory development work. Referring to the block diagram in Fig. 5, you will see that there are two oscillators at different frequencies. The signals from these two oscillators are mixed together and fed to the amplifier under test. The amplifier is terminated

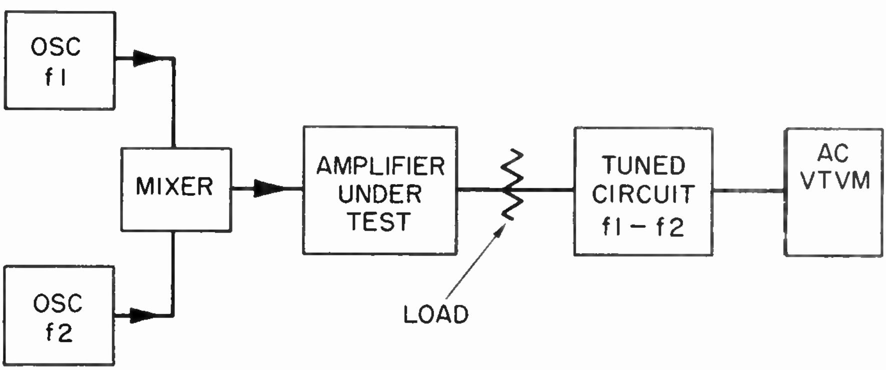


FIG. 5. Difference frequency IM test.

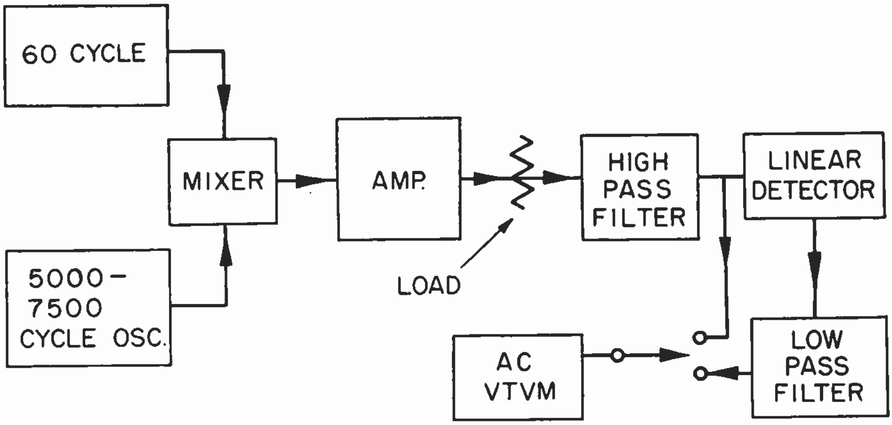


FIG. 6. Direct IM tester.

in its proper load and an amplifier which is tuned to the difference frequency between $f2$ and $f1$ is placed across the load. The output of this amplifier is measured by means of an ac vtvm. In this case both oscillators operate at relatively high frequencies. This type of circuit allows a choice of any desired beat frequency, and any pair of frequencies may be fed into the amplifier. Test records for aural IM distortion tests operate on this principle.

The most common type of intermodulation tester for service work is the direct type, shown in block form in Fig. 6. In this type of tester, an oscillator with an output of 5000 to 7500 cycles is mixed with a 60-cycle signal normally taken from the power supply. These mixed signals are fed into the amplifier; the amplifier is terminated in its proper load. From the output of the amplifier, the combined signals pass through a high pass filter which removes the 60-cycle signal. The high frequency signal, with any sidebands which might be formed by beating in the amplifier, pass into a linear detector. The output of the detector is passed through a low pass filter which completely removes the high frequency signal, allowing only the modulation to come through. The signal at the input of the detector is measured and the signal at the output of the low pass filter is measured. The comparison of these two signals gives the percentage modulation produced by beating within the amplifier.

There is little standardization as yet of test methods for IM distortion or in interpreting results. It is generally agreed, however, that no hi-fi amplifier should have more than 4% IM distortion. An extremely high fidelity amplifier should not exceed 2%.

The two test methods outlined above will not give the same results. They are actually measuring two different types of signal distortion as noticed by the ear. The first test method measures the strength of the new frequencies added. This is the more serious form. The second method measures the amplitude-modulation of high frequency signals by a strong bass accompaniment. Thus the voices of a choir might be amplitude-modulated by the deep tones of an organ to give a very unpleasant sound similar to turntable wow.

TEST RECORDINGS

Test recordings are very helpful and almost essential if you do much servicing of hi-fi systems. Almost every performance characteristic can be checked using test records. Some of the tests that can be made are: frequency response, IM distortion, noise level, audio sweep response, wow and rumble, and stylus wear. The test record serves as the signal source as shown in Fig. 7. Some typical test records and how they can be used are as follows:

Dubbings D-100. The D-100 has two identical sides that can be used to check many of the characteristics of a hi-fi system. The test information has been recorded in a series of bands. Bands 1 through 13 are used to check the frequency response of hi-fi equipment by generating tone signals in individual steps between 30 and 12,000 cycles. The approximate response of the system can be judged by ear, simply by listening to the output of the loudspeaker. Exact measurements of frequency responses can be made by using some type of an output indicator such as a vtvm, audio wattmeter or calibrated oscilloscope.

Band 14 of the D-100 test record is a 45-second unmodulated or quiet band. In this band no audio signal is picked up although the hi-fi system is operating from record to loudspeaker. Using this band, hum pickup and motor rumble as well as other background noises can be easily detected. This helps in adjusting the motor mounting and drive mechanism so as to have minimum turntable noise.

Band 15 provides a constant volume tone of 3000. The ear is very sensitive at this frequency and any wow or flutter will be apparent as a change in volume or a frequency variation. Defects in reproduction indicate a turntable with an uneven motion or an inconstant speed.

The same record in bands 16 through 20 supplies 400-cycle tone, each band having a 3-db volume increase over the previous one. In this way the tracking of the pickup cartridge can be checked by listening for any fuzziness and erratic needle motion in the record grooves.

Dubbings D-101. A second test record is available to check high fidelity equalization. It employs four

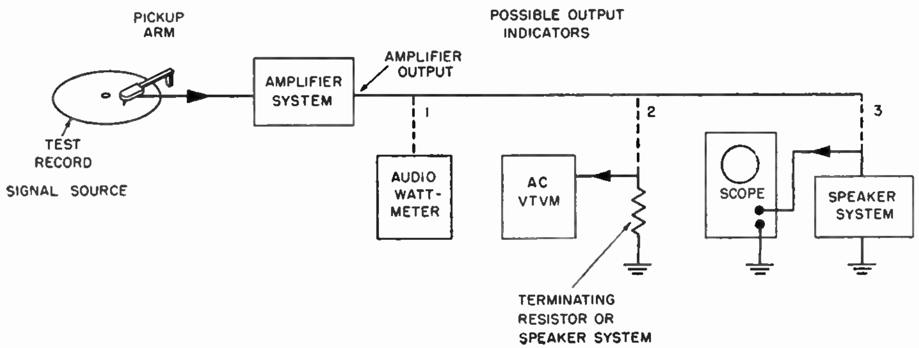


FIG. 7. Output indicators for use with test records.

individual frequency runs between 30 and 12,000 cycles. These thirteen-step runs have frequency-amplitude characteristics corresponding to four standard recording curves. This record, with an output indicator, is used to adjust and check the system for correct equalization as outlined in Fig. 8.

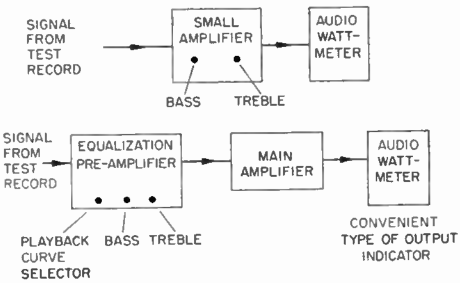


FIG. 8. Interconnection for equalization adjustments.

When a small hi-fi system which does not employ an equalization switch is adjusted, it is necessary to set the amplifier tone controls for proper equalization. Of course, for each standard recording curve, a different group of tone control settings can be jotted down to pre-set the controls for matching the various recording curves, or a compromise setting can be found to use with all types.

When adjusting the tone controls of an amplifier using an equalizer switch for the various recording curves, the tone controls are adjusted for a flat response. When the equalizer switch is set on the proper recording curve and the tone controls have been adjusted correctly, the amplifier output will be flat over the entire desired audio range.

Later the tone controls must be reset to accommodate the acoustical characteristics of the room. Flat settings should be jotted down or marked so you can return to them when you so desire.

The same company manufactures an inexpensive test level indicator, D-500, that can be used to make output measurements. This output indicator, which is shown schematically in Fig. 9, is connected across the output of the amplifier with the loudspeaker system connected. If just a single loudspeaker is used, it is possible to connect the output indicator right across the voice coil. It consists of a group of No. 48 pilot lamps and series resistors.

The output of the amplifier is adjusted until the center lamp barely glows. When there is an increase in output level of 3 db, the last lamp will glow. With a decrease of 3 db the first lamp will barely glow while the center lamp will go out. The indicator can be connected across any speaker having a voice coil impedance from 4 to 16 ohms. This indicator will not respond to output variations of less than 3 db.

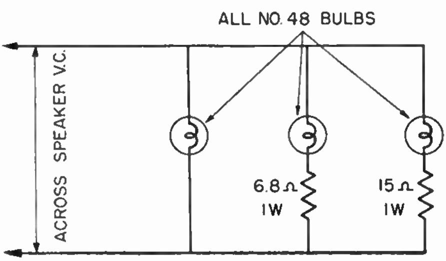


FIG. 9. Dubbings Output Indicator D-500.

Cook Laboratories, Series 10LP. The Cook series 10 test records provides output frequencies in the range from 30 cycles to 20,000 cycles. Records have a tapered low frequency response beginning at 1000 cycles, as shown in Fig. 10. The test record has about a a 6-db slope below 500 cycles. This is comparable to many of the recording curves which also have a so-called "turnover point" at 500 cycles. When the test record is played through an equalizer designed for this recording curve, the output below 500 cycles will indicate if the desired curve is reproduced.

Near the center of this side is a band containing 1000-10,000-1000 cps. It permits a rapid method of checking translation loss (loss of highs) and identification of a worn stylus. You can compare the output obtained on the 10,000-cycle band at the outer edge of side A with the 10,000-cycle output near the center. More than a 60% drop in level at the center indicates a worn stylus.

The second side of the same record can be used to check IM distortion. It provides simultaneous 100- and 7000-cycle tones to be picked up by the stylus and passed into the amplifier. These tones appear in two intermodulation bands—one with a distortion level of 4% and a second with not over 2%. After the signal is fed through the hi-fi system, the output is fed to an IM distortion analyzer and the percentage of IM distortion can be measured.

Side B also has a test frequency run as does side A. However, output levels follow the LP pre-emphasis curve instead of the flat output of side A. A flat output should be obtained when frequencies are passed through an LP-compensated equalizer.

A test for arm resonance and tracking ability is also included on side B. It is in the form of a high level frequency sweep from 1000 to 35 cycles. Defects in tracking cause fuzziness and wow. Resonant conditions cause erratic output levels.

Cook Intermodulation Distortion Record, Series 15. Cook Laboratories also have available an IM distortion record that can be used to obtain an aural check of system performance. This record uses the "A-N" method of radio range finders to obtain an audible output which indicates the distortion percentage.

Two high frequency tones are generated which gradually decline in frequency. However, a fixed separation of 1000 cycles is always maintained between the two fundamental tone frequencies. When the system reproduction is perfect, only the original frequencies will be reproduced at the loudspeaker output. With intermodulation present, however, a 1000-cycle tone will also appear in the loudspeaker output.

On the record there is also transcribed a 1000-cycle tone. This signal is in the form of a dot-dash signal, and has the same amplitude with reference to the high frequency tones, as a 2% IM distortion product would have.

When the intermodulation introduced by the hi-fi system is less than

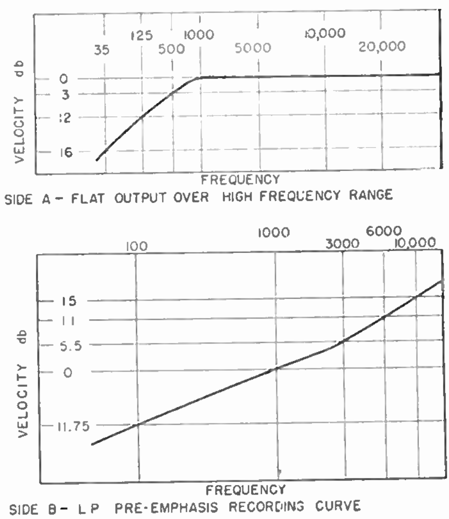


FIG. 10. Cook Series 10 test record recording curves.

this transcribed 2% distortion signal, the output will be a repeated dot-dash or "A." If the IM distortion in the system is greater than 2% it will dominate the transcribed 2% component and a dash-dot or "N" will be reproduced in the output. Thus, as the test recording progresses, an IM distortion greater than 2% in the amplifier system will cause a dash-dot or "N" tone signal to be reproduced by the loudspeaker. If the IM distortion is exactly 2%, the tone will be continuous.

Clarkston and Walsco Sweep Records. Audio sweep frequency records are also available and permit rapid frequency runs and simple adjustment of tone control circuits. These records sweep the range between 50 cycles and 10,000 cycles. However, an oscilloscope must be used to reproduce the response pattern on a screen. The response curves are calibrated with marker pips to permit frequency identification.

Various other tests can be made with additional test records of specialized types. For example, Audak makes available a special stylus disk which can be used to check needle conditions. It is recorded with special grooves so that needle wear can be determined by a close observation of the grooves after the needle has passed. Thus, by observing the nature of the groove wear and discoloration, the condition of the stylus can be learned. One test disk of this type will permit many checks and is a good investment because you can demonstrate the cutting effect of a poor needle on the record grooves.

The Cook Series 20 record is useful for checking noise in the hi-fi system. It supplies noise components in various bands and with specified amounts of high and low frequency noise. Just by listening to the noise output of the loudspeaker many types of noise conditions can be tracked down.

Walsco also has available test records that can be used to check wow and turntable rumble. As mentioned earlier, tones and quiet bands on the record are used to emphasize wow and rumble. The IM test records also give an indication of excess wow or rumble because the IM percentage increases sharply when these disturbances are present.

You should become familiar with these various types of test records. They can be used to demonstrate system performance to the customer. They provide convincing arguments and positive checks where one person's concept of good audio quality is not the same as another's. Various special test records are also available featuring musical instruments, demonstrating how faithfully their tones can be reproduced. Such recordings can be used effectively in demonstrating hi-fi characteristics to your customer.

Defects and Adjustment of Pickups and Turntables

In a hi-fi system, the over-all performance can be no better than the poorest unit of that system. Once a defect is introduced, it will continue on through the system and result in distorted or noisy reproduction. Much emphasis is placed on the amplifier system. However, a good amplifier system is of no use if the pickup and reproducer of the hi-fi system are poor. It follows, then, that the quality of the record pickup and turntable are important in obtaining good hi-fi music. You must be able to locate defects and make adjustments to turntable and pickup in order to obtain peak performance and minimum record wear. You should also instruct your customer concerning proper record, turntable, and pickup care.

Record wear and care are important considerations in the maintenance of a hi-fi system. If there is rapid record deterioration, all the advantages of the system are lost after a few playings.

Special liquids are available for spraying or wiping records to reduce static charges and dirt collection. There are also anti-static cloths available that keep records clean and minimize their attraction for dust particles. A wise recommendation to make is to clean the needle of dust and lint with a stiff but fine brush after each playing.

Record storage is an important consideration with the modern plastic types which are sensitive to humidity and temperature extremes. Records should be stored in their stiff containers in a dust-free location. Soft plastic record covers are also available. A closed cabinet or a filing cabinet type of storage is best to use. They should be stored where humidity and temperature change the least.

Records can be stored vertically provided they are enclosed in their stiff cases and are able to stand up straight without leaning. If a sufficient number of records are not available to fill a cabinet for vertical storing it is best to stack them flat to prevent warping. If you prefer vertical storage, add some additional bulk such as books to prevent any of the records from leaning.

RECORD AND STYLUS WEAR

Record wear is important if the hi-fi quality is to be preserved. The factors that influence record wear are the type of stylus, needle tracking or compliance, and needle pressure. Choice of stylus is quite important when you desire to preserve your records. When records are played, the tip of the stylus tends to conform to the shape of the groove, particularly when the needle is relatively soft. After the needle becomes worn, it begins to cut and wear the record. Record wear adds distortion and noise to the audio information and results in a decline of high frequency response. In terms of hi-fi reproduction, there is a choice between four types of styluses—diamond, sapphire, osmium, or steel. The diamond stylus is preferable and, of course, is most expensive. However, it is good for many thousand playings before there is serious wear. For a person with a large number of records the diamond is the most economical; the savings on record replacement more than cover the higher cost of the diamond stylus.

The sapphire needle is less expensive and is an improvement over the latter two types but is subject to wear. Despite the fact that it is referred to as a permanent needle, it is best not to use one for more than 500 playings. The steel and osmium needles are not recommended for hi-fi work and should be replaced after only a few playings.

As mentioned previously, stylus wear can be checked using the Audak test record. With experience, a microscope can also be used to detect stylus wear. The influence of a defective stylus is shown in Fig. 11. To reproduce the audio information, the stylus should ride the groove as indicated in Fig. 11. When the stylus is worn, it

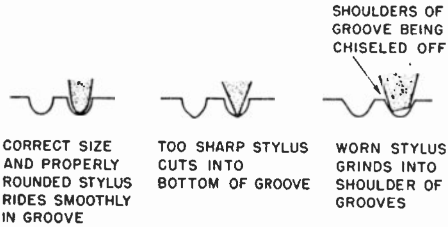


FIG. 11. Record grooves and stylus wear.

is in contact with more of the groove and, as it moves along, gradually wears the groove down. The wear and sluggishness prevents proper reproduction of the audio information and the ability to follow the high frequency variations.

The next step in reducing record wear is to make certain that the needle pressure is correct. Be certain that the needle pressure used is in accordance with the manufacturer's recommendations. It is obvious that the less pressure required, the less record wear.

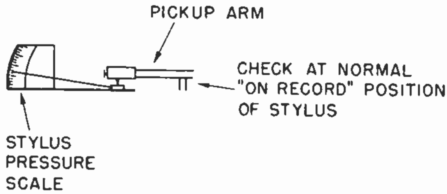


FIG. 12. Pickup arm pressure gauge.

However, the various styluses are designed for different pressures. If the pressure is less than normal, the needle does not follow the groove perfectly, resulting in intermodulation distortion. Also, when a light needle pressure is used, the pickup arm and stylus are inclined to skid which can result in record or stylus damage. Consequently, with light needle pressure, every precaution must be taken to shock-mount the turnable so that it is not subject to external motions and vibrations.

Most hi-fi pickup arms provide a pressure adjustment. Inexpensive pressure gauges designed for testing this are available. If you do considerable hi-fi service, you should have such a gauge. In using the pressure gauge, as shown in Fig. 12, the measurement should be made at the same level the pickup arm assumes when a record is in place on the turntable. Likewise, the pressure should be observed as the needle moves up and down slightly (approximately 1/8 inch). This corresponds to the up and down motion of the stylus as it rides the groove. The pressure should not vary more than 2 grams over the normal vertical up and down range of motion.

On occasion, the turntable top may

become magnetized and thus exert a greater "pull down" on the stylus. The effective pressure on the recording becomes greater and results in more rapid record wear. Special pads are now available for placing on top of the turntable when it is subject to this type of disturbance. The pad acts as an isolation surface and reduces the magnetic pull on the stylus and pickup arm.

TONE ARM TRACKING

Of perhaps even more importance than the stylus maintaining an exact pressure in the grooves, is the manner in which it follows them. The angle which the cartridge of the tone arm makes with the groove of the record, greatly affects the IM distortion of the signal and the wear on both the record and the needle. Fig 13A shows the relationship between the tone arm and the groove of a record. On this record is shown the radius between the center of the record and the point of contact of the needle with the groove. The line drawn through this point perpendicular to the radius is tangent to the groove. The axis of the pickup cartridge should, in a perfect pickup, always be tangent to the groove.

In a practical system, since the tone arm has a fixed pivot point, it is impossible to maintain the axis of the cartridge along this tangent. The reason for this is shown in Fig. 13B. Here the tone arm is shown positioned so that the pickup is tangent to the center groove. At grooves both inside and outside of this point, the cartridge axis no longer lies along the tangent. The angle between the tangent to the groove and the axis of the pickup cartridge is called the tracking angle, and since this angle is rarely zero, it is referred to as the tracking error. Unfortunately, a mounting which gives the minimum tracking error does not give minimum distortion, un-

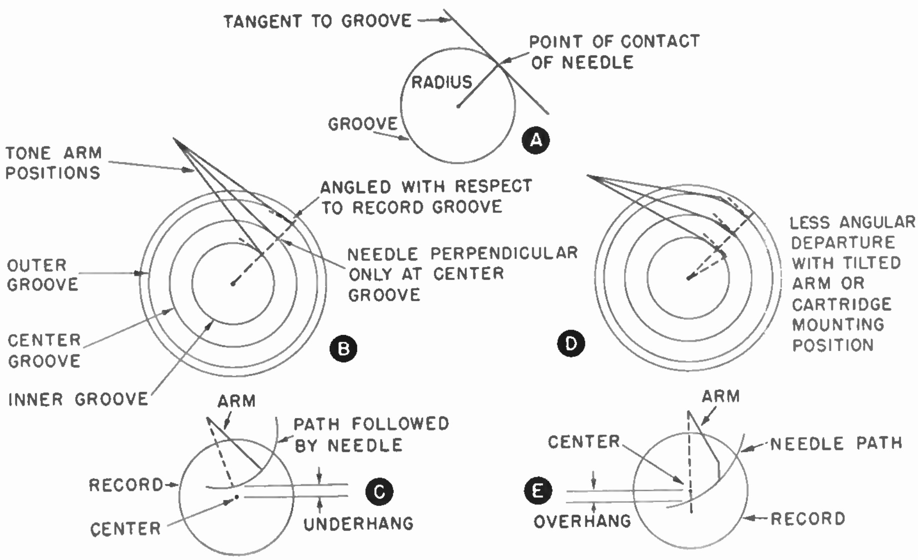


FIG. 13. Needle tracking.

less the tracking error is zero.

When using a straight tone arm it is not unusual for a tracking error to vary over the range from +35 degrees to -10 degrees. In a hi-fi system, the tracking error should never be more than 2 degrees at the outer grooves and less than 1 degree at the inner grooves.

The tracking error is reduced by the construction of the tone arm and location of its pivot point. This is the job of the manufacturer; once it is done, the serviceman must go along with the design.

When a straight tone arm is pivoted past the center of the record, the needle will fall short of, or "underhang" the center as shown in Fig. 13C. For any arm length there is a specific amount of underhang. The longer the arm, the less the underhang. Also, the best underhang is greater for large records than small ones.

In order to reduce the distortion caused by tracking error, a curved or bent arm is used. This places the pickup at an angle to the line between the needle and the pivot point. The pivot point is located where the least *change* in tracking error occurs as the tone arm moves across the record, as shown in Fig. 13D. The head is then offset at the angle that gives minimum distortion. The needle of a properly mounted offset arm will overhang the center, as in Fig. 13E. Again for any given distance from the needle to the pivot point, there is a definite overhang and also a definite offset angle for minimum distortion. The longer the tone arm, the less the overhang distance and offset angle. The underhang and overhang of any tone arm are very critical, and are measured to one one-hundredth of an inch.

The position of the needle tip in the cartridge is different for different types of cartridges. For example, in a crystal pickup the needle tip is well out to the far end of the pickup cartridge, whereas in most magnetic pickups the tip is back near the middle of the cartridge. Since this is the case, great care must be exercised when changing cartridge types in a tone arm to be sure that the tip of the new cartridge falls at the same distance from the pivot point as the tip of the old cartridge. If it does not, the tone arm must be remounted. Correct location of the pivot point of the tone arm is determined by measuring the overhang or underhang. The required overhang for any given tone arm is given by the manufacturer in the mounting data for that arm.

When excessive record wear is thought to be due to tracking error, it is well to check the overhang against that recommended by the manufacturer. When cartridge types are changed in a tone arm, care must be taken that the overhang of the needle in the new cartridge is that recommended by the manufacturer for the tone arm. If the overhang is incorrect, the tracking error may become very great.

Some pickup arms are provided with adjustable cartridge mounts; the position of the cartridge in the mount can be adjusted to obtain correct tracking.

When you are called upon to mount or replace a tone arm, you should make the measurement of overhang or underhang very carefully. If there is any doubt as to the accuracy of the measurement, it is best to have the underhang or overhang less than is normally called for. In this way, less wearing of the record will occur due to tracking error. That is, it is best to have the needle closer to the center than called for, rather than farther away.

The replacement of higher quality cartridges or pickup arms on present equipment can be a disappointment unless you carefully consider the factors of record wear, tracking, and needle pressure. An improper installation can produce poorer results than a direct replacement with the lower priced type used originally.

INTRODUCTION OF SPURIOUS SIGNALS

The input circuits are subject to the pickup of spurious noise components. Generally, the better the pickup device, the more subject it is to these disturbances, because of its lower output and broader frequency response. The most common disturbances are turntable rumble, hum, or wow. Rumble is a result of mechanical noises and vibrations in the turntable which are picked up by the sensitive cartridge. Wow is a result of an uneven motion of the turntable due to faulty adjustment or uneven wear. It can also be caused by binding between the stylus and the record groove. This binding in turn can be caused by improper tracking or sluggish vertical or lateral motion of the stylus in the cartridge.

Hum. Hum can be a troublesome defect in a hi-fi system, and can leak into the signal from a number of sources. It can result from improper power supply filtering or improper positioning of component parts with respect to sensitive pickup devices. The proper isolation between power cables and audio lines is important.

The crystal cartridge has a high output and is not as sensitive to hum pickup as the lower output variable reluctance and magnetic pickups. The magnetic cartridge is subject to inductive hum pickup from the magnetic fields of the turnable motor and record changer. If you find a changer particularly subject to hum pickup of this kind, it is often helpful to replace the pickup device with the ceramic type. The ceramic pickup has a high output and is less subject to hum. In addition, its frequency response and performance are nearly as good as the lower priced magnetic types when used with popular records.

If you have the task of mounting a pickup cartridge and arm on a turntable, be sure to choose the mounting position carefully to minimize hum pickup from the motor. The pickup arm should be mounted so that on its travel across the record, the cartridge is at the greatest possible distance from the motor. The four-pole motor is, of course, preferred over the two-pole type because of its lower hum radiation level. It is used on most hi-fi systems. A more expensive and even better motor is the hysteresis type.

A low impedance magnetic pickup and its transformer can be made less subject to hum pickup than the variable reluctance type. When using this type, however, its matching transformer should be mounted and oriented correctly with respect to the turntable motor and power supplies in order to minimize hum pickup.

A foam rubber turntable mat can also cure some disturbances. It acts as a cushion for the record and stylus.

At times it is helpful to ground the case of the motor to reduce hum. The lead dress between pickup arm and input of the preamplifier is very important in holding hum level low. The lead length should be as short as possible, and isolated from any power cords. This cable should have a low capacity between leads, and from leads to shield. High capacity causes

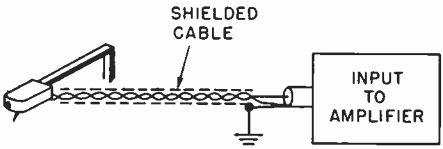


FIG. 14. Reduction of cable hum pickup.

loss of highs. If a long cable is necessary between units it should connect a low impedance source to a low impedance load. A two-conductor shielded cable, as shown in Fig. 14, is helpful in reducing hum pickup by the line. The shield should be grounded only at the input to the amplifier.

Turntable Rumble. Rumble is caused by mechanical vibration in the motor and drive assembly. The higher priced heavy turntable has much less rumble than a changer because of better armature balance and more critical bearing tolerances. When rumble is present, the vibration is picked up by the cartridge and results in a continual fluttering of the loudspeaker cone at a low frequency. This action interferes with the reproduction of low frequency audio components even though at times it occurs at lower than audible frequencies.

Outside of the inspection of suspension mounts, there is little you can do to reduce this disturbance. A small level can be used to align the turntable. This step will not only reduce vibration, but also will give better needle tracking and less record wear. A changer is more subject to rumble because of its more complicated mechanism. A foam rubber turntable cushion will help here.

Turntable lubrication should be checked and the manufacturer's procedure followed to the letter. Over-lubrication is just as dangerous as under-lubrication, since it permits grease or oil to reach the drive and idler wheels, and slippage results.

Most often, rumble occurs in the 20- to 30-cycle range. It is possible to design special high pass filters, as shown in Fig. 15, which have sharp cut-off characteristics in the 25-cycle range. They can be installed in the amplifier system and act as a rumble frequency filter, preventing the rumble vibration from reaching the loudspeaker.

Wow. Wow is a result of changes in turntable speed as the stylus rides the record groove. It is usually a sign of mechanical wear in the motor and

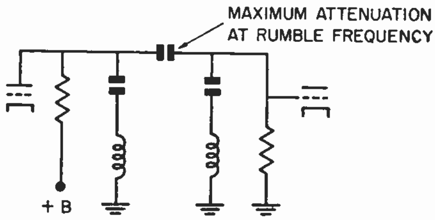


FIG. 15. High pass rumble filter.

drive assembly. It is caused by uneven wear or a flat place in the drive wheel or idler. Many changers and turntables employ rubber idlers and after long use they become worn and develop uneven surfaces. This gives the same effect as driving the turntable with an eccentric wheel and the turntable rotates with a changing speed. Thus if a continuous tone is played, the changing speed of the turntable motion will modulate the audio note. A wavering tone instead of a pure tone will come from the loudspeaker. Dirt, oil, or grease on the idler or turntable rim can also cause slippage and uneven turntable speed.

A test record giving a single tone frequency of about 3000 cycles is ideal for checking wow. If any wow is present it will add an easily heard waver to the 3000-cycle loudspeaker output.

A stroboscope can also be used to make this check. When it is placed on the turntable, the presence of wow will cause the pattern to move instead of standing still, as it would at a constant speed.

It is apparent that wow is generally a mechanical disturbance. Thus if wow develops in a system, you should inspect the turntable or changer mechanically and replace worn drive and idler assemblies. If wow has always existed in a system, it may be the result of an inferior design or a defect in construction, mounting, or adjustment. Follow the manufacturer's recommended adjustment procedures for the particular turntable or changer. If wow or rumble persists in a higher priced unit, it is advisable to seek the manufacturer's help concerning tests or possible replacement.

Wow can also be caused by improper leveling of the turntable. A small level is a very useful tool if you plan to do extensive hi-fi servicing. If wow is a result of a magnetic pull on the needle, it can be helped by the use of a good turntable cushion or a nonmagnetic turntable.

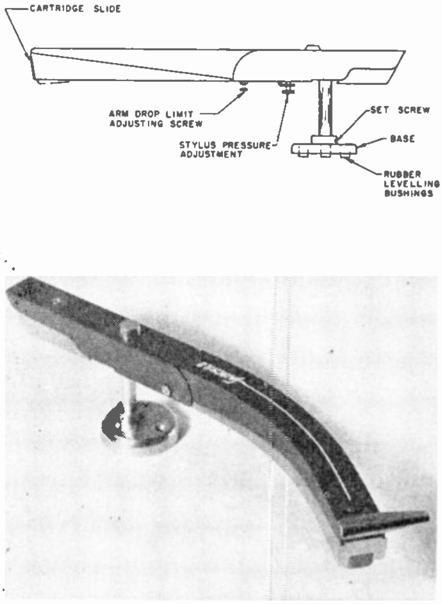
In replacing cartridges or needles, follow the manufacturer's recommended procedure as carefully as possible. For many cartridges, needle replacement is made by the factory. Do not attempt any needle changes unless you have the instructions for the particular cartridge with which you are concerned. A needle replacement can be made more easily with the cartridge removed from the arm.

PICKUP INSTALLATION

Most hi-fi replacement units, such as the tone arm shown in Fig. 16, have standardized dimensions. Standard mounting enables installation in practically all commercial pickup arms and changers.

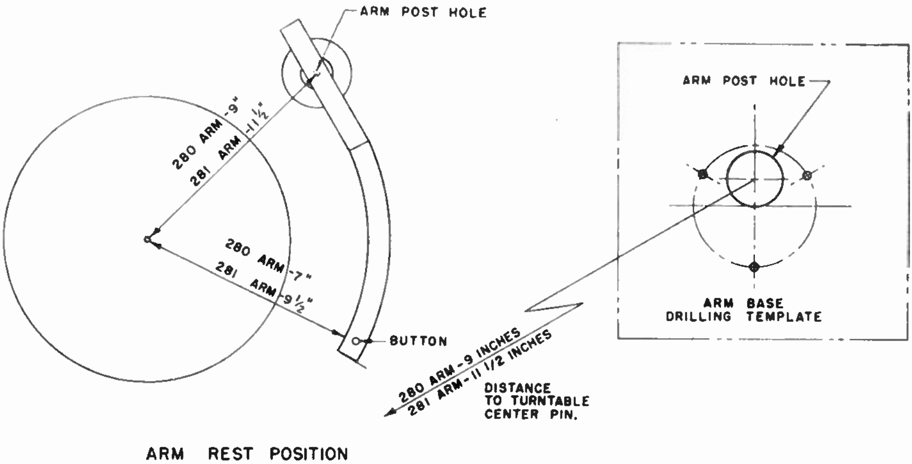
Most hi-fi cartridges have good compliance and track with little pressure. The manufacturer generally indicates the proper pressure and his recommendation should be followed to overcome friction and reduce record wear.

Follow any impedance matching



Courtesy Fairchild Recording Equipment Co.

FIG. 16. Typical tone arm.



Courtesy Fairchild Recording Equipment Co.

FIG. 17. Tone arm mounting template.

recommendations. If the cartridge has an output impedance of 200 ohms, it should be connected through a good 200 ohm-to-grid input transformer. In this way it gives maximum output with the least hum pickup.

With cartridges mounted in metal arms, it is sometimes found desirable to ground the arm to the turntable frame with a flexible lead.

Some other important considerations are:

1. Do not make a soldered connection to either output prong of the cartridge. Always solder to the clips which in turn slip on the prongs.

2. It is important that flexible leads attached to the arm do not catch or bind as the arm is rotated through its lateral swing across the disk.

3. Finally, it pays to keep the records free from finger marks. Dust and grit will adhere to the finger marks, causing a pile-up of dirt around the stylus. This oily mass will attack the rubber damping pads or the gland which is intended to keep magnetic and other foreign particles from getting inside the cartridge cover.

Notice the stylus pressure and drop limit adjusting screws. The stylus pressure may be adjusted by means of the knurled screw. Turning the screw "in" decreases the stylus pressure. When making the pressure measurement, the stylus tip should be the same height as when in playing position on a record.

The drop limit adjusting screw permits exact positioning of the stylus so it will just clear the turntable when there is no record on it. Thus stylus damage is avoided by preventing accidental contact with a running turntable.

Typical installation data for a tone arm often includes a mounting template. Its layout is shown in reduced size in Fig. 17. The template can be placed on the motor board to locate all holes in relation to the turntable center pin. This information is very important and permits you to mount the tone arm at a position that will give the most favorable tracking.

Tape Recorder Maintenance

Tape recorders are subject to many of the adjustment and maintenance problems of disc play-back units. Wow and flutter may occur in tape recording units due to mechanical wear of the motor drive and elements. A low cost tape unit will have a wow and flutter of about one-half of one percent when new, while professional equipment should have wow not exceeding one-tenth of one percent. The best check for excessive wow and flutter is to play back a tape which has a constant level high frequency tone.

This wow and flutter may be caused by drive capstans which are out of round, or idlers with flat sides. The correction for this condition is the same as with a record player; the capstan drive rubber should be cleaned or replaced. A second cause of flutter in a tape recorder is due to wear in the friction clutch used to drive the take-up reel. As these clutches wear they begin to slip and a variable tension on the tape results. When a variable tension tape is pulled by the capstan, wow and flutter result. The correction here is to clean and adjust or replace the clutch.

Two troubles which generally go together are noise and even-order harmonic generation. Regardless of the operation of the tape recorder, any noise or harmonics generated in the amplifier which drives the recording head will be on the tape. The recording and play-back heads can also introduce noise and even-harmonic distortion.

These conditions may be caused by improper bias level adjustment. The bias should be adjusted to a value slightly greater than that which gives maximum output on play-back for a constant input on recording.

The second common cause of noise and harmonic distortion is due to residual magnetism in the recorder head. This may be checked easily with a small pocket compass. If a magnetized head is found, it may be demagnetized by means of a commercial head demagnetizing unit or the head may be replaced.

The causes of head magnetization are passage of a direct current or large non-symmetrical pulses through the windings. The direct current may result from a leaky coupling capacitor or a leaky output transformer. A common cause of non-symmetrical pulses is a non-sinusoidal output from the bias oscillator. This condition may be checked with an oscilloscope. If it is found that the bias waveform is distorted, the operation of the bias oscillator should be corrected so that the output is a good sine wave. Large non-symmetrical pulses through the recording head can also result from switching input circuits when the amplifier output is connected to the head.

Head magnetization can raise the noise output by 5 to 10 db and at the same time introduce quite severe even-order harmonics.

Both the recording and play-back heads are subject to wear and possible misalignment. The gap of the head should always be at right angles to the tape edge. Misalignment of the gap by less than a degree can result in an output as low as one-quarter of what would normally be expected.

The heads are mounted with adjustment screws so that their position may be changed slightly with respect to the tape. The best way to make this adjustment is to use a standard head alignment tape and adjust the position of the head for maximum output. The head alignment tape is a high frequency signal recorded at a normal level and run at a constant speed.

As the tape runs over the recording and play-back heads, it wears down the surfaces slightly. This wear increases the size of the pole face in contact with the tape and may increase the gap width. Both of these effects lower the recording level and cause a great reduction in highs. The best check for head performance is by means of a frequency run tape in which constant levels at different frequencies are recorded on the tape and the output is checked by means of an oscilloscope or an ac vacuum tube voltmeter.

The head should be cleaned periodically with carbon tetrachloride to remove any dirt or gum which may have stuck to the pole faces. In doing this use a cotton swag or piece of soft cloth, but never use a metallic object to scrape them.

The moving parts of the tape recorder should be lubricated in accordance with the manufacturer's instructions. In all cases, avoid the use of excessive lubricants since they may cause destruction of idler wheel tires and capstan drive rims. When lubricant does get onto these rubber rims it should be removed with alcohol.

After continued use some of the older machines may tend to stall or to break the tape. This condition is caused by a "Johansson effect." It gets its name from the "Johansson test blocks" which are used for calibrating gauges and micrometers. These blocks are so smoothly polished that when they are in contact they will stick together. The continued motion of the tape over the recording head will polish the head so smooth that the tape will stick to it. This condition cannot be corrected by cleaning; that only makes it worse. The only repair that can be made is to rub the face of the head lightly with crocus cloth to roughen it a little, and then clean it with carbon tet. It is best to do this before the condition has reached the point of breaking tapes. This effect is first noticeable as a squeal as the tape passes over the recording head. When this squeal is first noticed, the head should be roughened or replaced.

There are test tapes available for use in checking tape recorders.

The Dubbings D110 tapes are available at speeds of both 7½ and 15 inches per second. These tapes may be used to check for wow and flutter, head alignment, frequency response, signal level, signal-to-noise ratio, and tape speed. These types are used on a recorder in exactly the same way that a test record is used to check a record player.

The Audio Devices No. 200 test tape is used to check head alignment with a tape speed of 15 inches per second. This tape contains pre-recorded signals at 2000, 10,000 and 15,000 cycles per second. By means of this tape, very precise alignment of the head may be made. It is available only at the 15-inch speed and consequently it is not usable on the majority of low priced tape recorders.

Before any test tape is used on a tape recorder, the head should be checked for residual magnetism and any uneven surfaces. Residual magnetism of a play-back head will distort the signal recorded on the tape.

The longer material is left on a tape, the harder it will be to erase. When a tape is used to record temporary information, it should be erased as soon as the need for the material on the tape is over. Recorded tapes should be stored away from any magnetic fields due to power lines or electrical equipment, and preferably in some place which is not subject to abnormal temperatures. Storage at high temperatures also tends to increase the permanence of the material and make the tapes more difficult to erase.

When a service call complaint is for improper erasure, you should find out how long ago the tapes were recorded. When the normal erase head on the recorder will no longer clear the tape, it is necessary to use a bulk eraser.

New tape or blank tape left in storage for some time should always be erased before recording. In this way any magnetism resulting from induction fields is removed and noise and distortion are reduced.

Defects in the Amplifier System

The major purpose of the amplifier system of a hi-fi installation is to build up the weak audio signal present at the output of a pickup cartridge to a sufficient power to drive the loudspeaker system. Of course the more elaborate the loudspeaker system, and the more space to be filled with sound, the higher must be the power of the amplifier. The amplifier system must amplify uniformly over the entire audio range. The flatter the frequency response of the system, and the more extended the low and high frequency ranges are, the more realistic becomes the audio reproduction.

Special compensating circuits are required to correct for the nonlinear output of some pickup cartridges as well as to compensate for whatever commercial recording curve has been used.

The three most common arrangements of audio equipment are shown in Fig 18. The usual changer or low-priced turntable and pickup combination uses a crystal cartridge. The crystal cartridge permits a good output and therefore can be used to drive the main amplifier directly. Usually a small low-power amplifier is used to drive a small loudspeaker system. This combination represents the economy-type high-fidelity system. When good quality components are used, it is able to reproduce a hi-fi record fairly well.

The higher-priced magnetic pickups require additional amplification and frequency equalization. When properly used, their frequency response and performance characteristics are superior to the crystal cartridge, but their output is substantially less.

To utilize the good frequency response characteristics of a cartridge, its output must be terminated correctly. Furthermore, when improved fidelity is desired, it is also helpful to have a stronger output available from the main amplifier. Once the hi-fi enthusiast has progressed to a high quality pickup and turntable, he generally desires a higher output amplifier and a more elaborate loudspeaker system. As a result, the amplifier system must be capable of delivering a stronger audio signal to the loudspeakers.

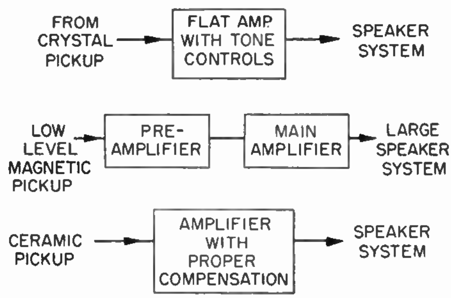


FIG. 18. Block plan of Hi-Fi methods.

A preamplifier, as shown in Fig. 18, may be used along with the main amplifier. These two units can be separate or mounted as a single unit. The preamplifier builds up the weak signal output of the cartridge to an adequate level for driving the main amplifier. In addition, it presents the proper termination to whatever type pickup cartridge is employed. Still another function of the pre-amplifier, as you have learned, is to supply equalization for the recording curves of the various standard types of hi-fi records. The main amplifier increases the strength of the moderate output signal of the preamplifier to the necessary power required to drive the loudspeaker arrangement (often as high as 25 to 40 watts).

The input tube should have a low noise level. Here, triode tubes are best. Hum and background noise can often be reduced by interchanging tubes to make certain the very best tube is used at the input stage. Special low-noise tubes are available and can be used to replace some of the standard types used in preamplifiers.

Aging tubes, poor filters, and deteriorating bypass capacitors should be looked for when there is any increase in hum level in the amplifier system. Any type of low resistance shunt across the B+ supply line will result in an increase in hum level because the greater drain placed on the power supply reduces the filter efficiency. In the construction of hi-fi amplifiers, you must be certain to choose well shielded transformers and mount them so that hum is not fed into sensitive circuits. Output circuit components and power supply lines must be kept well spaced from low level audio lines.

It is not advisable to crowd all the components into a single cabinet if hum level is to be at a minimum. There should be a safe spacing between the pickup and input stages, and the higher level output stages, power supply and loudspeaker. Keeping the loudspeaker away from the pickup reduces the effect of speaker vibration on the pickup.

In troubleshooting a hi-fi amplifier, there are four major performance standards. One consideration is the power output of the amplifier. It must be capable of driving the loudspeaker system fully so as to fill the required space with sound. Adequate power levels must be available to convey the instantaneous peaks in musical renditions. The frequency response of the amplifier must extend over the useful range of fundamentals and musical overtones. This range of frequencies must be reproduced equally to obtain the greatest benefit from the hi-fi system. The amplifier must be free of distortion and must not change the shape of the audio signals passing through it. Nor should it contribute spurious signals in the form of harmonics or intermodulation distortion. Finally, the amplifier system must have a low hum and noise level to permit an undisturbed reproduction of quiet musical passages.

FREQUENCY RESPONSE MEASUREMENTS

There are four basic plans for checking the frequency response of an amplifier, as shown in Figs. 19 through 22, depending on the type of test equipment available. In the method shown in Fig. 19, the signal source is an audio generator. The audio signal is applied to the input of the amplifier system under test. There are four possible choices of output indicators: ac vacuum tube voltmeter, audio power meter, bulb indicator, or a calibrated oscilloscope. An initial approximate check can be made using the audio signal generator and listening to the loudspeaker output. If there is a severe loss in low or high frequency response, it will be apparent as the audio signal generator is varied through its frequency range, keeping the output of the audio generator at a reasonably constant level.

The audio wattmeter is ideal for making frequency response observations. The wattmeter has a linear frequency response over the audio range and consequently it can be used to measure output wattages over the entire audio spectrum.

In making power output and frequency checks the audio signal generator is connected to the input of the amplifier. If the output of the audio generator is not constant over the audio range, it is advisable to connect an ac vacuum tube voltmeter to its output so that a constant amplitude input is fed to the amplifier at all frequencies.

With the gain control of the amplifier wide open, it is possible to measure the maximum output of the audio amplifier. Maximum output is indicated when there is no further increase in audio output as the input level is increased. For a precise measurement of power output it is helpful to attach an oscilloscope to the audio amplifier output. With the oscilloscope connected, the audio output of the generator is increased to the point at which the waveform seen on the oscilloscope begins to distort. Then the audio output is decreased to just below the distortion point. This level of output wattage indicates the maximum output of the amplifier.

To check the frequency response of the amplifier, it is only necessary to set the audio generator on various spot frequencies through the audio range and measure the audio output. You must be sure that a constant input voltage is applied to the amplifier by making certain (with the ac vtvm) that the output of the audio generator is set at the same level for each check frequency.

Frequency response can also be checked by using the oscilloscope as an output indicator. Many scopes now include internal calibrating voltages so that the screen can be calibrated to measure the voltage output. In using the scope to make the output measurements, it is necessary to terminate the output of the amplifier in the proper impedance. The termination should be a resistor of the proper ohmage and wattage. If the loudspeaker system is used as the termination, mechanical resonances of the speaker will vary the load impedance with frequency, and the voltage measurements will be inaccurate.

It is also possible to use an ac vtvm

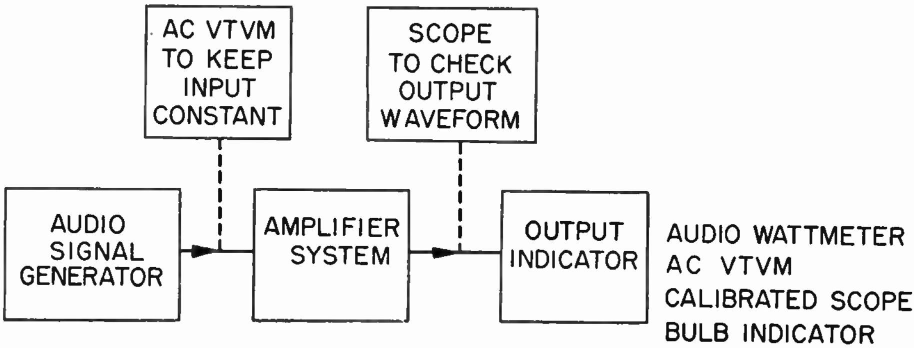


FIG. 19. Amplifier test using signal generator.

as the output indicator. In this arrangement it is again necessary to measure the voltage across a resistor that corresponds to the recommended load for the amplifier. In using the ac vtvm to make frequency response checks, it is possible to install a changeover switch so that the meter can be switched between input and output circuits. Remember that in checking frequency response, it is necessary to hold the output of the generator constant so that a fixed input reference level is applied to the amplifier at the various check frequencies.

The vtvm is a handy instrument because it can also be used to measure the output voltage at various stages throughout the amplifier system. It can be connected to the output of the preamplifier to check the frequency response of the preamplifier alone. It can be used to measure individual voltage amplifier stage gain by recording output and input voltage levels and dividing output by input.

Of course, various other frequency response defects can be found by varying the audio generator through its entire audio frequency range and observing the output indicator for any sharp dips or resonant conditions in the amplifier system. Any sharp change in output readings at specific frequency ranges can indicate a tendency toward instability or oscillation at certain frequencies. If the voltage across the voice coil of a loudspeaker which is driven by a flat amplifier is checked in this way, the resonance points of the speaker and its enclosure can be found.

A very effective method of checking the frequency response of a hi-fi system is to use a test record as shown in Fig. 20. The test record checks frequency response from record to loudspeaker. Generally, the use of instruments confines the frequency response measurements from the input of the amplifier to the output, and does not indicate the performance characteristics of the pickup cartridge and turntable or speaker. Just a limited wear of the stylus (even before the wear is great enough to damage the grooves) can cause a sharp decline in high frequency response. A frequency response check of the amplifier system would have indicated normal performance despite the fact that the stylus was causing a severe loss in high frequency response. Resonances in the pickup can be found by playing a test record through a flat amplifier. Voltage fluctuations across a resistor load on the amplifier show the response of the pickup.

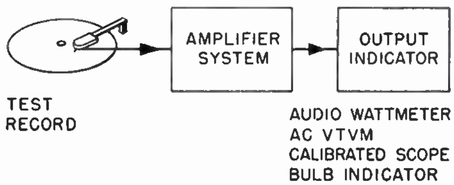


FIG. 20. Amplifier tests using test records.

The output indicators that can be used with the test records are again an ac vtvm, audio wattmeter, bulb indicator, or calibrated oscilloscope. The audio wattmeter is again ideal because of the ease with which it can be connected and its ability to provide a correct termination for the amplifier output. Armed with a good test record or two, along with an audio wattmeter, you can do a thorough job of checking the performance of the hi-fi system in the customer's house.

The test record can be used as a

signal source in checking frequency response by observing the output wattages for the various frequency tones on the record. By turning up the gain of the amplifier you can see if the amplifier is capable of giving its maximum rated output. Other bands on the test records can be used to check additional performance characteristics of the system as explained earlier in this lesson.

A very effective and convenient method of checking the over-all frequency response of a hi-fi system, as shown in Fig. 21, is to use an audio sweep test record and an oscilloscope. As mentioned earlier in this lesson, such a record provides a sweep signal over the audio range. As the stylus rides along the record grooves it picks up an audio sweep signal and applies it to the input of the amplifier. The scope is used to show the sweep signal at the output of the amplifier. Therefore the response pattern of the amplifier can be shown on the screen of the scope tube. The sync circuit and sweep adjustments of the scope are adjusted to lock in a single alignment response curve. If it is not possible to lock-in the pattern firmly with the scope, it may be an indication of turntable wow.

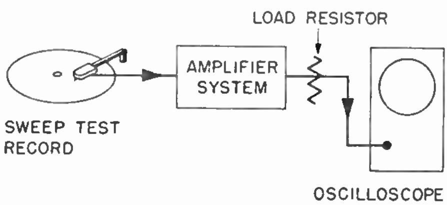


FIG. 21. Audio sweep record testing of amplifiers.

The sweep response records are particularly effective in adjusting the equalizer controls of a hi-fi system. A sweep record that would generate sweep signals corresponding to the standard playback curves is particularly effective in adjusting each playback curve equalizer of a preamplifier. A sweep record also indicates whether or not the cartridge sees the proper termination at the input to the preamplifier.

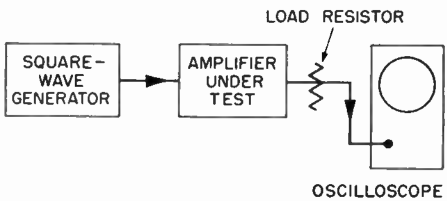


FIG. 22. Square-wave generator test of amplifier.

A final method of checking the response of the amplifier system is shown in Fig. 22. In this arrangement a square-wave generator is used as a source for applying signals to the input of the amplifier. The output indicator is again a good oscilloscope capable of passing a very low frequency square wave without distortion. A direct-coupled vertical amplifier is excellent. The performance of the amplifier is shown by its ability to pass the square-wave signals without distortion. The types of distortion appearing on the square-wave reproduction indicate particular defects in the frequency response of the amplifier system.

You have learned that a square wave consists of a fundamental frequency and an infinite number of harmonics. Thus, in the application of the square wave to the amplifier, the amplifier must not only pass the fundamental frequency but also its harmonics, if the square wave is not to be distorted. When a 1000-cycle square wave is applied to an amplifier, the amplifier must be able to pass up to the tenth harmonic of the 1000-cycle fundamental frequency in order not to distort the square-wave shape. It is apparent that the 1000-cycle square wave can thus be used to judge the frequency response of the amplifier up to 10,000 cycles and higher. You also learned that the higher order harmonics of a square wave determine the shape of the leading edges, while the low and middle range harmonics influence the flat-top portion. If there is poor high frequency response or high frequency phase distortion, the leading edge and the trailing edge of the square wave become rounded or distorted as shown in Fig. 23. In general, if a 1000-cycle square wave passes through the amplifier without distortion, the amplifier can be considered as having a flat response up to 10,000 cycles and higher. Of course, by increasing the frequency of the square wave up to 2000 cycles or higher, the frequency response can be judged up to as high as 20,000 cycles.

The low frequency response is checked using a low frequency square wave at some frequency between 20 and 60 cycles. Again, the lower the frequency of the square wave, the more critical it is of the low frequency response of the amplifier system. When there is a low frequency defect it distorts the shape of the flat-top portion of the square wave. Low frequency attenuation results in a dip in the flat-top portion of the square wave. If low frequency attenuation is accompanied by a phase shift, the square wave is tilted as shown. The degree of the dip or tilt in the low frequency response is an indication of the severity of the low frequency attenuation.

When an amplifier is not adjusted properly it is also possible to accent the low frequencies. If the low frequencies are accented there is a bulge in the square-wave output of the amplifier or, if accompanied by phase shift, an upward tilt of the reproduced square wave.

It is apparent that the manner in which an amplifier responds to an applied square wave is a very good indication of the performance of that amplifier at low and high frequency audio ranges. A square-wave check can also indicate other types of amplifier disturbances. For example, narrow dips and rises in the reproduced square

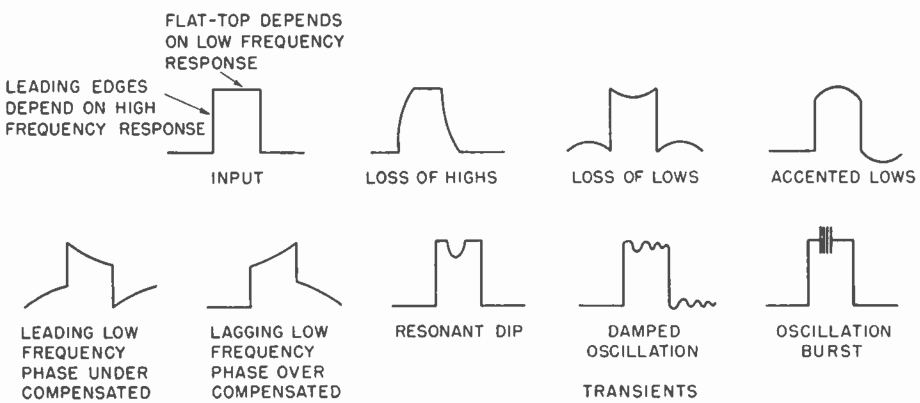


FIG. 23. Square-wave scope patterns.

wave can indicate a defect that only occurs over a narrow segment of the audio frequency range. Transients and spurious oscillations in the amplifier system also show up as a damped train of oscillations on the flat-top or specific oscillation bursts somewhere along the square wave.

An amplifier that will reproduce both 100-cycle and 2000-cycle square waves can be considered free of frequency and phase distortion over the range of 20-20,000 cycles.

In making square-wave checks of an amplifier, it is at times important to have some means of changing over between the output of the square-wave generator and the output of the amplifier under check. In other words, before making a square-wave analysis of an amplifier, it is important to know if the scope itself can pass the square-wave signal without distortion. Only if this is so, can you rely on the scope and know that any square-wave distortion is caused by a defect in the amplifier and not by the scope amplifier.

The output of the square-wave generator should not be made high enough to overdrive any of the amplifier stages. If an amplifier stage is overdriven, it is possible that the square wave observed on the scope will appear to be a good one because the amplifier is clipping and flattening the top of the square-wave signal.

PREAMPLIFIER ADJUSTMENTS

In addition to the equalizer switch (set according to the type of recording used) and the volume control, the preamplifier also contains individual bass and treble controls as well as a roll-off adjustment. Often the customer will not adjust these controls properly because of lack of technical knowledge, as well as a hearing acceptance based on listening to older and inadequate systems. The customer is inclined to adjust bass, treble, and roll-off controls so that the reproduction corresponds to what he considers good on the basis of what his ear is accustomed to.

The technician must educate the customer in terms of what to listen for in a hi-fi system. Often it is helpful to discuss the matter thoroughly with someone in the family who is musically inclined and who will gradually teach other members of the family how to listen to hi-fi records.

When a hi-fi installation is made, you should adjust the various controls properly, marking down the settings and giving them to the customer to keep. Thus the customer can make adjustments on the preamplifier and still be able to return the control to the optimum settings you have located. Many hi-fi installations have been made without precise setting of the preamplifier controls and without adequate customer instruction. Over a period of time the preamplifier controls require resetting to establish optimum performance.

A fast method of checking equalization is to use one of the sweep frequency test records and an oscilloscope. The usual sweep test record is recorded with LP pre-emphasis. When played back through an LP equalizer a linear response pattern should appear on the oscilloscope screen. If it does not, you can adjust the bass, treble, and roll-off controls to obtain a more linear response.

Generally, with the equalizer adjusted for one of the standard recording curves, it will then also be set correctly for the various other standard curves. It should be emphasized again that perhaps the most common cause of a change in frequency response and playback characteristics is a worn stylus. High frequency response drops off a small amount with each playing and consequently, after just a limited number of playings, it is worn to the extent that its frequency characteristics are changed.

More exact measurements can be taken using a test-frequency record and an output indicator such as an audio wattmeter. In using a test record for checking or adjusting the equalizer controls of the preamplifier, be certain you know the playback curves of the test record. Some test records available employ a flat output while others use the standard LP pre-emphasis. Test records are also available that have outputs that correspond to some of the standard playback curves. It is apparent then, that you must be familiar with the output characteristics of the test records you use and that you follow to the letter the instructions that come with the record.

Generally the best procedure is to adjust the equalizer for a flat response on the LP setting using a test record employing LP pre-emphasis. Performance with other standard playback curves can then be observed by changing the equalization selection on the preamplifier. Results are compared with charts that generally accompany the test record and show compensation for the various types of curves. With those records that correspond to each playback curve it should be possible to obtain a flat output as the equalization selector switch is changed when the recording moves into another standard playback band.

As the frequency runs are made, any resonant condition in pickup, preamplifier, or amplifier will make itself known by a sharp rise in output. Wow and improper tracking will also show up as you listen to the test record reproduction. As a frequency run is made, you should listen for any other disturbances that might exist in the hi-fi system. Finally, the bass and treble controls are readjusted to satisfy the room acoustics. Unfortunately this is a trial-and-error procedure because reproduction is not uniform at all parts of a room.

Frequency measurements can, of course, be made using signal generators and output indicators as detailed previously. However, the tests are most tedious as a number of test instruments must be manipulated. In addition, it does not give as thorough a picture of over-all performance because the influence of turntable and pickup cartridge do not become a part of the measurement.

BALANCE AND FEEDBACK ADJUSTMENTS

Most hi-fi amplifiers employ push-pull output stages. This means that in addition to the push-pull output stage itself, there must be some form of inverter or transformer to provide balanced signals at the input grids of the output stage. The advantage of the push-pull stage, in addition to the greater possible output over a single tube, is that it does not generate even order (second, fourth, etc.) harmonics. However, this freedom from harmonic generation of a push-pull stage depends on the maintenance of perfect balance. The output stage should be balanced to within a few percent and the excitation from the driver should be balanced to within 5 percent.

Balance. Many hi-fi amplifiers include a balance adjustment. Follow the manufacturer's recommended procedure for completing this adjustment. Generally the amplifiers are balanced by connecting a high impedance vtvm from plate to plate of the output stage as shown in Fig. 24. When the output stage is balanced there should be a zero reading on the meter. If there is a positive or negative meter reading, adjust the balance control to as near zero as possible. If the unbalance is in excess of 5 percent, check the output tubes (normally balanced tubes are used in push-pull output stage) and other circuits. Voltage measurements can be made on plate and screen supply lines to locate any point of unbalance.

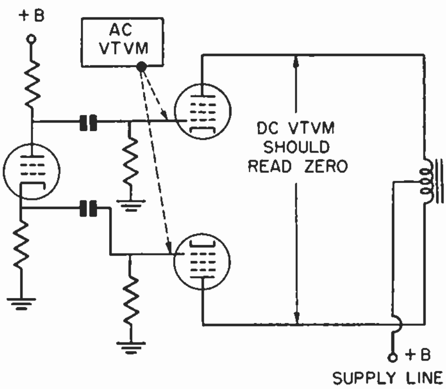


FIG. 24. Balance test.

If the amplifier uses an unbypassed common cathode resistor, an ac vtvm or scope will show no signal across this resistor when the amplifier is balanced.

To obtain balanced operation of the output stage, it is also necessary that the signals driving the two grids of the output stage be of opposite polarity and equal amplitude. To check for balanced excitation, an ac vtvm (or a calibrated scope) can be connected alternately to the grids of the output stage. A 1000-cycle audio signal should be applied to the input of the amplifier. A voltage measurement can now be made at each grid of the output stage. Signal voltage readings should be within 5 percent. If the unbalance is greater than this amount, the preceding phase inverter or driver stage should be checked. Signal voltages can be measured at the dual outputs of the driver stage. Resistance measurements can be made to check the balance of the phase inverter stage if balanced voltages are taken off across equal value output resistors. The resistance measurements should be within 5 percent. If a phase-splitter type of driver stage is employed the resistance readings of plate and cathode resistors should be within 5 percent of their schematic values.

Often the unbalance is the result of an aging coupling capacitor. A faulty coupling capacitor can be located easier by applying a low frequency signal to the input of the amplifier. At low frequencies the reactance of coupling capacitors is quite high, and any unbalance is made more noticeable. With the low frequency signal applied to the amplifier input, the ac vtvm can be used to check the relative signal voltages on the two grids of the output stage. If there is a great difference, the coupling capacitors can be checked one at a time by substitution.

Feedback. If balance in the main amplifier has been established but distortion or high hum level is still isolated to this part of the hi-fi system, it is well to check the feedback link. The feedback system of a hi-fi amplifier has much to do with holding a low noise and hum level as well as a very low IM distortion percentage. Thus the component parts of the feedback link should be checked carefully for open or leaky capacitors or resistors whose values have changed.

TUNER PERFORMANCE

The tuner, too, can have an influence on the quality of an FM broadcast being reproduced by a hi-fi system. If the system performs normally when playing records but is distorted for FM broadcast, the defect is in the tuner. Poor performance is often a result of improper alignment of the tuner or too narrow a band pass in the i-f stages. The alignment and balance of the FM demodulator is also very critical in obtaining a good signal for application to the hi-fi amplifier. Refer to the FM lessons for discussions of tuner problems and alignment procedures.

Loudspeaker and Acoustical Considerations

The loudspeaker, its enclosure and the acoustics of the room to be filled with sound are very important considerations. It is generally conceded that the loudspeaker is the weakest link in a hi-fi system. A mediocre loudspeaker system can destroy all the value of the other costly components in the system.

You have learned in the previous lesson on loudspeaker systems, that a large speaker is necessary to reproduce the low frequency audio range and is not efficient at reproducing the highs. A small speaker capable of reproducing highs satisfactorily has poor low frequency output. Thus the hi-fi loudspeaker in its simplest form consists of two loudspeakers—a small speaker for reproduction of highs and a larger one for reproduction of lows. These can be two separate speakers or in the form of one speaker frame with coaxial or triaxial sections.

The choice of a loudspeaker system is very important and warrants very careful consideration. It is best to choose matched components (speakers and enclosure) rather than try to build up suitable combinations using component parts picked up here and there. It is true that good hi-fi systems can be constructed by purchasing assorted components and building up the unit in the shop. However, this method is not recommended unless the shop has facilities for making loudspeaker measurements. Speakers and enclosures must be very well matched to eliminate improper damping, resonant conditions and output that varies with frequency. You will get fewer headaches and truer reproduction if you install a matched combination of speakers, cross-over network, and enclosure.

Since the loudspeaker system is the weakest link in the hi-fi system, it is economical to stress good quality. A good loudspeaker system can make a mediocre installation sound good while a mediocre loudspeaker used with a very high quality hi-fi system results in no better and generally poorer results. The trend toward smaller and smaller enclosures and smaller speakers is certainly a trend in the wrong direction. Although they are referred to as hi-fi speaker systems, they do not use the other expensive components to the best advantage. They should be considered as installations capable of rendering good audio reproduction but should not be classified as high fidelity.

Performance can be improved by adding more loudspeakers to the reproduction system. The influence of additional speakers is twofold. First, it helps to correct the influence of resonant conditions in loudspeaker and enclosure. A multiple speaker system tends to stagger the resonant points and thereby permits a flatter over-all reproduction. Second, it overcomes some of the acoustical difficulties of the room to be filled with sound. This is particularly the case when a large room or auditorium is to be filled with high fidelity audio. Of course any installation of this type requires proper phasing and matching of loudspeakers to the amplifier output.

The loudspeaker system should be checked carefully if you are called upon to service an installation you did not make. This applies particularly when one of the customer's complaints is that the quality of reproduction was not satisfactory from the beginning. In servicing a strange installation, a recommended first step is to put your test record on the turntable and make an aural frequency run on the system. As the frequency run is being made, you can look over the components used in the system and obtain some idea as to what performance can be expected from the system. This survey will permit you to judge whether the defects you hear are due to equipment limitations or actual troubles in the system.

Nearly all speakers in use today are of the permanent magnet dynamic type. The magnet gradually loses its strength with age. As the magnet becomes weaker the high frequency response is reduced. The response of a speaker which when new was 15,000 cycles, may fall as low as 8000 cycles. A second effect of a weak magnet is to reduce the damping of the speaker. When this happens the low frequency natural resonant point becomes more pronounced.

Wide range and low frequency speakers are subject to defects caused by aging of the cone and its supports. The material of the cone becomes soft with age. This causes the surface of the speaker to break into harmonic vibrations on strong tones. Cone break-up produces very strong odd and even harmonics, and can completely ruin the mid-range response. These harmonics give rise to a large number of resonance points throughout the 500-15,000 cycle range.

The cone is fastened to the rim at the outer edge through a flexible support. This support stiffens with age and causes standing waves on the cone surface at harmonically related frequencies. These harmonics can change the timbre of instruments on certain notes so much that the instrument is not recognizable.

The spider at the apex of the cone may become stretched. When this happens the cone no longer has one resting place in the center of its travel, but two—one on each side of the normal resting place. Since the cone no longer travels equal distances on both sides of its resting place, severe harmonic distortion results.

Both the cone and the voice coil mount can become warped. This condition also tends to change the resting position of the cone. In extreme cases the warping is so great that the voice coil rubs against the field magnet.

Speaker Location. An important consideration in filling a room with high fidelity audio is the proper placement of the loudspeaker system. The present trend is to favor corner mounting. In a corner-mounted installation it is possible to fill the room more fully with low frequency energy because of the horn-like influence of the side walls. The floor or ceiling gives additional energy conduction when the speaker system is mounted near them. Fig. 25 shows the mid-wall mounting which has been popular. It acts as a complete and infinite enclosure but does not radiate as much low frequency energy.

High frequency limitations in a room result from the tendency of the high frequency audio information to beam, and the ability of wall surfaces and other room objects to absorb the high frequencies while reflecting the low and middle ranges. Thus the flat setting of bass and treble controls does not always permit the best acoustical reproduction. In fact, the bass and treble controls are included to permit the customer or installer to adjust the amplifier output to match the room characteristics.

When there is a concentration of absorptive materials the treble output must be increased. Likewise if the room is not adequately filled with low frequency energy, it is necessary to add some bass boost. The spreading effect of multiple speakers also contributes to better room coverage so that high fidelity reproduction can be had in all parts of the room. Above all, if your customer desires good hi-fi reproduction, get him away from the idea of using just a simple single speaker, with

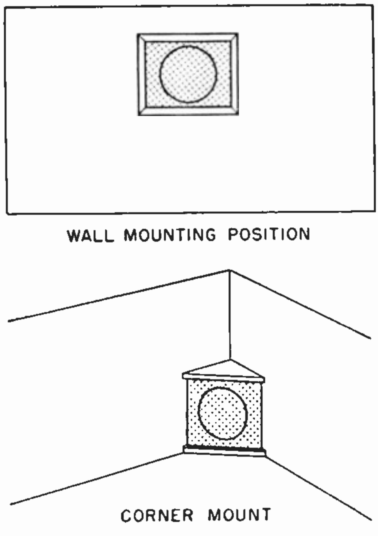


FIG. 25. Speaker mounting positions.

all the components including the speaker, crowded into a single enclosure.

The reflection and absorption characteristics of the room are important in obtaining distinct and clear high fidelity reproduction. The presence of severe multiple reflections can produce mushy reproduction or echoes. If there is too much absorption the room is dead and the music lacks sparkle and presence. Fortunately the average size room in a home is not as subject to these types of disturbances as large banquet rooms and auditoriums. In addition, the average home listening room has a good division of reflecting and absorbent surfaces. For the average basement installation the ceiling and one wall are often covered with an absorbent material such as celotex. Thus some absorption surface is added to the reflecting cellar wall. In general, the reflecting surfaces should be concentrated near the speaker system and can be the adjacent walls of a corner-mounted position. The opposite walls should have a generous area of absorption material to eliminate severe wall-to-wall reflections.

Lesson Questions

Be sure to number your Answer Sheet 44B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. What is the first indication of a worn stylus?
2. What causes "wow" in (a) a turntable; (b) in a tape recorder?
3. Why is needle pressure so important?
4. What are the two major functions of preamplifiers?
5. What is (a) harmonic distortion; (b) intermodulation distortion?
6. Why is intermodulation distortion more disturbing than harmonic distortion?
7. Why are more expensive pickups inclined to be more subject to hum pickup?
8. What are some of the causes of record scratch?
9. Give two common causes of noise and harmonic distortion in a tape recorder.
10. Which instrument, an ac vtvm, or a calibrated oscilloscope, would you choose to check the bias of a noisy tape recorder? Why?

GETTING AHEAD

We have all heard the old proverb, "If wishes were horses, beggars would ride." This is just another way of saying that if wishes could bring success, all men would be successful.

You need only to look around you to see that wishing is not enough. The world is full of failures. But our common sense tells us that these men are not failures because they did not *wish* to succeed. So what *is* the secret of success?

It is *what we do about our wishes* that makes all the difference. The secret is ACTION. Take two men with equal ability and the one who works harder will get ahead faster than the other man.

If one of the two men has less ability than the other, less education, fewer opportunities—but is energetic, active—does something about his problems—he will be more successful than the man who does nothing but wish for success. The men who get to the top and stay there are men of ACTION.

HOW TO ELIMINATE MAN-MADE INTERFERENCE

45B

RADIO—TELEVISION SERVICING

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE No. 45

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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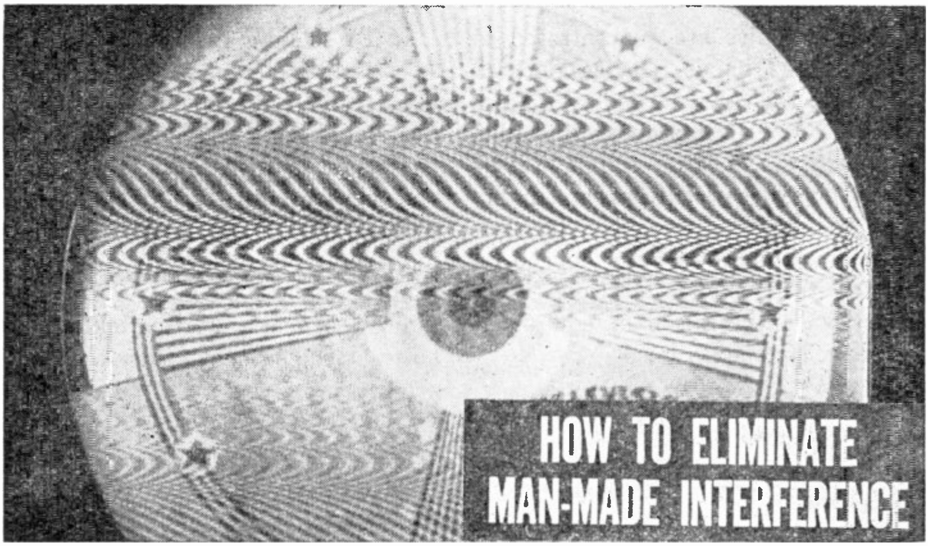


HOW TO ELIMINATE MAN-MADE INTERFERENCE

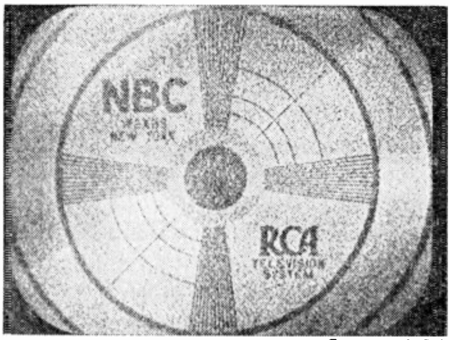
MAN-MADE interference includes any kind of disturbance to radio and TV reception whose source is not "natural" or atmospheric. In this lesson, we will discuss the broad group of man-made interferences that produce noise—crackling, sputtering, frying, whining sounds from a radio receiver—or noise interference patterns on a television picture. We will also cover interference that arises from the operation of transmitters, which produces squeals, whistles, and unwanted programs (or certain bar-shaped interference patterns in a TV picture) by causing various kinds of adjacent-channel co-channel, and image interference.

For the sound or picture to be enjoyable, the radio or TV signal must be considerably stronger than the noise level. However, since there is always *some* noise, there is a limit to how weak a signal can be and still be usable. Some of this noise is developed within the receiver; the input stage and the converter stage are both noise producers. This is a design problem—there is nothing the serviceman can do about this noise—he can be expected to reduce the internal receiver noise only when there is an *excess* of noise because of a defect. Internal receiver noise caused by defects is covered in another lesson.

There is also a certain amount of outside noise that is picked up by the receiver. Noise due to atmospheric conditions cannot be controlled on AM receivers, and it is not practical to eliminate *all* other noise interference, even when it arises from man-made devices. However, the worst of this interference can be controlled, and that is the subject of this lesson.

Although strong signals from near-by powerful stations tend to override and drown out even powerful noise signals, the steady increase in the number of home electrical appliances and industrial or commercial equipment has kept man-made noise interference a problem in broadcast-band and short-wave reception because the noise harmonics are concentrated in the lower rf bands. Devices located very near the receiver, and even those at a distance if improperly installed or defective, can cause trouble in relatively noise-free locations, and interference is always a problem for people in outlying areas who depend on distant stations, or in locations where a heavy concentration of equipment causes a high noise level.

In TV sets, the sound system is FM, so it is little bothered. However, the video (picture) signal is amplitude modulated, so it is subject to noise interference. Furthermore, the eye is very sensitive to disturbances in the picture, so that one is more aware of interference on television than of a similar amount of interference in a radio broadcast. Fortunately, many noise signals that interfere with broadcast-band radio reception do not have appreciable components in the VHF band used by television, but those that can interfere cause enough trouble as it is. The television signals in the UHF band have such high frequencies that very few man-made sources of noise can cause trouble.



Courtesy RCA

The test pattern shown here is covered by "snow." Snow is an indication of noise. Generally, this represents local noise, and if the signal is strong enough, it will lower the sensitivity of the receiver to where the snow is wiped out of the picture. However, where the signals are weak, as in fringe areas, some snow is always seen. Also, in neighborhoods where the over-all noise level is high, snow will be seen.

Of course, FM radio reception is almost completely noise-free as a result of the frequencies used for transmission, and because the limiter stage or the ratio detector in the receiver wipes out amplitude variations such as are produced by noise pulses. If everyone had an FM receiver, only the most powerful noise sources could cause interference. However, by far the majority of radio receivers are still AM, and these can be troubled by noise.

An FCC regulation places a limit on the amount of interference signal any device may produce. Proper shields or filters must be placed on all devices capable of creating interference signals, such as industrial, scientific, and medical equipment, and radio and television receivers themselves. To locate the source of interference or prevent the signals from getting into radio or TV receivers, if the source cannot be located or eliminated easily, you need to know how noise is produced, and what the characteristics of various kinds of noises are. Each kind of electrical equipment produces its own characteristic noise, and the nature of the noise or the time during which it interferes may be important clues as to the source. You must learn how the noise gets into a receiver, because most of the ways of reducing interference consist of blocking the paths over which noise signals travel.

When you are called upon to service a receiver that is noisy, you must determine whether there is a defect within the set, or whether the noise is being picked up. In this lesson, we will go over the tests for determining whether the noise arises in the set or outside. Sometimes this is not easy to prove right away.

Once you have found that the noise is coming from outside the radio or television receiver, you can try filters at the receiver, shielding at the receiver, or changing the antenna system. Usually, however, far better results can be obtained by installing a filter right at the noise source itself. This means you must not only determine that the noise is coming from outside the set, but also that you will have to locate the actual source of the noise.

Let us turn now to each of these subjects in turn, starting first with a study of how noises are produced.

How Man-Made Interference Is Produced

Fundamentally, all man-made noise interference is produced by extremely sharp, irregular variations in current. The amount of variation may not be very high—the wave shape is more important. The main difference between a hum current and a noise pulse is that the hum is produced by a regularly recurring, smooth variation in current, whereas noise is produced by far more irregular current variations.

The irregular variation that causes noise can be produced in two ways: (1) by static electrical discharges such as are produced by friction; and (2) by a disturbance in an electrical circuit.

In turn, the disturbance in the electrical circuit can be broken into several classifications: (1) a sharp change in circuit current like that produced by turning a circuit on or off; (2) an irregular change caused by a poor connection or by a rapidly changing contact such as at the armature of a generator or motor; (3) a sharp change as in neon signs and fluorescent light devices where voltage must build up before conduction occurs; and (4) leakage from power lines as where power lines touch trees or where salt spray or conductive fumes cause leakage across insulators.

We shall consider all these in this section, and, in addition, we will describe the effects on TV reception of interference from local transmitting stations (amateur, AM broadcast, and FM), local receiver oscillators, and diathermy equipment. We will also see how TV stations interfere with each other to produce co-channel and adjacent-channel interference.

Now let us examine each method of causing interference in some detail.

CURRENT INTERRUPTIONS

In a 60-cycle power line, the current reverses its flow regularly and sinusoidally sixty times each second. Since there are no harmonics of this 60-cycle variation, there can be no rf component, so hum cannot get into the rf sections of receivers except in those rare cases where the hum voltage is mixed with another signal in an rf stage that is overloaded or is acting improperly as a detector. Otherwise, the power line ac causes very little trouble.

However, as soon as this current flow is interrupted, a noise interference develops. When the circuit is opened, as when a switch is turned off, the current must change from whatever value it happens to be, to zero, and this change must be practically instantaneous. Therefore, when a switch is turned off, there will be a sharp change in the current. Also, if the circuit contains any devices that can cause the current to be changed erratically and sharply, interference can develop. A motor with a commutator is a typical example of this; the contact resistance varies, and the current is interrupted as different commutator segments come under the brushes. A discharge device such as a neon or fluorescent lamp is another example; current does not start until the voltage reaches a certain value, then it rises abruptly to normal.

If the electrical circuit were purely resistive, the disturbance would not be so bad. However, it is made worse by the fact that practically all electrical circuits contain considerable amounts of inductance. Whenever there is a sharp change in the current flow through an inductance, the magnetic field collapses in an effort to prevent the current change. The rate at which the energy is returned to the circuit from the field depends on the rate of change of current, so the more abrupt the change, the higher the inductance voltage kick will be. (This principle is used in automobile ignition systems where a low-voltage circuit is interrupted sharply and thus produces voltages of several thousand volts.) The result is that a considerable amount of interference energy is produced every time the current changes. Thus, the effect of inductance in the circuit is to increase the interference energy greatly. Because of the high voltage, sparking occurs at the place where the circuit is broken. The contacts of a switch, or the commutator of a motor may be burned by this arcing.

Why does a sharp change in current cause trouble? To begin with, harmonics are produced. A sine wave has a fundamental frequency but no other. A square wave, however, is formed by adding together a fundamental frequency and all the odd harmonics of it up to about the 99th. In other words, the fundamental frequency, plus the third, fifth, seventh, etc. harmonics are combined to make up the square wave. Therefore, as the waveform departs from the sine-wave shape to a more abrupt one with steep sides like the square wave, we have generated not only the fundamental frequency but many harmonics of it, and some of these harmonics may cause interference.

Most noise sources do not generate wave shapes even as regular as that of a square wave. Instead, most noise pulses are a series of high, sharp, narrow pulses containing many even and odd harmonics. Because of this production of harmonics, it is possible for a noise source with an audio-frequency fundamental to have harmonics at radio frequencies that will interfere directly with the reception of any receiver tuned to one of them. If the fundamental frequency is low, these harmonics will be fairly close together, and the interference may appear over a broad band of frequencies rather than just at certain specific spots. On the other hand, if the noise source has a fairly high fundamental frequency, its harmonics may cause random interference over a band of frequencies.

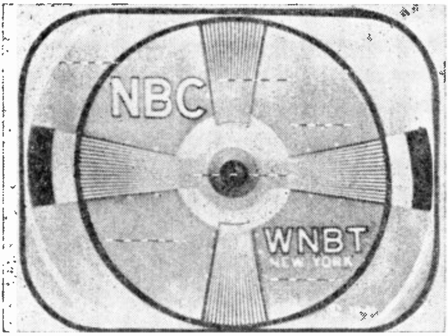
If the noise source produces pulses at a regular rate (such as may be the case from sparking at a commutator on a motor turning at a constant speed), there will be a repetitive pattern that forms a fixed fundamental frequency. However, many sources of noise produce a random pattern that may appear and disappear; this can occur even from a motor commutator. This changes the fundamental frequency, and therefore produces the effect of a broad smear of interference.

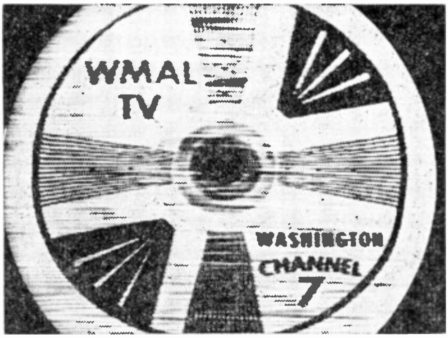
Shock Excitation. In addition to producing harmonics of its fundamental frequency, there are two ways in which a noise pulse can produce frequencies it may not originally have. If a sharp pulse is applied to a resonant circuit, the circuit is shock-excited into producing several cycles at its resonant frequency. Therefore, a strong noise pulse may excite an input resonant circuit in a receiver and thus produce an interference at whatever frequency that circuit is tuned to, regardless of the fundamental frequency of the pulse. In such a case, no matter where the set is tuned, the noise will be heard.

Similarly, any resonant circuits associated with the noise source or the power lines to it may be excited, causing a wave to be radiated at that frequency (in addition to being conveyed along the lines away from the source). This may cause the interference to be concentrated at a particular frequency, rather than spread over the dial as when the excited resonant circuit is in the receiver. The resonant circuits in electrical systems are not "lumped" inductances and capacities; they are formed mostly by the distributed inductance and capacity along the wires. These distributed constants are such that the length of line bears a direct relationship to the wavelength of the wave at which it is resonant.

Every electromagnetic wave has a wavelength (distance from peak to peak), found by dividing the velocity at which it travels by its frequency. A two-wire line is resonant to the wavelength at which its length corresponds to ¼, ½, or one wavelength. Since there are wavelengths corresponding to distances ranging from fractions of a centimeter up to many miles, *any* power line section is resonant to *some* wavelength, and will produce an electromagnetic wave at that frequency when it is shock-excited sufficiently.

The power line is divided into sections by "discontinuities"—that is, every branch line going to an appliance, and each separately fused line,





Courtesy RCA

FIG. 1. Light ignition interference causes streaks of the kind shown at the left across the picture. A series of black streaks as shown at the right indicates ignition interference such as may be produced by a passing automobile, and sometimes by certain oil-burner equipment. The interference may be light or heavy, depending on the strength of the interfering signal.

is independent and each has its own resonant wavelength. Once interference pulses have excited any or all sections into oscillation, they then radiate interference, or transfer it along by capacitive coupling from section to section. Even the small amount of wiring within electrical devices may produce an interference on the higher frequencies. An automobile ignition system is a good example of this kind of interference producer. The effect of light auto ignition noise pulses on the TV picture is shown at the left in Fig. 1. The effects of severe auto ignition or motor commutator noise are shown at the right.

The rf wave produced by such shock-excitation is modulated at the rate at which the current change occurs, but the interference is primarily concentrated at the frequencies at which resonance exists. If the receiver is not tuned to or near these frequencies, there will be little interference. However, if a desired station frequency is at or near one of the interfering frequencies, then there may be a great deal of interference.

LEAKAGES

It is possible for leakage from a power line or between power lines to cause interference. Any such leakage paths are unwanted, but they may develop as a result of insulation breakdowns. A power line rubbing on a wet tree limb is a common source of trouble, and near the seashore, salt encrusted on the insulators of high-voltage lines is a common source. These paths provide intermittent contact, which of course produces erratic, irregular variations in the line current.

When driving around in a car, you will frequently hear a heavy, low-frequency buzz on the radio as you pass a pole transformer. This noise is characteristic of a poor power line connection. Power companies are interested in having people report the location of power line noise of this type so that they can send their repair men to the proper place to correct the difficulty.

STATIC DISCHARGES

When certain objects are rubbed together, static charges are produced. For example, rubbing a glass rod with a piece of silk will produce charges on both the cloth and the rod. Similarly, wherever friction is involved and one or more of the parts is a non-conductor, static electricity is produced. Machines handling paper (printing presses, for example) and belt-driven machines are common sources of trouble. In a belt-driven machine, friction between the belt and the drive pulley produces electric charges on the belt that jump erratically to nearby grounded objects, thus producing sudden momentary currents that are like any other noise current.

In paper-handling machinery, static electricity causes so much trouble that proper grounding and the use of static-collecting devices are necessary for operation. Belt drives may or may not have static collectors installed, however. The usual static collector for a belt is a brush or "comb" with many flexible wires or fingers that contact the surface of the belt. The comb and the drive pulley are both grounded and thus bleed off the static charges.

Interference develops when static combs are not installed, or where the comb is worn or no longer attached to a ground.

RF RADIATION

In the rest of this section, we will study some of the interference problems that occur primarily in TV reception or are produced by TV receivers. First, we will describe interference that can be caused by rf signal radiation from nearby receiver circuits and from diathermy equipment. Then, we will take up the interference that can be produced by local broadcasting stations.

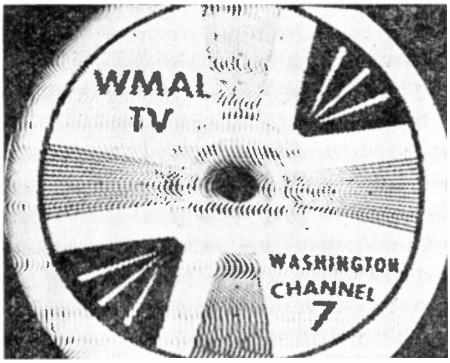


FIG. 2. Interference of this sort can be produced by the local oscillator of a nearby TV or FM set. You can distinguish it from other kinds of rf AM interference by the fact that the number and positions of the lines will change when the tuning of the interfering oscillator is changed.

Receiver Interference. Interference may be caused by radiation from the local oscillator and harmonic frequencies from the horizontal sweep circuits of nearby TV receivers. The waveform from the horizontal oscillator is sharply peaked and, therefore, contains many high-frequency harmonics. An example of the interference pattern produced on the picture tube screen is shown in Fig. 2. The wavy lines move as the frequency of the interfering oscillator changes.

There is frequently trouble of this type in apartment installations where there are many receivers close by. It is not common in installations in private dwellings where TV antennas have a reasonable separation between them.

The number of lines produced by the interfering signal and the position of the lines (whether they are horizontal or vertical) depend on the frequency of the interfering signal with relation to the receiver's horizontal sweep frequency. The horizontal sweep frequency of a television receiver is 15,750 cycles per second. An interfering signal having a frequency less than the frequency of the horizontal sweep of the receiver will produce one or more horizontal bars across the picture as shown in Fig. 3. Horizontal bars of this type can be produced by a low-frequency signal produced when two higher frequency signals beat together. It can also be caused by a receiver defect,

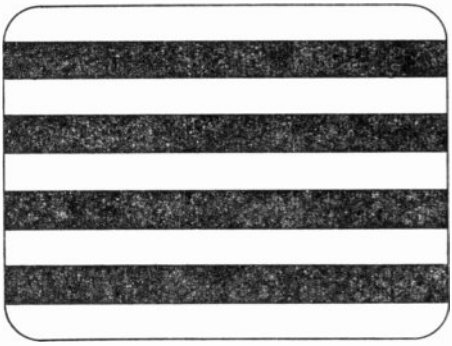
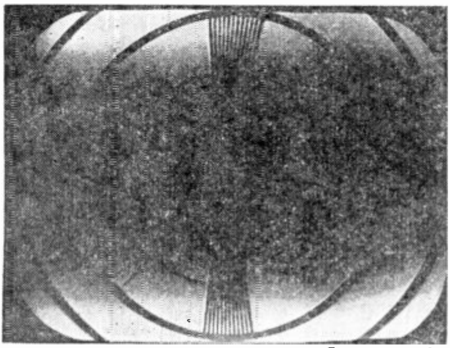


FIG. 3. Horizontal bars like this are produced by interference with a frequency less than that of the horizontal sweep. The frequency of the interference is roughly equal to 60 times the number of bars.

such as cathode-to-heater leakage in one of the tubes. This 60-cycle hum will produce a single bar across the picture as shown in Fig. 4. If there is a defect in the power supply, such as a defective filter capacitor, the resultant 120-cycle hum will produce two bars across the picture.



Courtesy RCA

FIG. 4. 60-cycle hum in picture.

It is easy to see why an interfering signal occurring at a frequency less than the horizontal sweep rate will produce a horizontal interference pattern. If the frequency of the interfering signal is less than that of the horizontal sweep, the horizontal sweep will go through one or more complete cycles while the interfering signal is going through one cycle. Therefore, several lines will be affected and the interference pattern will be horizontal.

Of course, if the frequency of the interfering signal is higher than the horizontal sweep, then it will go through one or more complete cycles while the horizontal sweep is going through one cycle. Therefore, the interference pattern will show up several times on each line. This will produce a series of vertical bars as shown in Fig. 5. If the frequency of the interference signal is changing, you will get a series of wavy bars like those shown in Fig. 2 instead of the straight vertical bars. From this, you can see that the pattern produced by the interference signal is helpful in determining what may be causing the interference.

About the only practical way of eliminating interference of this type is to locate the antenna as far as possible away from the antenna or the receiver from which the interfering signal is being picked up. Sometimes part of the interference is picked up by the transmission line—in this case, the use of a shielded transmission line will greatly reduce, if not completely eliminate, the interference.

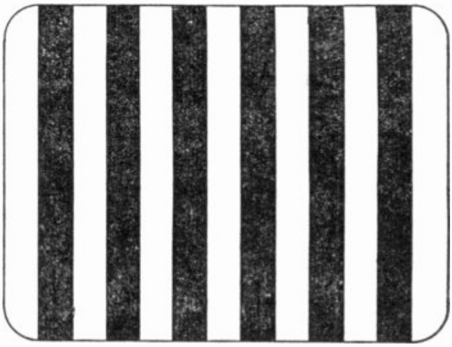


FIG. 5. Vertical bars of this sort are produced when the frequency of the interference applied to the picture tube is higher than the horizontal sweep frequency. The frequency of the interference is roughly equal to the horizontal sweep frequency times the number of bars.

This type of trouble is quite common in many of the older TV sets. RF radiation interference from receiver circuits, as from all other sources, is forbidden by FCC regulations. Filters and shielding must be used at the offending receiver to eliminate the interference.

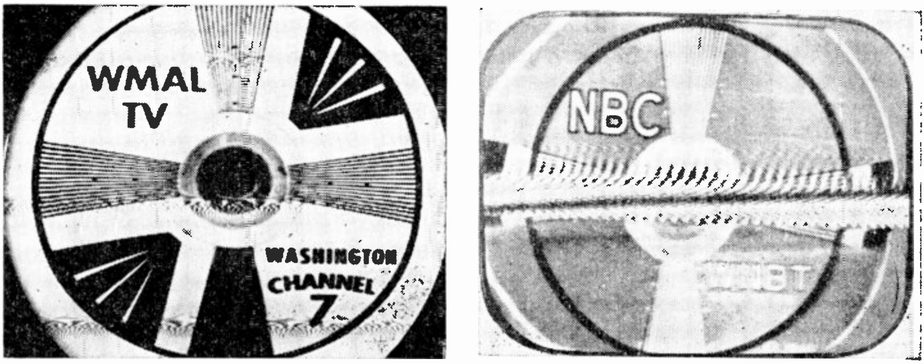


FIG. 6. Diathermy interference; weak, to the left; heavy, to the right.

Diathermy Interference. Diathermy interference is caused by radiation from the oscillator of a diathermy machine. Examples of this type of interference are shown in Fig. 6. Interference of this type is common near a doctor's office or a hospital.

Because of the FCC regulations governing radiation from these machines, modern machines are made so that radiation is seldom very serious. However, there are still a number of older machines in use and they may cause this type of interference.

Diathermy interference can definitely be eliminated at the source, if the source can be found. Shielding the diathermy oscillator completely will keep the radiation from the oscillator itself to a minimum. In addition, radiation can be reduced by using an rf filter on the power supply of the equipment.

BROADCAST STATION INTERFERENCE

Interference may be caused by nearby AM broadcast stations. This interference will look something like a wire mesh across the face of the picture or diagonal lines as shown in Fig. 7. The most effective method of reducing this type of interference is to use a high-pass filter. Commercially manufactured high-pass filters are available. If a filter of this type is mounted directly at the tuner where the transmission line goes into the tuner, it will generally eliminate the interference even when the receiver is right beside the broadcast station.

FM signals also can interfere with both low-band and high-band VHF TV stations. The interference, if it occurs on channel 2, might be image interference. If it occurs on the other

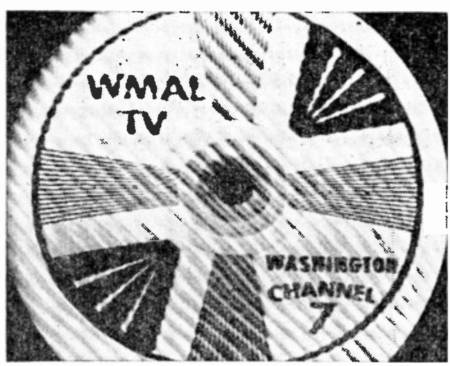


FIG. 7. The diagonal lines shown here indicate an interference from an AM station or signal.

channels, it is usually caused by a strong FM signal getting through the front end of the receiver and for one reason or another producing this interference. The interference pattern produced on the picture tube screen is similar to that shown in Fig. 2.

There are several methods that can be used to reduce or eliminate FM interference. A series wave trap, an absorption trap, or a stub can be used. A quarter-wave open stub is the most commonly used, because it is effective and is comparatively simple to make and adjust. These devices will be described in detail in another section of this lesson.

In addition to using a stub or a wave trap to eliminate this type of interference, sometimes reorienting the antenna will help. You may find that there is a position for the antenna where pickup from the FM station is at a minimum but the signal pickup from the TV station is still satisfactory.

Amateur Interference. The interference from an amateur station produces a pattern similar to that produced by any other AM transmitter. There are three possible ways in which an amateur transmitter can cause interference in a TV set. There may be excessive harmonic radiation from the transmitter, the signal may be getting directly into the i-f stages, or the station may be operating on a frequency near that of one of the TV channels.

Most amateurs are aware of the interference that can be caused by harmonic radiation from the transmitter and will take the necessary precautions to be sure that harmonic radiation is kept down. If there is interference it is usually because the amateur signal is getting directly into the i-f stages.

The 21-mc amateur band is very close to the i-f used by many of the older TV receivers. Amateur signals from this band can pass through the front end and enter the i-f amplifier in the receiver. The interference produced may be so severe that the picture will be lost completely. Interference of this type can, in most cases, be completely eliminated by the use of a good low-pass filter. Sometimes the filter can be connected between the transmission line and the antenna input terminals on the receiver. Sometimes, it may be necessary to install the filter at the tuner where the lead-in passes into the tuner assembly.

When there is interference because the amateur station is operating on a frequency near one of the TV channels, parallel resonant traps inserted in the transmission line will be helpful in eliminating it. Usually the amateur will be helpful in working out problems of this type and will be glad to furnish information as to the band in which he is operating to help you make up the trap. Wave traps of the absorption type are also excellent for eliminating interference of this type. We will discuss them later.

Interference in channel 2 from a transmitter operating in the 28-mc amateur band is probably due to a harmonic radiation from the transmitter. Usually the amateur will take whatever steps may be necessary to eliminate radiation of this type.

Amateur transmitters operating single-sideband can also cause interference, although it is unlikely that they will, because of their operating frequencies. You will be able to recognize this type of interference easily; the pattern will appear on the picture tube only when the operator is speaking.

Remember, the amateur transmitter has a legal right to be operating, and the FCC recognizes that certain harmonics may be radiated. However, usually interference due to harmonic radiation is confined to the immediate vicinity of the transmitter. Amateur operators are very careful to design their equipment so that as little harmonic radiation as possible is produced. Therefore, if there is an interference pattern on your customer's TV screen, the interference is probably caused by radiation from a source other than an amateur transmitter.

The preceding information on reducing amateur interference can also be applied to interference caused by commercial short-wave stations operating at frequencies near the TV channels or at frequencies having harmonics that fall in the TV channels.

Co-Channel Interference. Sometimes interference occurs when it is possible to pick up signals from two different stations operating on the same channel. This might happen in some fringe areas where you may be able to pick up the signal of a station operating on channel 4 that is fifty miles away and at the same time pick up interference from another station, say 125 miles away, in another direction, operating on the same channel. When this happens, an interference pattern similar to Fig. 8 may appear on the screen. The use of a highly directive antenna will often help cut down interference of this type.

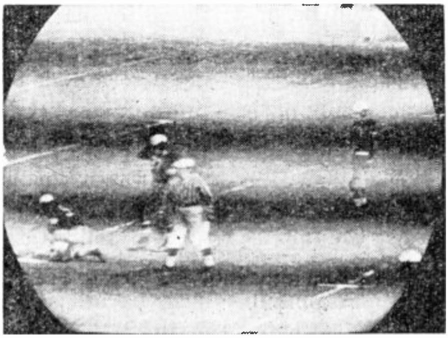


FIG. 8. Co-channel interference.

Fortunately, a simple method of adjusting the two transmitters to eliminate this interference has been worked out and is in use. Both transmitters are adjusted so that there is a difference of about 10 kc between them. The interference pattern on a TV screen due to this difference frequency is so fine that the bar pattern disappears completely. Therefore, this particular type of interference is seldom encountered.

Adjacent Channel Interference. Adjacent channel interference is interference from a station on the channel immediately above or below the channel to which you are tuned. This type of interference is rare in large cities to which TV channels have been assigned, but may be found in some fringe areas where it may be possible to pick up a station on almost every channel.

Many receivers have adjacent channel interference traps, and if these traps are properly adjusted, this type of interference should not be objectionable. If the receiver does not have traps of this type, the use of a more directive antenna may be helpful in reducing the signal from the interfering station to such a low level that it will not be objectionable.

It may also be possible to use a stub cut to a frequency near that of the interfering station to attenuate the interference. This is practical, of course, only if the presence of the stub does not reduce the strength of the desired signal too much. You will learn how to make and adjust devices of this type in a later section of this lesson.

SUMMARY

There are two main kinds of external rf interference—"blanket" interference and "station" interference. Blanket interference, such as diathermy interference, ignition interference, etc., can best be eliminated at the equipment causing it. The use of appropriate filters and shielding will usually eliminate the interfering radiation.

On the other hand, interference caused by a particular station, whether it is an FM, an amateur, a short-wave or some other station, can be eliminated by the use of wave traps or stubs at the receiver. Of course, if the interference is caused by excessive harmonic radiation from an amateur station, the elimination or the suppression of the harmonic at the station will be the most effective means of combating the difficulty. When the interference is due to nearby stations operating on frequencies near the TV channel or near the TV i-f, however, the best way to eliminate the interference is to trap the interfering signal at the receiver.

How to Localize Interference

Interference signals may travel from the source to the receiver by conduction directly along the power line, or by radiation from the device or its associated power line into space.

When the noise signal is radiated, it may be picked up by the receiving antenna, it may be picked up directly by the receiver chassis or some part on it, or it may be induced in another power line and travel along this power line to the receiver.

To produce interference, a radiated signal must get into the normal signal path in the receiver. If the receiver antenna picks up the interference signal, then it acts just like any other signal and will travel directly to the receiver input. There, if it is at a frequency near that to which the receiver is tuned, it will travel like any other signal along the usual signal path. Even if it is at a frequency far removed from that to which the receiver is tuned, if it is strong enough, it may drive the first rf stage into acting as a detector, in which case the interference signal will be cross-modulated with the desired signal. This causes the modulation of the undesired signal to be impressed on the desired one, after which the desired signal travels through the receiver with both modulations—desired and undesired—on it.

If the signal is strong enough, a voltage can be induced directly in the receiver wiring. This is true whether the interference is coming in by radiation or has come in by conduction over the power line. Stray capacity between the power cord and a signal circuit, or direct radiation from the power cord to a nearby signal circuit can induce the interference in the signal path.

Because of differing sensitivities and different amounts of exposed wiring within the sets, it is impossible to say whether a particular set will or will not pick up interference. Two receivers of different makes or models in the same home may both be noise free, both be noisy, or one may have interference and the other be relatively noise free. (Sometimes this means that the noisy receiver has an internal defect.)

When confirming a complaint of man-made interference, the first thing to do is to listen to the receiver or look at the pattern on the picture tube. If the interference is of the kind that could be produced by diathermy equipment or by TV sweep oscillator radiation, you know that it is external to the receiver, and the problem becomes one of preventing radiation or conduction by applying the proper filters or shielding. However, if the complaint is one of noise, you can't be sure right away that the difficulty is not somewhere within the set.

INTERNAL OR EXTERNAL

There are certain basic test procedures that will help you determine whether the noise is internal or external. The first procedure is that of disconnecting the antenna, if the receiver is operating from an outside one. If the noise disappears, it probably was being picked up by the antenna, but you cannot be sure that it was, because sometimes a difficulty within the set will show up only when a signal is coming through. By connecting a signal generator to the antenna terminals of the receiver, and by feeding an rf signal into the set, you can determine whether noise now occurs If it does, it probably is originating somewhere in the rf or i-f section of the receiver. (When the noise originates in the audio amplifier, it usually will appear without the need for a signal.)

If the antenna is built in so that it is impossible to disconnect it, or if disconnecting it does not have much effect on the noise, then a line filter (to be described later) can be used between the receiver and the power line to block any noise from coming in over the power line. If this has much effect on the noise, it again indicates an external noise source.

In cases of doubt, the receiver can be removed from the home and tried in another location (your shop). If the receiver is still noisy, then the noise is probably originating within the set, or the noise covers a very wide area. However, if the noise disappears when the set is moved away, it probably was being picked up at the original location of the set.

Another test is to try another receiver in place of the noisy one. If the noisy set is an AM radio, one of the 3-way (ac-dc-battery) portables is good as the test set because you can operate it either from the power line or from batteries. First try power-line operation. If you hear the same noise as on the original set, then it is being picked up. Try the portable on batteries—if the noise disappears, it is coming in over the power line; if it remains, it is being picked up by the antenna or chassis of the portable.

Intermittent Interference. If, when you arrive to test the receiver, the interference of which the owner complains is not evident, it is possible that the interference comes from within the set and is intermittent, or that it is being picked up, but the source is in operation only at times. In such a case, it is necessary to question the customer carefully. Try to determine the characteristics of the interference, what the noise sounds like, or the type of pattern it produces on the picture tube, and the hours at which it is evident. If it occurs rather frequently, it may pay to wait for it to show up.

While waiting for the interference, you might try thumping or jarring the receiver chassis, to see if the interference will appear. In many instances, intermittent interference due to a receiver defect will respond to mechanical vibration of this kind.

In particular, watch for interference that occurs consistently a short time after the receiver is turned on, no matter what time of the day the receiver is put into use; a receiver defect is indicated in such cases.

An interference that occurs at more or less regular intervals during the day, exists for a short period of time and then disappears, usually comes from a device that operates cyclically. An oil burner is a good example of this. The burner may be in operation for five or ten minutes, and then may shut off for twenty minutes or more before repeating this action.

As a similar time clue, an interference that occurs only around mealtimes may indicate a household electrical appliance used in preparation of food. Devices like toasters, coffeemakers, mixers, etc., may be the offenders.

Interferences that occur only at hours that a nearby factory is operating almost directly indicate that the source is in that factory or plant. Similarly, an interference that occurs only when a nearby neon sign is illuminated, or that occurs only when a streetcar passes, likewise more or less definitely indicates its source.

If you cannot be sure that the interference is originating outside the receiver, it may be best to take the set to your shop for an operational test over a period of time, or to arrange to come back at some future time to try to catch the noise or interference. Remember that moving a receiver may jar it enough to cause the intermittent defect to clear up for a time. Even when the set is quiet in your shop for a few hours, you can't always be sure that it still does not contain a defect.

THE NOISE DETECTIVE

Once you are sure the interference arises from something outside the receiver, it is desirable to try to locate the source. A simple filter installed at the source may clear up interference better than very elaborate filters elsewhere.

In general, curing the interference is usually far simpler than locating the source in the first place. With so many kinds of electrical devices in use, often a careful, systematic search is necessary to find the particular one that is causing the interference.

If the receiver is located in a detached house, particularly one in a suburban or farm area, first search the home, unless the nature of the interference definitely leads you to suspect an outside source. This is logical because interference signals are attenuated as they travel through space or along power lines, so a nearby device is a more likely offender than a distant device.

This same procedure should be followed even if the receiver is in an apartment house or is near stores or factories. If the source could be in the home, you may save quite a lot of time by searching there first.

Whether you are searching within the home or outside of it, it is important to keep in mind that the kind of noise and the times at which it occurs are valuable clues to possible sources. With this in mind, and a little experience, it will frequently be possible for you to go directly to the offending device and prove that it is the source of trouble by merely turning it on and off, demonstrating that the interference appears and disappears. Table 1 gives a list of some of the common sources of trouble and the kinds of sounds they produce in radio receivers. Many of them produce characteristic interference patterns on the picture tubes of TV sets, so with experience you will be able to recognize them, too.

In a large home, it is not always practical to go around turning on and off various lamps and devices. Instead, there is a simpler, more direct approach to take—that of opening branch electric circuits within the

TABLE I.

Whirring, crackling, buzzing, humming, droning, and whining sounds are characteristic of motors and generators. When motors start, the pitch of the whine increases until it reaches a steady level. This is especially true of commutator-type motors. Look for such electrically operated equipment as:

Adding Machines	Elevators	Sewing Machines
Air Conditioning Units	Fans	Small Blowers
Barber Clippers	Floor Polishers	Toy Electric Trains
Beauty Parlor Devices	Hair Dryers	Vacuum Cleaners
Cash Registers	Portable Electric Drills	Valve Grinders
Dental Engines	Printing Presses	Vibrators
Drink Mixers	Refrigerators	Washing Machines

Rattles, buzzes, and machine-gun fire sounds indicate interference from buzzers, telephone dials, or doorbells. These noises are usually intermittent, starting and stopping at irregular intervals. Short machine-gun firing sounds indicate telephone-dialing interference.

Violent heavy buzzing or rushing sounds are often heard over a large area or even a whole town, the sounds being at times so loud that they drown out the radio program. They may be louder at one end of the tuning scale of the receiver, indicating high-frequency noise-modulated radiation; they may be heard only on certain bands. These sounds may be traced to:

Battery Chargers	Neon Signs	Violet-Ray Apparatus
Diathermy Machines	Oil Burners	X-Ray Machines

Crackling, sputtering, snapping, short buzzes, or scraping sounds, indicate loose connections; if in the house, they will be especially noticeable when someone is walking about; and heavy traffic or street cars may increase the intensity of the sounds. Look for:

Elevator Controls	Street Cars	Loose connections in floor lamps and appliance cords; broken heater elements in household appliances. Unbonded rubbing metal contacts in houses, such as adjacent pipes.
High Tension Lines	Wet Line Insulators	
Power Lines Grounded to Trees		

Clicking sounds are a definite indication of make-and-break connections essential to electrically controlled equipment, such as:

Elevator Controls	Incubators	Percolators
Flashing Signs	Irons	Thermostats
Heaters, Automatic	Electric Typewriters	Traffic Signals
Heating Pads	Ovens	

Heavy violent buzzing sounds, usually of short duration, are characteristic of heavy sparking or arcing across a gap. Such sounds are traceable to:

Arc Lights	Elevators	Street Car Switches
Automobile Ignition	Motion Picture Projectors	Toy Electric Trains

TABLE 1. Several typical interference sources are indicated in this table.

home and thus cutting off a number of devices at a time. To do this, have an assistant or someone in the home listen to the radio or watch the TV set while you unscrew fuses in the main electric fuse panel, one at a time. By unscrewing a fuse, you will completely kill one branch of the electric circuit in the home and will thus stop any noise production that arises from any device on that particular branch. If the noise disappears when you unscrew one of the fuses, then that branch must be gone over carefully and the devices on it examined or turned on and off individually, to locate the source.

Unscrewing a fuse will also stop a noise that is due to loose electrical wiring in that branch of the circuit. This is important to keep in mind, because in many instances the noise occurs because of a poor connection between a plug and a wall outlet, or because too many devices are connected into a wall outlet through a cube tap or a similar multiple-connection device. Such devices invariably develop poor contacts.

Poor connections of this kind can be fixed by you or by any appliance serviceman. However, if there are poor connections in the outlets themselves, or in the electrical wiring, an electrician should be called in.

Of course, when you unscrew the fuse controlling the branch on which the receiver is operating, it will stop operating. The receiver should be connected to another branch while its own branch circuit is cut off.

Rubbing Pipes. If the source of noise is an electrical device within the home, the noise will stop when the device stops working, so this procedure of blocking each branch circuit in turn should localize the trouble. However, there is one rather common source of noise within homes that is not electrical. This is noise interference that will be heard when someone walks around, or when heavy trucks pass the house and set up vibrations in it. Once you are sure that the trouble is not within the receiver, the next thing to look for in a case of this kind is pipes in the basement that can touch each other. The cure is either to bond the two pipes together so that they make good electrical contact (use flexible metallic braid, and clamps or solder), or to wedge them apart so they cannot touch. The latter is usually the easier; a small wooden wedge driven between the pipes where they cross each other will clear up this trouble.

LOCALIZING OUTSIDE INTERFERENCE

If the home in which the receiver is located has been cleared of suspicion, the interference must be coming from some source outside the home.

There is no longer the question of who will pay for the filters or repairs needed on the equipment producing the noise signals once the noise source is located. The FCC regulations state that the owner of the device must see to it that his equipment does not radiate harmful interference signals. What you have to be concerned about now is who is going to pay you for the time you spend in finding the interference source. It may take you a considerable amount of time to find it. Should your customer pay for it, or should you do this at little or no charge to try to earn the good will of the neighborhood? It is likely that the noise signal is also causing interference in many other receivers in the immediate vicinity. Sometimes the receiver owner will be willing to pay because he is anxious to be free of the interference. It is best to have an agreement beforehand, however, before spending too much time.

Because of these financial considerations, it may be best to see if installing a filter at the receiver will reduce the interference to a reasonable level. Even if this works fairly well, the interference remains with other receivers in the neighborhood, and if the interference gets worse, this solution may be only a temporary one.

Practically all electric power companies have crews that specialize in locating noise sources and defects on their power lines. Many power companies will use their equipment to help you locate the interference source if you ask them, even if the interference is originating somewhere other than from their lines.

Let us assume that you can find no one who will help you, and you have decided that it will be economical to try to localize the source of the noise yourself. What must be done?

We have already mentioned that a small 3-way portable receiver (ac-dc-battery operated) may be used to determine whether the noise is due to a receiver defect or to an interference signal outside the receiver. These portable sets may also be used to localize the source of noise. Of course, most of these portable sets cover only the broadcast band, so they are useful only if the noise is in the frequency band between 500 kc and 1600 kc. Since these receivers are fairly sensitive, you can move the receiver to different points to see if the noise level changes. Obviously, if you move to a point where the noise becomes louder, you are approaching the source of the noise.

Furthermore, most of these receivers use loop antennas, which are somewhat directional. The loop antenna is usually arranged along the back of the receiver chassis in such a way that maximum energy will be picked up from directions in line with the ends of the receiver cabinet, and minimum energy from directions directly in front of or directly behind the cabinet of the receiver, as in Fig. 9. Rotate the receiver cabinet through a semicircle. When you have turned it to a position in which the noise is greatest, the receiver cabinet indicates a line along which the noise source probably exists.

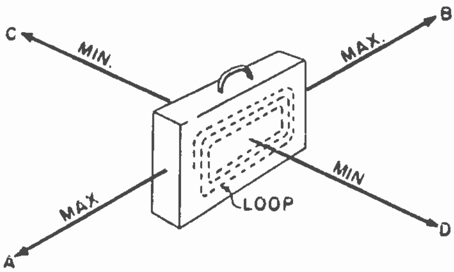


FIG. 9. A portable receiver receives best along the line A-B and poorest in the directions C-D.

Of course, even if the receiver does indicate the line along which the noise exists, you don't know whether it is in direction A or direction B. However, by moving along this line in one direction or the other, you can determine whether the noise becomes louder or weaker. If it is becoming louder, you are, of course, approaching the source.

In a somewhat similar manner, it is possible to drive around in an automobile having a sensitive receiver and listen for the greatest amount of noise. This is helpful when there is a single device somewhere in the neighborhood creating a large amount of interference. However, if the interference is being carried along power lines, this method isn't very effective.

10 shows how a dc voltmeter is connected to measure the avc voltage level. If you do much work of this kind, it would pay to bring out connections on the receiver you are using, so that you can plug in a meter.

For the man with a great deal of interference-locating work, there are special interference localizers. These are receivers that have been specially modified for this service. The loop antenna that is used on them is designed to be much sharper in directivity than those found on the average

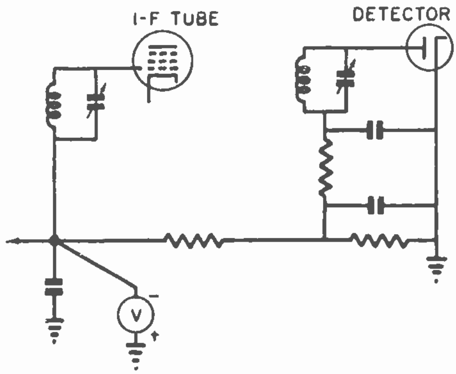


FIG. 10. How to connect a dc voltmeter to the avc circuit of a receiver.

In either case (portable set or auto set) you must use judgment as to the strength of the noise interference you hear. It isn't very easy to judge signal strength this way, particularly when a receiver has an avc system, which will tend to keep the output at a fairly constant level by changing the gain as the signal strength changes.

It is possible to add an indicating meter to the avc system of a receiver and thus get a more accurate indication of the strength of the signal, because the avc voltage will vary directly with the signal strength. Fig.

portable receiver. They also have a built-in vertical antenna of the whip type much like that found on an automobile. By combining the reception characteristics of the two antennas, it is possible to get pickup from a single direction as a maximum, rather than to have to worry about which direction along a line the signal may be originating from. This permits you to move directly toward the source by rotating the receiver to the point of maximum response, then moving in that direction.

Such interference locators have a

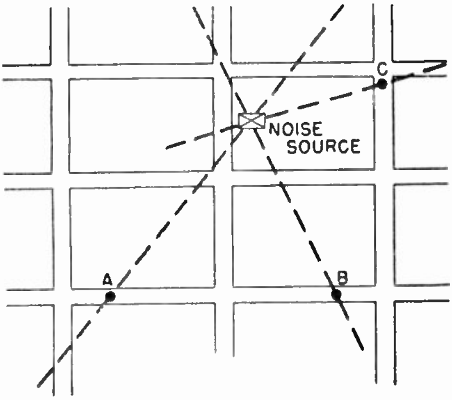


FIG. 11. How to locate a noise source by determining the direction from which the noise signal comes.

built-in signal-strength meter. They generally also have as extra equipment a pickup coil mounted on a pole that can be used as a probe. When this is brought near an electrical device, it is possible to determine whether the noise level increases, thus picking out the offending device among many that may be in a large store or factory.

Usually it is not possible to move in a straight line toward an interference source because of buildings in the way. In such cases, you can localize the source of noise by a method known as triangulation, if the interference is radiated directly from the source rather than carried along power lines. As shown in Fig. 11, the noise locator is rotated for maximum interference at a location such as A, then a line is drawn on a sketch of the neighborhood. The locator is then moved to another point such as B, a new direction is determined, and a new line is drawn. Where the two lines cross will be approximately the location of the noise source. Two or three readings will usually be enough to allow you to move almost directly to the building in which the source is located. This same general method can be used with a portable receiver, but the lack of sharp directivity does not make the portable receiver as good for this.

Once the interference is traced to a building, you can inform the owner or occupant that the interference source has been localized to his building. It is then up to him to eliminate the interference. Perhaps he will want you to install the necessary filters or make the necessary repairs. The method used to eliminate interference is the subject of the following section.

Eliminating Interference

Once the source of the interference has been located, there are four basic steps in reducing or curing the interference: (1) repair or replace the noise source; (2) connect the device to a good ground; (3) use a filter; and (4) shield the device. If these steps do not completely remove the interference, or if some of them cannot be carried out, then you can: (1) install a line filter at the receiver; (2) move the receiver to another outlet or another position to get as far as possible from the noise source; (3) try a noise-reducing antenna when the receiver uses an outdoor antenna. Let's consider each of these procedures in turn.

REPAIR OF APPLIANCES

The first step in any interference-elimination procedure is that of restoring the electrical equipment to first-class condition. A motor with worn, dirty commutator segments can have so much sparking that even an elaborate filter is unable to clear up the trouble completely. In many instances the trouble will be cleared up once the equipment is properly repaired, or is replaced if repair proves impossible.

For all motorized devices, it is important that the commutator be cleaned and properly shaped, and in many instances new brushes will have to be installed in the motor.

If the trouble occurs because of poor connections, a repair is all that is necessary.

Contacts on thermostats and on large power switches can be cleaned, or the control replaced. An ordinary ON-OFF switch usually must be replaced if its contacts are worn and pitted.

A careful check should be made of all sockets and other means of connecting and disconnecting electrical power. With age, they all give trouble. Incidentally, light bulbs themselves very frequently cause interference just as they are about to burn out. If you trace interference to a lamp, try new bulbs as one of your first steps. Also, examine all appliance cords and recommend the replacement of any that are frayed and worn, even if they do not directly contribute to the interference.

PROPER GROUNDING

Another very important step to take in interference elimination is making sure that all industrial equipment is grounded. The metal frames of most pieces of machinery will act as a shield, and if the machinery is grounded, this will reduce the interference radiation.

Generally such equipment is grounded when originally installed, but it is always possible for the ground wire to break, or become disconnected.

Of course, for small household appliances, grounds usually are not provided. Because an extra lead to ground would get in the way or reduce the portability, it is usually not advisable to attach a ground to appliances that are not built in. Generally, such equipment creates interference of such a low level that filtering can take care of it without the necessity of grounds.

If a ground is to be connected, be certain that it goes to a cold water pipe or to a ground rod driven in the earth. Never depend on gas pipes or heating systems—the "dope" used by plumbers in joining sections of gas or steam pipe together acts as an insulator, thus making the series of pipe sections a poor ground, and the practice of using gas pipes is dangerous anyway, and is against fire regulations, because of the danger that a spark will cause an explosion.

NOISE FILTERS

The same kind of filters can be used at the device creating the disturbance and at the radio receiver. Fundamentally, a noise filter is just like the hum filter used in a power supply. It is arranged to have a high impedance in series with the power line, plus a low impedance across the line to set up a voltage divider to reduce the interference voltage that can travel along the line.

In general, the simplest filter that will work should always be used. Cost and size are important reasons for this. Fig 12 shows the basic types that are used most commonly. They are arranged approximately in their order of effectiveness, that at F being the most effective.

When used to filter the noise source, terminals 1 and 2 connect to the source, and 3 and 4 connect to the power line. When used at the receiver, terminals 3 and 4 connect to the set, and 1 and 2 to the power line.

At A we have nothing but a capacitor across the power line. One side

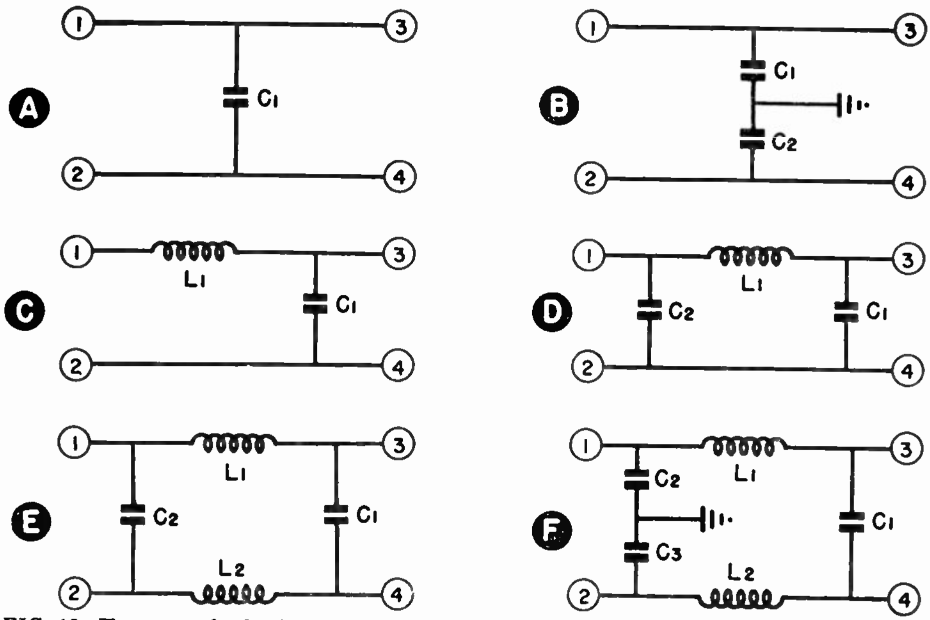


FIG. 12. Here are the basic filter circuits. The parts values for best results should be determined by experiment.

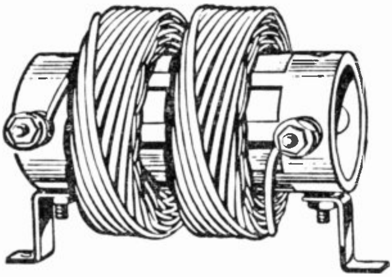
of the power line is grounded; the capacitor offers a low-impedance path between the ungrounded side and the grounded side of the line. If there is enough series impedance in the line or device connected to terminals 1 and 2, a voltage divider action will be set up so that very little of the interference voltage will appear across the low reactance of the capacitor. This reduces the transfer to terminals 3 and 4.

If a 220-volt power line is used to operate the noise source, or if the effectiveness of the ground on the power line is questionable because of extra long lengths of wire, an "artificial ground" filter as at B in Fig. 12 can be used. Here both sides of the power line are connected through capacitors to a short, direct wire to a ground. Essentially, this is the same filter as at A except that it is not necessary for one side of the power line to be grounded.

The filter shown at C is a basic "brute-force" type. Here a choke coil has been placed in the line. This makes a much more effective filter, because we can obtain a high impedance ratio between L1 and C1, so most of the interference voltage will be lost across L1 with little across C1 for transfer to terminals 3 and 4.

The filter shown at D is a capacitor input type. It is better than that at C only when the line or source connected to terminals 1 and 2 has appreciable impedance so that with C2 it forms another filter section.

At E and F are shown examples of filters in which choke coils are placed in both sides of the power line. The one shown at F provides an extra ground connection similar to that shown at B.

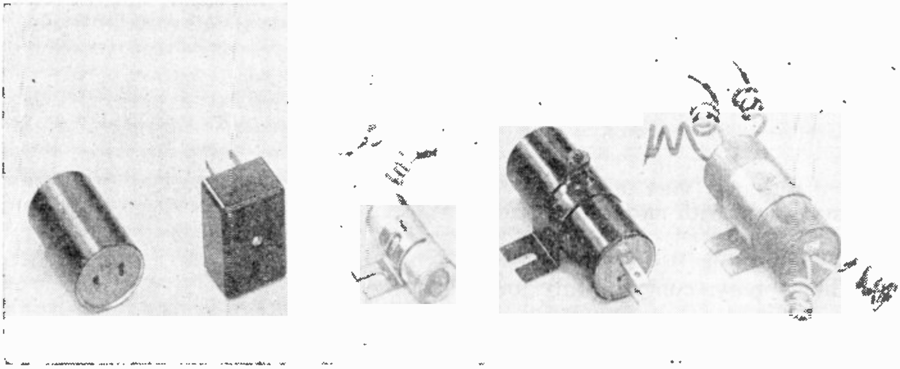


Courtesy J. W. Miller Co.

FIG. 13. A typical interference filter choke.

In most filters the capacitor values are relatively small, ranging from .005 mfd to .5 mfd. The smaller capacitor sizes bypass the rf noise signals to ground better than the larger ones, but if there is a large audio component developed as a part of the interference, then the larger capacitors will be necessary.

The bypass capacitors should be paper with voltage ratings of 600 volts when used on 120 and 240-volt power lines. Electrolytic capacitors are unsatisfactory—they can be used on ac only in a "back-to-back" arrangement; they have relatively short life, and they have too much inductance to be good rf bypass capacitors.



Courtesy P. R. Mallory & Co.

FIG. 14. Several typical interference filters. Each type shown is intended for a specific appliance.

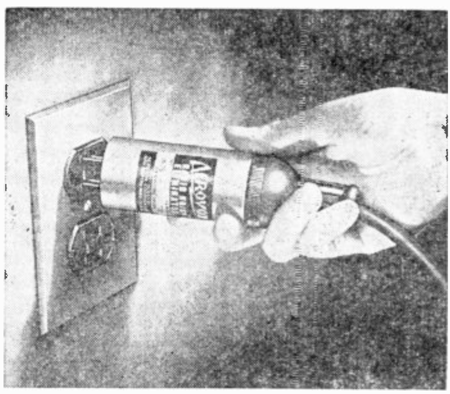
The choke coils used must be made of wire heavy enough to carry the current being drawn. For industrial equipment, very large and rather costly chokes are required.

Since the portion of the interference that causes the most trouble is at rf rather than audio frequencies, air-core chokes rather than iron-core are generally used. This simplifies the problem of insulating the choke for the power-line voltage. Fig 13 shows a typical commercial choke designed for this service. These chokes come with a wide range of inductances. Usually the choke coil with the lowest inductance that will do the job is the one to use because of cost and size. These chokes have the "universal" winding shown in Fig. 13, rather than a layer winding, to reduce the stray capacity between turns that would reduce its effectiveness.

Since the interference voltage across the choke coil is high, it is necessary to shield the filter to prevent radiation from the choke. Also, a metal housing is desirable for safety reasons. Small size and a neat appearance are also desirable, particularly on filters to be used in a home.

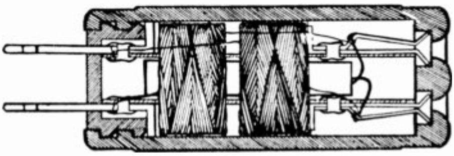
The problem of obtaining a suitable filter is greatly simplified by several of the coil and capacitor manufacturers who have specialized in developing filters for various purposes. The shapes of these filters vary with the application. Fig. 14 shows several typical styles. By purchasing the filter designed to work on the particular appliance, you will get a neat, properly assembled unit at lowest cost.

The plug-in style shown in Fig. 15 is available in models ranging from



Courtesy Aerovox Corp.

FIG. 15. A typical plug-in filter.

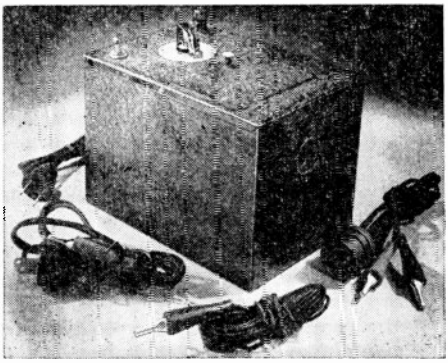


Courtesy J. W. Miller Co.

FIG. 16. A cut-away view of a filter designed to be used with an electric razor.

very simple filters to more elaborate ones. They may contain only one capacitor, or, as shown in the cut-away view in Fig. 16, they may contain a pair of capacitors and two choke coils.

If the correct filter for the particular device is not available, or if you are uncertain what filter type to use, then you can use an interference analyzer to find the proper filter. Fig. 17 shows a typical commercial analyzer. Essentially, this is an arrangement of a number of different filter elements, as shown in Fig. 18. A multi-position switch allows you to try each of the basic filters. For example, in one position of the switch only capacitor C1 is across the line. At other positions of the switch various other elements are added, and there is even a tapped choke-coil arrangement so that different sizes of choke coils can be tried. By starting at the simplest filter arrangement, and then moving to more complex ones, it is possible to determine just how good each filter type is, and thus to determine the cheapest one that will give adequate filtering.



Courtesy Aerovox Corp.

FIG. 17. An interference analyzer containing a number of basic filter units and a switch to combine the units.

Of course, you can try individual capacitors and chokes, but the process is so time-consuming that an interference analyzer of this kind is very desirable if you do much of this kind of work.

The filter used must not interfere with the proper operation of the device it is connected to, and it must meet all safety requirements. Filters installed on industrial equipment come

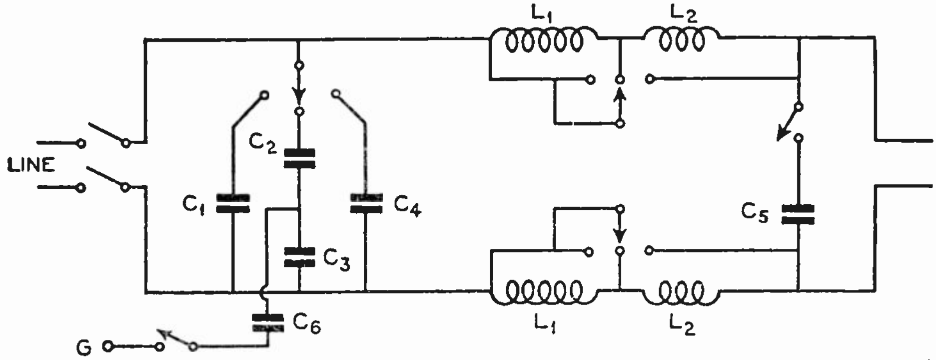
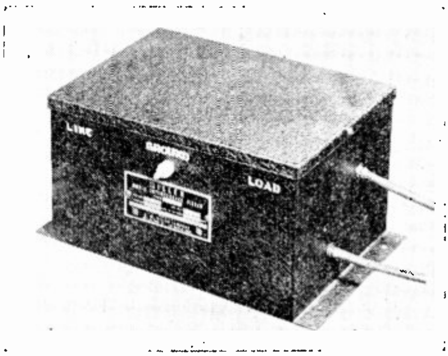


FIG. 18. A simplified schematic of an interference analyzer.



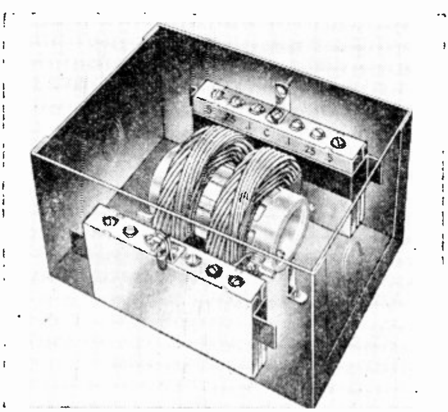
Courtesy J. W. Miller Co.

FIG. 19. Typical housing for an industrial filter unit designed for high-power equipment.

under electrical codes, so it may be necessary to have such a filter installed by a licensed electrician.

Fig. 19 shows the appearance of a large industrial filter case. Fig. 20 shows a view of the inside of one such filter. This one has several different capacitors arranged so that it is possible to try different sizes. In some, however, fixed capacitors are used, and it is assumed that the proper size has been found beforehand.

Switch Filters. In an inductive circuit, there is likely to be excessive



Courtesy J. W. Miller Co.

FIG. 20. A cut-away view showing the interior of an industrial filter.

sparking at a switch contact whenever the circuit is opened. This is a common source of interference, and it also produces excessive burning of the switch contacts and thus leads to short switch life. A capacitor connected across the switch contacts will be helpful in reducing this sparking, but a capacitor-resistor combination as shown in Fig. 21 is better. The sizes are not critical. A capacitor from .05 to .5 mfd can be tried, and the resistor can be 100 to 200 ohms. This same filter can be used with thermostats, relays, and other on-off controls.

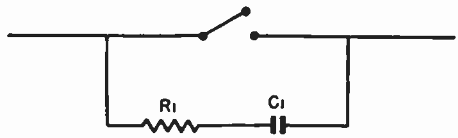


FIG. 21. A typical filter for a set of on-off contacts. This kind of filter can be installed across a switch, relay, or thermostat.

TV INTERFERENCE ELIMINATION

Radio-frequency interference, whether it is from a broadcast station operating in the standard broadcast band or from an FM broadcast station, can usually be kept out of the receiver by means of a suitable stub or trap. Let's look into these devices and see how they can be used to eliminate interference.

Stubs. You already know that a parallel-resonant circuit presents a high impedance across the terminals at the frequency to which the circuit is resonant. We can, therefore, use a parallel-resonant circuit to eliminate an undesired signal by connecting one tuned to the interfering signal, in series with one of the leads to the receiver. Most of the interfering signal will then be dropped across the parallel-resonant circuit, and very little applied to the input of the TV receiver.

If coaxial cable is used to connect the antenna to the receiver, insert the parallel-resonant circuit in series with the ungrounded conductor. If 300-ohm twin lead is used to connect the antenna to the receiver, it is usually worthwhile to install two parallel-resonant circuits, one in each side of the transmission line.

Since a series-resonant circuit acts as a very low resistance at resonance, it can be used to eliminate an undesired signal by connecting it across the antenna terminals of a television receiver and tuning it to the frequency of the interfering signal. The resonant circuit will then act as practically a short across the set terminals as far as the interfering signal is concerned, and the interference will be eliminated completely or greatly reduced.

The series-resonant circuit can be made up of a suitable coil and capacitor, or it can be a piece of transmission line cut to the correct length. This is called a stub. A stub is shown connected across the receiver input terminals in Fig. 22.

There are two types of stubs, the "open" and the "shorted" stub. The shorted stub is about a half wavelength long at the frequency of the signal to be eliminated. The open stub, on the other hand, is approximately one-quarter of a wavelength long.

To make a shorted stub, the ends of a transmission line are stripped clean of insulation, twisted together, and soldered to form a short circuit at the end of the line. An open stub is made simply by cutting off the correct length of transmission line, leaving the ends open. Obviously, an open stub is much easier to make. Furthermore, it is easier to work with, because a stub must be adjusted to the correct length to make it perform properly after it has been connected to the set. It is much simpler just to cut a small piece off the end of an open stub than it is to connect the ends of a shorted stub together again after cutting off a piece.

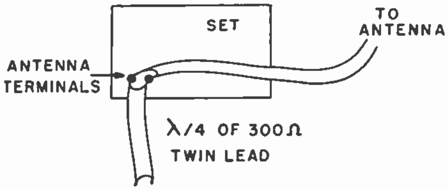


FIG. 22. How a stub is connected to the input terminals of a TV set.

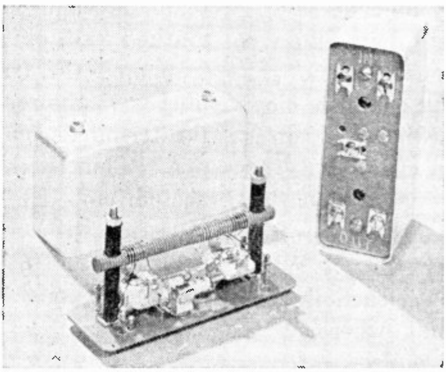
Stubs are frequently used to eliminate interference from a nearby FM station. However, they can be used to eliminate any interfering signal in the VHF or UHF range. A stub is not practical for use in the elimination of low-frequency signals, because it would have to be too long. The following procedure illustrates the method of constructing a stub for the elimination of the interfering FM broadcast signal. However, the same procedure can be used to construct a stub to eliminate either interfering signals.

To make an open stub, the first thing you should do is to determine how long a quarter-wave open stub should be. The FM broadcast stations operate in the band of frequencies from 88 to 108 megacycles. Since the lowest signal will have the longest wavelength, cut the stub for 88 megacycles to start, and then adjust it to the correct length later.

To determine a quarter wavelength at 88 megacycles, use the formula for determining the length in inches for a half wavelength of 300-ohm transmission line $(\frac{5905}{f} \times .82 = \text{length})$, and divide the result by 2 to get the length of a quarter-wave open stub. Thus, the length of the stub at 88 mc is approximately 27 inches. To be sure that the stub is long enough to start with, cut the stub 30 inches long and connect one end of it to the receiver antenna terminals. Note whether or not the stub has any effect on the interference. The chances are that there will be no noticeable reduction of the interfering signal.

The next step is to adjust the stub to the correct length. You can start by cutting off about one inch from the open end of the stub. Continue this procedure until you notice some effect on the interference. As soon as the interference has started to decrease, you should cut off small bits of the stub until you have either completely eliminated the interference or have reduced it as much as possible.

In most cases it will be impossible to eliminate the interference completely. Instead, as you continue to cut off lengths of the stub, you will find that the interference first decreases, then begins to increase again. When this happens, you will have made the stub too short, and you will have to start over again. This time, however, you will know approximately how long the stub should be, and you will be able to recognize when you have made it the length that gives the maximum interference elimination.


Courtesy Crystal Devices Co.
FIG. 23. A commercial wave trap.

During your adjustment of its length, the stub should be placed as nearly as possible in the position that it will occupy after you have finished. Changing the position of the stub frequently has an effect on its performance. Thus, if you stretch it out on the floor in the front of the set for convenience while you are shortening it, you may find that it does not work properly when you place it behind the set. Another reason for not changing the position of the stub as you adjust its length is that its performance can be affected by nearby objects.

The use of a stub may cause a change in the rf response curve of the front end of the set on channels close to the frequency to which the stub is tuned, especially on channel 6. In some cases this may cause smearing in the picture. This effect can often be prevented by inserting a small capacitor in series with each line of the stub at the point where it is fastened to the front end or antenna input of the receiver. A 5-mmf capacitor can usually be used for this purpose if the stub is cut for the FM band; but if the interfering signal is a higher frequency, around 200 mc, you may find that capacitors smaller than 5 mmf are more satisfactory. The addition of capacitors in series with the stub will usually make it necessary to use a longer piece of line for the stub.

WAVE TRAPS

If the station causing the interference has a comparatively low frequency, the transmission line stub may have to be impractically long to eliminate the interference. In such cases, you should use a wave trap tuned to the frequency of the interfering station instead of a stub. Wave traps are even used for some of the higher-frequency stations to avoid the need for having an extra piece of transmission line hanging from the set. Commercial wave traps are available; one is illustrated in Fig. 23.

Electrically, the wave trap may take one of several different forms. Fig. 24A is a schematic diagram of the commercial wave trap in Fig. 23.

The transmission line from the antenna is connected to the terminals marked "in" or "input" on the wave trap, and the transmission line running from the receiver is connected to the terminals marked "out" or "output." Thus, with the wave trap connected, coils L1 and L3 are inserted in series with the transmission line. Coil L2, tuned by capacitor C1, is coupled to coil L1; and coil L4, tuned

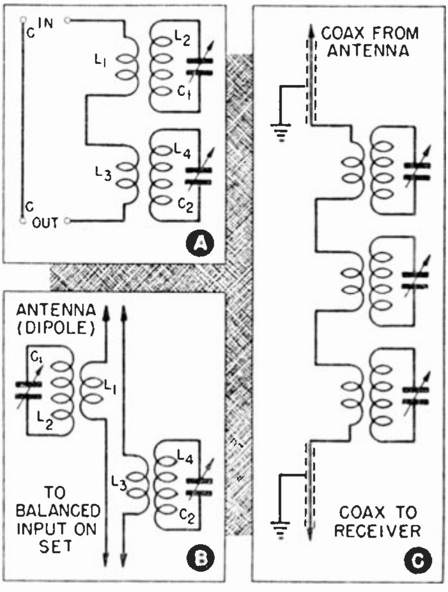


FIG. 24. Three forms of absorption wave trap.

by capacitor C2, is coupled to L3. L2-C1 and L4-C2 act as absorption wave traps, absorbing energy from the line at the frequency to which they are tuned. To use this trap, therefore, all you need do is insert it in the transmission line and adjust C1 and C2 until the interference is minimized.

Slightly different arrangements of absorption wave traps are shown in Figs. 24B and 24C.

A series-resonant wave trap that is connected directly across the antenna input terminals is shown in Fig. 25. Electrically, this is approximately the same as the quarter-wave open stub with each conductor of the transmission line. Since each wave trap has a very high impedance at its resonant frequency, most of the interfering signal will be dropped across the traps, and very little will be applied to the receiver input terminals.

SPECIAL INTERFERENCE INSTALLATIONS

To indicate how some special power line filter units are used, and to show how the problems have been explored by filter manufacturers, let's consider several typical examples of filter installations.

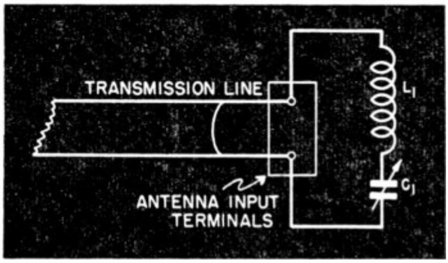


FIG. 25. A series resonant wave trap. As the text shows, this is often not as effective as an absorption trap.

or the half-wave shorted stub previously described. A wave trap of this type is often not as effective as an absorption trap, because the attenuation it produces in the undesired signal depends upon how low its impedance becomes at resonance in comparison to that of the receiver. Since the input impedance of a receiver is comparatively low, a series trap may not be able to produce a low enough impedance to produce sufficient attenuation of the undesired signal.

Fig. 26 shows how parallel-resonant wave traps can be used. Notice that a trap is connected directly in series

Fluorescent Lamps. Fluorescent lamps cause severe interference to reception if the receiver or its antenna lead-in is close to the fixture, or if the fixture is not properly installed. It has been found that, in general, direct radiation from the lamp is negligible beyond ten feet, so if the receiver can be kept at least this far from the fluorescent lamp, direct radiation from it should not be troublesome.

However, most fluorescent lamps are in metal fixtures, and it is very important that a good ground be used on the fixture. Usually the BX cable armor or the conduit in which the power wires are placed is depended upon to provide the ground. If the fixture makes poor contact at the outlet box, or there is a poor connection between this box and the eventual ground point for the electrical system, then considerable radiation will occur, and interference pulses will be transferred to the power line. Before trying a filter, have an electrician go over the electrical system to check on the grounding.

A built-in interference-eliminating capacitor is found in most modern starter units used with fluorescent lamps, but some of the older starters may not have had such capacitors. Furthermore, the filtering obtained this way may not be enough for some conditions. In such cases a line filter can be used between the lamp connections and the power line. Since it is impossible to tell exactly what kind of filter will work in every case, it may be necessary to try several different ones. Manufacturers of interference filters make different models. Fig. 27 shows the diagrams of three typical filters.

Notice that in each case the filter is shielded, and that this shield must be grounded. If the filter is of the kind that grounds to the frame holding the lamp, then the frame must also be well grounded.

Oil Burners. Oil burners cause interference in two ways. They contain a pump or blower assembly operated by a motor, which may cause interference as any other motor may. In addition, many oil burners use electrical ignition systems to light the fuel. These systems consist essentially of a transformer designed to develop a high voltage, and a spark gap arrangement somewhat similar to the spark plug used in an automobile. Like all spark-discharge devices, this ignition system can cause severe interference.

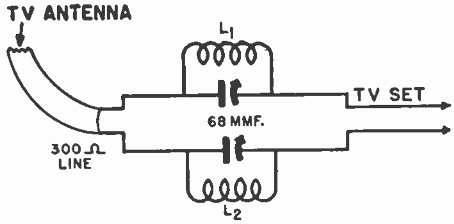


FIG. 26. A pair of parallel resonant wave traps. The inductance and capacity should be chosen to make the traps resonant at the frequency of the interfering signal.

With modern oil burners, the high-voltage leads to the spark gap are carefully shielded to cut down the radiation from them, and the transformer is shielded and filtered. However, on some of the older models you may find that no particular care was taken to prevent interference.

On a device of this kind, it is very important that nothing be done to prevent the electrodes from sparking properly, because a dangerous condition, possibly leading to an explosion,

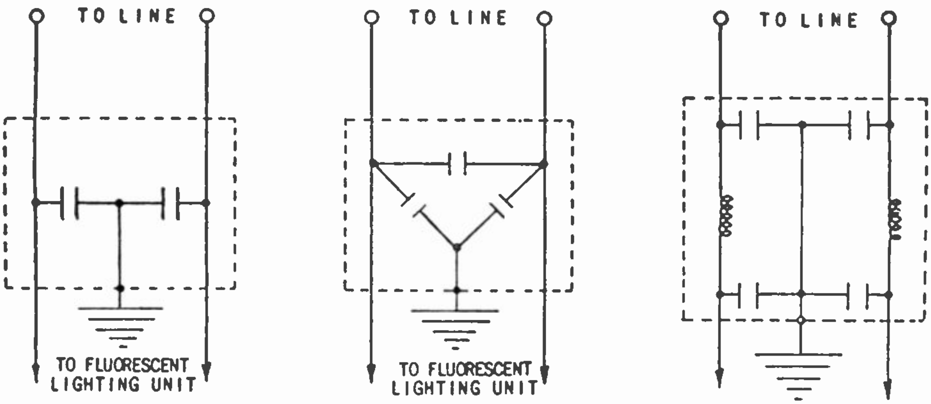


FIG. 27. Circuits of typical fluorescent light filters.

can exist through faulty firing of the furnace.

Practically all oil burner manufacturers are aware of the noise problem. If you find a poorly filtered unit, contact the local distributor or the manufacturer of the oil burner. They have either complete conversion kits that in effect install new wiring, or filters that work satisfactorily on their units.

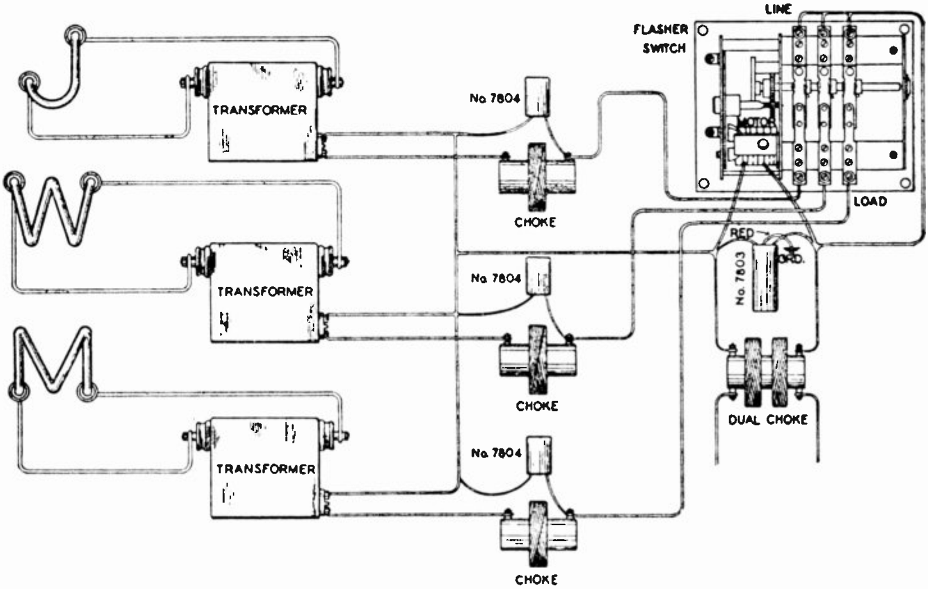
Neon Signs. Most of the interference that is developed by neon signs comes from the high-voltage discharge through the neon tubing. Direct radiation may occur, but the interference field generally dies out within a few yards.

However, practically all neon signs are mounted in metal frames, and if these frames are not properly grounded, the radiated interference from the frame is severe over a wide area. Likewise, some of this interference may get onto the power line and travel along it.

When you find interference which is obviously due to a neon sign, it is best to contact the people who installed the sign rather than to work on it yourself. Very high voltages are produced on these devices, and it is best to have someone familiar with the characteristics of the sign install the proper filters. Actually, with such devices, the improper installation of chokes and capacitors in the high-voltage circuit may even increase the interference instead of reducing it.

Much of the interference produced by neon signs is caused by dirt and dust collections along the tubing, which provide leakage paths. Therefore, carefully cleaning the sign will frequently reduce the interference. Grounding the surface of the tubing is also helpful. A ground can be made by wrapping a small piece of tin foil around the tubing at its center point, and running a ground wire from this foil to the metal frame. However, this should be done only by an expert on neon signs, so as to avoid causing trouble with its operation.

Finally, if it is necessary to install filters, they should be installed in the power line leading to the sign rather than in the sign wiring itself. Fig. 28 shows a typical filter installation, as



Courtesy J. W. Miller Co.

FIG. 28. Schematic showing the filter connections for a low-tension neon sign installation.

recommended by manufacturers specializing in this field.

SHIELDING

There are some devices whose very nature makes it impossible to do a perfect filtering job. Diathermy equipment is a good example. If the proper filter does not clear up the interference, it is sometimes necessary to shield the apparatus. However, since the plates and coils used for medical treatment may also radiate, it is necessary to provide room *within* the shield large enough for the patient and the doctor.

Essentially, a shield cage of this type consists of two layers of copper screen wire, carefully insulated from each other. The inner layer is connected to the outer layer and to a ground in a special way so as to make the shield effective. Filters are used in all power lines that come into the shielded cage. Such shielding is rather expensive, so it is usually not installed except as a last resort.

TV Sweep Radiation. Radiation from the horizontal sweep circuit of a TV set may cause interference with a nearby AM radio. The radiation occurs from the deflection yoke and the circuits associated with it. Sometimes a filter installed in the TV set power line will prevent radiation this way, but usually the trouble occurs because of direct radiation from the yoke. Careful shielding of the yoke itself and the wires going to it has been the best cure found to date, but the kind of shielding necessary varies with the TV receiver and its layout. Many set manufacturers are aware of this problem, and, if a case of this kind is found, it is sometimes possible to get factory information and, occasionally, a complete shielding kit for the elimination of the interference.

NOISE-REDUCING ANTENNAS

Most interference is produced in a relatively limited area, hence in those cases where the receiver is operating from an outside antenna, it is sometimes possible to erect the antenna itself far enough away from the noise source so that little noise energy is picked up. A noise-cancelling lead-in between the antenna and the receiver should also be used.

For AM receivers the lead-in usually consists of a twisted pair of wires. Equal interference voltages are induced in both lead-in wires. By connecting the input of the receiver as shown in Fig. 29, it is possible to cause the interference signals to be equal and to travel in opposite directions through the primary coil and thus cancel transfer of interference signals to the receiver.

Television receivers ordinarily use either a pair of parallel wires, or a shielded transmission line. In either instance there is little interference pickup. Where the pickup is excessive, the shielded transmission line is somewhat better than the twin-lead transmission line. However, the shielded line cannot always be used because of impedance-matching problems and increased signal loss.

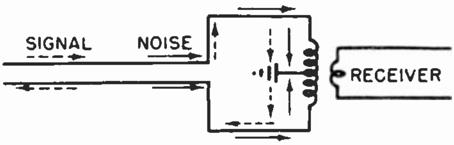


FIG. 29. How noise signals induced in the two wires of a transmission line will cancel because they flow in opposite directions through the primary, and hence induce no voltage in the secondary. The dotted arrows show the desired signal current from the antenna. Because this current circulates, it will not be cancelled.

SUMMARY

In this lesson you learned the probable causes of noise and other types of interference in radio and TV receivers. You also learned how to recognize the various types, and what steps to take to eliminate or reduce them. Any device producing interference signals must be repaired, filtered, grounded, or shielded, depending on the device producing the interference.

After you find the interference source, the owner of the device will in most instances give you his full cooperation in eliminating the noises. However, you may find that everyone is not so cooperative. If this happens, and all your attempts to get his help fail, as a last resort write to the Federal Communications Commission, Washington 25, D. C. In your letter give the location of the interference source, the owner's name and the names and addresses of the people whose receivers are being interfered with. Be sure to sign the letter and give your own name and address. The FCC will make a complete check to see if the amount of interference is higher than that allowed by the regulations. If it is, they will give notice that the interference must be cleared up in a specified length of time.

Lesson Questions

Be sure to number your Answer Sheet 45B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. What characteristic of the waveform of a noise signal permits it to interfere with radio and TV receivers?

2. Which of the following will cause the interference signal to increase if installed in a switch circuit: (1) a capacitor; (2) an inductance; (3) a resistor?

3. If a noise signal shock-excites a resonant circuit, what will the resultant frequency be?

4. How can you tell by observing the pattern on a TV tube screen whether the frequency of the interfering signal is above or below 15,750 cycles?

5. If you are called in to repair a receiver having a complaint of noisy reception, what is the first thing you should find out?

6. What would you use to eliminate power line interference picked up by the antenna?

7. Does a quarter-wave open stub act as a series-resonant circuit or a parallel-resonant circuit?

8. Under what conditions would you use a wave trap in preference to a stub, and why?

9. Which circuits of a TV set produce interference in AM radio receivers, and how can you eliminate the interference?

10. Why must air-core chokes be used instead of iron-core chokes in the power-line filter circuits?

WASTED TIME

A minute seems such a little thing—something most of us thoughtlessly throw away. But, just as pennies make dollars, so do minutes make hours. Few people realize that ten minutes wasted daily make over sixty hours—more than a work-week—in a year's time.

Study the habits of most successful men and you will find that they made use of odd moments, reading or writing, or *thinking*. Those precious minutes gave them the *extra* weeks, months, and years of time necessary to prepare and to advance themselves.

Now, time spent in healthful recreation is not being wasted. But, how much of your time is spent in idle amusements instead? How much time do you waste "stalling" before starting a task—doing unnecessary or useless things—or doing nothing at all?

Study your actions during the day. Make a list of the things you do. You'll be surprised at the number of five- or ten-minute intervals you can put to better use, in studying or planning for the future. Be ready for your opportunity when it comes!

J. E. Smith

PUBLIC ADDRESS SYSTEMS, INSTALLATION, AND SERVICE

REFERENCE TEXT 45BX

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE

FM3M660 **1960 Edition** Printed in U.S.A.

PUBLIC ADDRESS SYSTEMS, INSTALLATION, AND SERVICE

WHEN you are called on to install a PA system, the first thing to do is to look over the installation and see what will be required. Find out whether the system is to be used indoors or outdoors. If it is to be indoors, the wattage rating of the amplifier and the number of loudspeakers to be used will depend on the size of the auditorium or room. If it is to be outdoors, it will require more power to cover the same area.

The amount of amplifier output power needed to fill a given indoor area with sound also depends on the noise level and the acoustical characteristics of the area; the higher the noise level, the more power needed to over-ride the noise. The acoustical characteristics depend upon the material on the walls and ceiling. The more sound-absorbing material used, the more power required to get the same sound level. You will have to consider these factors in each PA installation. You will probably never actually have to calculate the sound-absorption quality of a room; charts and tables are available that will enable you to get a rough estimate of the sound power needed. This is all that is usually required.

Finally, find out what type of program material will be sent over the system and the type of sound source that will be used, whether microphone, phono pickup, tape head, or tuner. With this information, you will be able to choose the amplifier and the other components to meet these requirements.

In this lesson, you will find out how to determine the amplifier rating, and learn how to place microphones and loudspeakers to get the best sound coverage. Next, you will study low, medium, and high-power amplifier circuits. Then you will study typical examples of public address systems. These include multi-outlet distribution systems like those used in factories, hotels, and schools, and several types of specialized systems. Finally, you will learn how to service and maintain PA systems. The circuits in the PA amplifiers are basically similar to those found in the audio stages of radio and TV sets, so you can use many of the same servicing procedures on both types of equipment. In a PA installation, the important thing is to prevent a complete failure by periodically checking the entire system. The procedure to follow is discussed in the last section of this lesson.

Power Requirements

One of the first things to consider in planning a PA installation is the way the physical surroundings of the installation will affect the sound waves. We call this the "acoustics" of the area. Let us see how acoustical characteristics affect power requirements.

ACOUSTICAL CHARACTERISTICS

When sound strikes an object, part of its energy is absorbed by the object, and the rest is reflected. A smooth, hard surface such as plaster reflects more energy than it absorbs. Soft porous materials such as carpets and Celotex absorb more energy than they reflect.

The sound-absorbing qualities of various types of material are given in Fig. 1. A coefficient of 1 means that the sound energy is entirely absorbed; an example of this is an open window. Some sound reflection is desirable, but too much can cause trouble.

When the surfaces of a room are hard and smooth, sound reflections will occur and recur so that it takes a certain interval of time for the sound to die out. As shown in Fig. 2, the walls of the enclosure prevent the sound energy from escaping and reflect it back and forth. The sound, therefore, reaches the listener over more than one path.

Materials	*Coefficients*
Floor Coverings:	
Carpet	**.20**
Cork flooring	**.08**
Linoleum	**.03**
Rug, Axminster	**.20**
Wood flooring	**.03**
Hangings:	
Fabrics:	
Light	**.11**
Medium	**.13**
Heavy	**.50**
Hard Wall:	
Brick, painted	**.017**
Cement	**.025**
Plaster on lath	**.03**
Openings:	
Window	**.5—1**
Balcony	**.5—1**
Audience and Chairs:	
People	**3—4.3**
Chairs, wooden	**.17**
Chairs, upholstered	**1.6**
Acoustic Materials:	
Acousti-Celotex C-2	**.67**
Acousti-Celotex C-4	**.99**
Acoustone F	**.87**
Fiberglas Tile (1")	**.97**
Permacoustic (1")	**.71**

FIG. 1. The absorption coefficients of various materials. The figures given for audience and chairs are in terms of absorption units per person or per chair; the other figures are for absorption units per square foot. These units were determined at 512 cycles. The absorption at other frequencies differs somewhat, usually, though not always, increasing at higher frequencies.

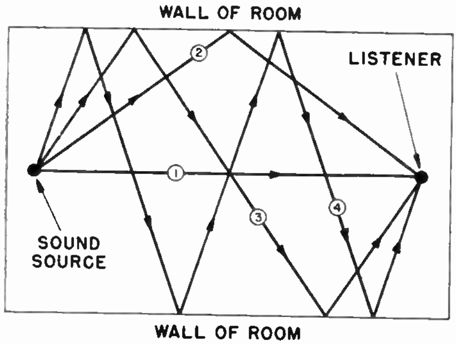


FIG. 2. The direct sound wave between the source and the listener travels over path 1, which is the shortest path between these two points. Waves traveling over paths 2, 3, or 4 must go a greater distance to reach the listener, and consequently arrive somewhat later than those taking path 1.

In Fig. 2, the direct sound wave is shown by path 1. Paths 2, 3, and 4 show the influence of the reflective surfaces on the paths taken by the sound to reach the listener. Since some paths are longer than others, the over-all effect is to prolong the sound; it takes a certain interval of time for the sound to die out. This is called the reverberation time.

If the reverberation time in a room is too long, the sound information will blend together, and the intelligibility will be reduced. On the other hand, if the reverberation time of a room is too short, the room will be "dead" acoustically, and music and speech will sound flat. A certain amount of reverberation makes a room "alive," and adds brilliance and richness to the quality of the sound.

In an auditorium or hall, the amount of reverberation and liveness depends on the treatment of the walls and the construction of the room. A reverberation or die-out time of approximately 2 seconds provides the proper liveness for a large auditorium. For the most intelligible speech, the reverberation time should be approximately one-half to two-thirds of this.

The shape and size of the room also must be considered in planning a public-address installation. For example, the auditorium shown in cross-section Fig. 3 is shaped so that the sound paths tend to concentrate the sound at a spot in the balcony. This is called a focal point. If the sound waves arrive in phase at this location, the sound will be excessive. It is also possible for the shape of a room to cause dead spots. Here the phases of the sound waves arriving along different paths are such that there is a cancellation effect. Such spotty responses are common in large auditoriums, rather than small rooms.

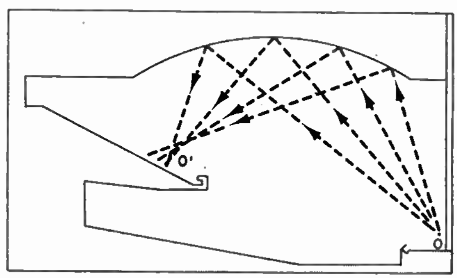


FIG. 3. Sounds reflecting from various points on the curved ceiling of this auditorium are brought to a focus at a single small area in the balcony, making the volume level there considerably higher than it is elsewhere.

A room can be treated acoustically to break up the reflection points and prevent excessive reverberation, focal points, and dead spots. However, the cost of such acoustical treatment may be more than the customer will want to pay. Your responsibility, then, is to place the loudspeakers so that you will get the most even distribution of sound with the least sound interference.

If the customer is willing to have the auditorium or hall treated acoustically, you should have the work done by someone who is familiar with the materials used for that purpose. Call in an engineer or a representative of a company manufacturing sound-absorbing materials for consultation. Do not try to do the job yourself unless you have had considerable experience in this type of work.

In making a PA installation in a large auditorium or hall, always make spot checks throughout the seating area to be sure there are no severe dead spots. Likewise, if reverberation is high and intelligibility is seriously affected, place the loudspeakers so that the sound is directed toward areas where reflections do not occur or where reflections cannot seriously affect the over-all intelligibility.

For example, you can place directional loudspeakers over the stage. This will sometimes help to deaden a hall with a high reverberation factor. To reduce wall and ceiling reflections, tilt the speakers forward so that the sound is directed down over the heads of the audience. People filling the hall will reduce floor reflections.

In small halls, reverberation does not build up to as high a level, and the area is not large enough to develop serious focal points and dead spots. In treating a small hall, the sound-absorbing material is usually placed in the rear of the room. The front and side areas near the sound source are used as reflective surfaces; the sound energy reflected from the walls is used to improve the sound level at the rear of the room. Often the ceiling, if it is low, is allowed to remain a reflective surface and the walls at the side and rear are treated. The ceiling can be used to reflect the sound down over the audience all the way to the rear of the room. At the same time multiple reflections will not occur, and reverberation will not be objectionable.

NOISE LEVELS

Every location has a certain amount of background noise. Most of the time we do not notice it because it is a normal part of the location. Nevertheless, you must consider the noise level in planning a public address installation; it has an influence on the amount of amplifier power output needed to fill the area with sound.

Sound levels of various common noises, and the noise levels found in typical places where PA systems may be used are shown in Fig. 4. The levels are given in terms of human ear response. The threshold of hearing is represented as the reference level of zero db, and the threshold of painful sound is 130 db above this reference level.

Notice that the noise level in the average quiet home is about 35 db above the threshold of hearing. Since the average conversational level is about 60 db, no amplification is needed to overcome the noises in a home. Public address systems are needed only where the noise level is above that of the desired sound. The average sound level for speech should be maintained at least 10 db above the surrounding noise level. This may not be practical in locations where the noise level is near the threshold of pain. Fortunately, such locations are not common.

If musical programs are to be sent over the PA system, the sound should be from 15 to 25 db above the noise. A high-fidelity reproduction of symphonic music should maintain an average of 35 db above noise level.

You must measure or estimate the noise levels in order to determine the audio power requirements for a given installation. Sound measuring instruments are expensive, and the measurement techniques become very tedious. The tests must, of course, be made when conditions and crowds are the same as they will be when the public address system is in operation.

For most PA installations, you can get reasonably satisfactory results by estimating the noise level from a chart like that shown in Fig. 4. Other types of charts are also available from manufacturers of public address equipment (especially those that manufacture public address loudspeakers). Often the manufacturer's charts recommend specific speaker types best suited for particular noise conditions.

Let us see how you would use the chart in Fig. 4. Suppose you want to install a PA system in a ballroom. The chart shows that the average noise level is 80 db. Thus, 90 db of audio power should be used for speech, and 95 to 105 db should be used for music reproduction. (Remember, this is the acoustic power needed—not the amplifier output power. You use this figure to calculate the amplifier power in watts.) Of course, this is only a rough estimate; the actual noise level will depend on the location.

Type of Sound Source	*DB Level*
Threshold of painful sound	130
Hammer blows on steel	120
Riveting machine	100
Factory (very noisy)	90
Machine Shop (average)	90
Heavy street traffic	85
Printing Press	80
Ball Rooms	80
Restaurant (noisy)	80
Factory (average)	75
R.R. waiting room	75
Auditorium (average)	75
Office (busy)	65
Department store (average)	65
Auditorium (quiet)	65
Ordinary conversation	60
Quiet residential street	60
Restaurant (average)	60
Store (quiet)	60
Office (quiet)	60
Hotel lobby	55
Hospitals	55
Average quiet residence	35
Quiet garden	25
Average whisper	20
Rustle of leaves in gentle breeze	10
Threshold of hearing	0

FIG. 4. These are the levels in db above the threshold of hearing of various common sounds and noises. The figures have been compiled from several sources.

The power required also depends on the room acoustics. If it is a very live room, the sound will be dispensed to all sections of the room, so less output is needed to fill the room with sound. A dead room which is highly absorbent and has a low reverberation factor requires a greater power output to obtain full coverage. However, keep in mind that too much liveness or a high reverberation factor affects the intelligibility of the audio information.

ACOUSTICAL POWER

Before we can figure out how much electrical power we need for a particular location, we must find out how much acoustical power is needed; that is, how much power the loudspeaker needs to give out. Then we can figure out how much power needs to be delivered to the speaker for it to give this output.

The acoustical power needed in a particular indoor application depends not only on the noise level, but also on the size of the room. Typical acoustical wattages for various noise levels and room sizes are shown in the chart of Fig. 5. Notice that the chart is divided into two parts—one for speech only, and another for both speech and music. We have shown only some noise levels. You can fill in the lower and higher noise levels by dividing or multiplying the acoustic powers by 10 for each 10-db decrease or increase in noise.

To use the chart, first find the area of the room in square feet by multiplying the length by the width. Then find the approximate height from the floor to the ceiling. From the chart, find the noise level that is average for the particular location. With this information, you can find the acoustic power you will need.

Now, you want to know the wattage rating the amplifier should have to produce the required acoustic power. Before you can convert acoustic power into electrical power, you must know the efficiencies of the loudspeakers you intend to use. Cone loudspeakers are usually considered to be 2% efficient when installed in baffles, and 5% in projectors. Large horn loudspeakers have efficiencies up to 30 or 40%. By dividing the acoustic power in watts by the speaker efficiency expressed as a decimal, you will find the electrical power needed.

For example, let us find the suggested acoustical power for a noise level of 80 db for a room area of 2000 to 5000 sq ft. The ceiling height is about 15 ft. As shown in Fig. 5, to cover this area with speech and music

Noise Level (db) Above Threshold of Hearing	*Area (sq. ft.)* 500-2000 *Assumed Room Height (ft.)* 10-15	*Area (sq. ft.)* 2000-5000 *Assumed Room Height (ft.)* 15-20	*Area (sq. ft.)* 5000-10,000 *Assumed Room Height (ft.)* 20-25	*Area (sq. ft.)* 10,000-30,000 *Assumed Room Height (ft.)* 25-35	*Area (sq. ft.)* 30,000-70,000 *Assumed Room Height (ft.)* 35-50
			SPEECH ONLY		
70	**0.001-0.004**	**0.004-0.010**	**0.010-0.019**	**0.019-0.056**	**0.056-0.126**
80	**0.012-0.044**	**0.044-0.100**	**0.100-0.199**	**0.199-0.562**	**0.562-1.26**
90	**0.126-0.447**	**0.447-1.0**	**1.0-1.99**	**1.99-5.62**	**5.62-12.6**
100	**1.26-4.47**	**4.47-10.0**	**10.0-19.9**	**19.9-56.2**	
			SPEECH AND MUSIC		
70	**0.039-0.141**	**0.141-0.316**	**0.316-0.631**	**0.631-1.78**	**1.78-3.98**
80	**0.398-1.41**	**1.41-3.16**	**3.16-6.31**	**6.31-17.8**	**17.8-39.8**
90	**3.98-14.1**	**14.1-31.6**	**31.6-63.1**		

Courtesy John F. Rider

FIG. 5. Minimum acoustic power required to override noise for normal PA requirements for sound reproduction in indoor coverage areas indicated. Areas are in square feet.

Noise Level (db)	10-30 ft.	30-75 ft.	75-150 ft.	150-300 ft.	300-500 ft.	500-1000 ft.
70	0.002-0.017	0.017-0.112	0.112-0.501	0.501-1.78	1.78-5.01	5.01-20.0
80	0.020-0.178	0.178-1.12	1.12-5.01	5.01-17.8	17.8-50.1	
90	0.200-1.78	1.78-11.2	11.2-50.1			
100	2.0-17.8	17.8-112				

Courtesy John F. Rider

FIG. 6. Minimum acoustic power required to override noise for reproduction of speech outdoors for coverage of indicated distance in feet. A coverage angle of 30° is assumed. More power is required if larger angles of coverage are used.

requires an acoustical power somewhere between 1.5 and 3 watts. Let us assume that the recommended acoustical power is approximately 2 watts. If the speaker efficiency is 5%, the amplifier output wattage would have to be 40 watts (2 watts ÷ .05 = 40 watts).

As you can see, a considerable amplifier output is required to obtain a rather low acoustical wattage. Of course, if you use a more efficient loudspeaker, the amplifier wattage rating can be less.

In outdoor public address work, there is no reverberation problem, but there is the problem of the very rapid attenuation of sound. Since there are no walls to reflect energy back to the audience area, sound power decreases rapidly (6 db for each doubling of the distance between loudspeaker and listeners). As a result, horn loudspeakers because of their higher efficiency are preferable for most outdoor installations. In general, they are more rugged than the conventional cone speakers. Likewise, the horns can be shaped to give the necessary coverage angles to make the most efficient use of the audio power by directing it specifically into the listening area only. Often a group of narrow-angle horns are used to give effective coverage of a wide area and overcome high noise levels better.

As shown in the chart in Fig. 6, the acoustic power needed outdoors is far higher than that needed indoors. Notice that the chart is for a coverage angle of 30 degrees. The power must be higher if a wider coverage angle is required. Compute the amplifier wattage rating in the same way as described for the indoor installation.

PLACING LOUDSPEAKERS

After you have found the power output requirements of the amplifier, the next step is to place the loudspeaker or loudspeakers to get the best coverage of the area to be filled with sound. Cone speakers are available with power-handling capacities from as low as 1 watt to about 40 watts. If the required power level is so high that it cannot be handled by one speaker, you will have to use several to divide the power load properly. Often a given area can be covered more efficiently with two low-wattage speakers than with a single high-wattage speaker. This technique is also effective in eliminating acoustical dead spots and focal points in a large hall or auditorium.

In very large installations, most of the power load is handled by several large speakers. Smaller speakers can be used to cover particular dead spots or small areas off the main auditorium. Multiple speaker installations also are used in hotels, hospitals, factories, and other locations where more than one area must be covered. In this type of installation, the sizes of the loudspeakers will depend on the area sizes. For example, in a hotel installation, a group of high-powered speakers can be used in the ballroom and lobby, and individual smaller speakers in each guest room.

When the loudspeakers are installed in the same room in which the performance is occurring, you should put the loudspeakers somewhere near the source of sound so that the audience will have the feeling that the sound is coming from the source. Generally, the loudspeakers are placed slightly ahead of the microphones to minimize acoustical feedback howl between the microphones and the loudspeakers. A speaker that is baffled or mounted as a directional horn is more effective in minimizing feedback, because it is completely enclosed, and has very little side and back radiation.

Directional and baffle-mounted speakers must be positioned carefully to provide the best coverage. Usually these speakers have a wide coverage angle at low audio frequencies, but a narrower coverage for the middle and high-frequency ranges. Place the speakers so that the middle and high-frequency response is as uniform as possible over the area to be covered. Generally, two loudspeakers, one above the stage, to the right and one to the left, directed downward toward the audience are better than a single speaker. If there are loudspeakers along the side walls, they should never be more than 40 feet apart to prevent echo effect.

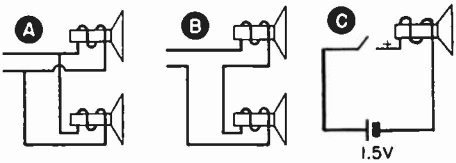


FIG. 7. Connecting loudspeakers in phase. A, parallel connection; B, series connection; C, finding polarity of speaker.

LOUDSPEAKER PHASING

When more than one loudspeaker is used in a PA installation, the voice coils must be connected so that the loudspeakers operate in phase. One method of checking the phase is by listening. With one person in the center of the audience area, a second person reverses the leads to one pair of speaker terminals. When the speakers are connected out of phase, there will be a cancellation effect in the audience area; sound reinforcement will result when they are in phase.

When the loudspeakers are identical and made by the same manufacturer, you can usually assume that the connections from the voice coil to the terminals on the loudspeaker are the same on each speaker. Thus, you can connect similar terminals together when the loudspeakers are in parallel, as shown in Fig. 7A. An in-phase series connection is shown in Fig. 7B.

When the speakers are not identical, you can use a listening check or you can use a 1.5-volt dry cell battery to check the motion of the cone, as shown in Fig. 7C. Mark the speaker terminals according to which way the cone moves. It is customary to mark the speaker terminal "plus" that causes a forward motion of the speaker cone when the positive terminal of the battery is connected to it. Once the markings have been made on the speaker terminals, they can be used time and time again with the certainty that all loudspeakers will be phased correctly.

PLACING MICROPHONES

The position of the microphone with respect to the loudspeakers, performers, and audience is important in all PA installations. If only voice is being picked up, it is common practice to place the microphone directly in front of the person who is speaking. If it can be done tactfully, people should be told to speak over the microphones instead of into them. Likewise, it is not advisable to speak too close to high-quality microphones, such as expensive dynamic and velocity ones.

Close-speaking microphones should be used in noisy locations and the speaker should not be permitted to wander too far away from the microphone. Directional microphones are also used in noisy locations, because they can be designed to have minimum pickup from a noisy audience or machinery.

Stage and orchestral pickups generally require anywhere from one to four microphones. The microphones can be placed near the footlights of the stage or suspended above the stage. Suspended microphones are not as subject to vibrations and stray noise pickup as those on the stage. So if there is anything to cause vibrations, such as an organ or percussion instruments, a suspended microphone is definitely superior.

The suspended microphone also removes the hazards of tripping over microphone cords or knocking over microphone stands. It must be emphasized that all microphone and loudspeaker lines as well as ac lines should be sheltered as much as possible to prevent interruption, damage to equipment, or injury to someone.

Some typical examples of good microphone placement are shown in Fig. 8. In Fig. 8A a microphone having a bi-directional, figure-eight pattern is used to pick up equal sound from two pianos. In Fig. 8B, a single microphone is used and instruments are placed so that the weaker string instruments are nearest the microphone. Next are the intermediate, and finally the bass strings.

Typical placement for a small dance orchestra is shown in Fig. 8C. Here individual microphones are used

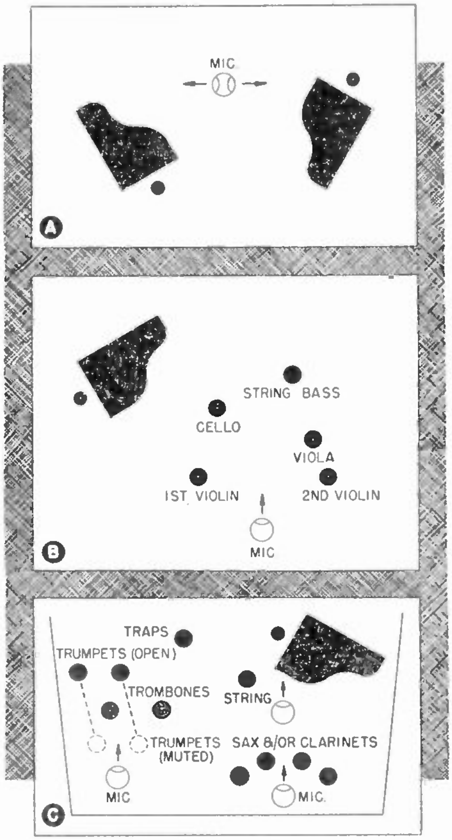


FIG. 8. Practical microphone placements for picking up (A) a 2-piano team, (B) a small salon orchestra, and (C) a dance orchestra.

for the brass, woodwind, and string and percussion instruments. The main advantage of a multiple-microphone installation is that the level of each microphone channel can be adjusted to obtain proper musical balance.

One factor that should always be considered is the proper balance between voice and instrumental accompaniment. If one microphone is used, the singer's voice may be almost hidden by the orchestra. The best method is to use separate microphones for the singer and the musical accompaniment, and adjust the gain as necessary.

Remember that installing a system and operating it properly are two different things. No matter how well a system is planned and installed, the customer will not get best results unless it is operated correctly. Unfortunately the microphone levels cannot be adjusted, in most cases, from the back-stage operating position of the public address amplifier. Adjustments should be pre-set during rehearsal or, if they must be set during the program, you should have someone out in the audience to help you establish the correct levels. If you are not to operate the system, you must instruct some responsible person as to its operation.

Commercial PA Systems

Public address amplifiers range in size from about 8 watts to over 50 watts. The basic circuits are the same regardless of the power, but the sizes and ratings of the parts vary according to the power requirements.

There are also differences in some of the amplifier circuits to meet the needs of different installations and the components to be used with the amplifier. For example, the amplifier may have three or more microphone inputs and one or two inputs for phonographs, tape heads, or tuners. The amplifiers usually contain tone controls, and some have provisions to regulate the amount of acoustic feedback. We will discuss some typical amplifier circuits in this section beginning with the low power units used in portable and semi-permanent PA systems; then we will take up medium-power installations; and, finally, high-power installations.

LOW-POWER PA AMPLIFIERS

Low-power PA amplifiers have output wattage ratings of between 8 and 15 watts, and are provided with at least one microphone and one phonograph input. A typical portable 15-watt system is shown in Fig. 9. The amplifier, phonograph, microphone, and two loudspeakers are enclosed in a carrying case so that they can be moved easily from one place to another. If the system in Fig. 9 is used for a semi-permanent installation, the speakers and transmission lines are mounted permanently; the amplifier and microphone can be brought in and connected when they are needed.

A schematic diagram of this amplifier is shown in Fig. 10. Notice that the microphone preamplifier and phonograph input circuits are similar to those described in an earlier lesson. The output of the microphone ampli-

Courtesy Lafayette Radio

FIG. 9. A 15-watt PA system.

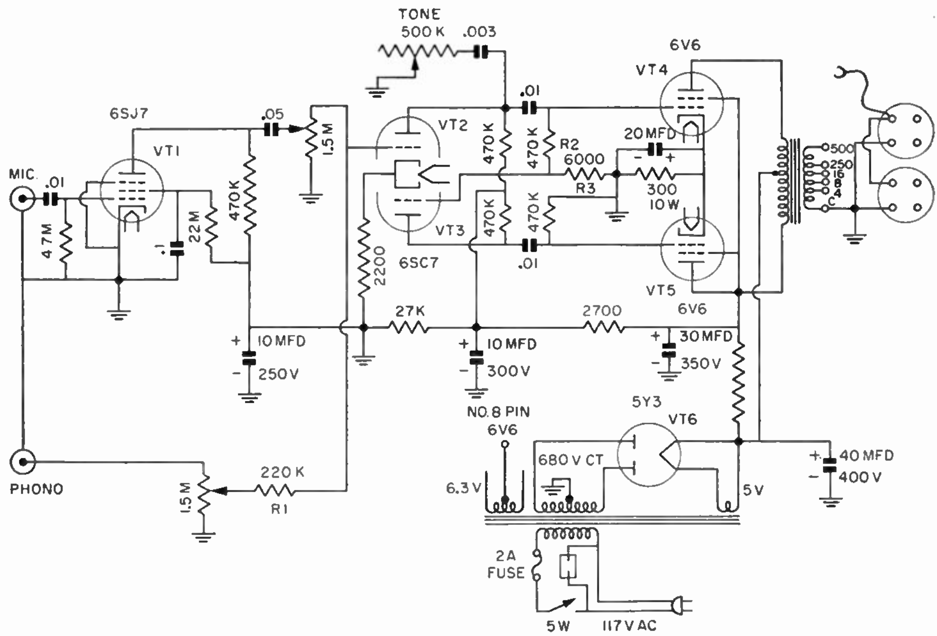


FIG. 10. Schematic diagram of Lafayette 15-watt amplifier.

fier is coupled through a microphone gain control to the grid of the phase inverter stage. The phono signal is also introduced to this same grid through its own gain-control potentiometer. Resistor R1 isolates the two signal inputs to minimize interaction between mike and phono controls.

The plate circuit of tube VT2 supplies signal to the grid of the output tube VT4. A low-amplitude version of the same signal is applied through a voltage divider arrangement consisting of resistors R2 and R3 to the grid of VT3. A signal equal in amplitude but opposite in polarity to that on the plate of VT2 is developed by the lower triode and is applied to the grid of VT5. The output tubes are beam-power pentodes that provide the power sensitivity necessary to develop a high power output with the minimum of grid signal drive. The stage is operated class A push-pull, and therefore, self-bias can be developed in its cathode circuit.

A universal output transformer is provided so that the amplifier can be made to match various speaker impedances or audio lines. Dual output receptacles are included so that both speakers or only one speaker can be plugged in quickly in setting up the system. The hot side of the receptacles must be connected to the correct tap on the universal output transformer according to the impedance of the speaker system to be driven.

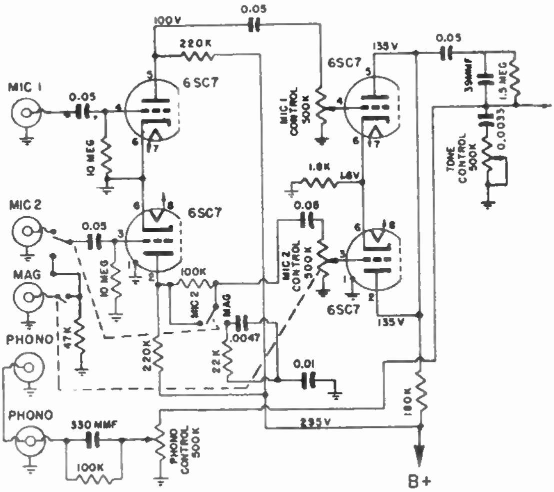
A tone control is also connected in the plate circuit of tube VT2. It is the simple series capacitor and potentiometer combination of the type found in some radio and TV sets.

The phase inverter and output stages in higher power amplifiers are essentially the same as shown in Fig.

10, except higher powered output tubes, such as types 6L6, 5881, 807, 1614, etc. are used instead of the 6V6. The power supply, output transformer, and circuit parts, of course, must be physically larger to handle the power. Since the output stages are similar, we will not include them in each diagram; we will show the output circuit only when it is considerably different from that in Fig. 10.

high-impedance input and a triode amplifier to feed a separate gain control that links to the input of a second audio amplifier tube. The outputs of this second pair are connected in parallel and supply signal to a phase inverter. A tone control is located in the grid circuit of the phase inverter.

The second microphone channel includes a single-pole double-throw switch arrangement that converts this



Courtesy Allied Radio

FIG. 11. Input circuit of a 30-watt amplifier.

MEDIUM-POWER AMPLIFIERS

A medium power amplifier is needed for sound coverage of an auditorium seating from 300 to 1000 people. If the noise level is high, a medium-power system is best even for small crowds. Medium-powered installations are generally semi-permanent or permanent.

The input circuit of a 30-watt medium power amplifier is shown in Fig. 11. Notice that it has two separate microphone channels. Each has a second stage input from a high to a low impedance. Consequently, a magnetic pickup cartridge can be used to supply a phono signal into the second audio channel. The switch throws in the proper termination resistor for a magnetic cartridge.

Two high-impedance phono jacks are also provided to supply phono signal through a gain control directly to the grid of the phase inverter stage. The phase inverter is the same basic type used in the previously discussed public address amplifier.

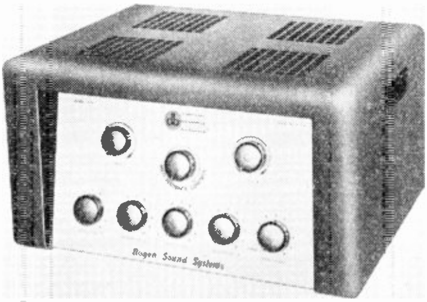
A more elaborate version of a medium-power amplifier is shown in Fig. 12. This is the type that is more often used in permanent installations.

The schematic diagram in Fig. 13 shows that the amplifier contains four microphone channels. Each channel has its own triode amplifier and output gain control. The gain controls through separate isolating resistors supply signals to the grid of the second audio amplifier stage. Low-noise triode tubes are used to get a good signal-to-noise ratio for each microphone input. Each microphone signal is amplified before it is applied to the mixing circuits.

Either low impedance or high impedance microphones can be used with this amplifier as shown in Fig. 14A. When a high-impedance microphone is used, a shorting plug must be inserted into the 9-pin socket. The plug shorts pins 8 and 9 so that the microphone signal is fed directly to the grid of the microphone preamplifier. When a low-impedance microphone is used, as in Fig. 14A, a special plug-in transformer that matches the microphone to the high impedance input is inserted in the 9-pin socket. The transformer connections are shown in Fig. 14B.

The microphone signals mix at the grid of tube V1A. Proper relative levels are set with the separate microphone gain controls. The output of the mixing stage is developed across resistor R1, and the signals are supplied to the next grid through a special tone control network.

A separate phono input jack supplies signal through a phono gain control to the grid of tube V1B. The amplified output signal across resistor R3 is coupled through an isolating resistor R4 to the tone control circuit. Resistor R2 and capacitor C1 act as a scratch filter.

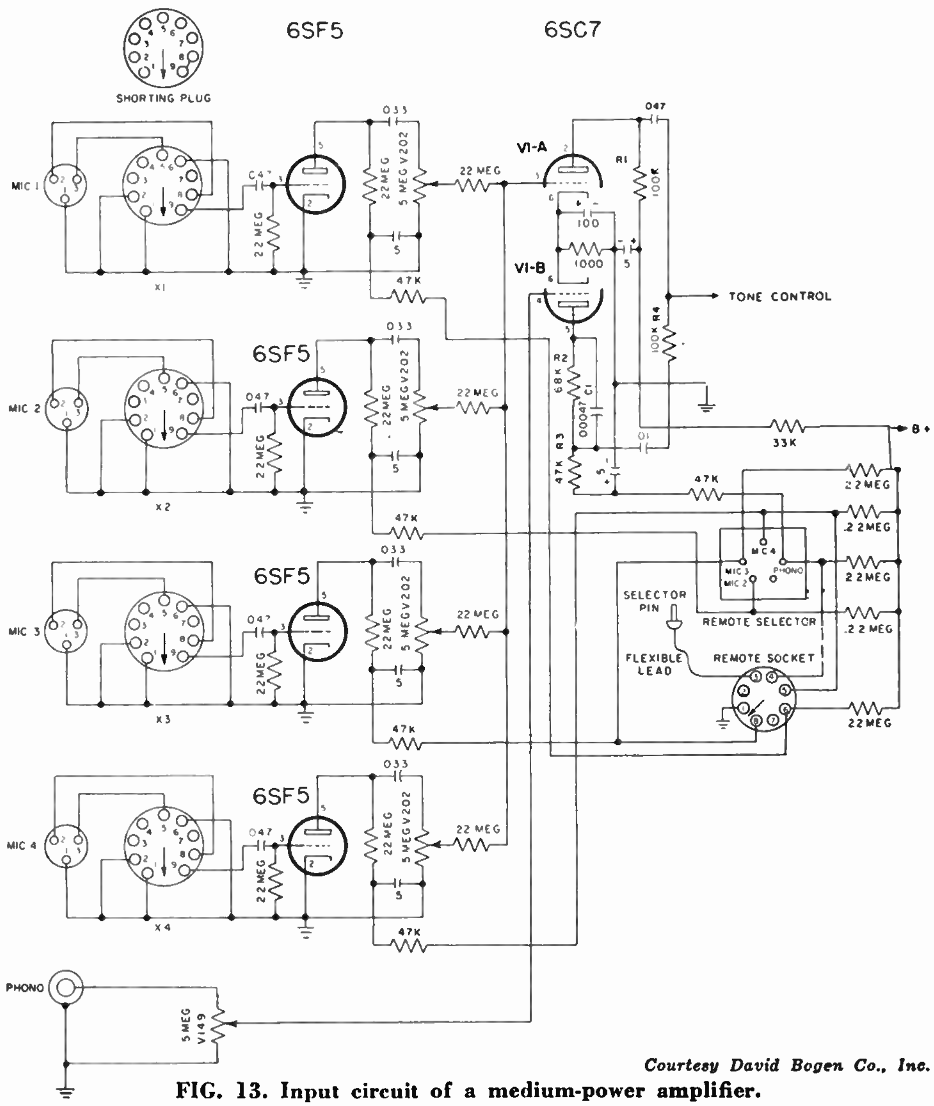


Courtesy David Bogen Co., Inc.

FIG. 12. Bogen 30-watt amplifier.

Remote control facilities are included. It is possible to operate the first microphone channel and either of the other channels by volume controls. These controls are connected to the amplifier by cables, which may be any length up to 2000 feet, plugged into the remote socket.

The remote control (which is not shown here) is composed of two potentiometers which are used to vary the plate voltage on the preamplifier stages, and thus control the gain. One side of each potentiometer is grounded

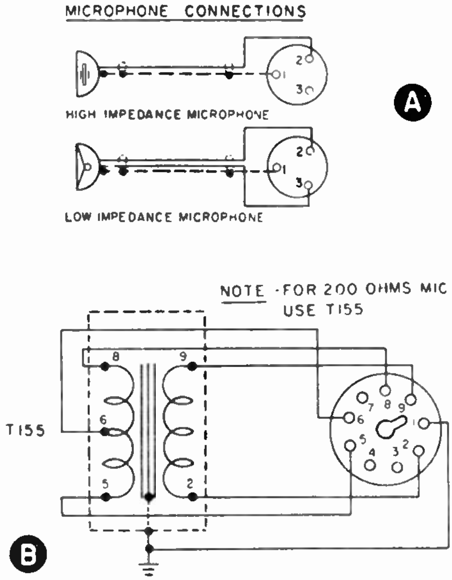


Courtesy David Bogen Co., Inc.

FIG. 13. Input circuit of a medium-power amplifier.

by the connection to pin 1 of the remote socket in Fig. 13. Pin 6 is connected to the adjustable slider on one potentiometer. Thus, Channel 1 is connected to the circuit at all times during the remote operation. The adjustable slider on the second potentiometer connects to pin 3 of the remote socket. By plugging the selector pin into the remote selector at the amplifier, any of the other channels can also be controlled from the remote location.

Fig. 15 shows the tone control and anti-feedback circuits that follow the mixer stage in Fig. 13. The tone-control network is similar to those used in high-fidelity amplifiers. The



Courtesy David Bogen Co., Inc.

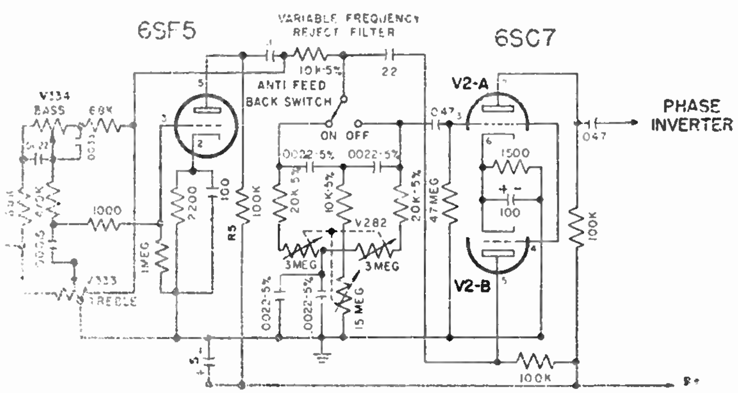
FIG. 14. A, Low-impedance microphone connection for Bogen JX30, and B, impedance-matching transformer connections.

bass and treble can be adjusted separately without interacting or disturbing the middle range gain. With both bass and treble tone controls set at the mid-position, the amplifier response is flat.

The output of the tone control stage is developed across resistor R5, and is then supplied to the parallel grids of audio amplifier V2A and feedback tube V2B. The output of the amplifier is supplied to the following phase inverter stage, while the output of the feedback tube is fed back to the variable-frequency reject filter section.

The filter, which is referred to as an "anti-feedback control," can be switched in or out of the circuit. The control is used to eliminate the squeal and howl that often occurs because of acoustic feedback from the loudspeakers to the microphone. This feedback takes place in the range of frequencies from about 300 to 4000 cycles. The parts in the anti-feedback circuit are chosen to tune sharply and reject narrow bands of frequencies within this range. Since the circuit tunes sharply, it does not affect the flat characteristics of the amplifier except at the selected frequency to be rejected.

In use, the gain control of the selected channel is advanced until feedback howl occurs. Then, the feedback control is rotated through its range



Courtesy David Bogen Co., Inc.

FIG. 15. Tone control and anti-feedback circuits for the Bogen JX30 amplifier.

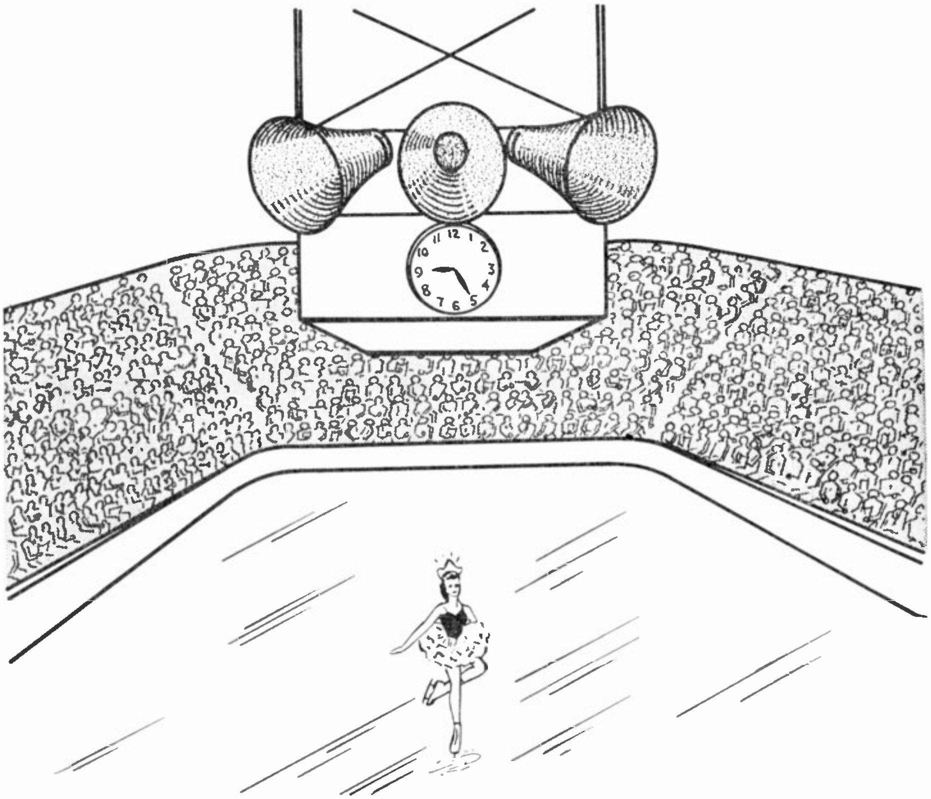


FIG. 16. A typical loudspeaker set-up for a large indoor arena.

slowly until the howl stops. The gain control may now be turned up to a point just short of further feedback. Thus, it is possible to get a greater audio power output from the system without squeals and howls from acoustic feedback.

HIGH-POWER AMPLIFIERS

The high-power installation is used for covering large areas. A typical installation for an indoor arena is shown in Fig. 16. The PA system is used for making announcements during sporting events and other special shows, and for providing musical interludes during intermission. In an installation of this type, clarity of speech and power handling ability are generally more important than fidelity. The fidelity should be as good as it is practical to make without sacrificing intelligible coverage.

For covering such a large open area, the loudspeakers can be suspended over and directed toward the audience. All the listeners will be about the same distance away from the loudspeakers, and the sound coverage will be uniform. The suspended mounting method also helps to minimize the acoustical problems of dead spots.

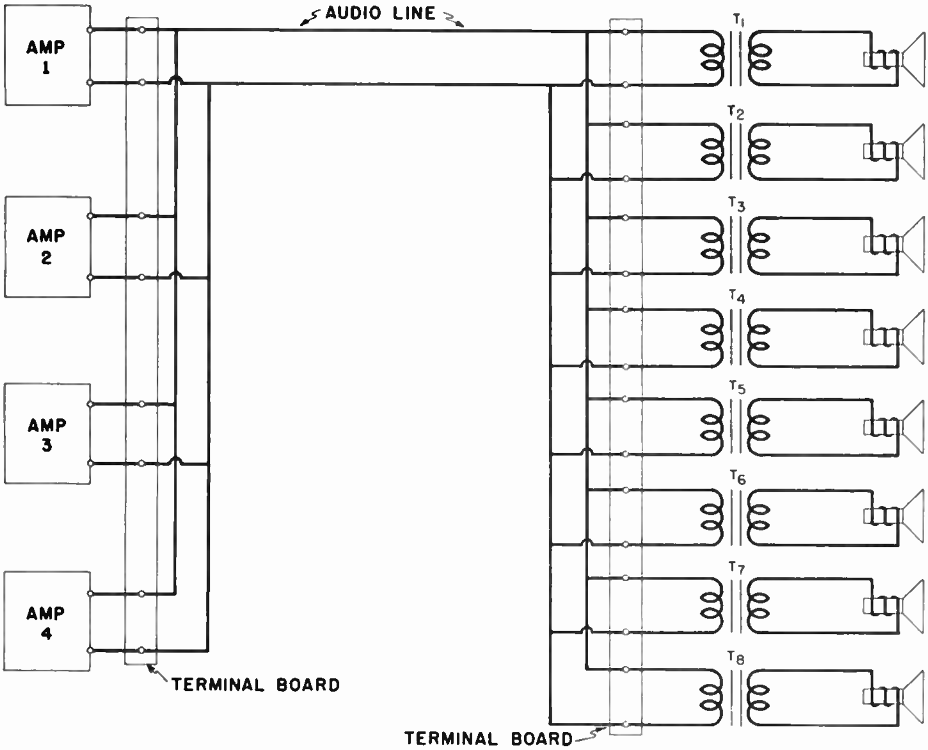


FIG. 17. Power distribution system used to feed 8 loudspeakers from the outputs of 4 amplifiers. Eight matching transformers are used.

A typical installation of this type might require 200 watts of audio power to be divided among 8 reflex horn speakers. This would require a single 200-watt amplifier or four 50-watt amplifiers as shown in Fig. 17. The amplifiers feed parallel signals into an audio line, which distributes the sound to the eight speakers. To obtain suitable match and permit the use of long audio lines, a separate transformer is used with each speaker.

A typical high-power public address amplifier is shown in Fig. 18. The input circuits, which consist of two microphone inputs and one phono input, are similar to those shown in previous diagrams, so they are not included here. The bass and treble tone controls, however, are shown between the second audio stage and the phase inverter.

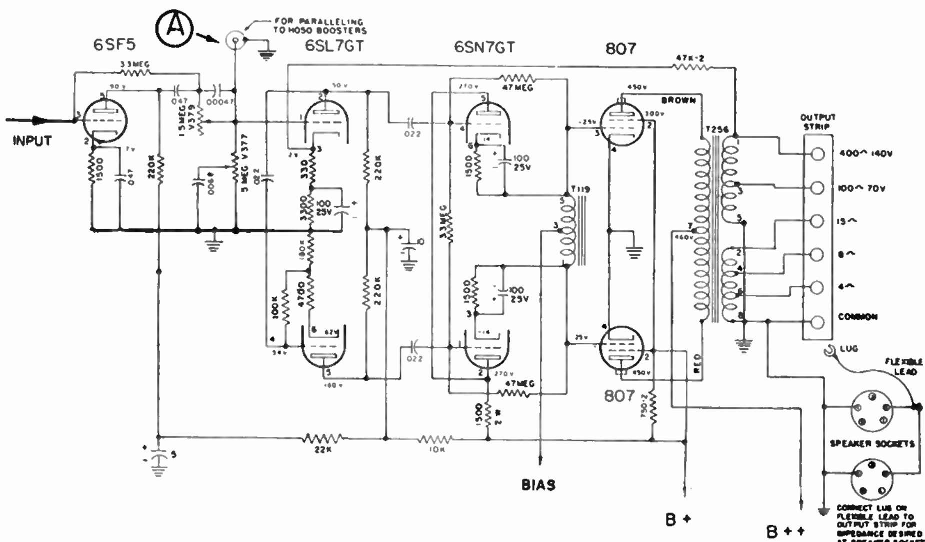
The balanced outputs from the phase inverter drive the grids of a push-pull cathode-output driver stage. The cathode-follower output provides low-impedance drive for the beam-power output stage. High-powered 807 tubes are used to develop a full 50-watt output. The secondaries of a universal output transformer connect to a special impedance terminal strip. A lead from the speaker sockets is connected to the proper terminals on the strip to provide correct impedance match with whatever loudspeaker system or line is used. Notice that this amplifier can also be used in a 70-volt or a 140-volt constant-voltage system.

When the estimated power output required for a particular PA installation is in the hundreds of watts, there are several methods that you can use. You can connect two or more complete amplifiers, containing microphone input circuits, in parallel as shown in Fig. 17. Another method is to plug additional booster amplifiers into the receptacle at point A in Fig. 18. The booster amplifiers contain just the push-pull drivers and the push-pull output stages shown in the schematic diagram. A third method is to use a mixer preamplifier to supply signal to all the high-powered booster amplifiers. The amplifier outputs can be connected in parallel to a single distribution line, or each booster can operate its own distribution line.

Any of these methods can be used to increase the power of an existing PA system to take care of future expansion. Thus, if the customer wants to increase the power from 50 to 100 or 200 watts, he need not remove the present system and install a completely new one. You should mention this fact to those customers who want to start their public address system modestly. Of course, for a large arena or other large enclosure, full power must be provided to obtain complete coverage. In an installation of this type, never start with a low powered amplifier system.

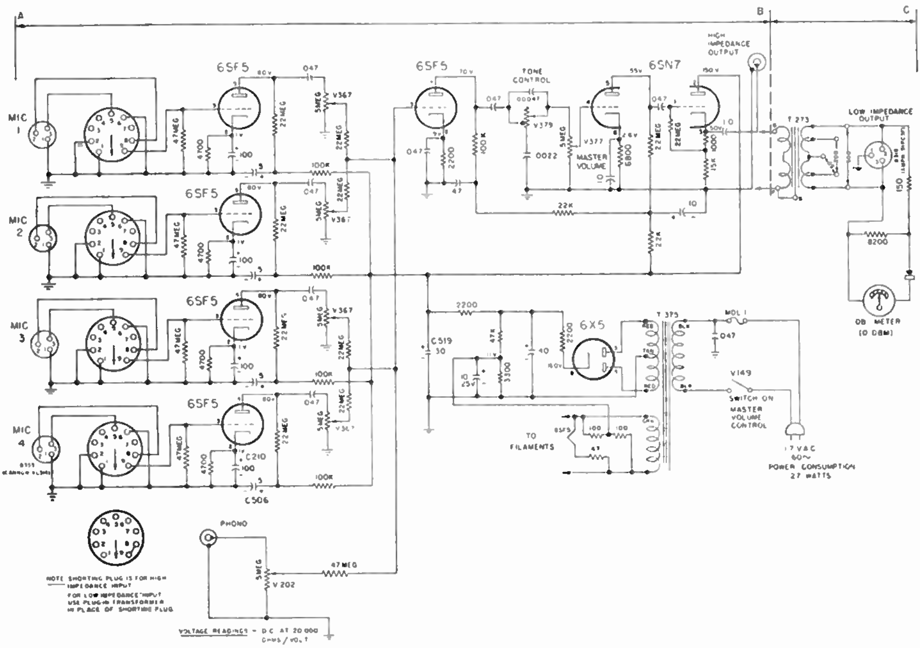
A typical mixer preamplifier is shown in Fig. 19. Notice that the microphone and phonograph inputs are similar to those shown in Fig. 13. The main difference between the two circuits is in the output circuit.

The mixer preamplifier in Fig. 19 can be purchased with either a high impedance or a low impedance output for making connections to the booster amplifiers. If the distance between the



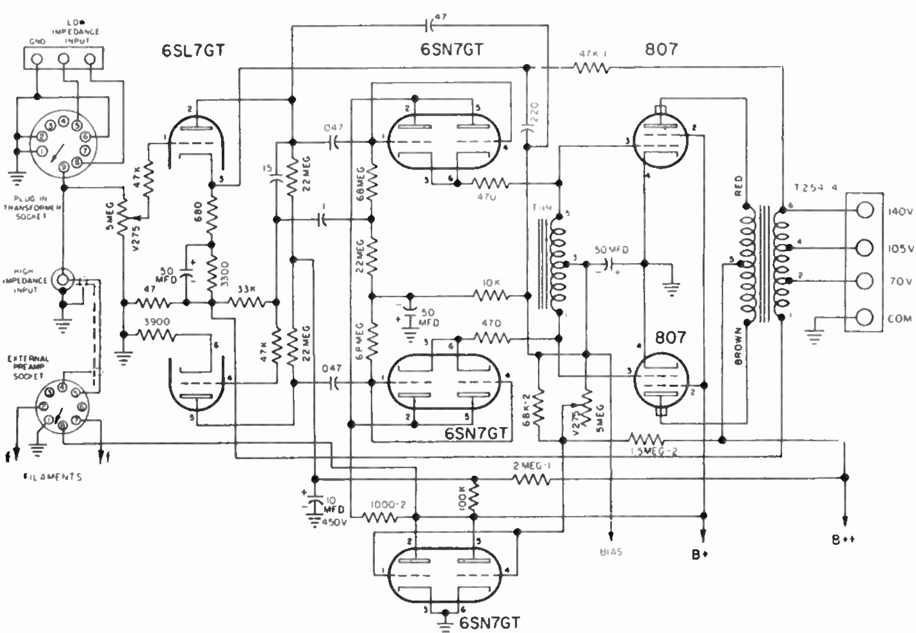
Courtesy David Bogen Co., Inc.

FIG. 18. A 50-watt amplifier.



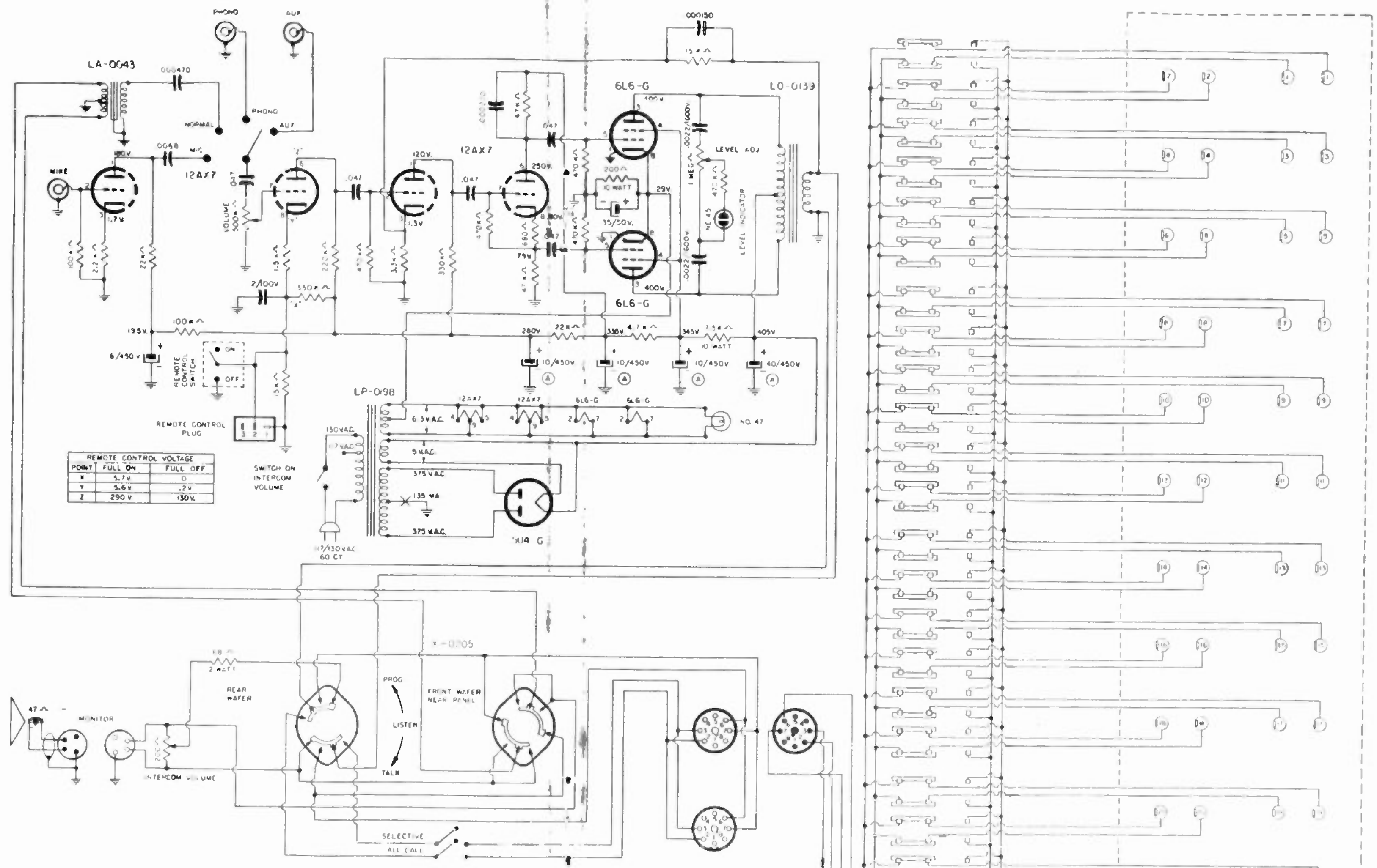
Courtesy David Bogen Co., Inc.

FIG. 19. Schematic of a mixer preamplifier.



Courtesy David Bogen Co., Inc.

FIG. 20. A typical booster amplifier.



REMOTE CONTROL VOLTAGE		
POINT	FULL ON	FULL OFF
X	5.7 V	0
Y	5.6 V	1.2 V
Z	290 V	130 V

NOTES:

1. ALL VOLTAGES ARE MEASURED TO GROUND WITH 20,000 OHMS PER VOLT METER WITH NO SIGNAL.
2. ⏚ INDICATES CONNECTION TO GROUND.
3. K = 1000
4. Ω = OHMS
5. ALL RESISTORS ARE 1/2 WATT AND HAVE A TOLERANCE OF ± 10% UNLESS OTHERWISE SPECIFIED.
6. ALL CAPACITORS ARE RATED IN MICROFARADS, AND HAVE A VOLTAGE RATING OF 600 VOLTS UNLESS OTHERWISE SPECIFIED.
7. PLUGS AND SOCKETS VIEWED FROM WIRING SIDE.
8. PUSHBUTTONS SHOWN IN RELEASED POSITION.
9. CONNECTIONS MADE TO POWER TRANSFORMER PRIMARY TAPS AT TIE LUGS ON 5U4-G SOCKET AS FOLLOWS
   117 V TIE LUG NO 3
   130 V TIE LUG NO 5

SEE INSTRUCTIONS FOR FURTHER INFORMATION

(4) X 0237

KNIGHT CENTRALIZED SCHOOL SOUND SYSTEM - SCHEMATIC

FIG. 21. Schematic diagram of school sound distribution system.

Courtesy Allied Radio Corp.

Typical PA Installations

You have learned how to determine the power requirements of a PA installation, and studied various sizes and types of commercial PA amplifiers. Here we will discuss examples of several typical PA installations to give you an idea of what each type requires.

First, we will take up PA systems that can be used in industrial plants, hotels, and schools. Next, we will cover mobile PA systems that are installed in a truck or car. The last type of installation we will discuss is the intercommunication (intercom) system. These systems are not actually classed as public address; they are similar to a telephone hookup in that they are used between one person and another.

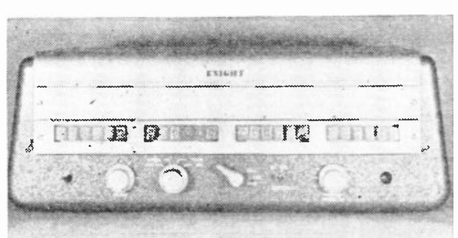
SCHOOL SOUND SYSTEM

A school communication system must be able to provide programs to all rooms or any chosen group of rooms in the school building. Often, the same system is used as a public address amplifier for the auditorium, gymnasium, or large lecture hall.

A typical school system is shown in Fig. 21. The amplifier is shown in Fig. 22. The unit shown can be used for intercommunications or supplying programs for as many as 24 rooms. Forty-eight-room systems are also available. When a lecture or other special program material is to be sent over the system, a good quality microphone can be attached to the microphone input terminal. This input supplies signal directly to the grid of a microphone preamplifier shown in Fig. 21. With the selector switch set to the microphone position, the output of the microphone amplifier supplies signal through the volume control to the grid of the second audio stage.

The signal is further amplified by a third triode audio amplifier and then passes on to a phase inverter which supplies balanced signals to the beam-power audio output stage. The secondary of the output transformer supplies signal through a switching arrangement and push-button output system. There are individual push-buttons for each classroom, and separate lines run from the amplifier to each of the loudspeakers.

When the selector switch is set on the normal position, the school system can be used for paging purposes. A paging microphone-speaker unit is used, operating in conjunction with the listen-talk paging switch. All rooms can be paged simultaneously by setting the control toggle switch to "all calls." Individual rooms or groups of rooms can be called by setting this switch to "selective" and depressing the appropriate push buttons.



Courtesy Allied Radio Corp.

FIG. 22. A school communications system.

preamplifier and the boosters is short, the mixer preamplifier can have a high impedance output, as shown between points A and B in Fig. 19. However, if the transmission line is very long, the booster amplifiers should be driven from a low impedance output. This output circuit is shown between points B and C.

The output of the mixer preamplifier can be used to drive as many as ten separate booster amplifiers. The output meter (db meter) is used to make sure that there is a constant signal level on the distribution lines so that the booster amplifiers will be excited properly.

The diagram of a typical booster amplifier that can be used with the mixer preamplifier unit is shown in Fig. 20. With the proper amount of audio signal fed to the booster input, the booster will develop 100 watts of output power. The input signal level required is about 5 volts. Notice that the booster amplifier can be fed from either a high-impedance or a low-impedance source.

As you can see from the schematic diagram in Fig. 20, the input signal is supplied directly to a phase inverter stage. Its output is fed to the two dual-triode driver stages which are cathode-coupled to the grids of the push-pull 807 output tubes. The output transformer has taps for matching 200 ohms at 140 volts, 110 ohms at 105 volts, or 50 ohms at 70 volts constant-voltage audio lines. The output provides a constant voltage across this impedance line for driving a multi-speaker distribution line that reflects the proper impedance back to the output transformer.

The lower 6SN7GT tube acts as a voltage regulator for the screen grids of the output tubes. Thus, the plate dissipation of the output stage is held to a safe value regardless of the applied signal levels.

To talk, the intercommunication switch is held on talk and the information is spoken into the microphone. To listen, the switch is released and held on listen. Talk-back information can then be heard from the classroom being paged. The permanent-magnet speaker in the classroom acts as a microphone and supplies signal to the grid of the second audio stage. The classrooms can reply to calls from the central office, but cannot originate calls. The system can be modified so that the classroom can originate calls, by running a second line to each room and installing a special switch.

With the selector switch set on the phono position, a high-impedance cartridge can be connected to the phono input receptacle to supply a signal through the volume control to the grid of the second audio stage. The output from a radio tuner or tape recorder can be plugged into the auxiliary receptacle.

A remote, low-impedance microphone should be connected to the input when the school system is used for public address work in the auditorium. This microphone is linked through a cable and matching transformer to the high impedance microphone input of the amplifier. Likewise, a remote volume control can be attached through a remote control socket at the back of the amplifier. The remote volume control can be installed in the auditorium, and used to regulate the volume whenever the amplifier is used for public address work. Accessory matching transformers are available that connect to the output terminal strip of the amplifier, and permit driving a pair of 12-inch speakers which can be mounted on each side of the auditorium.

These elaborate public address units can be used in public buildings, offices, and other places that have a number of rooms to be served. Probably the most difficult part of a job of this type is running the wires between the amplifier location and the individual rooms. Remember, the electrical code in your locality may require that a licensed electrician do the actual installation. If you are allowed to do the work yourself, run the wires over the shortest route that requires the least construction work, such as boring holes in the walls. Use multi-wire cable or run the wire through conduit.

INDUSTRIAL SOUND SYSTEM

In most areas of an industrial plant, the noise level is very high, perhaps from 70 to 85 db or more. The acoustic power must be high enough to overcome this noise level. If the noise is higher, say about 100 db, it would be impractical to use a PA system at all; the audio power would have to be near the threshold of pain to overcome the noise.

The sound power needed in one part of the plant may not be the same as that in another. You will want high-powered loudspeakers in the production area, but low-powered speakers in the offices. All the power requirements must be considered in planning the installation.

An example of a factory installation is shown in Fig. 23. We will assume that the average noise level is from 70 to 85 db. By multiplying the length of the room (300 feet) by the width

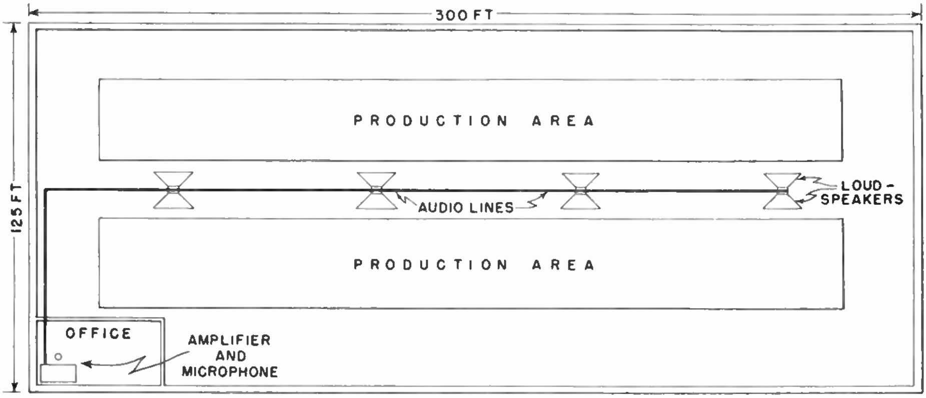


FIG. 23. A PA installation in a factory.

(125 feet), we find that the area is 37,500 square feet. This installation will probably be used for speech only. The chart in Fig. 5 shows that the acoustic power needed for a noise level of 90 db is about 7 watts. (We used 90 db rather than 80 db to make sure the sound would be above the noise level.) If we use loudspeakers that have an efficiency of about 5 per cent, the amplifier must have a minimum wattage rating of 140 watts (7 watts divided by .05 = 140 watts). Of course, there will be some power loss in the transmission lines, and aging parts will cause the amplifier output to decrease over a period of time. Thus, to have some reserve power, it would be best to use 200 watts of output power. The components needed for the job, therefore, are two 100-watt or four 50-watt booster amplifiers and eight 25-watt loudspeakers.

After you have determined the power requirements, look over the location and decide where the loudspeakers can be placed to give the

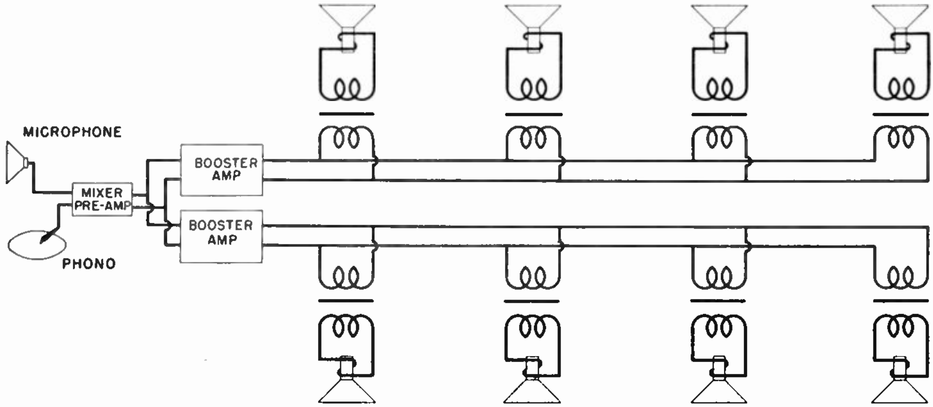


FIG. 24. Block diagram of a factory PA installation.

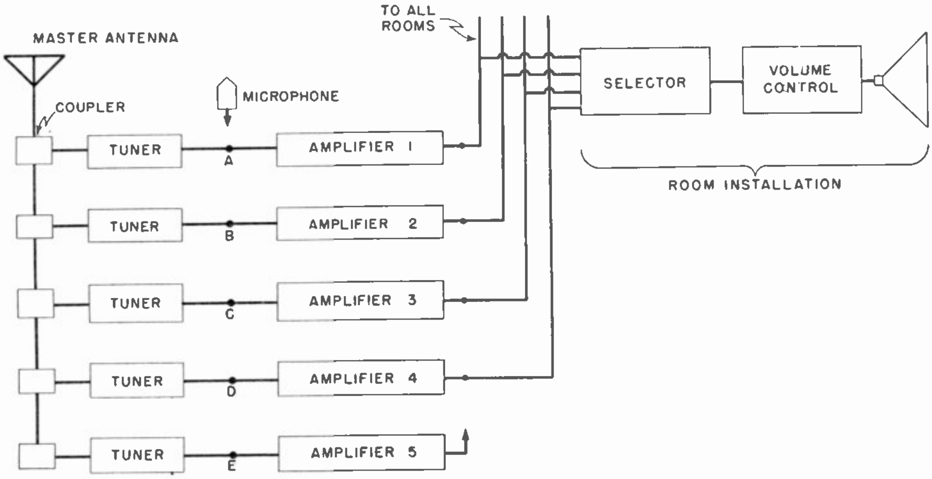


FIG. 25. Block diagram of a typical hotel PA installation.

best sound coverage. In Fig. 23 there are two production areas, one on each side. The eight 25-watt loudspeakers should be placed down the center of the room, properly hung from a supporting beam in the ceiling.

Other factory installations may not be as simple as the one shown in this diagram. The loudspeakers may have to be quite far from each other, and connected by a high-impedance transmission line. Fig. 24 shows an installation where a mixer preamplifier is used to feed separate booster amplifiers in separate buildings or parts of the factory. Each loudspeaker has its own impedance-matching transformer. Therefore, the power can be divided according to the needs at the loudspeaker location.

HOTEL SOUND SYSTEM

The sound systems used in hotel dining rooms and ballrooms are basically the same as those used in a factory installation, except that they must carry music as well as speech Therefore, the quality of the microphones, amplifiers, and loudspeakers should be better than the components used in a factory sound system.

Another type of hotel PA system is one in which there is a small loudspeaker in each guest room instead of a radio, and all of them are fed from tuners and amplifiers in the office or some other part of the building. A block diagram of such a system capable of supplying four separate radio programs is shown in Fig. 25. Usually each tuner is adjusted to receive one local radio channel, and its tuning remains fixed. The extra tuner and amplifier are for emergency use. If one of the tuners or amplifiers fails, there is another to take its place. Also, a microphone can be plugged into the amplifiers for making special announcements.

The outputs of the amplifiers are fed along separate lines to each room. Each room contains a loudspeaker, a program selector, and a volume control. Thus, the programs as well as the volume can be adjusted at the loudspeaker location.

The amplifier output rating depends on the number of rooms to be supplied with signal. Usually 1 watt per room is enough. Thus, a 90-room hotel would require an amplifier with a 90-watt output. To allow for amplifier aging and line loss, a 100-watt amplifier would be considered adequate in this case. One such amplifier is needed for each tuner. Likewise, a separate group of amplifiers is needed for each group of 90 rooms to be supplied with signals. It would also be possible to use a booster amplifier arrangement as discussed previously for supplying signals to the hundreds of rooms of a large hotel.

An important problem for any multiple-outlet system of this type is proper impedance matching to the distribution line. If the loudspeaker impedances are matched, the audio levels and frequency power will remain constant throughout the system regardless of the number of speakers that are operating on the same channel. To do this a selector arrangement must be used that reflects a constant load on each channel. Such a switching arrangement must connect a load resistor across each channel whenever the loudspeaker is disconnected, to keep each channel fully loaded at all times.

A typical arrangement for one room is shown in Fig. 26. Notice first that a constant impedance volume control is provided for the loudspeaker. As the guest regulates the gain control, the load placed on the distribution line remains constant.

Resistors R1, R2, R3, and R4 load the distribution lines that are not being used. With the selector set as shown, the loudspeaker is reproducing the audio program present on line A. Resistors R2, R3, and R4 present the proper load to each of the other program lines B, C, and D. If program line B is chosen by the guest, the selector switch supplies signal to the output transformer from line B. At the same time the selector switch throws in the terminating resistors R1, R3, and R4 to terminate each of the other program lines properly. As shown in the diagram, the ground return for the system is through the shield surrounding the cable.

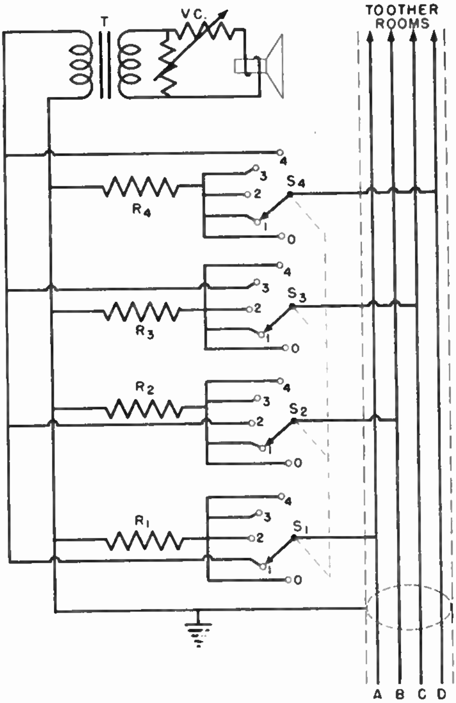


FIG. 26. Multi-channel constant-impedance switching system.

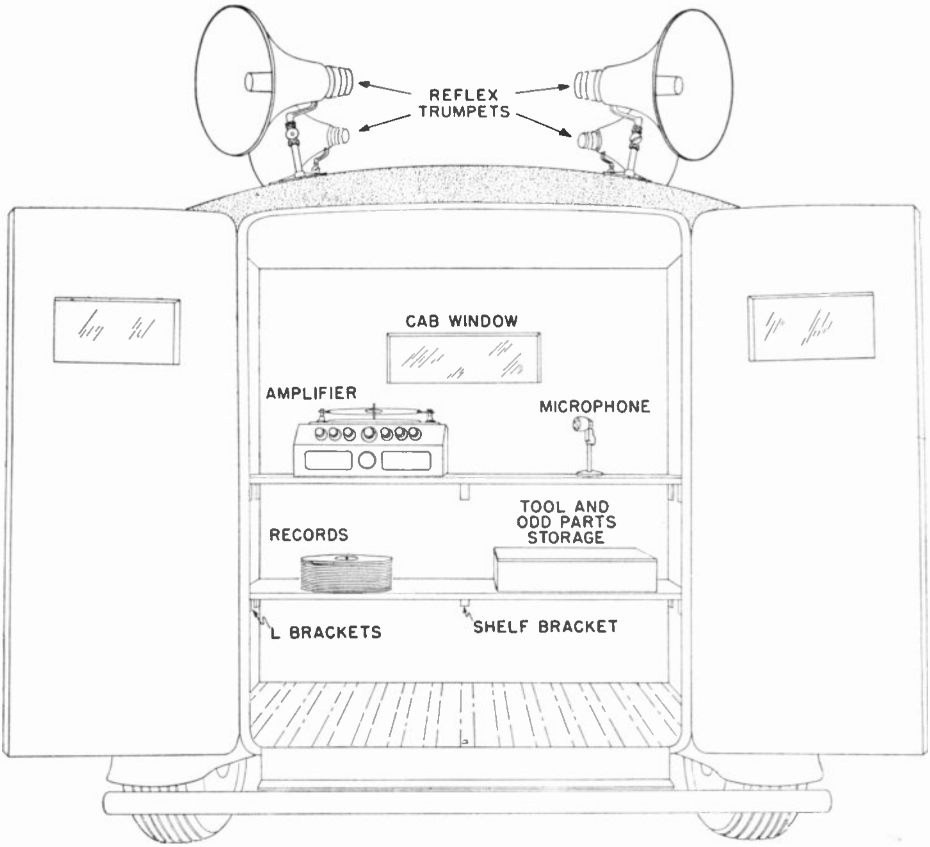


FIG. 27. Suggested arrangement of equipment in a sound truck.

MOBILE SOUND SYSTEMS

There are many specialized sound services that you can give if you decide to go into large scale sound work. In addition to renting and installing sound equipment, you will probably find it profitable to have either a sound truck or a portable mobile system that you can install in your car or station wagon.

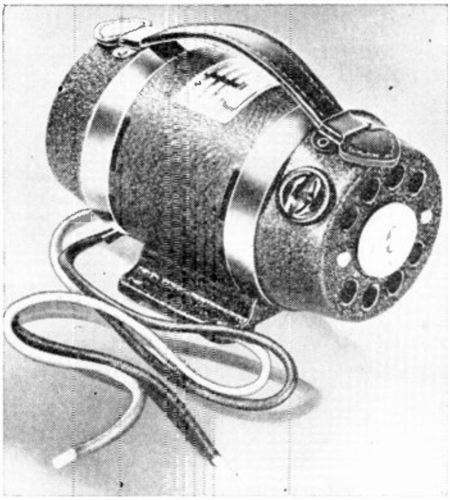
If you own a radio shop and already have a delivery truck, you may be able to convert it into a sound truck and still have enough room in it for deliveries. An example of a mobile installation in a light or medium panel truck is shown in Fig. 27. Notice that the loudspeakers are mounted on the roof, and the amplifier, microphone, and other equipment are placed on shelves in back of the cab.

If you use a passenger car for mobile sound service, you can mount a platform on the roof, similar to a luggage carrier, and attach the loudspeakers on it. The record player and microphone can be located inside the car; the amplifier itself can be mounted in the trunk of the car.

The size and complexity of the system depends on the amount of power output desired. Even the small portable 8 or 12-watt ac-operated systems can be adapted for mobile service. Such a unit can be operated by one of the small vibrator converters now available. The converters produce 110 volts ac from the 6-volt battery supply at a continuous power rating of from 60 to 150 watts. The average 8 to 12-watt ac-operated public address amplifier requires approximately 60 to 100 watts of input power.

Although it is not too common, the ac power for a high-powered mobile public address system can also be obtained from ac generators or dynamotors. A dynamotor is a combination motor and generator. The motor section is driven by power from the 6 or 12-volt battery. The motor turns over the generator, which develops the 110 volts ac for operating the public address equipment. AC generators are also available that can be attached directly to the fan belt. Thus, the car motor turns over the generator to provide a suitable ac power source for the public address system.

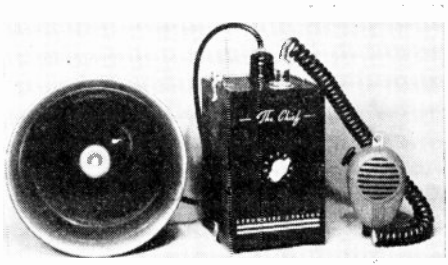
A typical dynamotor is shown in Fig. 28. It is capable of developing 115 volts ac at 150 watts from a 6-volt dc source. Notice the receptacle on the dynamotor for plugging in 110-volt ac-powered equipment.



Courtesy Carter Motor Co.

FIG. 28. Dynamotor power source for mobile PA system.

The storage batteries used to supply power to the mobile PA system must be in good condition to withstand the severe power drain of the public address amplifier. The battery should be checked frequently and kept in the best operating condition. Remember that the battery cannot withstand a severe current drain over a long period of time. Even the lowest powered public address amplifier can



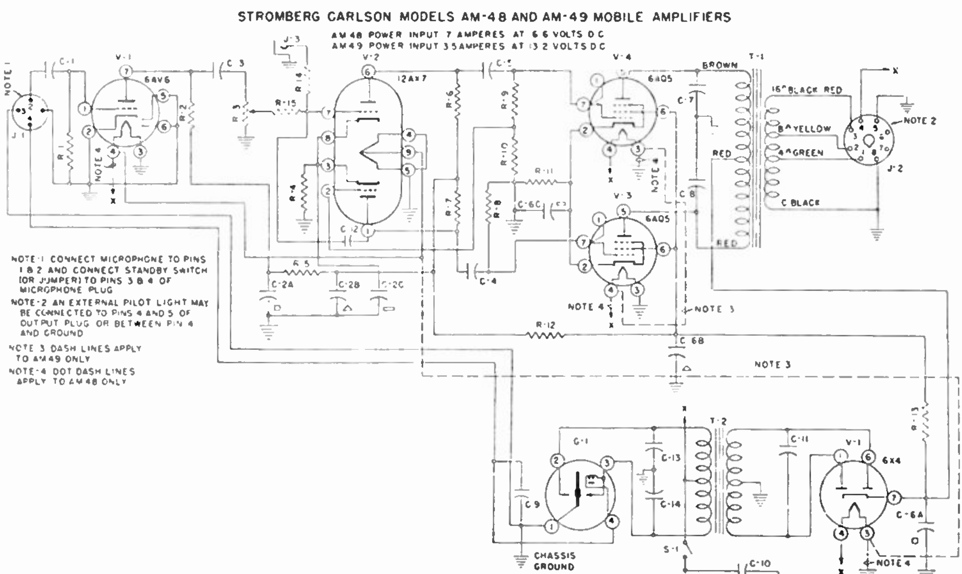
Courtesy Stromberg-Carlson

FIG. 29. An 8-watt mobile PA system.

drain a battery rather quickly if the battery is not kept under charge. Because of the heavy drain, another battery can be connected in parallel with the truck or car battery. Also, a heavy duty generator should be installed in place of the original one. This makes sure that the battery gets a proper charge when the PA equipment is operating.

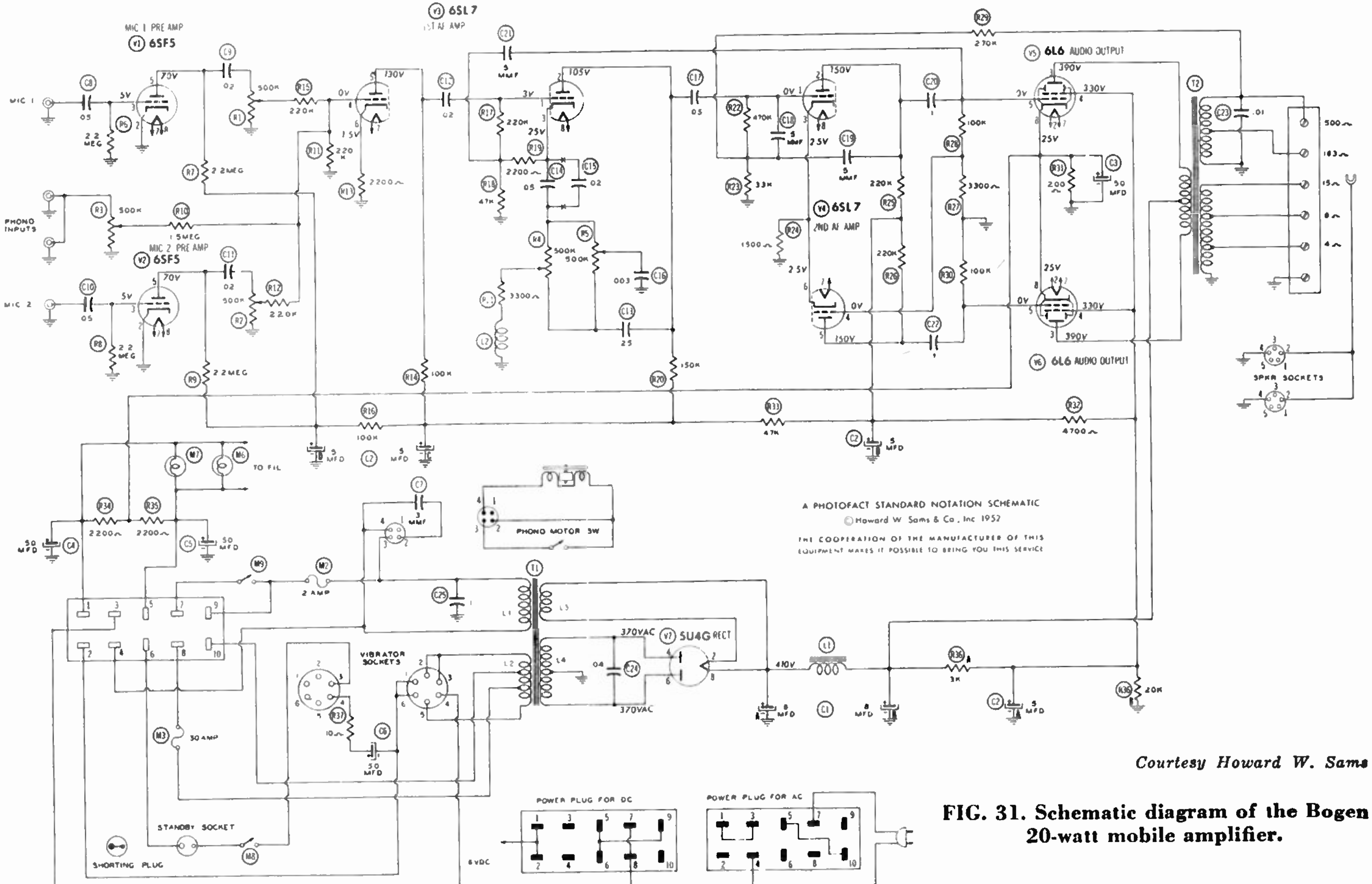
A small unit designed specifically for mobile operation, and completely self-contained, is the Stromberg Carlson model shown in Fig. 29. Notice that a push-to-talk microphone and a small reflex horn can be used with the amplifier. The schematic diagram in Fig. 30 shows that units are available for 6-volt or 12-volt battery operation. For 6-volt operation, the filaments are connected in parallel. They are connected in series-parallel if 12 volts is used. Of course, different vibrators, power transformers, and buffer capacitors (part C-11) are needed for the two voltage values.

The amplifier has a self-contained vibrator power supply. A single triode input stage amplifies the microphone signal, and applies it through a gain control to the grid of the phase inverter. Phono signal through isolating



Courtesy Stromberg-Carlson

FIG. 30. Schematic diagram of 8-watt mobile PA system.



Courtesy Howard W. Sams

FIG. 31. Schematic diagram of the Bogen 20-watt mobile amplifier.

resistor R14 is also applied to this grid. The phase inverter applies balanced signals to the pentode push-pull output stage. The output transformer is capable of matching 4, 8, and 16-ohm load impedances.

A single-conductor lead containing the fuse holder and fuse is wired to the amplifier. This lead must be connected to the ungrounded side of the battery. If more lead is needed to reach the battery, No. 10 or larger insulated wire should be used and routed over the shortest possible distance to the battery. Always keep in mind that in low voltage and moderate power circuits, the loss due to the resistance of the power line can be serious. Thus, wire size must be chosen so that there is a low resistance and a high current-carrying ability. Of course, resistive losses can be held down by keeping the power leads to the battery as short as possible. This unit is designed with a special mounting bracket and snap clips so that it can be fastened securely to the flat surface of the bulk head or dash board.

In all mobile installations, ignition noises should be held to a minimum. If there is severe interference in the ignition system, it may be amplified and heard in the audio output of the amplifier. Be sure that spark plug and distributor suppressors and generator bypass capacitors are installed on the motor. Remember too that the proper voltage must be applied to the phonograph motor. Motors are available that operate from 6 to 12 volts dc. A second choice is to use a regular 110-volt phono motor, and operate it through a suitable vibrator-converter.

Medium-power mobile systems up to 20 or 30 watts are also available. A typical 20-watt mobile amplifier that can be used for 6-volt dc as well as 110-volt ac operation is shown schematically in Fig. 31. The amplifier is changed from ac to dc simply by changing power cables; separate cables for ac and dc operation are furnished.

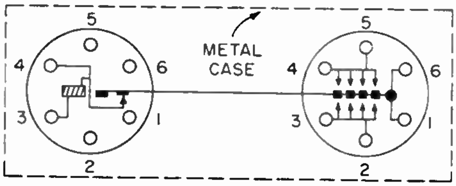


FIG. 32. Diagram of a heavy-duty vibrator used in medium-powered mobile PA amplifiers.

The input and output amplifier circuits are similar to those found in the PA amplifiers discussed in an earlier section. Therefore, we will concentrate on the power supply.

With the dc cable plugged into the receptacle, power is supplied to a heavy duty vibrator which vibrates at a frequency of 60 cps. A diagram of the vibrator used in this amplifier is shown in Fig. 32. The vibrator assembly is enclosed in a single container, and the electrical connections are made through two 6-pin plugs. The vibrator changes the 6-volt dc supply to 60-cycle ac, which is supplied to the transformer primary L2. The transformer action produces high voltage for the rectifier circuit across winding L4, and 110-volts ac to operate the phonograph motor from winding L1.

When the ac cable is plugged into the receptacle, the electrical connections to the vibrator are broken, and the 110 volts ac is applied to winding L1. Again there is 60-cycle ac across windings L2, L3, and L4. Notice that the filament voltage for the tubes is taken off the lower part of winding L2. The filaments operate from the 6-volt dc supply when the dc cable is plugged into the receptacle.

When the amplifier is operated from the 6-volt battery supply, the system should be turned on only during the time that it is actually in use, to conserve the battery. Most amplifiers of this type contain a standby switch to turn off the vibrator supply. The filaments remain lit during these periods. Switch M8 is the standby switch in Fig. 31.

The vibrator supply can be turned off at a remote location by connecting a long two-wire cable containing a switch on one end and a plug on the other to fit the standby socket. The standby switch M8, of course, should be closed when the remote switch is used.

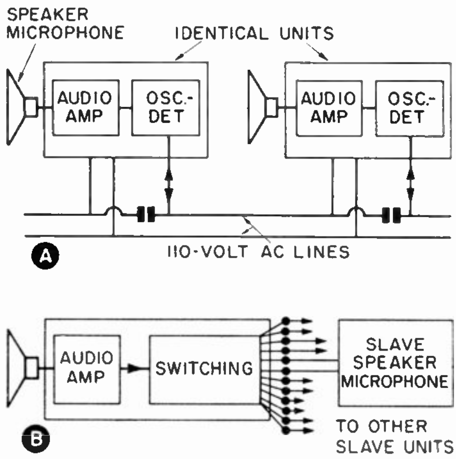


FIG. 33. Basic intercommunication systems. A, wireless; B, direct wire.

Most of the mobile assignments you will get will be to canvass a specific area with a special announcement. The work will generally have to deal with politics, charity drives, or some other special event. In some areas, you cannot make public announcements of this type unless you get special permission to do so. Therefore, find out if you will need a special permit or license before you accept a job of this type in your community.

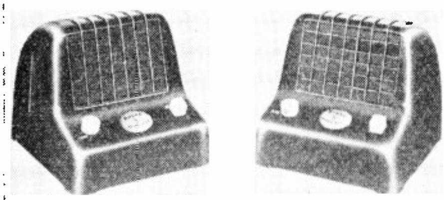
INTERCOMMUNICATION SYSTEMS

All the PA systems you have studied so far have been designed primarily to communicate with large groups of people. The intercommunication, or intercom system is usually a person-to-person communicator similar to an amplified telephone system.

Intercom systems can be useful in almost any large or small business, office, dwelling, farm, or estate. For example, an intercom is helpful in restaurants or other locations where frequent verbal instructions must be given above a high noise level. By using an intercom, an executive can contact various departments throughout the office or plant without having to wait or burden telephone connections. In large and small dwellings, an intercom is useful in communicating between rooms or floors, or between the dwelling and the garage.

Intercommunication equipment, of course, can be obtained to meet the needs of almost any installation. In many cases, the intercom is easier to install than a regular PA system. Therefore, you should not overlook the sales and installation possibilities of these simple devices.

The diagrams in Fig. 33 show the two basic intercommunication systems—wireless and direct wire. The direct-wire type uses audio line between units, and all signal frequencies are in the audio range. For the wireless type, the sound first modulates an oscillator. This signal goes out at a radio frequency over the power line to the receiving unit. At the receiver, the rf signal is detected and the audio output is amplified to operate a loudspeaker.

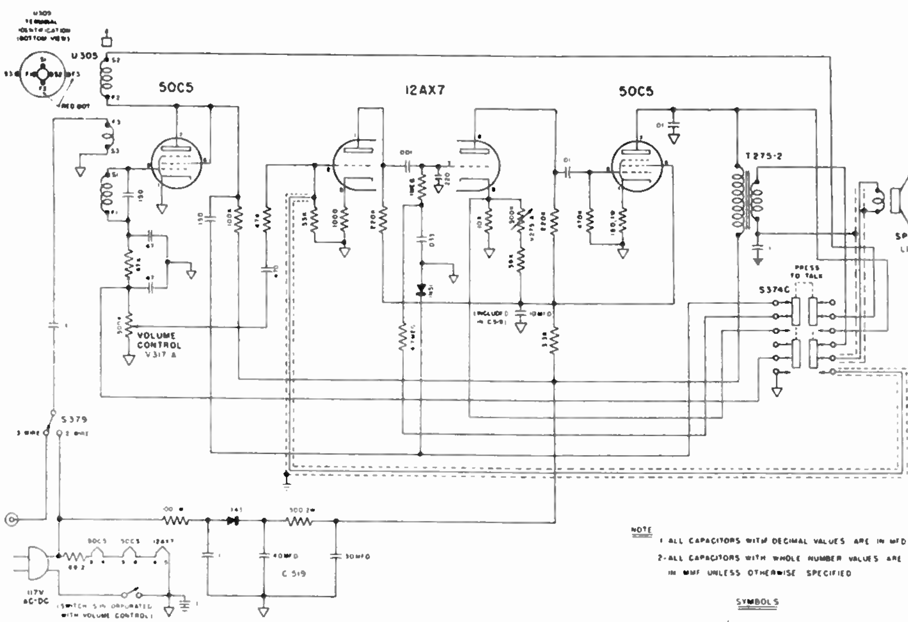


Courtesy David Bogen Co., Inc.

FIG. 34. Wireless intercom system.

In either system, the sound is picked up and reproduced through a loudspeaker. In fact, intercommunicators are inexpensive because it is possible to use the small permanent magnet loudspeakers as microphones as well as loudspeakers. The pressure of the sound wave moves the voice coil back and forth in a magnetic field. Consequently, audio output is developed across the voice coil. The intercom is able to pick up sound over distances of 10 to 20 feet away from the unit. With a telephone system, the person must speak close to the telephone microphone.

A simple switching system makes the changeover between talk and listen. For most intercoms, the changeover switch is held in the listen position so that a station can hear



Courtesy David Bogen Co., Inc.

FIG. 35. Schematic of one unit of Bogen wireless intercom.

any other station that may be calling. When the operator at a station wishes to talk, he presses down the change-over switch, connecting the loudspeaker for use as a microphone in the talk position.

Now, let us study examples of both wireless and direct-wire intercom systems.

Wireless System. A simple wireless system is shown in Figs. 34 and 35. The intercom shown is a two-station system; the two units are identical. Such a twin rf system is ideal because the units can be placed in operation at any ac receptacle and thus can be moved about from room to room to meet changing needs. Communications can be established between dwellings with ease, and can be extended up to a few miles provided all the stations are located on the same side of the utility power transformer.

Each unit is tunable between 160 and 196 kilocycles, generally factory-adjusted to 175 kilocycles. By using different frequencies, two or more private systems can be operated close to each other without interference.

As shown schematically in Fig. 35, each unit consists of a modulated oscillator, an audio amplifier, and an audio output stage. When the switch is in the receiver position, as in the diagram, the oscillator functions as a grid detector and supplies signal through the volume control to the grid of the first audio amplifier. The signal is amplified by two triode audio stages and a beam-power audio output amplifier which drives the speaker.

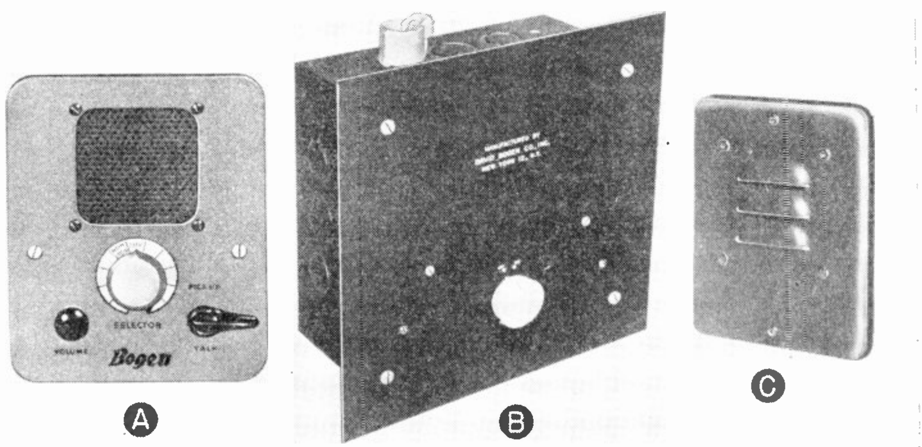
In the talk position, the speaker is used as a microphone, and is connected through the press-to-talk switch to the grid of the first audio stage. The microphone signal is increased in amplitude by the audio stages to a level sufficient to modulate the radio frequency oscillator. The plate of the output stage is connected to the plate circuit of the oscillator through the press-to-talk switch. Thus, plate modulation is accomplished.

A pickup coil couples the modulated rf signal through a 0.1-mfd capacitor to the ac line plug. When the line cord is plugged in, the radio frequency signal goes out over the power distribution lines.

At the remote location, the rf modulated signal enters the second intercom unit through its line cord and reaches the 50C5 oscillator tube. This tube is now functioning as a receiver-detector for the modulated signal. Of course, the unit also becomes a transmitter when its press-to-talk switch is held down.

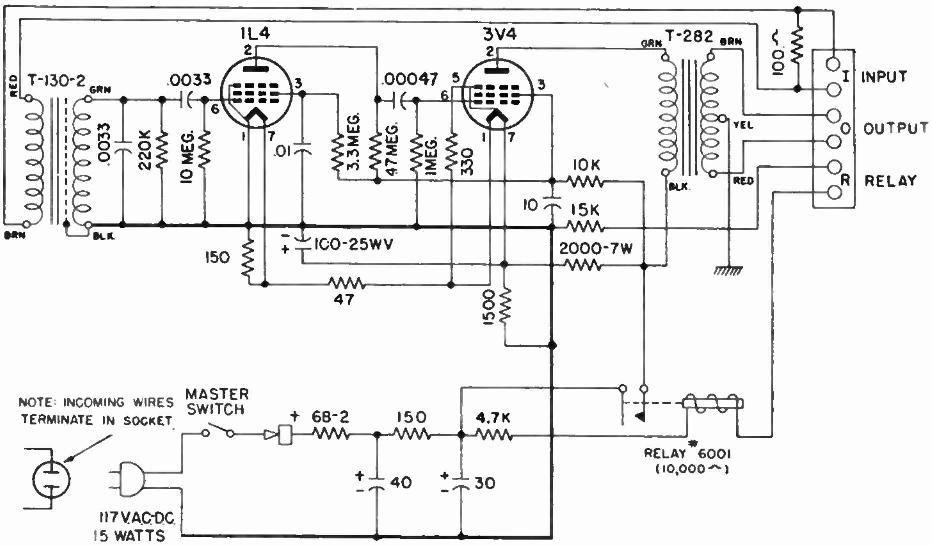
Wired System. The direct intercom system is similar to the school sound system in that it contains master stations and a number of remote or slave stations. Also, cables are used to interconnect the master units and each of the remotes. The three major units of a typical intercom system are shown in Fig. 36. These are the control station, the amplifier and power supply, and the remote speaker. Usually a system of this type contains one amplifier and one or more control stations and remote speakers. The amplifier and power supply once installed can be turned on and need not be touched during normal operating procedure. When the system is not in operation, the standby current is very low. Thus, the operating cost is low. If the system is not to be operated for an extended period of time (more than two weeks), it is advisable to turn off the system.

The amplifier shown in Fig. 37 has two stages with input and output con-



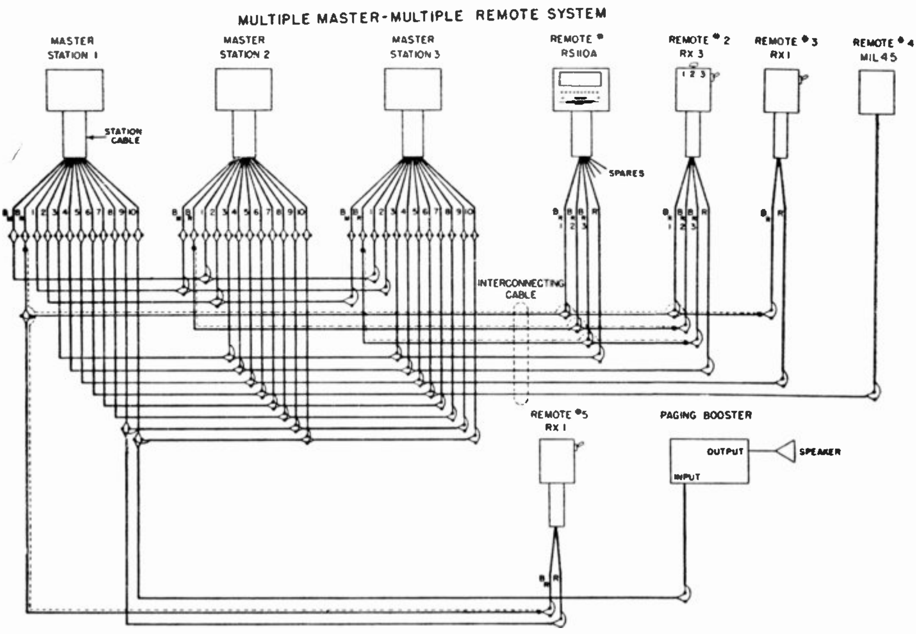
Courtesy David Bogen Co., Inc.

FIG. 36. Three major units of a typical intercom system. A, the control station; B, the amplifier and power supply; C, the remote speaker.



Courtesy David Bogen Co., Inc.

FIG. 37. Intercom amplifier and power supply.



Courtesy David Bogen Co., Inc.

FIG. 38. An elaborate intercom system.

nections. The selector switch on the control station is used to switch to the other control units and remote speakers. Then, the position of the pickup-talk switch determines whether the speakers in these units are used as microphones or speakers. With the switch in the talk position, the loudspeaker in the control unit is connected across the amplifier input and the remote speaker across the output. When the switch is in the pick-up position, the connections are reversed.

A relay is located in the power supply circuit. Whenever a control station is set on talk position, the relay closes and supplies power to the amplifier. Thus in "standby" only filament power is drawn.

A remote or "slave" station consisting of speaker alone cannot originate calls. However, replies can be made when such a remote is switched in by a control station. The Bogen system can have as many as six control stations or "masters" and four remotes or "slaves."

The plan of a more elaborate plant or office-type intercom is shown in Fig. 38. This system is very versatile and many arrangements of master and slave stations can be used to fit specific commercial needs. The installation consists of three master stations providing push-button selection of ten or twenty remotes. The number, of course, depends on the model used.

The rest of the system consists of a number of types of remotes—baffle-mounted cone-speaker, reflex horn remote (for noisy or outdoor stations), and remote units with break-in switches that can be used to call a selected master station or stations.

The wireless intercom is usually best for a small business or a home, and the wired system is better for larger, more complicated installations. In the wired system, you have a choice of several types of remote stations designed to fill the needs of various locations. Keep this in mind when you are called on to install a large intercom system.

Maintenance of PA Systems

In some respects servicing and maintaining public address systems is similar to radio and TV servicing. Although the amplifier contains more stages than are usually found in the audio sections of radio and TV sets, you can use many of the same trouble-shooting procedures on either type of equipment.

The microphones and loudspeakers connected to a PA system present problems not found in receivers. These units are attached to the amplifier by cables and connectors, so a poor connection or a break in the cable can always occur. Defects of these types, however, are usually easy to find.

The servicing procedures for a PA system should be designed to prevent a complete breakdown of the system while it is being used. A radio or TV set, on the other hand, can be operated until it fails. Preventive maintenance procedures will be discussed in this section. You should follow these procedures on your own rental equipment as well as on your customer's equipment.

PREVENTIVE MAINTENANCE

Preventive maintenance is a testing procedure that is designed to prevent a PA system from breaking down completely. It involves a definite step-by-step procedure for regular and frequent inspection and testing of the equipment and the installation. For a permanent installation, the maintenance service is usually given on a contract basis. The serviceman agrees for an annual fee to make periodic inspections and to repair any defects he finds. Generally the fee also includes all labor costs, but does not, in most cases, cover the cost of the parts. Parts are not included in the contract because there is always the possibility that the failure could be a large and expensive loudspeaker or a high quality microphone. If you contracted to pay for the parts too, your charges would have to be very high to cover the failure of these components. Hence, it is best to contract for a definite preventive maintenance schedule and for labor costs only.

A well planned preventive maintenance schedule is good insurance against breakdowns. You will have to develop an ability to notice small defects in performance or operation that serve as advance indications of future failures. This ability will improve with experience. The schedule you will follow will apply in general for most systems, but each system will have a few specific requirements of its own. Nevertheless, there are three procedures you should follow at each periodic visit to a permanent installation. You should listen to it, inspect it carefully, and make various instrument tests.

Naturally, the first thing you should do when you make a maintenance call is to ask the user of the equipment if there are any complaints or apparent defects. Follow through with his remarks when you are going over the maintenance schedule. Train yourself to be alert to any possible causes of trouble.

A good procedure to follow when an installation is first made or when you are first called in and have the equipment operating normally is to jot down various gain control settings that produce a specific output amplitude. If you know when speaking into a microphone at a given distance with the controls set at certain positions the volume level in the room should be normal, you can always reset the controls and the microphone position to duplicate this test. If the volume level has declined in the room or the amplifier noise level is higher (room conditions being unchanged), it is an indication of performance deterioration in the system.

Turn on the equipment and listen for excess hum. Run the gain and tone controls up and down quickly several times to make certain that they have not become excessively noisy. Always replace a noisy control because it will usually become noisier over a period of time. Check each microphone and loudspeaker individually to see that each unit and channel is performing normally.

Audio lines, cables, and connectors in particular should be checked carefully. You can inspect them while you are performing the listening test. Jiggle all the lines and cables to make certain that there are no loose, dirty, or intermittent connections. Inspect each loudspeaker while you are listening to it, making certain that it is fastened firmly and that the cables are in good condition.

Inspect the amplifier. See that all knobs and controls are tight, and that all connectors fit snugly. Be certain that all tubes are firmly seated and that all shields are in place. Dust out the amplifier and use your eyes intelligently to detect any changes that were not there at your last visit. Look in particular for signs of overheating. It is true that some of the parts will run hotter than others, but after you have made a number of inspections, you will learn which parts in a particular amplifier normally run hot and which remain cool.

In general, the resistors used in the power circuit and the supply-line voltage-dropping resistors run quite hot. However, there should be no excessive sign of overheating, such as burned or smoking parts. Capacitors will operate cool unless they are defective or are located close to a resistor that runs hot normally.

Instrument tests are also effective in localizing possible sources of trouble. Check all the tubes on a good quality tube checker and discard any that are questionable or weak. Always remember that tubes are the most common causes of trouble in an amplifier, and you should not hesitate to replace them at the first sign of weakening.

Make voltage measurements at key test points in the amplifier. Often the instruction manual for the public address amplifier will indicate the voltage that you should measure at various points. If it does not, draw up a voltage test procedure from the schematic, and check the same points during each preventive maintenance visit.

First measure the power supply voltages at each tap-off point. Jot these readings down on your chart

Next, measure and record the supply voltage line into each vacuum tube stage. Finally, measure and record the bias supply voltage, if this circuit is used in the amplifier. Each time you perform the maintenance procedure, you can compare the voltage readings with previous readings. From them you can easily determine whether or not there is a marked change between the values that indicates the possibility of future trouble. Small variations may be due to lower than normal power-line voltage, and should be ignored.

A small, portable audio wattmeter is a useful device for checking the power output of a PA amplifier. If you have an audio signal generator with a calibrated output, you can use it to supply a signal of a specific amplitude into each channel. Set the gain and tone controls at specific settings, and connect the audio wattmeter across the output. Make a note of each input and output value and the control settings. Each time you check the equipment, you can set up the equipment in the same way and compare the new output measurements with the previous ones.

You should carry out a similar maintenance schedule on your own amplifier systems. At times we are inclined to worry less about our own equipment than that for which we have contracts. However, in the case of public address work, your own amplifiers should be kept in peak operating condition so there are no operating failures on the job. No matter how much you know about the public address equipment and how efficiently you can repair it, any breakdown on the job is to be avoided. To too many people not familiar with electronics, any type of breakdown reflects on the ability of the technician.

The well-established sound man always has spare microphones, amplifiers, and speakers to take care of in-use breakdowns. Often the emergency amplifier is smaller and lower-powered than the original. The unit can be connected into the system temporarily while the main amplifier is being repaired.

You should always keep one or two complete sets of spare tubes on hand; one set should always be available on the job. You should also carry spare cables so that you can substitute them quickly if an audio line is broken or a connector is damaged.

You can check a microphone by substituting a microphone known to be good in its place. If the performance and response of the system improves when the test microphone is installed, either the original microphone, the matching transformer, or the connecting cable is defective. The test microphone, of course, should be a similar type to the one being checked.

If you find that a microphone is defective, do not attempt to repair it yourself, except for replacing cartridges in some of the crystal and ceramic types. If it becomes inoperative, contact the manufacturer. Generally the manufacturer will request that you return the microphone for repair.

You can also check loudspeakers by substitution or with an ohmmeter. Connect the ohmmeter across the voice coil terminals. If the meter shows that the voice coil is not open, check the cable and its connectors back to the amplifier. Never use an ohmmeter to check the crystal or ceramic microphone.

PUBLIC ADDRESS SERVICING

The most common defects of public address systems are oscillation or motorboating, hum, noise, low volume, no output, distortion, and intermittent operation. The standard signal-tracing techniques you have studied can be used to localize defects in a public address system. Be certain in making any public address tests or adjustments to connect a loudspeaker or proper dummy load across the amplifier output while it is in operation. If the public address amplifier is not terminated, the output stage may be damaged by very high peak voltages.

Dead System. When you are repairing a public address system that is dead, your first step should be to make sure that the amplifier is plugged in correctly and that supply voltages are being applied. Then check each input to see if the complete system is dead, or just a single channel. If all inputs are inoperative, the trouble is in the amplifier or loudspeaker system. If only one input circuit is dead, look for the defect in that particular channel, or in the microphone, phonograph, or cable associated with that section.

When all the input circuits are dead, first check the connections between the amplifier and the loudspeaker. If the loudspeakers are connected properly, the defect is in the amplifier. From here you can follow the usual service procedures to locate the defective part. Remember again that tubes are the most common source of failure in electronic equipment. Also check to be certain that the fuse has not been blown by a momentary overload.

Low Output. Low output is another common complaint for public address systems. The same procedure you followed in checking a dead system can be used to locate a low output defect.

First determine whether all input circuits produce a low output, or whether the output is low on just a single channel. Make certain too that the amplifier has been operated properly and that the volume and gain controls have not been accidentally turned too low. If more than one speaker is used, check to see that they are all connected properly.

Noise Defects. Hum and intermittent noises are common defects. Most hum defects are a result of poor ground or incomplete shielding of the microphone or loudspeaker lines. When poor connections develop between the cable shields and the amplifier chassis ground, hum pickup is magnified, producing a loud hum or roaring noise. Hum can also be picked up directly by a microphone located near a strong hum field.

Hum in a public address system is often due to a defective filter capacitor or high cathode-to-heater leakage in a vacuum tube. Hum also increases when the output stages become unbalanced with changing operating conditions over a period of time.

Intermittent noises in a public address system are not generally caused by an intermittent in the amplifier itself. Rather the intermittent is most likely to develop in microphone and speaker cables, in connectors, and in microphones. These are the components that are moved about and subjected to rough handling and accidental jarring or tipping.

Look for common noise troubles when a complaint is made. The high noise complaint may be caused by old worn recordings. Perhaps the noise level in the establishment has increased since the system was installed, or some particularly noisy device has been placed close to one of the microphones.

When you are sure the noise source is due to an amplifier defect, you can use the same trouble-shooting procedure as for a dead amplifier or one with a low output.

Distortion. If the sound from the PA system is distorted, your first step should be to determine whether the defect is in a single channel or on all channels. If the distortion occurs in a single channel, check the microphone by substituting one known to be in good operating condition. Next, check the tube or tubes associated with that particular channel.

If all channels produce a distorted output, check the audio output tubes, because distortion is often due to tube defects. For example, the audio output stage may be unbalanced because of dissimilar aging characteristics of the output tubes. It can be corrected by substituting two new balanced output tubes. If these tests do not help you find the trouble, use signal tracing techniques using an oscilloscope if you have one available. Remember that interstage coupling capacitors are frequently defective and result in a distorted audio output because of improper tube biasing.

SUMMARY

In these lessons on public address, you have been given information on almost every phase of PA work. You have learned how each component of a PA system works, and have been given examples of typical circuits, components, and installations. You also know how to connect the various components together, how to maintain the equipment, and how to repair it when the system breaks down.

There may be so much radio and TV repair work in your service shop that you may not have time to go into PA work. However, if you live in a small town, or if competition in your community is high, PA work can be a source of additional income.

THE MAN WHO COUNTS

The man who counts is the man who is decent and who makes himself felt as a force for decency, for cleanliness, for civic righteousness. First, he must be honest. In the next place, he must have courage; the timid man counts but little in the rough business of trying to do well the world's work. In addition, he must have common sense. If he does not have it, no matter what other qualities he may have, he will find himself at the mercy of those who, without possessing his desire to do right, know only too well how to make the wrong effective.—Theodore Roosevelt.

* * *

This statement of Theodore Roosevelt's has always appealed to me as being a very sound piece of practical advice. Read it carefully. It can be of real value to you.

J. E. Smith

SERVICING RECORD CHANGERS

46B-1

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

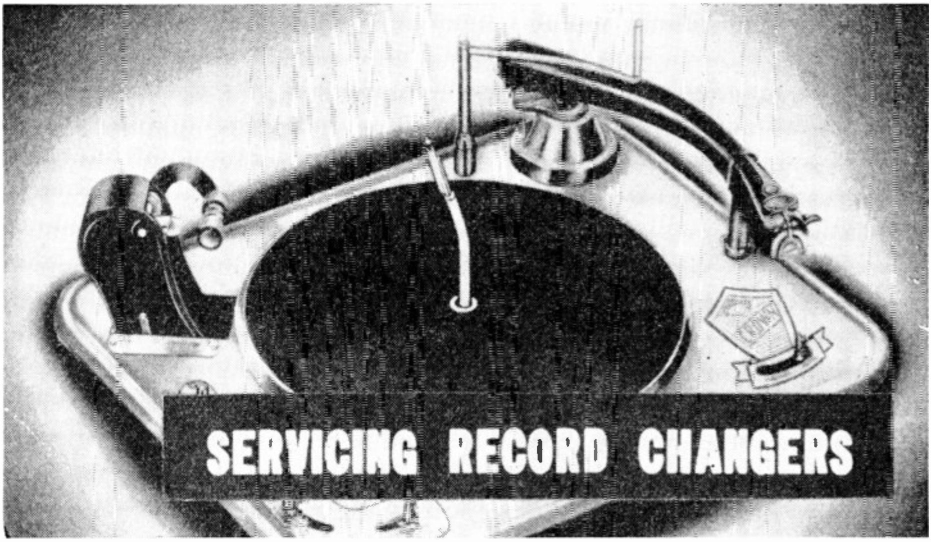
STUDY SCHEDULE NO. 46

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 8. Answer Lesson Questions.

☐ 9. Start Studying the Next Lesson.

FM3M1060 **1960 Edition** Printed in U.S.A.



SERVICING record changers is rapidly becoming an important part of the radio serviceman's business because of the tremendous increase in popularity of records and record players. Millions of phonographs are sold every year. Some record changers are built into radio and TV consoles, but most are separate units. There is also a widespread interest in high-fidelity equipment.

Since record changers must use some sort of amplifier and reproducer system, servicing them is a logical part of a radio-TV serviceman's business. The serviceman should not avoid working on changers simply because they are more mechanical than electrical.

Since very few service shops specialize in servicing record changers alone, when a serviceman advises a customer to take his changer to another shop that can service it, he is likely to lose all of that customer's business to the other shop. It is most important for a serviceman to provide complete service, and, besides, servicing record changers can be quite profitable.

SERVICING AIDS

Detailed repairing and adjusting instructions for record changers are available from the manufacturers and in the record-changer manuals published by John F. Rider and Howard W. Sams, which are available from radio wholesalers. Refer to this information whenever necessary. Until you are quite experienced, check it for each servicing job.

As you gain experience with particular models and types, you will find that you do not need to refer to the service-changer manuals as often. As with certain radio and TV receivers, the same problems come up again.

Your first step in servicing a record changer, after finding out the customer's complaint, is to confirm that complaint, and at the same time familiarize yourself with the record changer and its operation. Do this by carefully examining the mechanism on top of and underneath the record changer while rotating the turntable by hand. While doing this, press the reject button, and the cycling action should begin (unless this is the cause of the trouble). Very often binding parts, weak or missing springs, bent parts, etc. can be located simply by

Photo above Courtesy Garrard.

following this procedure. Otherwise, hours of time can be wasted by just poking around in a changer trying to determine by inspection just what doesn't look right.

TOOLS NEEDED

In order to observe the working mechanism under a record changer it is necessary to support the changer in some convenient position where it will be rigidly held, but where it will be easy to get at the underneath surface. Since some record-changer actions operate on the principle of gravity, you must work on it in its normal position. If you turned it on its side or upside down to get at it, it wouldn't work. A changer must be held in its normal horizontal position. Although the record changer can be supported on the service bench with wooden blocks, this is seldom a satisfactory method, since the changer can easily be pushed off the blocks and severely damaged. To aid in servicing record changers, changer cradles are available from radio wholesalers and mail-order houses. One such record-changer cradle is shown in Fig. 1. A simple wooden frame with three or four legs could easily be built.

One of the most convenient methods of holding a record changer is to support it by small light chains attached to the ceiling. One slight disadvantage of this system is that the changer is not held perfectly rigid, but the weight of the changer itself generally holds it steady enough for most work.

Most servicemen have enough tools for servicing record changers, and additional ones need not be purchased. However, there are some tools, such as a greater selection of screwdrivers, wrenches, and pliers, used in servicing record changers that are not always used in radio-television servicing.

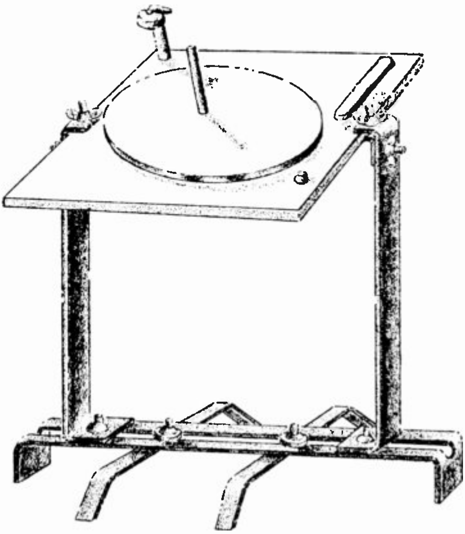
For bending the parts in a record changer, a pair of duck-bill pliers is essential. The jaws of duck-bill pliers are short and broad. The inner surfaces of the jaws are smooth to prevent marring of metal surfaces. Actually, they look like large size long-nosed pliers with the tips broken off.

To adjust some record changers it is necessary to have a set of allen-head wrenches and bristo-head wrenches. In addition to this, a ball-peen hammer is often quite useful to remove pins or rivets.

All of these tools can be purchased from either a radio wholesaler or a hardware store.

Since burring of parts often occurs in record changers, it is necessary to have a selection of files.

Selections of both single-cut and double-cut files are useful. In a single-cut file, a single row of parallel teeth is set at an angle across the face of the file. As might be expected, a double-cut file has an additional row of parallel teeth which cross the first row at right angles, giving a criss-cross appearance.



Courtesy General Cement Co.

FIG. 1. A commercial adjustable cradle for holding record changers. This style can be tilted for cleaning.

Besides single- and double-cut files, both coarse and fine files are necessary. Incidentally, files are graded according to coarseness in the following order: coarse, bastard, second-cut, and smooth.

In addition to flat files of all these different types, there are half-round files, round files, and triangular files all in different lengths.

Don't go overboard on the purchase of files. Obtain just a few to start with, and you'll soon decide just what other types you need. Although hundreds of different types and sizes could be obtained, each serviceman seems to prefer to use only a few for all jobs.

Incidentally, it is most important for you to keep your files clean. Obviously, if the grooves in the file are filled with metal chips, the file would be useless. A stiff wire brush, called a "file card," is used to clean files, and is obtainable at hardware stores.

A vise is very often necessary in changer repair work. Only a small vise is necessary. It can be obtained at any hardware store.

Of all the tools used in record-changer repair, the most useful and most often used are lubricants.

There are two greases recommended for record-changer work: Lubriplate and Sta-Put. These can be obtained from radio wholesalers.

Oil is often necessary in record changer work to lubricate fast-moving parts. The recommended oil is SAE-10W motor oil. It can be obtained from any automobile service station. A small pressure-squirt oil can is convenient for applying it.

To clean the parts in a record changer both alcohol (or naphtha) and carbon tetrachloride are used. Refer to the manufacturer's instructions for cleaning parts—especially any rubber, synthetic rubber, or parts other than metal. Also, be sure to follow all safety precautions when you are using any of these cleaners.

In the servicing of record changers, the customer will very often complain that the changer is not working properly, since the phonograph does not sound right. This trouble is very often caused by a worn needle in the cartridge, or a defective cartridge.

There is little doubt that most record changers in operation today (including those only a few months old) are using worn needles, or styluses, as they are called. It is a good plan to try a new needle in the record player after repairs have been made. (This does not apply to the record changers in high-fidelity systems that use diamond-pointed styluses.) Unfortunately, the stylus can be considerably worn before affecting the sound of the record except to the most critical ear, but even though the distortion cannot be heard, the record grooves are being gouged and the records are slowly but surely being destroyed. The serviceman should warn the customer of this, since he may not be aware of it.

The tone arm must properly track the record. That is, the needle must ride in the record groove at the proper angle in the center of the groove. Improper tracking can cause the needle to skip grooves or to repeat a groove. Even if the tracking is not far enough off to cause groove-skipping, the grooves of the record are being damaged by the excessive pressure of the stylus against the wall of the record groove.

One common cause of improper tracking is an unlevel mounting. This can easily be checked with a small pocket-size level.

Needle pressure is of primary importance to both correct tracking and proper treatment of records. Excessive needle pressure will cause excessive record wear and will also prevent proper high-frequency response. It can also cause distortion.

TYPES OF CHANGERS

Because there are several different sizes and speeds of records on the market, there are different types of changers available. Standard record sizes are 7, 10, and 12 inches, and standard speeds are 78, 45, and 33-1/3 revolutions per minute. There have also been some records made with a speed of 16-2/3 rpm.

Some record players can play all of these various types of records; others play only some types. Some record changers will play inter-mixed sizes of records of the same speed; others can play only the same size at one time.

CHANGER OPERATION

Although there are many types of record changers, they all do just about the same thing. After the records are placed on the changer and the manual adjustments have been set, the changer goes through the following operations:

1. The turntable rotates.
2. The pickup arm rises from its resting position, moves over to the outer edge of the record, and is lowered to the lead-in groove of the record.
3. As the record rotates, the tone arm is moved by the spiral formation of the grooves, toward the center of the turntable.
4. The stylus in the pickup arm enters the fast-finishing or eccentric grooves at the inside of the record, and the record-changing mechanism is actuated.
5. The tone arm rises and moves over to or toward its resting position.
6. Another record drops to the turntable.
7. The tone arm again moves over to the outer edge of the record and is lowered to the lead-in groove of the record.
8. The process repeats itself until all the records are played.
9. The record changer then turns itself off or repeats the last record.

MANUAL ADJUSTMENTS

Let us go over the manual adjustments that must be made before a record changer can be operated.

Speed. On multispeed models, there must be a manually adjustable speed control. Although there are record changers that change speed according to record size, playing 7-inch records at 45 rpm and larger records at 33-1/3 rpm, on most record changers, records played at one time must all be of the same speed.

Needle Size. Different sizes of needle or "stylus" are used. The stylus used for micro-groove records, as 33-1/3 and 45 rpm records are often called, is smaller than the stylus used for 78-rpm records, and therefore we must also have some means of choosing the proper one. Most record players have cartridges with a dual-stylus system by which the proper stylus can be easily switched, rotated, or tilted into the proper position. In some changers, the cartridge end of the pickup arm, called the "head," is a separate piece, which plugs into the arm by means of two or three pins. In such a case, two heads are provided, one using a .001-inch stylus for micro-groove records, and the other a .003-inch stylus for "standard groove" or 78-rpm records.

Record Size. In addition to selecting the proper speed and stylus, it may also be necessary to adjust a record-size control. In some record changers, a special larger spindle must be placed over the regular record changer spindle when 45-rpm records are to be played.

ON-OFF Switch. All record changers have a switch to turn them on and off.

Record-Changer Mechanisms

In studying radio and television receivers, you have found that there are certain basic components—tubes, resistors, capacitors, and coils—with which we build electronic circuits. In the most complicated electronic circuitry, we find that circuit action is possible because of the individual characteristics of these components. Even the most complicated circuit can be understood when we understand the working of the various parts.

The same thing is true with record changers, except that tools such as the lever, the wheel, the gear, etc. are used, instead of coils, capacitors, and resistors.

Let us study the characteristics of these mechanical tools in order to understand the seemingly complex mechanisms of record changers.

First of all, just what do we want to do with all of these mechanical tools? Basically we want to do only three different things: Change the direction of a motion, change a motion of one type to a motion of another type, and obtain mechanical advantage. Mechanical advantage simply means a method of making work easier. An example of mechanical advantage is using a claw hammer instead of our fingers to remove nails. Sometimes, we may deliberately give up mechanical advantage in order to accomplish either or both of the first two aims.

MECHANICAL TOOLS

The Lever. The most common mechanical tool is the lever. This is illustrated in Fig. 2. A lever can be used to increase motion or to obtain mechanical advantage, depending upon the position of the fulcrum or pivot. The product of the force applied and the distance the point at which the force is applied is moved, will always equal the product of the weight moved and the distance it is moved. The position of the fulcrum determines the amount of force required to move a weight. With the fulcrum in the middle as at A, 9 pounds of force applied for one inch will lift a 9-pound weight 1 inch. With the fulcrum ¼ of the way from the left as at B, a force of 9 pounds applied for one inch will lift 3 pounds 3 inches at the other end. With the fulcrum ¾ of the way over as at C, a force of 9 pounds applied for 1 inch will lift 27 pounds 1/3 of an inch. At B, motion is increased, and at C mechanical advantage is obtained.

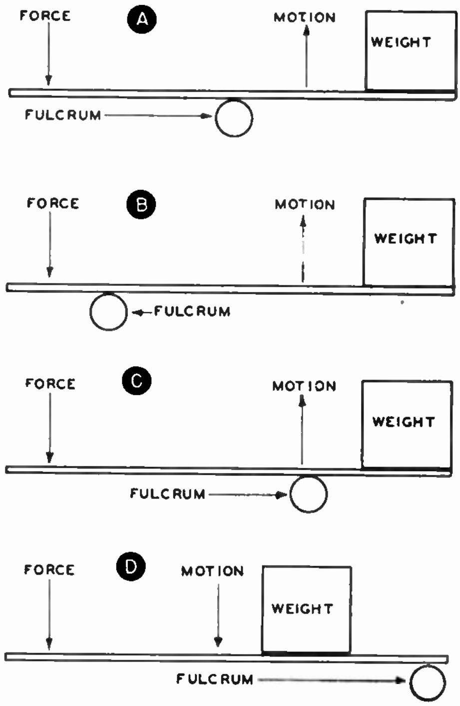


FIG. 2. Lever action. The direction of motion depends upon the position of the fulcrum and the direction of the applied force.

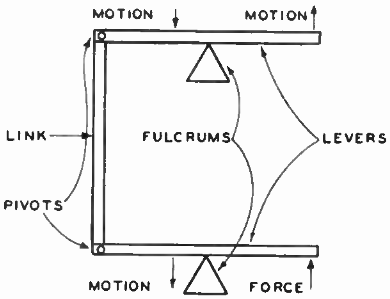


FIG. 3. The link, which is used to transmit motion from one lever to another.

If the fulcrum is at the end, and the weight is ¼ of the way from the fulcrum as at D, the direction of force and the direction of motion will be the same. Again a 9-pound force applied for 1 inch will move a 27-pound weight 1/3 of an inch.

An example of a lever in a record changer is the pickup arm itself, which is the lever, and the point to which it is attached to the changer is the fulcrum. The fulcrum and the point where force is applied are placed to avoid mechanical advantage so that a small movement of the arm near the fulcrum will result in a larger motion near the "cartridge" or needle end where it is needed.

The Link. The link is used to connect two levers to each other in order to transmit the motion of one lever to the other as shown in Fig. 3. This is very often desirable if two pickup arms on a changer must have the same motion at the same time. Such systems are very often used in two- and three-shelf changer mechanisms.

The Wheel and Axle. Fig. 4A shows the combination of a wheel and axle. The wheel and axle provide mechanical advantage if the force is applied to the wheel, since their radii are different. Notice in Fig. 4A that point B on the outside of the wheel must move through a greater distance for each revolution than point A on the axle. If the center is considered the fulcrum, the wheel and axle is similar in operation to the lever shown in Fig. 2D.

Gears. A gear is merely a wheel with teeth. The same principles that apply to the wheel, apply also to the gear, and a gear has less tendency to slip.

In many applications, it is not necessary to use a complete gear and axle assembly, but only a section as shown in Fig. 4B.

Gear and Wheel Trains. Wheels and gears can be combined to work with each other and obtain mechanical advantage, a change of direction of motion, or a change in speed of rotation, as shown in Fig. 5.

Mechanical advantage is always accompanied by a change in speed. The small wheel always rotates faster than the large one. The greater the difference in size between the two wheels, the greater the difference in their speeds will be. If the large wheel is twice the size of the small one, the small one will rotate twice as fast as the large one. If one wheel is three times as large as the other, the small one will rotate three times as fast.

You can see from Fig. 5B that when a third wheel, called an "idler wheel," is used, the direction of motion is not changed, and if the drive wheel and the driven wheel are of the same size, mechanical advantage is not obtained either. However, by using rubber tires

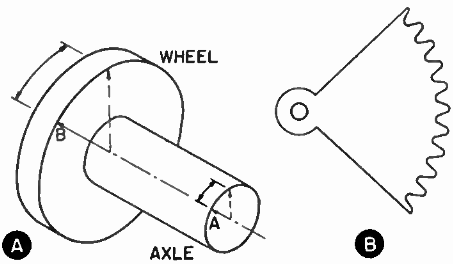


FIG. 4. A wheel and axle combination is shown at A. Sometimes only a segment of a wheel or gear is used, as shown at B.

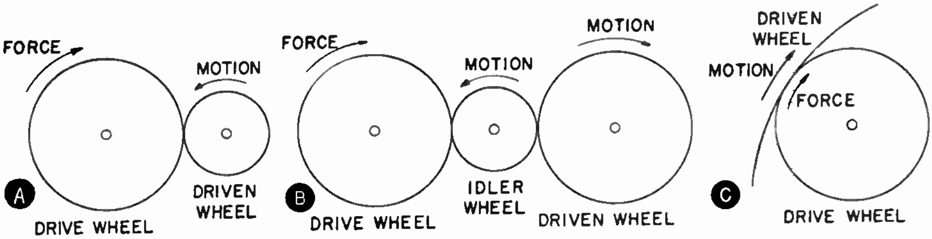


FIG. 5. Different types of wheel trains. At A, the drive wheel and the driven wheel rotate in opposite directions; in B, the drive wheel and the driven wheel rotate in the same direction because there is an idler wheel between them; and in C, they rotate in the same direction, because their centers are both on the same side of the point where the wheels touch.

on the wheels, isolation is obtained between the drive wheel and the driven wheel. This system is very often used to rotate a turntable and thereby isolate the motor from the turntable to help in reducing rumble and hum.

Many turntables are driven on the inside of the rim as shown in Fig. 5C. In this case, both wheels rotate in the same direction. Whenever the centers of the drive and driven wheels are on the *same* side of the point at which they touch, they will rotate in the *same* direction. If the centers of the two wheels are on *opposite* sides of the point of contact, they will rotate in *opposite* directions.

Belt Drives. An endless belt around two wheels can be used instead of an idler wheel. This is sometimes more convenient than using a third wheel if the drive wheel and the driven wheel are some distance apart. With this arrangement, the drive wheel and the driven wheel both rotate in the same direction, as shown in Fig. 6. The belt drive may provide more isolation than an idler wheel.

The Cam. The cam is a rotating piece, similar to a wheel, but its surface is grooved or contoured so as to control the movement of a roller or pin moving against it. Fig. 7 shows a roller moving against a track on a cam that controls the vertical movement of the arm to which the roller is attached. When the roller reaches point X, it will be higher than it is at the point shown. Fig. 7B shows a pin or stud riding in a groove on the cam. The groove or track can be shaped to con-

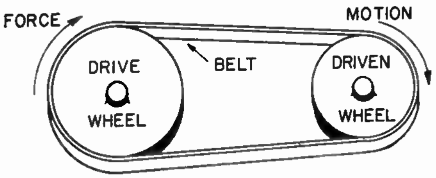


FIG. 6. When a belt instead of an idler wheel is used, the drive wheel and the driven wheel rotate in the same direction.

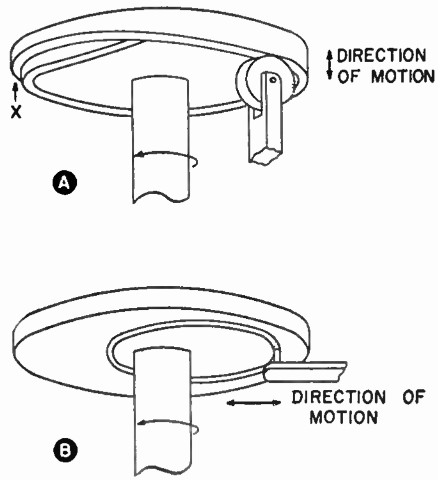


FIG. 7. A cam can change rotary motion to either horizontal or vertical motion as shown here.

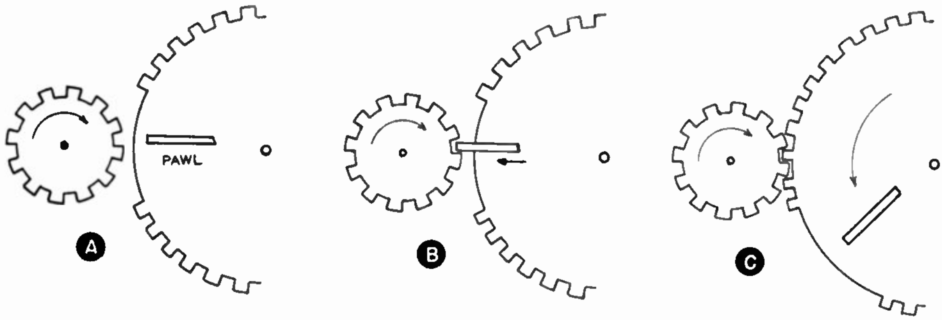


FIG. 8. How a mutilated clutch mechanism works.

trol either the horizontal or the vertical movement of the arm to which the roller or the pin is attached, or both. Cams are used to change rotary motion to back-and-forth or up-and-down motion.

Perhaps the operation of a cam can best be understood from one of the actions it can cause. When the pickup arm reaches the inner grooves of a record, it must be lifted up from the record surface and then moved toward the outside of the record. If it were not lifted, the needle would scratch across the grooves of the record. Thus, two motions are necessary: the vertical movement of the arm, and the horizontal movement of the arm. Such operations can be accomplished by means of cams.

It is important to remember that the cam wheel is not in use at all times. It must be disengaged during the playing of the record, and put into operation only when it is desirable to lift the arm from the record surface and move it out of the way for the next record to drop (or to turn off the changer after the last record has been played).

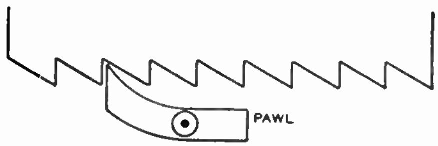


FIG. 9. A ratchet and pawl.

The Clutch. This brings us to another tool—the clutch, which is a coupling for working parts that permits them to be engaged or disengaged. Fig. 8 shows an example of a clutch for engaging and disengaging two gears.

One section of the large gear has no teeth. When that section is toward the small gear, the two gears are disengaged, as in Fig. 8A. On the large gear is a projection, called a pawl, which can be pushed out beyond the edge of the gear. When this happens, as in Fig. 8B, the pawl catches on the teeth of the small gear, which is rotating clockwise. This pulls the large gear around in a counter-clockwise direction, causing the teeth to mesh with those of the small gear as in Fig. 8C. The large gear will continue to rotate until the section without teeth is again toward the small gear. The large gear will then stop rotating until the clutch pawl is pushed out again.

The Ratchet and Pawl. A ratchet is a series of notches that works with a pawl to permit us to have motion in one direction but not in the other, or to transmit motion. Fig. 9 shows an example. The pawl is pivoted in the middle. As you can see, if the notches are moved to the left, they will slide right over the pawl, and it will have no effect. If the part with the notches is moved to the right, however, the teeth will catch on the pawl, and either the motion will be stopped, or the piece to which the pawl is attached will be moved along with the notched piece.

The Inclined Plane and the Wedge. The inclined plane and the wedge are similar to each other, and their effect can be seen by studying the directions of force and motion shown in Fig. 10. Notice that in both cases, not all the motion is in the same direction as the applied force. With an inclined plane, two motions are obtained from the one applied force.

The Spring. A spring is a piece of metal that tends to resume its original shape if it is stretched, compressed, or bent, as shown in Fig. 11A. Although a coil spring is the kind most often used in changer mechanisms, you will sometimes find a leaf spring, whose action is shown in Fig. 11B.

This short discussion covers most of the mechanical tools used in a record changer. The various parts in a changer will consist of one of these tools or a combination of them. Even though their shapes may vary, other characteristics will be similar. It cannot be overstressed that an understanding of these basic components is essential, just as an understanding of the components of a radio is essential

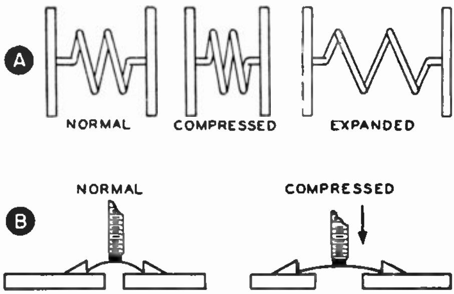


FIG. 11. Two types of springs are used in record changers, the coil spring shown at A, and the leaf spring shown at B.

to an understanding of the over-all action of the radio.

Gravity and Friction. Gravity is often used in a record changer. For example, we might invert the ratchet and pawl mechanism shown in Fig. 9, and hold the pawl away from the notches by means of a lever. When the lever was removed, the pawl would then drop by force of gravity to the notches.

Friction is the resistance to motion between two bodies in contact. Sometimes it is desirable, and sometimes it is not. For example, friction is desirable in wheel trains and in belt drives, but is very undesirable in an inclined plane.

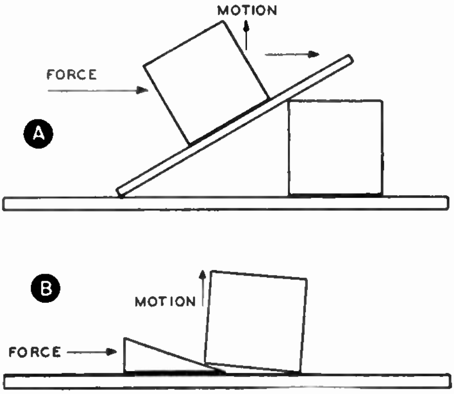


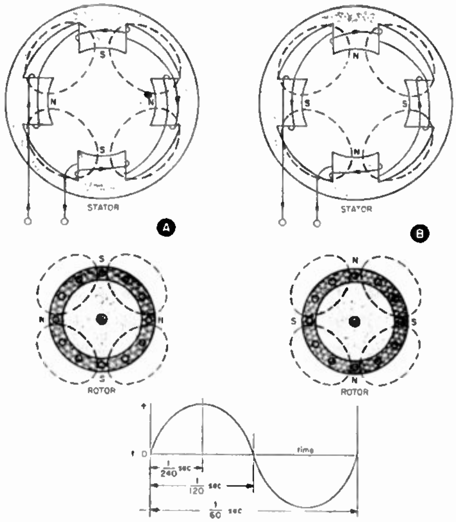
FIG. 10. The inclined plane is shown at A; the wedge at B.

MOTORS

The first important function of any record changer is to rotate the turntable on which the record is placed. Turntables are rotated by motors, which may be electrical or mechanical.

In old phonographs, mechanical motors were used, but today practically all phonographs use electric motors. If you are ever called upon to repair a turntable using a mechanical motor, where the motor is causing the trouble, it is best to replace the motor rather than try to repair it.

There are three basic types of electric motors used: two-pole and four-



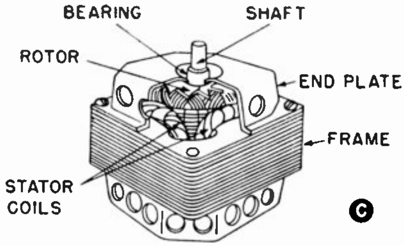


FIG. 12. The operation of a 4-pole induction motor is shown at A and B. C shows what the motor looks like.

pole induction motors, and hysteresis-synchronous motors. Two-pole motors are quite simple, and synchronous motors are quite complicated. The two-pole motors are the least expensive; the synchronous motors are the most expensive and are used only in turntables of very high quality.

Most record changers use the two-pole or four-pole motors.

In this type of motor, there are two parts. The electromagnet portion of the motor remains stationary and is called the stator or field coil. The part that rotates is called the rotor or armature.

These two principal parts of the motor are shown in Fig. 12. In this example, the stator has 4 poles. The four poles are wound with coils to which is applied the 115-volt, 60-cycle power line voltage. When current flows through these coils, the entire stator becomes an electromagnet. Thus, lines of force are set up as shown in the illustration. This operation is very similar to transformer operation, which you have studied. The inductor motor is so-called because it uses induced current to create the magnetic field in the rotor or armature.

The armature, or rotor, consists of copper or aluminum bars imbedded in a laminated iron core, and connected together at each end by a copper ring. The rotor is inside the stator, so that the magnetic field of the stator or field coil, will induce current in the copper bars, which will, in turn, create a magnetic field of their own in opposition to the magnetic field of the stator.

Fig. 12 shows how this induction motor operates. Below the stator diagram is a graphic representation of one cycle of alternating current. Fig. 12A shows the positions of the rotor and the stator during one half-cycle. The dotted lines represent the magnetic fields that are created in these parts. Current is flowing from the left-hand terminal of the field winding on the stator through the winding back to the right-hand terminal as indicated by the arrows on the winding. This current creates magnetic fields as shown by the dotted lines, of the polarity indicated by N (north) and S (south). The induced fields in the rotor are again represented by dotted lines. The polarities of these induced fields are in opposition to those of the stator, since like poles repel each other. Therefore, the rotor will tend to rotate until the north poles of its fields are adjacent to the south poles of the stator fields. However, as shown at B, before these poles can be lined up, the polarity of the alternating current reverses, and the armature must continue to rotate in its attempt to line the fields up. Of course, this continues as long as power is applied to the motor, so the motor continually rotates. The drive shaft attached to the rotor also rotates, and drives the turntable.

The rotor of a four-pole motor generally rotates at about 1750 rpm; the rotor of a two-pole motor at about 3500 rpm. Because of the lower speed of the four-pole motor and its greater power capabilities, it is preferable. Furthermore, because of the lower speed, vibrations are at low frequencies, which are not as objectionable as vibrations at high frequencies. Because, in a four-pole motor, the rotor is larger, it can be more easily balanced than in a two-pole motor.

The rotor turns inside the stator of the motor and is held in position by bearings, as shown in Fig. 12C, which are held in place by the end plates attached to the motor frame. The bearing retainer in some changers contains a felt washer saturated with oil; in others it is necessary to oil the bearing itself periodically. In some expensive motors, ball bearings packed in grease are used.

The motor is mounted on the motor board by means of springs or rubber grommets or both. You can usually tell the mounting method by examining the motor and motor board assembly.

Motor Repairs. One very common trouble is hardening of the rubber grommets of the motor mounts. This makes them useless, so motor vibrations are transmitted to the turntable. This causes excessive rumble. You can test them simply by feeling them. If springs are used alone or in combination with the grommets, they should not be so tight that their action is useless. The motor should be mounted loosely enough so that it can be bounced up and down with the fingers.

When the motor itself does not rotate, the trouble may be due to the jamming of a part or parts in the changer. By manually moving the turntables, the trouble can be isolated to jamming in the changer or to trouble with the motor itself.

If you find that the changer mechanism is not jammed, then the rotor of the motor may be frozen. This can happen if the motor is knocked out of its bearing. The trouble can sometimes be cleared up by tapping on the end plates after they are loosened.

The motor lubricant sometimes hardens and glues the rotor to the stator or gums up the bearings. If this happens, the motor must be disassembled and the rotor removed. The rotor can sometimes be cleaned by using an emery cloth to remove the film, and then polishing with a crocus cloth. Be careful when using the cloth not to remove enamel from the wire, thereby causing a short circuit. The motor should then be completely cleaned with carbon tetrachloride and lubricated with light, high-grade motor oil such as SAE-10W. Do not use any other oil. Be extremely careful when using carbon tetrachloride not to breathe its fumes, as they are poisonous.

Very often a motor becomes dirty with a heavy accumulation of lint, dust, dirt, and oil. If the motor runs erratically or slowly, it should be disassembled, cleaned, and oiled as described above.

Constant use and age sometimes loosens the laminations of a motor, which causes buzzing. Tightening of the motor bolts will usually clear up this trouble. If the motor is riveted together, or if it isn't possible to tighten the motor bolts sufficiently, lamination buzz can sometimes be stopped by forcing small wedges of wood between some of the laminations. Check the turntable speed after doing this. If it has changed, the motor will have to be replaced.

Finally, the windings in the motor may open. If this happens, since the serviceman is usually not equipped to rewind the motor, it must be replaced or, if it is an expensive motor, returned to the manufacturer for rewinding. Replacement motors are available at radio wholesalers.

A short circuit sometimes occurs between a motor winding and the core of the motor. If this happens, the entire changer and the amplifier to which it is connected becomes a shock hazard. The short circuit can sometimes be repaired, but most often the motor must be replaced.

It is important that all parts of the motor be lubricated with SAE 10W motor oil. Do not use the usual household general-purpose lubricant.

Motor Drives. Since two-pole and four-pole motors run at approximately 3500 rpm and 1750 rpm, respectively, it is necessary to use a drive mechanism between the motor shaft and the turntable in order to obtain turntable speeds of 78.26 rpm, 33-1/3 rpm, 45 rpm, and 16-2/3 rpm.

A direct drive is seldom, if ever, found in commercial record changers, since it would be necessary for the motor to have a great number of poles in order to turn at all of the standard speeds.

One method of changing speeds would be to use a gear train. In this case, a gear would be attached right to the motor shaft and then one or more gears would be used in a train to drive the turntable directly.

This method of driving a turntable has been used quite frequently, even though it has the undesirable feature that precision machining of the gears is required to reduce gear noise and speed variations. Furthermore, this system is likely to transmit motor vibrations to the turntable.

The most common drive method in record changers is the rim drive in which there are three or more wheels in a wheel train, the turntable being the final driven wheel, and the main idler having a rubber tire. Such a basic mechanism is shown in Fig. 13. At A is shown the arrangement for a single-speed changer. The motor turns the drive wheel, which turns the idler wheel, which turns the turntable.

At B is shown one method of changing speed. There are two idler pulleys, connected to the drive wheel by belts, so that when the drive wheel rotates, they rotate in the same direction. The position of the idler wheel is set by the speed-change switch. When the

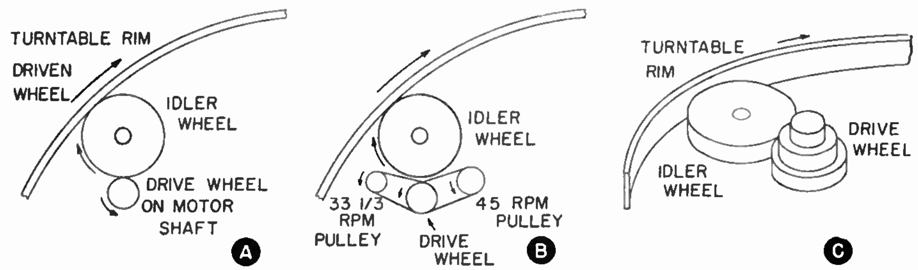


FIG. 13. Different methods of driving the turntable. A is for a single-speed changer; B and C are for three-speed changers.

switch is set for 78 rpm, the idler wheel will come in contact with the drive wheel itself. When the switch is set for 45 rpm, it will be moved over, and will contact the 45 rpm pulley. When the switch is set for 33-1/3 rpm, it will contact the 33-1/3 rpm pulley. Its speed is determined by the size of these pulleys.

Another system is to have three different levels on the drive wheel with different diameters as shown in Fig. 13C.

There are many variations of these systems, but they are quite simple, and you will usually be able to figure them out quite easily.

Drive-Mechanism Servicing. The most common effects of trouble in a drive mechanism are improper turntable speed, and rumble.

Improper turntable speed causes a change in pitch. A stroboscopic disc can be used to determine the actual speed of rotation. These discs can be obtained from most radio wholesalers. A portion of one is illustrated in Fig. 14. The disc is placed on the turntable. On the disc are rows of dots, labeled with the different speeds to be tested. When the row of dots for a particular speed appears to be stationary as the turntable is rotated, the speed of rotation is correct. The light from a neon bulb, which flashes on and off 120 times a second, must be used with a stroboscopic disc to synchronize the speed of the dots with the flashing of the light. Light from an ordinary incandescent lamp will not work.

The rubber tires of rim-drive mechanisms often become coated with oil or grease, which causes slippage. Clean them carefully with a dry cloth. This is a very common trouble.

Caked lubrication on the gears in a drive can cause binding. The gears should be cleaned and then lubricated. The lubricant should be a high-quality grease such as "Sta-Put" or "Lubriplate," which can be obtained at most radio wholesalers or hardware stores.

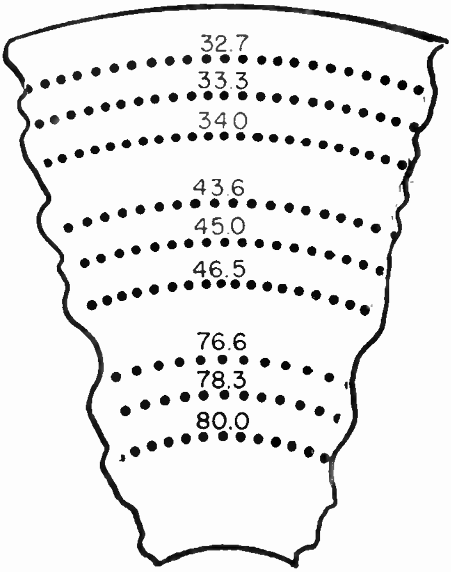


FIG. 14. A section of a stroboscopic disc, which is used for checking the speed of a record player.

Rumble in a rim-drive mechanism is often caused by a flat developing on the rubber tires of the idler wheels. In high-quality changers, the idler wheels are removed from contact with the turntable and other idler or drive wheels when the mechanism is shut off. If this is not done, the rubber tire rests tightly against a hard surface and a flat develops. This flat will cause a variation in speed and result in rumble and/or "wow," which is a slow variation in speed as the flat comes in contact with the turntable. This results in a change of pitch, which is most noticeable on a sustained sound. The only solution is to replace the rubber tire or the entire idler wheel. Do not attempt to repair the wheels.

When cleaning the rubber tire, do not use carbon tetrachloride or other solvents that might dissolve or damage the rubber. Alcohol is the best cleaning agent for the rubber tires.

After the rubber idler wheel is cleaned, the inner rim of the turntable as well as the other idler wheels should be cleaned.

In belt-drive mechanisms, the belt very often becomes stretched and causes wow. Replacement of the belt is the only solution. Be sure to keep the belt free from grease and oil, or it will slip. Very often rubber belts become cracked and hardened and cause considerable rumble. A temporary cure is to turn the belt inside-out, but a hardened belt should be replaced if at all possible.

Since friction plays such an important part in drive mechanisms, it is most important to keep oil and grease away from the rubber tires and pulleys. Be careful not to use too much lubrication. Too much lubrication will cause friction-driven parts to slip. When you are lubricating parts that are near the friction-drive mechanisms, it is better to use too little lubricant than too much.

Actuating the Change Cycle

As we saw when we discussed mechanical tools, we can get all types of motions in a record changer with these tools, but in all cases, some primary force has to be applied. In a record changer this primary force is obtained from the motor. The motor rotates the turntable. On the turntable hub is a gear, which drives other gears, as shown in Fig. 15. This hub gear is generally smaller than the gear or gears it drives. It is called a pinion gear. The usual method of driving the changer mechanism is to use a large gear, called the drive gear, which meshes with the hub gear. The drive gear very often has a cam mechanism built into it, or the cam may be directly above or below it. The main drive gear is coupled to other levers, gears,

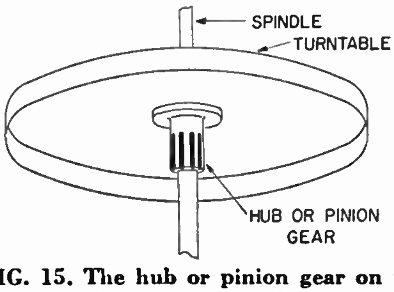


FIG. 15. The hub or pinion gear on the turntable drives the other gears.

and mechanical tools that carry out the actual changing process. The first problem is to arrange the drive gear so that it comes in contact with the hub gear only when records are to be changed. The drive gear should not be engaged with the hub gear at other times during the playing of records. The section of a record changer that is used to actuate the changing mechanism is called the "trip" mechanism.

CLUTCH MECHANISMS

The first requirement of the trip mechanism is some sort of clutch to disconnect and connect the drive gear to the hub gear when necessary.

Mutilated Clutch. One of the simplest clutches is called a "mutilated gear" clutch. This is the type mentioned earlier in which one section of the large gear has no teeth.

When the change cycle is to start, the drive gear must be turned enough so that its teeth will mesh with the teeth of the hub gear. This is done by means of a lug or pawl on the drive gear which is forced into the hub gear. The drive gear will then rotate until the mutilated section again moves op-

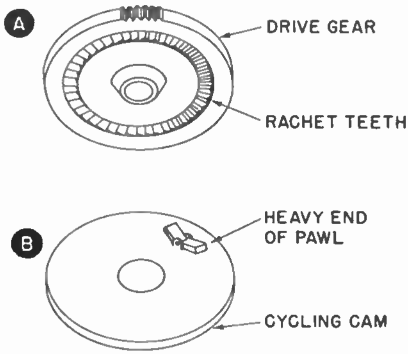


FIG. 16. A gravity clutch mechanism using a ratchet and pawl.

posite the hub gear teeth. The drive gear will then stop until the clutch pawl is again actuated.

Gravity Clutch. Another popular type of clutch mechanism is the gravity type, illustrated in Fig. 16. This uses the ratchet and pawl arrangement described earlier. In this mechanism the drive gear is directly over the cycling cam and the pawl is between the cycling cam and the drive gear. At A is shown the under side of the drive gear, and at B is shown the upper side of the cam. The pawl is freely pivoted and fastened to the cycling cam. One end of the pawl is heavier than the other. The light end of the pawl is shaped so that it will fit into the teeth in the lower face of the upper drive gear. Thus, if it is not prevented, the light end of the pawl will rise and engage the teeth in the drive gear, so that the drive gear and the cycling cam will be locked and rotate together. This is the position during the changing cycle. At other times another part of the changing mechanism is used to hold the pawl away from the upper gear. A great number of changers use this mechanism.

TRIPPING MECHANISMS

There are three popular types of tripping mechanisms used in record changers. The velocity trip, the eccentric trip, and the position trip. In all of these, the trip mechanism is actuated by the pickup arm through a lever attached to the lower end of the pickup arm shaft, which therefore moves with the pickup arm.

The velocity trip operates on the principle that when the record is playing, the pickup arm is moved slowly toward the center of the record by the spiraling action of the grooves. When the record is completed, the pickup arm moves into the fast-finishing grooves and moves very rapidly. The velocity trip uses this rapid movement to actuate the clutch mechanism.

The eccentric trip operates on the eccentric movement of the pickup arm when it is in the fast finishing grooves at the inside of a record. The pickup arm moves quickly toward the center of the record and then outward again in the fast-finishing grooves. The inward and outward movement of the arm actuates the eccentric trip.

The simplest tripping mechanism is the position trip which operates when the pickup arm has reached a specific distance from the center of the record or spindle. The distance is usually 1-7/8" from the spindle.

Position Trip. Record changers most often use the position trip because of its simplicity. It is seldom used alone today because of its limitations, but it is often used in conjunction with the eccentric trip.

A simple position trip is shown in Fig. 17. The trip lever is attached to the pickup arm underneath the changer, and as the pickup arm moves toward the center of the record, the trip lever moves toward the clutch pawl, which is attached to the cycling cam. When it strikes the end of the clutch pawl, it rotates the other end into contact with a lug on the hub gear. This turns the cam enough so that its teeth mesh with those of the hub gear, and

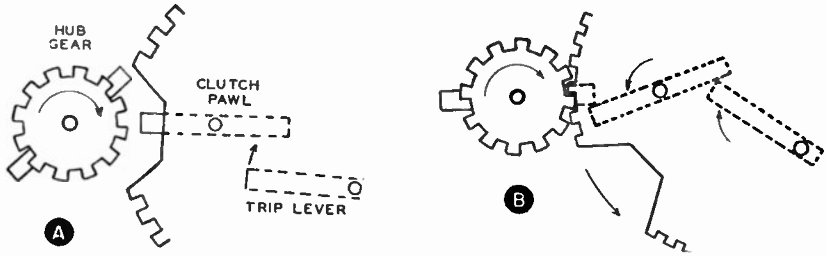


FIG. 17. The operation of a position trip.

it starts rotating, and the change cycle is actuated.

Velocity Trip. The velocity trip mechanism depends upon some friction device that does not trip the mechanism until the pickup arm travels at a high rate of speed as it does when it enters the fast-finishing grooves of a record.

In the system shown in Fig. 18, the pickup arm is connected through a link to the friction plate, which is pushed in the direction of the pickup arm. This motion is transferred to the trip arm through a friction pad attached to the trip arm. Although there is little friction here, it is sufficient to move the trip arm as shown.

There is a projection, called a striker, on the spindle at the center of the turntable. This rotates with the turntable. As the record is being played, the trip arm moves with the pickup arm, and the trip lever is brought closer to the striker. This movement of the trip lever toward the spindle is very slow. Gradually the lever is moved far enough in so that the tip end is hit by the rotating striker. Since only the tip end is hit, the blow is light, and the trip lever is pushed back away from the striker. The amount of friction between the trip arm and the friction plate is such that the trip lever merely moves back through the hole in the trip bar instead of moving to the left and actuating the trip bar. When the pickup arm reaches the eccentric or fast finishing grooves of the record, it is moved in very rapidly toward the spindle. As a result, the trip lever is moved rapidly toward the striker and the striker hits the side of the trip lever very hard. Since the blow is at the side of the lever, it does not move the trip arm back across the friction plate but instead strikes it against the trip bar and actuates the changing mechanism.

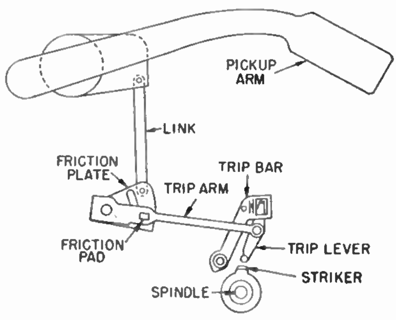


FIG. 18. The operation of a velocity trip.

There are many variations of this velocity trip mechanism but they all work on the same principle of friction preventing the actuating of the trip mechanism for small or slow movements of a part, but permitting the tripping action for larger or faster movement of a part.

Eccentric Trip. The eccentric trip operates on the principle that the pickup arm reverses its normal direction of moving toward the center of the record when it enters the fast-finishing or eccentric grooves of the record. It is this outward movement toward the edge of the record that actuates the trip mechanism.

One simple eccentric trip mechanism is shown in Fig. 19. As the pickup arm is moved toward the center of the record, the pickup arm lever with the pawl at the end moves in toward the trip lever ratchet. The spring-loaded trip pawl contacts the teeth of the ratchet lever near the end of the record. As the pickup arm enters the eccentric, fast-finishing groove of the record, it moves toward the center of the record and then back toward the outside. This backward movement also causes the pickup arm lever to move backward and the trip pawl is rotated to a position in line with the trip lever. This causes the pawl to stick farther out from the end of the trip lever. The pawl then forces the ratchet lever away from the trip lever. The ratchet lever is pivoted and its far end starts the change cycle.

TRIP MECHANISM TROUBLES

The most common difficulty in a position trip mechanism is improper setting of the part that causes the actual tripping. This part is generally called the trip shoe—it is always an adjustable part. If it is incorrectly set, or jarred loose, the mechanism may not trip at all, or may trip too soon. If this happens, the screws holding the trip shoe should be loosened and then readjusted so that the mechanism trips when the needle is 1-7/8″ from

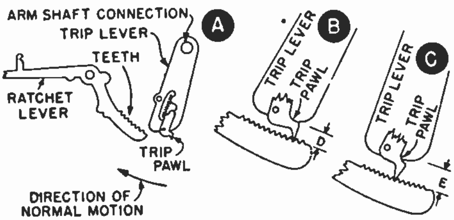


FIG. 19. The operation of an eccentric trip.

the center of the record.

Even if the trip shoe is not loose, it may still need readjustment. However, if it needs to be readjusted more than a fraction of an inch, there is probably trouble elsewhere in the changer. The pickup arm lever may have slipped in relation to the pickup arm itself. This can easily be checked by holding the pickup arm and trying to move the pickup arm lever. If the lever will move while the pickup arm is held steady, then it is loose and should be tightened to the pickup arm shaft.

A broken or worn tooth on the trip shoe, a bent edge on the trip pawl, or a defective or missing spring on the pawl will cause failure in an eccentric mechanism. Bending and light filing will generally clear up such troubles. If a gear tooth is completely missing, the gear itself will probably have to be replaced. Defective springs can sometimes be repaired, but since their cost is low, replacement is usually best.

If a velocity trip fails to actuate the change cycle, there is generally a weak or oily friction connection. Sometimes a customer will try to oil his record changer himself and drop oil down on the friction pad. All friction connections must be clean and dry, or there will not be enough friction.

In some changers, a spring is used to provide friction-loading of the pickup arm lever. The spring will often slip out of the tab to which it is attached, or break.

A felt washer may be used between the clutch weight and the pickup arm lever. If it is worn, it can become slippery, there will not be enough friction, and the record changer will trip too soon.

Since a great number of springs are used in a record changer, missing and weakened springs are very often causes of trouble. It is usually not advisable to try to repair a spring, especially since they are so inexpensive. Assortments of springs can be purchased from a radio wholesaler. When using such replacement springs, be sure the substitute spring not only is of the same size as the original but also has the same tension (springiness). Occasionally a special type of spring that must be replaced with an exact replacement from the manufacturer is used.

Record changer parts must be able to move freely; any tendency to bind is a cause of trouble and should be cleared up. Most binding is caused by a bent part or an accumulation of dirt. Cleaning and straightening of parts will usually clear up the trouble.

Burring of parts in a record changer will very often cause undesirable friction. The burrs must be removed by filing and cleaning.

All record changers are completely oiled and lubricated when they leave the factory. This lubrication usually lasts for a year or more.

Unless the manufacturer's instructions specifically state that certain sections of the tripping mechanism are to be lubricated, then all oil and grease should be kept away from the tripping mechanism. In friction-type mechanisms, any lubrication will prevent proper operation.

Gear teeth and sliding surfaces in a tripping mechanism are generally lubricated with Sta-Put or Lubriplate.

Cycling and Indexing the Pickup Arm

The movement of the pickup arm out of the way of the record stack after a record is played so that another record can drop to the turntable is known as "cycling." The return of the pickup arm to the beginning groove of the next record, another part of this operation, is known as "indexing."

The indexing section of the record changer is a very common source of trouble, since the pickup arm is on the top of the record changer and is subject to mishandling by the owner.

In the type of record changers that turn off after the last record is played, trouble is seldom found in the indexing system. However, in changers where the last record is repeated until the changer is turned off, trouble is frequently found. The owner often lets the last record play two or three times and then decides to turn off the mechanism or change the records. He may move the pickup arm in the middle of a record and cause the tripping action to begin. However, the user suppresses the normal movement of parts by holding the pickup arm and this places a strain on the mechanism.

Force should never be used to stop a changer mechanism from going through its usual routine. It is also important not to shut off the changer during the change cycle. At all times let the change cycle be completed before shutting off the changer or changing records.

In a non-mixing record changer, the size of record being played must be set on the changer itself by a switch or lever. On an intermixing changer, all sizes of records can be played. The size of the record itself determines the set-down position of the pickup arm.

For all records, the pickup arm must be lowered between the outer edge of the record and the first recording groove. There is a single turn groove here, running from near the edge to the first recording groove, known as the starting groove. It brings the needle quickly into the regular playing grooves. Naturally if the pickup arm is not moved far enough in toward the record before it is lowered, it will miss the record completely. If it is moved too far in, it will miss the first few grooves of the record. Both of these troubles are common in record changers and can usually be cleared up by a simple adjustment.

Along with the lateral movement of the pickup arm toward the record stack, there is also a vertical movement. The arm must rise high enough to clear the pile of records already on the turntable but not high enough to rub the underside of the records that are still to be played.

CYCLING THE PICKUP ARM

Let us follow the operation of a changer through the change cycle. Do not be discouraged if you find it a little hard to understand. When you actually have a changer in front of you to work on, you will be able to follow its operation much more easily. When you are actually working on a changer, refer to this lesson to help you understand it.

Fig. 20 shows the cycling mechanism of a popular record changer.

When the tripping mechanism (not shown) causes the cycling cam to rotate, the stud on one end of the pickup-arm raising lever begins to ride in a track on the under side of the cycling cam. As it does so, because of the formation of the track, it is pushed down and rotated by the cam. Notice that the lever has pivots for moving in two directions. As one end of the lever goes down, since the fulcrum or pivot of this raising lever is

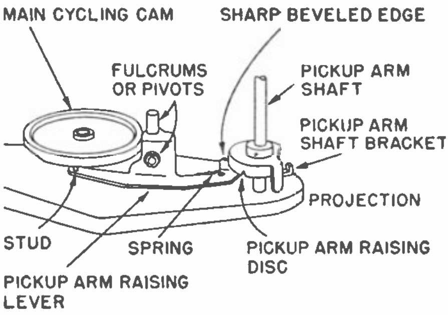


FIG. 20. The cycling mechanism of a popular record changer.

in the center, the other end of the lever moves up. At this end of the raising lever, a sharply beveled edge is in contact with the pickup-arm raising disc. The upward movement of the beveled edge causes the raising disc to move up. This in turn moves the pickup arm up from the record surface.

The raising lever is pivoted to move in a horizontal direction also. As it moves, the beveled edge of the lever rotates the pickup-arm raising disc. This in turn moves the pickup arm away from the center of the record toward its resting position. The raising disc rotates until the projection on it strikes against the pickup arm shaft bracket, which prevents further movement. The beveled edge then slips on the pickup-arm raising disc until the cycling mechanism finishes its action. As this beveled edge moves on the pickup-arm raising disc, after the pickup arm is moved to its resting position, it finally slides into a small V cut in the pickup-arm raising disc. The beveled edge then rests in this V until a record drops on the turntable. After this happens, the track on the cycling cam reverses the movement of the pickup-arm raising lever. The beveled edge is now in the V cut of the pickup-arm raising disc, and the entire assembly (including the pickup arm itself) will swing a distance set by the same groove.

When the determined distance is reached, the pressure exerted on the stud end of the pickup-arm raising lever is relieved, the beveled edge is lowered out of the V cut, and the entire assembly of the pickup arm, shaft, and raising disc is lowered. Thus the needle is set down again in the starting groove of the record. Fig. 21 shows the under side of the cam used to actuate the movement. This view is "looking through" the cam from the top. The stud rides in the outside of the groove for 10″ records and in the inside of the groove for 12″ records.

INDEXING THE PICKUP ARM

Since the stud on the pickup-arm raising lever must ride in one side of the groove in the cycling cam for 10-inch records and the other side of the groove for 12-inch records, we must have some simple method of moving the stud from one side of the groove to the other. The pickup-arm raising lever is pivoted as shown in Fig. 20 and can be moved horizontally as well as vertically. All we need to do is use a spring or lever to shift the stud.

Manual Control. There are many methods of controlling the set-down of the pickup arm on the record, depending on the type of pickup arm cycling mechanism and record-dropping mechanism. One such method is shown in Fig. 21. This is for a non-intermixing changer; in other words, one that will take only one size of record at a time. On this changer, the size is selected and set by the operator. One end of a spring lever is attached to the pickup-arm raising lever and the other is connected to a selector shaft. The top of the selector shaft projects above the turntable to a knob indicating the positions to which it is to be turned for each record size. When the selector shaft is turned in a clockwise direction, the index spring will expand as shown in Fig. 21A, so the tension on the lever is decreased and the stud will follow the inside of the groove on the cycling cam. With the index spring compressed, as shown in Fig. 21B, the action of the spring against the pickup-arm raising lever forces it over to the outside of the groove in the cycling cam.

Automatic Control. In many record changers, it is possible to intermix 10- and 12-inch records. In this case, the manual control is not used to index the pickup arm.

A typical indexing and set-down mechanism for this type of record changer is shown in Fig. 22.

In this type of record changer, the center spindle actually supports the records, which are stabilized by an arm that projects across the records

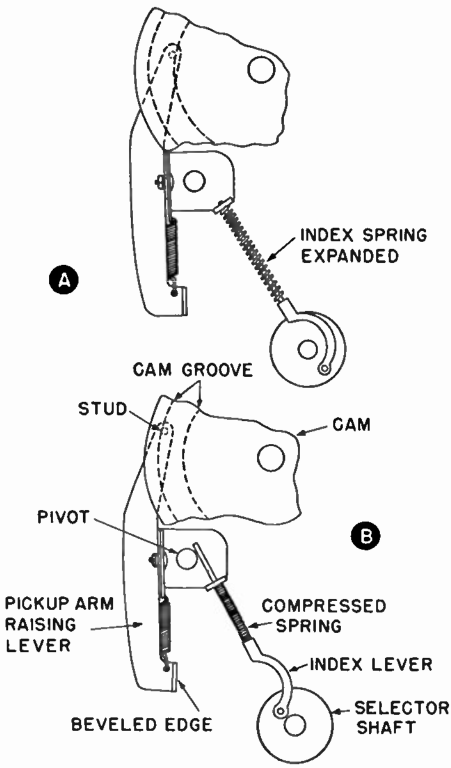


FIG. 21. One method of controlling the set-down position of the pickup arm.

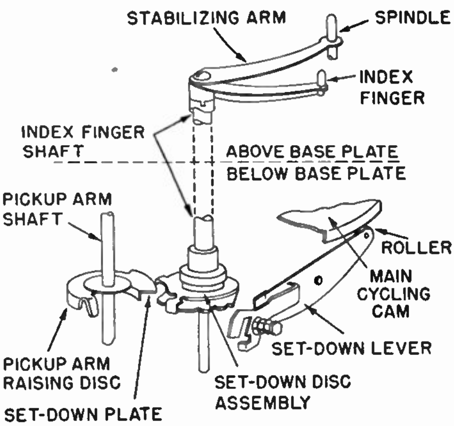


FIG. 22. An automatically controlled indexing system.

to the spindle. In addition to this, there is a special index finger, which is an arm extending out from the index finger shaft; the side rests against the bottom record in the stack as shown in Fig. 23. Under the turntable, on the lower end of the index finger shaft, is the set-down disc assembly as shown in Fig. 22. This is rigidly attached to the index finger shaft, so the position of the index finger controls its position. When the index finger is all the way out, for a 12-inch record, the set-down disc assembly is turned all the way clockwise. When the index finger is all the way in, that is, when no records are on the spindle, the set-down disc assembly is all the way counter-clockwise.

The pickup-arm raising disc and the set-down disc assembly work together to control the set-down indexing. As shown in Fig 22, there is a lever, called the set-down lever, which has a roller at one end, in contact with the cycling cam. When the change cycle starts, the pickup arm is lifted from the record and is moved by the action of the pickup-arm raising lever, which you have already studied.

The under side of the cam against which the roller of the set-down lever is riding, is shaped so that at this point, the roller is pushed down. This causes the other end of the lever to move upward to one of the notches in the set-down disc assembly, to hold the set-down assembly in place. The position of the set-down disc assembly has already been determined by the amount of rotation of the index finger. The notch into which the set-down lever is pushed depends upon this setting. When the index finger is all the way out, for 12-inch records, the set-down lever will go into the notch farthest to the right in the illustration. For a 10-inch record it will go into the next notch clockwise, and for a 7-inch record into the next notch after that. When there are no records on the spindle, the index finger will be all the way in, and the set-down disc assembly will be turned all the way counter-clockwise. The set-down disc has two "ears" that control the stopping position of the pickup-arm raising disc, which has a projection on it called the "set-down plate." When this plate comes in contact with one of these ears, its rotation is stopped, and the pickup arm is lowered at that point. Fig. 24 shows the positions of the set-down disc assembly and of the pickup-arm raising disc for different record sizes. Notice that the set-down plate does not contact the pickup-arm raising disc when a 7-inch record is on the stack. The groove in the main cam is made so that as the stud on the pickup-arm raising lever follows it, the pickup arm will be set down in position for playing a 7-inch record unless it is stopped sooner.

If a 10-inch record is to be played,

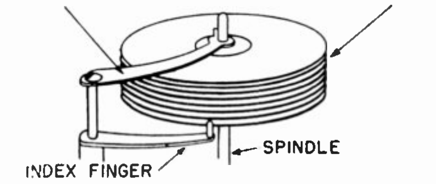


FIG. 23. The index finger rests against the bottom record in the stack as shown here.

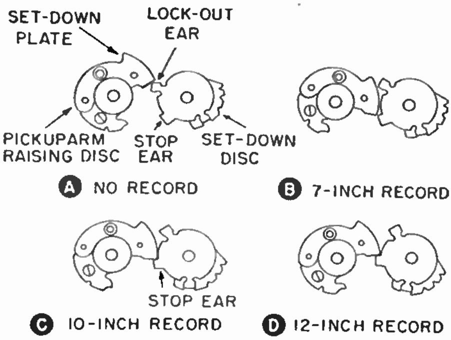


FIG. 24. The positions of the set-down disc assembly and of the pick-up-arm raising disc for different record sizes.

the set-down disc position is as shown in Fig. 24C. Here the pickup-arm raising disc is stopped in position for a 10-inch record by the stop ear, which comes in contact with the set-down plate. When a 12-inch record is to be played, the same stop ear stops the pickup-arm raising disc, but since it is turned farther clockwise, it will stop it sooner.

When there are no records on the spindle, the index finger is as far counter-clockwise as possible. This puts the lock-out ear in position so that the raising disc is stopped when the pickup arm is over the pickup rest point. This is shown in Fig. 24A.

ADJUSTING THE INDEXING SYSTEM

There are usually two methods of adjusting the indexing system of the record changer; one a very coarse adjustment, the other a fine adjustment.

Obviously the indexing will be incorrect if the pickup arm position is out of alignment with the pickup-arm raising disc. To synchronize these parts movements, the pickup arm can very often be slightly readjusted on the pickup arm shaft, since it is generally attached to the top of the shaft on a hinge arrangement. A small eccentric screw can usually be found on the pickup arm itself, for fine adjustment. If adjustment of this is not sufficient to provide proper indexing, then the pickup-arm raising disc itself will need to be loosened, then rotated until it is in its proper position.

The best method of setting the index system is to place a record on the changer and then rotate the changer by hand, while it is raised off the workbench so that you can get at the parts underneath. After the record is dropped to the turntable, the pickup arm will rise from its resting position and then move above the record and slowly descend to the record surface while you are rotating the turntable by hand. Keep rotating the turntable by hand until the needle is within one-quarter inch or less of the record surface. Then, locate the two set screws that control the position of the pickup arm lever, and alternately tighten one and loosen the other until the needle is brought (in a horizontal direction) over the lead-in groove of the record.

After you carry out this operation for a 10-inch record, try it on both a 12-inch record and a 7-inch record to see if the indexing system is correct. Usually a slight readjustment of the eccentric screw on the pickup arm (on top of the changer) will be necessary for the other record sizes.

When the adjustments are completed so that the indexing is correct for all size records, tighten both set screws in the pickup arm lever. Be sure that both screws are tightened at the same time, or the indexing may change.

A great deal of trouble is caused in indexing systems by mistreatment of the record changer. Very often the trouble is caused by misalignment of the pickup arm lever in relation to the pickup arm itself, and readjustment will usually clear up the trouble. Of course, defective parts may cause this trouble also.

When the pickup arm is being set down on the record, it is important for it to move slowly. If the pickup arm pivot screw is loose, the arm will move down rather rapidly, and the needle may bounce on the record, skipping grooves at the beginning of the record and causing damage. Tightening the pivot screw will clear up this trouble. After tightening the screw, check the operation carefully, to be sure that it is not too tight, preventing freedom of vertical movement.

Incorrect set-down of the pickup arm on the record can be caused by a defective pickup arm return-lever spring. When replacing the spring, be sure to use one that is just strong enough to cause correct set-down. Too strong a spring may damage some other part; too weak a spring will prevent proper set-down.

Excessive friction between the pickup arm lever and the parts it contacts very often causes trouble. Hardened lubrication and dirt is a common offender. After washing the parts with carbon tetrachloride, lubricate them with a light grease such as "Sta-Put."

Binding and bending of parts often occurs in the mechanism. If this happens, the parts should be bent back into position, and any burrs removed with a file.

Record-Dropping Mechanisms

There are two popular record-dropping mechanisms in use today: The spindle type in which the spindle supports the records and drops them to the turntable, and the pusher type, in which the shelf and the spindle both support the record, and the shelf causes the record dropping.

In addition, older changers used slicer-type mechanisms with two or three posts.

SLICER CHANGERS

A typical two-post slicer type of record changer is shown in Fig. 25.

In this changer, only the record holder shelves hold the records. The spindle is straight and merely guides the record down to the turntable and holds it in position for playing. When a record is to be dropped, the pickup arm is elevated and moved out of the

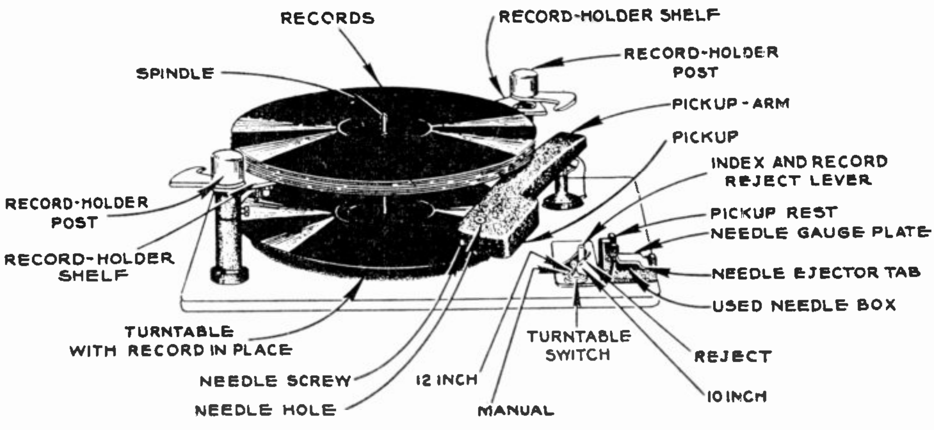


FIG. 25. A typical two-post changer.

way; then the record-holder posts begin to rotate. Each of these posts carries a knife just above its record-holder shelf. The knife is a sharp-edged shelf that is spaced the thickness of the average record above the record-holder shelf. As each knife comes around in contact with the record stack, the pointed tip of the knife is in the right position to go between the bottom record of the stack and the next one above it.

As the knife penetrates the record stack, the record-holder post continues to rotate; this places the knife under all the records except the bottom one. When the record-holder shelf is rotated completely, the bottom record will drop to the turntable. Finally, the record-holder posts rotate back to their normal position, the knives are withdrawn, and the records rest on the shelves again in their original position.

It is important that the record-holder posts be synchronized and rotate together. This is easily accomplished by means of links and segments which you studied earlier in this lesson. Fig. 26 shows an example in a 2-post changer. The roller riding in the cam groove which controls the changing mechanism, actuates the drive link which in turn moves the segments rotating the selector gears. The selector gears are firmly attached to the record-holder shelves, so the shelves are rotated accordingly.

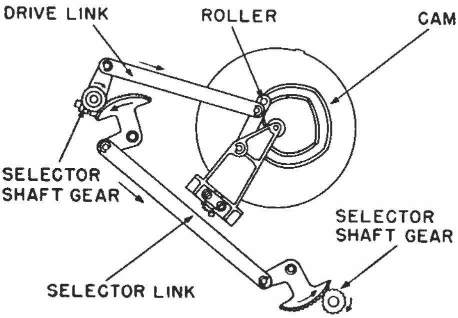


FIG. 26. How links and segments are used in a two-post changer.

These two-post and three-post changers were used in older changers and are now obsolete.

Because of the operation of the support shelves and slicer blades, extremely thick or unusually thin records can cause trouble. If a record is thin, the slicer blades may miss it completely, and two records will then be dropped to the turntable at once. If the record is thick, the blades may hit the record edge and break it. Warped records will also cause this trouble. With warped records, one shelf may drop one edge of the record and the other shelf hold the opposite edge. The same trouble can happen to records of average thickness when the slicer blades are slightly bent. If this happens, place an average record on the turntable and rotate it by hand. Carefully examine the slicer blade. The action will show you which one is bent.

Another common trouble in this type of changer is binding of one or more of the selector shafts. Filing, cleaning, and lubricating will usually clear up this trouble. Also be certain that the spindle is straight. If it is bent, more of the record will be on one shelf and only one side will drop.

BENT-SPINDLE CHANGERS

The bent-spindle type of record changer is very popular. Its basic operation can be seen in Fig. 27; in this record changer, the records are supported both by the indenture on the bent spindle and by the record-supporting post.

A small shelf on the post forces the bottom record in the stack out slightly more toward the spindle than the rest. To drop this bottom record to the turntable, the support post itself is moved slightly toward the spindle. The record center hole will then be dislodged from the notch in the spindle and will slide down the spindle to the turntable. The

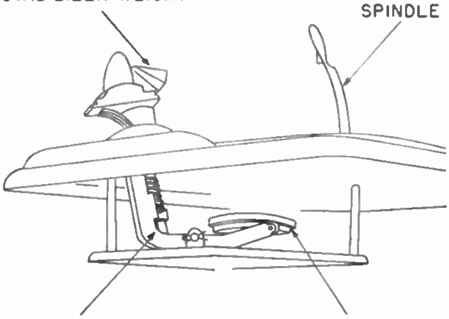


FIG. 27. A bent-spindle type of changer.

other records will drop toward the notch in the spindle but will catch on the notch, since the smaller shelf on the record support holds only one record. When the support post moves to its maximum distance away from the spindle, the next record in the stack will drop into the small shelf on the post. Since the center hole of this record is in the notch on the spindle, it cannot drop to the turntable until the support post again moves toward the spindle.

The weight shown in the illustration is used to stabilize the record stack.

Several methods are used to actuate the record-dropping mechanism. Essentially all connect the bottom of the record support shelf shaft to a lever called a rocker-arm assembly. A small stud or roller, attached to the other end of the lever, rides in a groove on the main cam. As the stud or roller riding in a cam groove moves out away from the center of the turntable by action of the rotating cam, the lever action of the support shelf moves the shelf in toward the turntable center.

PUSHER CHANGERS

Another popular type of record dropping mechanism is a variation of the shelf type called a pusher type. In this type, the records rest both on the spindle and on the record-selector post. However, to drop the record onto the turntable, neither the spindle nor the post moves. Instead, a small section of the post slides out and pushes the bottom record off the shelf and the record then slides down the spindle.

The moving shelf mechanism operates in the same way as the record-dropping mechanism just discussed.

The pusher type of record-dropping mechanism is probably the most reliable and is less likely to cause trouble than the other types. However, sometimes the entire selector post itself becomes bent, which will cause the records to drop onto the pickup arm. Carefully bending the post back will usually clear up this trouble. Sometimes, however, the record shaft and rocker-arm mechanism underneath the turntable is provided with an adjustment screw. The servicing information should be consulted for such troubles with this type of mechanism.

SPINDLE TYPE OF CHANGER

Another type of record-dropping mechanism is called the spindle type. In this mechanism the spindle itself

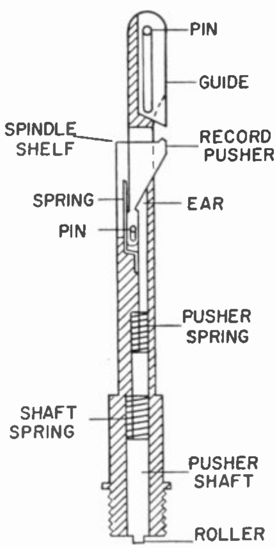
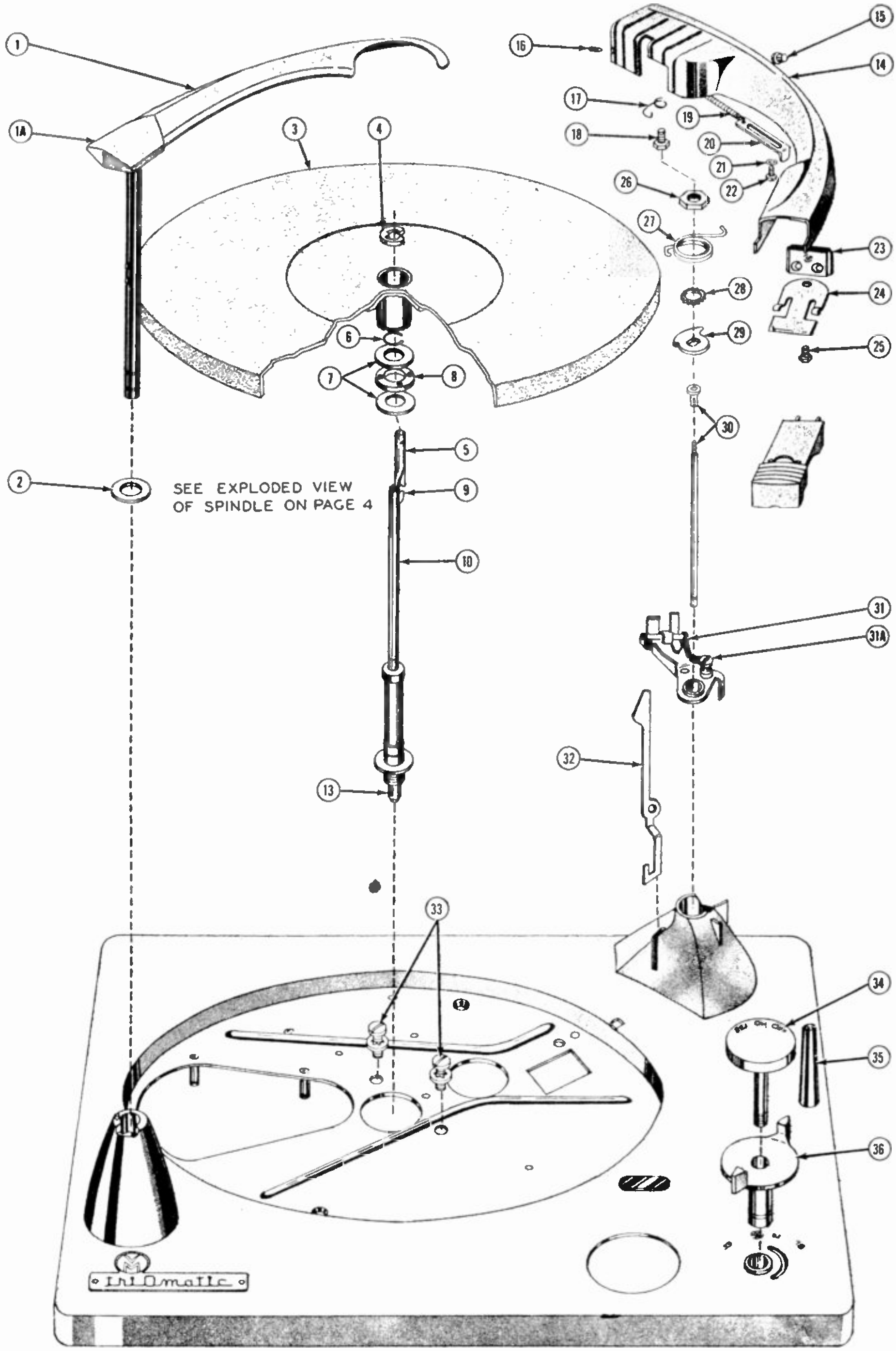


FIG. 28. A cross sectional view of the spindle in a spindle-type changer.



A PHOTOFACT "EXPLODED" VIEW

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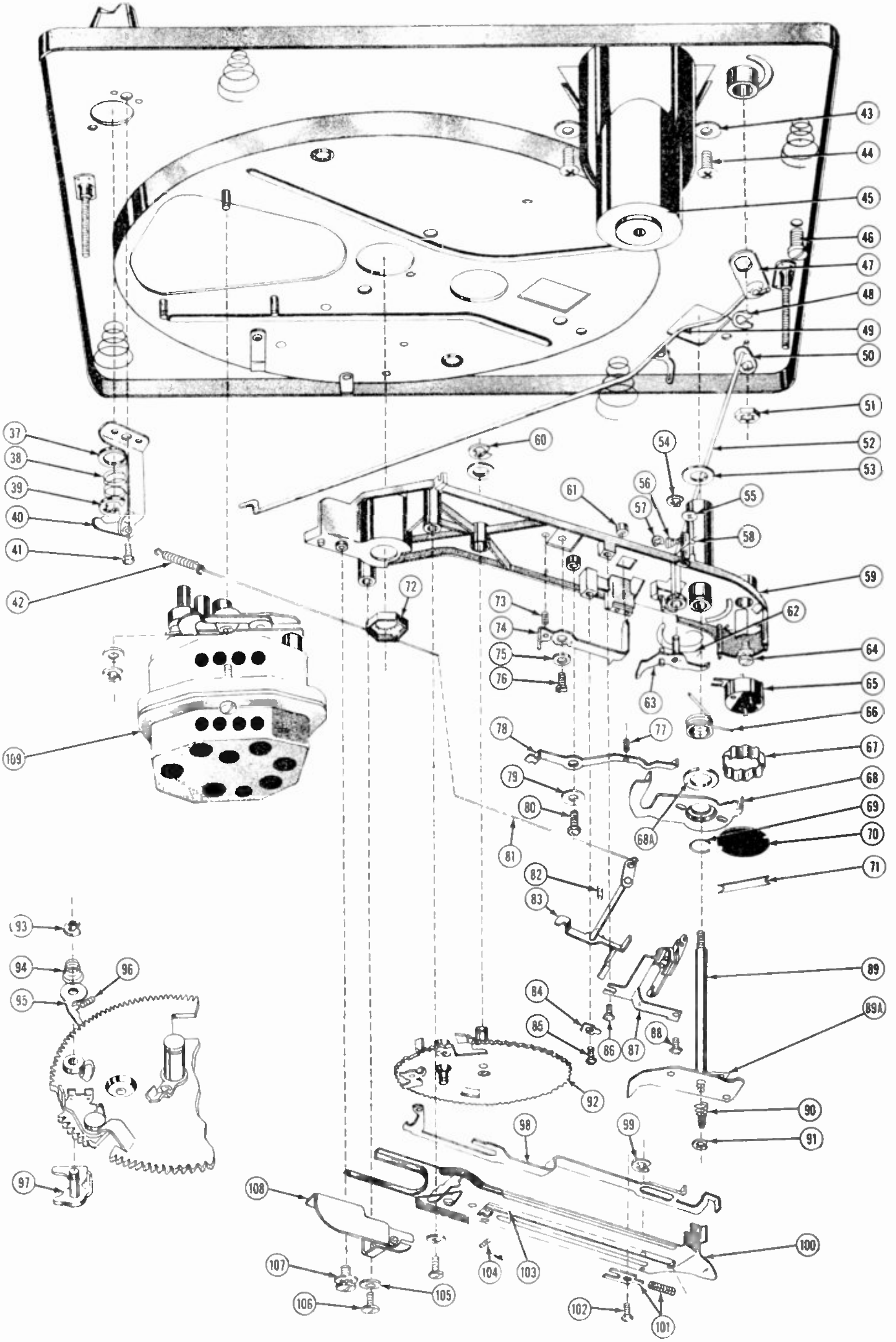
FIG. 29. An exploded view of the parts above the base plate on the VM Tri-O-Matic record changer.



A PHOTOFACT "EXPLODED" VIEW

Courtesy Howard W. Sams

FIG. 30. An exploded view of the parts below the base plate of the VM Tri-O-Matic.

does the record dropping, and a shelf or a record stabilizer helps hold the records above the turntable.

In this type of changer the record spindle is hollow and contains a pusher shaft attached to the cycling cam underneath the changer with a roller, and a special pusher mechanism at the top of the spindle. A cross-sectional view of the spindle is shown in Fig. 28. The top of the spindle is formed to have a small shelf and notch to hold the records. When the cycling mechanism is activated, the roller of the pusher shaft rotates on an inclined surface of the cam, forcing the roller, shaft, and pushing mechanism upwards. A small record pusher at the top of the spindle then dislodges one record from the stack, and it drops to the turntable surface. This type of mechanism is quite simple and can easily be understood by observing the dropping mechanism of the record changer while rotating the turntable by hand.

Except for a bent pusher shaft or spindle, no special problems are encountered with this type of changer. It is extremely difficult to straighten out the shaft, when it is bent, and a new one almost always needs to be installed.

The V-M Tri-O-Matic, Model 935

As an aid in servicing, we will now discuss the operating cycle of a modern record changer—the V-M Tri-o-matic, Model 935. Remember when you are servicing any record changer, the best way to understand its operation is to rotate the turntable manually while watching the motions of the various parts. This particular changer is popular as a complete plug-in unit, and quite similar models have been installed in many commercial radio and television combinations.

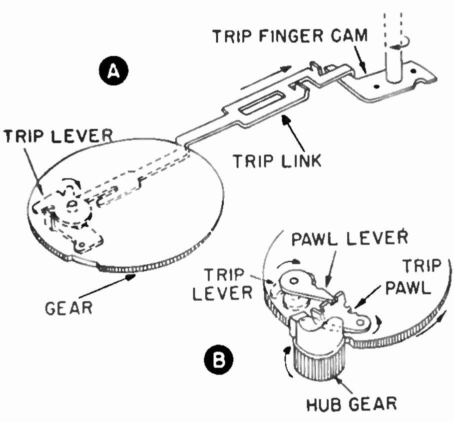


FIG. 31. As the pickup arm moves toward the center of the record, the trip finger cam moves toward the trip link, as shown at A. B shows how the trip lever, underneath the drive gear, turns the pawl lever above the drive gear, which in turn catches the trip pawl.

Since this changer is provided with a velocity trip mechanism, the change cycle is started by the rapid inward motion of the pickup arm when the needle enters the fast-finishing grooves at the end of the record.

Two exploded views of this changer are shown in Figs. 29 and 30. Refer to these throughout the discussion.

STARTING THE CHANGE CYCLE

In this changer, a trip finger cam is attached to the lower end of the pickup arm shaft so that the pickup arm and the trip finger cam move in unison. As the pickup arm moves toward the center of a record, the trip finger cam moves toward the trip link. This is shown in Fig. 31. As the trip finger cam engages with the trip link, it pulls it toward the right in the figure; a small upward projection on the other end of the trip link catches on the trip lever, which is attached to the under side of the drive gear. This causes the trip lever to turn.

As the trip lever turns, it turns the pawl lever, which is on the upper side of the drive gear, and attached to the trip lever with a spring-loaded friction connection. This moves the pawl lever clockwise, as shown in Fig. 31B, toward the trip pawl.

A mutilated-clutch mechanism similar to the one you studied earlier is used. The teeth are missing from the section of the drive gear that is toward the hub gear during the playing of the record. This is how it works:

As the pickup arm moves slowly toward the center of the record, the trip pawl moves toward the turntable hub. On the hub is a projection, or lug, which contacts the projection on the trip pawl, pushing the trip pawl back again.

Since the movement is slow, and the connection between the pawl lever and the trip lever is a friction connection, the pawl lever simply slips back. However, when the pickup arm reaches the fast-finishing grooves at the end of the record, its motion is accelerated, and this rapid motion is transmitted to the trip link, the trip lever, the pawl lever, and the trip pawl, so the projection on the trip pawl is hit by the lug on the turntable hard enough to make the drive gear to which it is attached turn far enough so that its teeth mesh with those of the hub gear, and the change cycle is started.

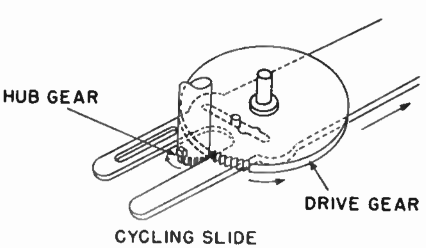


FIG. 32. The cycling slide shown here is moved back and forth by the action of the pin on the drive gear moving in a slot on the slide.

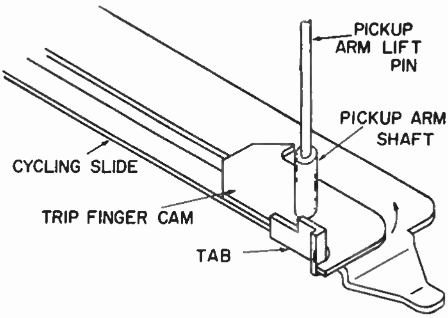


FIG. 33. The tab on the cycling slide contacts the trip finger cam, turning it, and therefore the pickup arm shaft, counter-clockwise.

RAISING AND ROTATING THE PICKUP ARM

This changer uses a slide rather than a cam to control the cycling. It is below the drive gear. On the drive gear is an eccentric stud, which moves in a cross slot on this slide when the gear turns, causing the slide to move back, as shown in Fig. 32. The rear end of the slide is sloped so that as it moves back, the pickup arm lift pin, which is resting on the end, is pushed up. This causes the pickup arm to rise off the record.

At the same time, the tab on the end of the slide, shown in Fig. 33, contacts the trip finger cam, and turns it counter-clockwise; this turns the pickup arm shaft to which it is attached, counter-clockwise, also, swinging it clear of the turntable so that the record can be dropped.

DROPPING THE RECORD

Dropping the record is accomplished by means of the ejector link assembly at the other end of the cycling slide. It is shown in Fig. 34. In one side of the forked end of the slide is a slot. As the slide moves back, the front edge of the slot contacts the lift arm on the

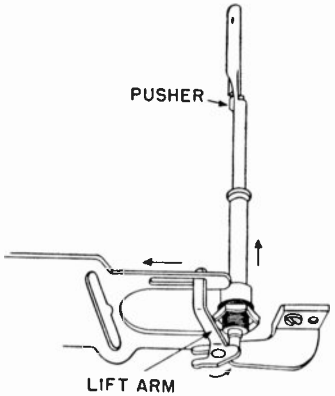


FIG. 34. The ejector link assembly shown above is used for dropping the record.

ejector link assembly. The lift arm is pivoted at the other end, on which is resting the pusher shaft in the spindle. This pushes the pusher shaft up, the pusher goes up into the center hole of a record, is pushed forward, and the record drops.

LOWERING THE PICKUP ARM

The cycling slide then reverses its direction because of the action of the gear pin in the cross slot of the slide. The tab on the slide, which was holding the trip finger cam, moves away from it, allowing the trip finger cam to move clockwise, and the pickup arm starts back toward the spindle. As the trip-finger cam rotates, it carries with it a plate, called the tone-arm return locator plate, which is mounted directly above it on the pickup arm shaft, as shown in Fig. 35. The return locator plate has two indentations on it, which match the two holes in the trip finger cam, and the two parts are held together by the force of a spiral spring.

These two parts, and therefore the pickup arm, will continue to rotate clockwise until stopped by the reset lever. Let us see how the reset lever works.

The return locator has a raised edge with three steps in it. When one of these three steps comes in contact with the reset lever, the clockwise rotation is stopped. The reset lever has been set by the action of the two other levers, called the "12-inch record selector" and the "7-inch set-down lever," so that for 12-inch records it will contact the first step in the return locator plate; for 10-inch records, it will contact the second step; and for 7-inch records it will contact the third step.

The 12-inch selector and the 7-inch set-down lever are operated by the record itself as it drops to the turntable. These two levers are shown in Fig. 36.

The 12-inch selector operates when it is hit by a record. The 7-inch set-down lever operates when it is not depressed by a record, but free to rise. When a 12-inch record drops, it strikes the 12-inch selector, and the 7-inch set-down lever. When a 10-inch record drops, it strikes the 7-inch set-down lever, and when a 7-inch record drops, it does not strike either, and the 7-inch set-down lever is free to rise. Because the 7-inch set-down lever must be free to rise for the changer to work right for 7-inch records, they cannot be intermixed with other sizes.

When a 10-inch record is dropped, one end of the reset lever is held down by a tab on the main gear, and the other end latches on the end of the 12-inch selector lever as shown in Fig. 37. When a 12-inch record is dropped, it hits the end of the 12-inch selector

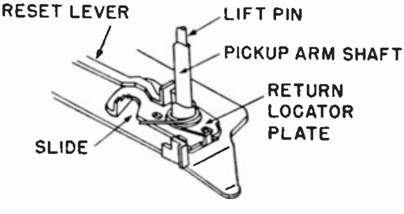


FIG. 35. The pickup arm is lowered when the lift pin slides down the inclined end of the slide.

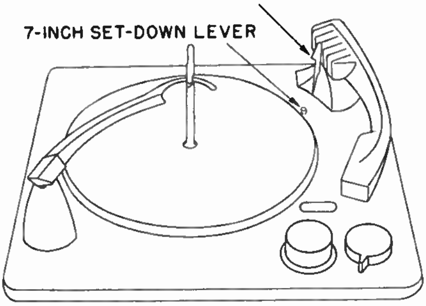


FIG. 36. Upper view of the record player showing the 12-inch record selector and the 7-inch set-down lever.

lever, which pushes the lever back. Since it is pivoted in the middle, the lower end of this lever is pushed forward, under the end of the reset lever, causing the reset lever to drop as in Fig. 37B.

When 7-inch records are played, the 7-inch lever is free to move. There is a hole cut in the main gear, so that when the hole in the gear comes around, the lower end of the 7-inch lever drops into the hole, causing the other end of the lever to rise. As it rises, it raises the reset lever also, because of a small projection or "finger" that extends from it under the reset lever, as shown in Fig. 37C.

Therefore, as you can see, the reset lever will be in the highest position for a 7-inch record, the next position for a 10-inch record, and the lowest position for a 12-inch record, and will stop the tone-arm locator plate and therefore the pickup arm in the proper position for each size of record.

The slide continues to move forward, and when the inclined end of the slide comes under the pickup arm shaft, the pickup arm lift pin slides down the inclined surface, and the pickup arm is lowered to the turntable in place to start the next record.

As the lift pin slides down the end of the slide, the pressure is released from the conical lift spring. Between the trip finger cam and the return locator is a spring washer, called the locator plate separator. When the pressure on the conical spring is released, this spring washer pushes the two parts apart, and the pickup arm can ride freely over the record.

SHUTTING OFF THE CHANGER

When the last record has been dropped, the record support arm drops below the shelf on the spindle. The lower end of the record support post contacts the stop arm of the shut-off lever on the shut-off lever bracket assembly as shown in Fig. 38. This pulls the control link, rotating the crank of the shut-off lever assembly, and forcing the lever assembly against the escape lever on the slide assembly. At the end of the change cycle the slide has moved all the way forward, and the end of the lever assembly drops into the main slot on the slide. The other end of the lever assembly is pushed up against the pickup arm re-

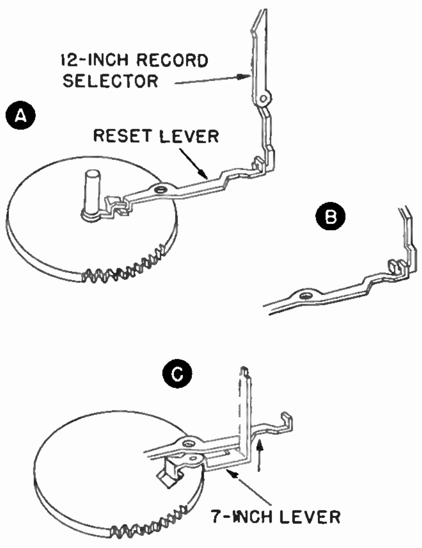


FIG. 37. The 12-inch record selector and the 7-inch set-down lever control the position of the reset lever as shown here.

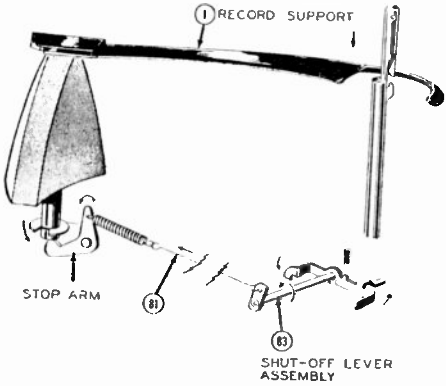


FIG. 38. How the lowering of the record support actuates the shut-off mechanism.

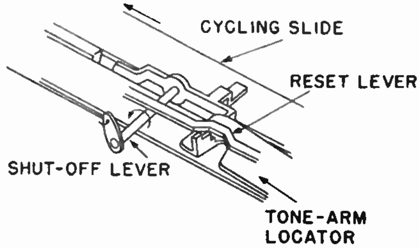


FIG. 39. Operation of the shut-off lever.

turn locator as shown in Fig. 39.

After the last record has been played, the change cycle starts again. However, this time as the pickup arm return locator is pivoted clear of the reset lever by the tab on the slide assembly, it also clears the shut-off lever, and the shut-off lever assembly rises. As it rises, a tab on its side pushes the trip link up, as shown in Fig. 40. As the pickup arm return locator starts to return the pickup arm toward the spindle, it is stopped by the shut-off lever assembly when the pickup arm is over the pickup arm rest post. The main gear continues to rotate, pulling the trip link forward with it. A tab on the upper surface of the trip link contacts a lever on the control shaft assembly, as shown in Fig. 40, rotating the control shaft assembly clockwise. An arm on the other side of the control shaft assembly contacts the on-off switch, turning it off, and returning the control knob to the OFF position.

The slide assembly continues to move forward, until the pickup arm lift pin rides down the inclined surface at the back of the slide, lowering the pickup arm to the pickup arm rest post.

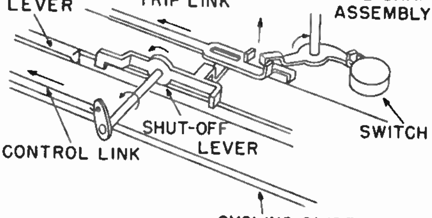


FIG. 40. The shut-off lever raises the trip link, which turns the control shaft assembly, and shuts off the switch.

The 45-RPM Changer

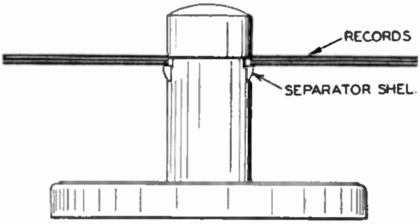
Since the 45 rpm record is different from other phonograph records, the special 45 rpm changer was designed along with the record. This record comes only in the 7-inch size with a center hole 1½ inches in diameter.

Even though the 45 rpm changer may look vastly different from other record changers, the same basic principles that apply to the record changer mechanisms we have discussed also apply to this type of changer. There are, however, some different physical appearances and locations of the parts.

The best way to understand how a record changer works as well as how to troubleshoot it, is to rotate the record changer by hand through the changing cycle while observing the action of the various parts above and underneath the turntable. Let us imagine that we are doing this with the RCA 45-rpm changer, and follow the action of the changer parts.

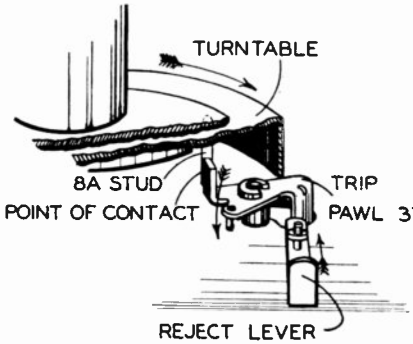
The record stack rests on special separator shelves, shown in Fig. 41, which protrude from both sides of the large center post on the changer. As we begin to rotate the turntable, a record is being played (on the turntable) and there is a stack of records on the spindle. We then begin by pushing the start-reject lever shown in Fig. 42. This moves the trip pawl (37) into tripping position. Referring to Fig. 42, you can see that as the turntable rotates clockwise, it carries the trip pawl (37) along for a short distance. The trip pawl stud (37A), as seen in Fig. 43, pushes against the director lever (41), rotating it clockwise, in opposition to the force of the tension spring (42). This force is applied until the director lever stud (41B) has been forced through the slot of the cycling cam (8B).

As shown in Fig. 44, the end of the director lever (41C) which extends below the motor board moves away, allowing the muting switch (63) to close. This switch disconnects the cartridge so that the noise of the changing operation will not be reproduced. At the same time, the stud (41A) pushes the pickup arm lift lever (35) which raises the pickup arm. The end (41E) of the director lever (41) contacts the trip lever stud (58A) which rotates the trip lever (58) counter-clockwise as shown in Fig. 45. This also turns the pickup arm shaft to which it is attached, and moves the pickup arm out toward the edge of the record. The trip lever stud (58A) then moves against the pickup arm return lever (50) and pushes it outward against the tension spring (51), as shown in Fig. 46. When the



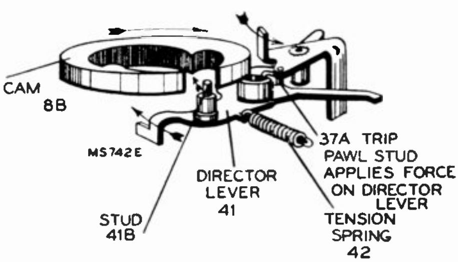
Courtesy RCA

FIG. 41. Records resting on the separator shelves on the center post.



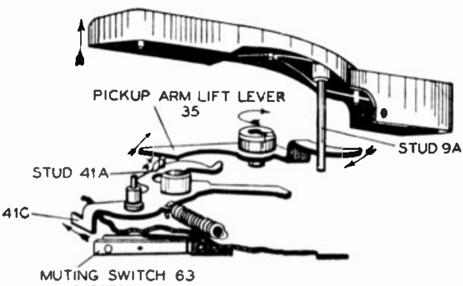
Courtesy RCA

FIG. 42. Starting the change cycle.



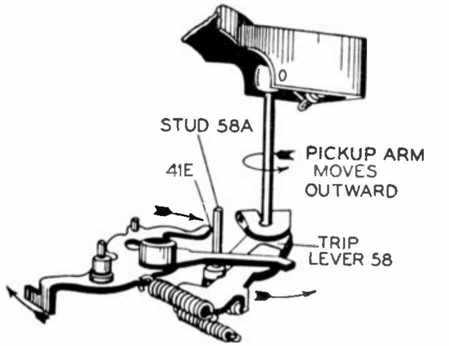
Courtesy RCA

FIG. 43. The stud on the director lever goes into the cam groove.



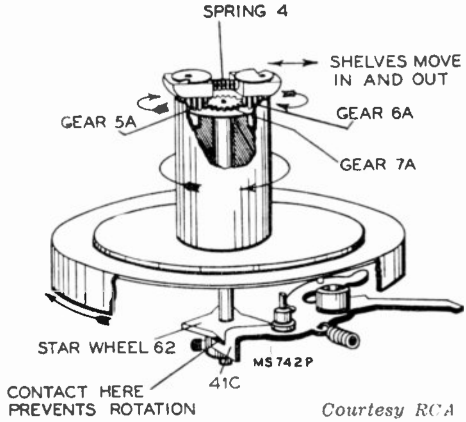
Courtesy RCA

FIG. 44. Raising the pickup arm.



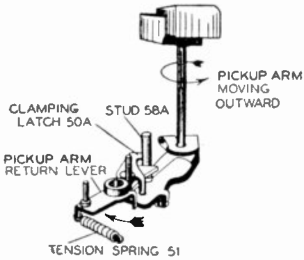
Courtesy RCA

FIG. 45. Moving the pickup arm out.



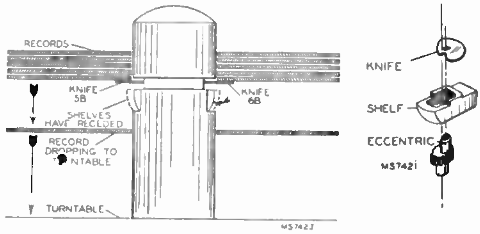
Courtesy RCA

FIG. 47. Spindle mechanism.



Courtesy RCA

FIG. 46. The pickup arm is locked in its outer position by latch 50A.



Courtesy RCA

FIG. 48. Exploded view of the shelf mechanism.

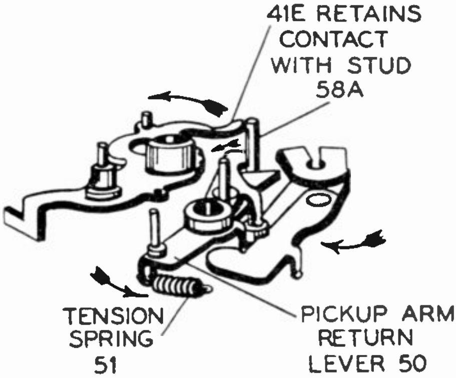
pickup arm has moved over as far as it can, it is held in position by the latch (50A) clamping the stud 58A on the end of the pickup arm return lever as shown in Fig. 46.

While the pickup arm is moving outward, the end of the director lever (41C) below the motor board moves against the star wheel (62) and prevents it from rotating, as shown in Fig. 47. The turntable continues to rotate but the star wheel and shaft remain stationary. Two small gears (5A and 6A) in the upper section of the center post rotate around the star wheel shaft gear (7A).

The eccentric shown in the exploded view in Fig. 48, extending from the upper end of gears 5A and 6A turning in a slot in the separator shelves 5 and 6 causes the shelves to move in toward each other against the tension of the spring (4). As the shelves move in, the separator plates 5B and 6B above each separator shelf move out between the lower record of the record stack and the remaining records. Since the shelves are no longer in the way, the lower record drops to the turntable while the knives support the remaining records.

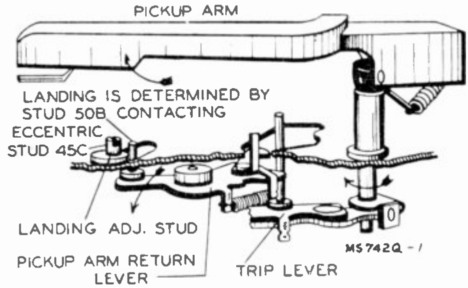
The director lever (41) continues to move toward the out-of-cycle position and the end (41E) of this lever retains contact with the trip lever stud (58A). This contact stabilizes the inward movement of the pickup arm which is being pushed in by the pickup arm return lever (50) as shown in Fig. 49.

The movement of the pickup arm toward the spindle is stopped directly above the landing position by the pickup arm return lever stud (50B) coming in contact with the eccentric



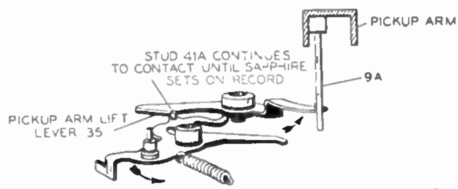
Courtesy RCA

FIG. 49. Moving the pickup arm in for a landing.



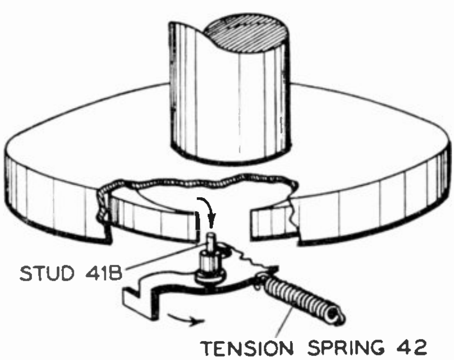
Courtesy RCA

FIG. 50. The inward motion of the arm is stopped by stud 50B.



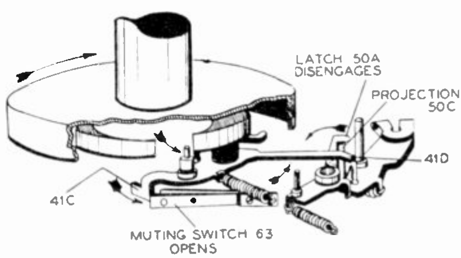
Courtesy RCA

FIG. 51. Needle is lowered to record.



Courtesy RCA

FIG. 52. Stud 41B is pulled out of the cam slot.



Courtesy RCA

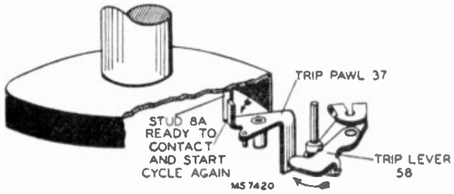
FIG. 53. The muting switch is opened.

stud (45C), as shown in Fig. 50.

The stud (41A) on the director lever continues to contact the pickup arm lift lever (35) which lowers the cartridge stylus to the starting groove of the record as shown in Fig. 51. As the turntable completes one revolution the tension spring (42) pulls the director lever stud (41B) through the slot in the cycling cam, as shown in Fig. 52. The end of this director lever (41D) disengages the pickup arm return lever (50) by contacting the projection (50C), as in Fig. 53. The end (41C) of the director lever below the mounting board then moves away from the star wheel and opens the muting switch.

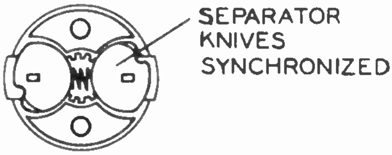
After the record has been completed, the stylus moves into the tripping grooves causing the trip lever (58) to push the trip pawl (37) into position for engagement with the stud (8A) on the underside of the turntable, as shown in Fig. 54. When the stud (8A) contacts the trip pawl (37), another change cycle starts and the entire process is repeated.

The same sort of troubles found in other record changers are found in this type of changer: excessive, insufficient, or incorrect lubrication; binding and burring of parts; bent and broken



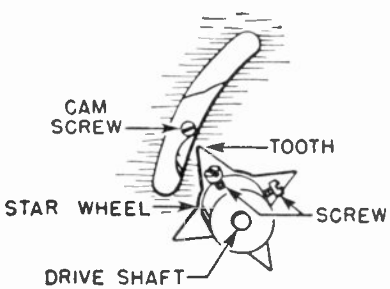
Courtesy RCA

FIG. 54. Change cycle is ready to start again.



Courtesy RCA

FIG. 55. Position of knives when adjusting star wheel.



Courtesy RCA

FIG. 56. Adjusting the star wheel timing.

parts; missing or defective springs; etc.

One common trouble is the record dropping on the pickup arm because of improper star-wheel timing. Along with this trouble and in addition to it, the separator knives very often fall out of synchronization.

To adjust the star-wheel timing, turn it until the separator knives are in the position shown in Fig. 55, by feeling the knives with your fingers while turning the star wheel. Then loosen the two set screws, Fig. 56, enough to permit the star wheel to rotate freely without disturbing the drive shaft.

Rotate the star wheel so that one tooth points directly to a cam screw (Fig. 56) and tighten the two set screws. Finally, rotate the mechanism through a complete cycle by hand to check the operation. Both the separator knives and shelves must move completely in and out of the spindle, and while the knives are out, the shelves should be in (and vice versa).

In many record changers, a large diameter spindle similar to the one used in a 45 rpm changer fits over the smaller regular changer spindle to play 45 rpm records. This type of spindle operation is very similar to the mechanism just discussed. However, a star wheel is not used. Instead, the drop is actuated by the spindle shaft being pushed upward as it was in the spindle type of mechanism. A beveled cam surface at the top of the spindle shaft operates the slicers and selector shelves.

Lesson Questions

Be sure to number your Answer Sheet 46B-1.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. Why should a record changer always be serviced in its normal operating position?

2. What two movements must the main cam in a record changer produce?

3. The drive wheel in Fig. 13C has three steps. One step contacts the idler to drive the rim at 78 rpm, the middle step is used for 45 rpm, and the third step drives the turntable at 33-1/3 rpm. With the large step of the drive wheel in contact with the idler, what is the turntable speed?

4. Why are the idler wheels on some changers removed from contact with the turntable and other idler or drive wheels when the mechanism is shut off?

5. Why should over-lubrication be avoided in a record changer?

6. Name the three most often used types of tripping mechanisms.

7. What is the best method of adjusting the indexing system?

8. Name the two record-dropping mechanisms most often used today.

9. What type of trip mechanism is used in the VM Tri-O-Matic, Model 935 changer?

10. What may cause the record to drop onto the pickup arm in the 45-rpm changer?

INITIATIVE

The man who does only the routine tasks, the ordinary jobs in his profession, always waiting for the other fellow to take the lead, can expect only moderate returns for his labors. He who is continually on the alert for new ideas and new uses for his talents—who is alert to grasp each new opportunity—gets the greatest profits. The immediate financial returns from work in a new and specialized branch of your profession may not be great, but the reputation which you gain for progressiveness will soon result in more profitable routine jobs. It all boils down to these simple facts—you must do out-of-the-ordinary things, stand above the crowd in some way, to attract favorable attention. People remember you first for the unusual, then for your ability to do ordinary work well.

J. E. Smith.

HOW TO CHOOSE AND INSTALL REPLACEMENT PARTS

47B-1

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL
NRI

NATIONAL RADIO INSTITUTE

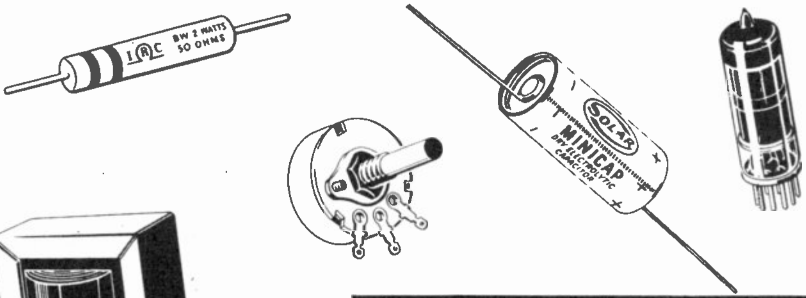
WASHINGTON, D. C.

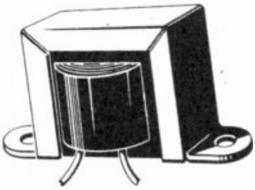
ESTABLISHED 1914

STUDY SCHEDULE NO. 47

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

JDL3M160 **1960 EDITION** Printed in U.S.A.





HOW TO CHOOSE AND INSTALL REPLACEMENT PARTS

ALTHOUGH the final steps in making a repair—removing the defective part and installing a replacement—are purely mechanical, it is possible to waste a great deal of time in taking these steps unless you know what to buy, where to buy it, and how to install it. We will give you this important information in this lesson, along with a number of hints on testing parts. We will discuss both radio and TV replacement parts; the same procedures are used in both cases. In discussing TV parts, we will talk about some parts that will be new to you. You will study these parts and their use in more detail later. We are covering them in this lesson so you will have all the information on selecting replacement parts in one convenient place. Let's start by learning something about the kinds of parts that are usually avai able.

KINDS OF REPLACEMENT PARTS

Replacement parts fall into three groups: exact duplicate replacements; universal replacements; and general replacements. Let us see how each type is used.

Exact Duplicate Parts. These parts are exact duplicates of the originals, both physically and electrically.

Universal Parts. Universal parts are designed so that with minor physical or electrical alterations they can be used as replacements for a wide variety of radio and TV parts. For example, potentiometers come with extra long shafts. In replacing a volume control in a radio, or a contrast or brightness control in a TV receiver, once you have chosen a control with the proper electrical characteristics, you can make it fit the receiver by cutting off the shaft to the required length. Thus, the same control can be used in any receiver requiring a control that has its electrical characteristics.

Another example is output transformers with tapped secondaries; by choosing the proper taps, you can match practically any loudspeaker to almost any output tube (or tubes). The manufacturer packs instructions with each transformer.

General Replacement Parts. Finally, we have parts, such as tubes, resistors, and capacitors, that can be used in any receiver, as long as the proper electrical characteristics are chosen and as long as there is room.

We include among these, parts which, although not designed for the particular receiver, can be used by making some slight change in the original circuit to fit the new part characteristics. Changes of this kind are rarely necessary, because the widespread distribution of exact duplicate and universal replacement parts generally makes a direct replacement possible.

Whenever possible, tubes should be replaced with exact duplicates. Although the same tube may be used in a variety of receivers, it is never a good idea to install a tube of a different type from the one originally used in the set, unless the original type is unobtainable. This will avoid your having to make extensive circuit changes.

STOCKING PARTS

You can start a service business with a surprisingly small stock of parts. However, you will want to build up your stock gradually so you can cut down the number of trips or orders you must make to the parts suppliers, and so be able to give the fastest possible service.

When you start in business, you will need a kit of resistors, a few electrolytic, paper, mica, and ceramic capacitors, a stock of tubes, an assortment of pilot lamps, and some hookup wire and hardware. With this small stock as a beginning, you can gradually increase the amount and variety of these parts. Keep a list of the replacement parts you use. By referring to this list, you will see what parts you use most frequently and how many of each item you should stock.

Some servicemen make the mistake of acquiring too large a stock. It is not wise to invest much money in slow-moving parts. Increase the quantity and variety of your stock only as your service experience indicates the need for such expansion. At the beginning, ask your local distributor to help you choose parts that he has found move rapidly in your area. This is particularly important for tubes. There are several thousand different types of radio and TV tubes, yet perhaps only seventy-five to one hundred types may be widely used in your district.

WHERE TO BUY PARTS

There are many sources of supply available to the serviceman. Perhaps the best known are the large mail-order parts suppliers, who carry very complete stocks of radio and TV parts and who can usually get any special parts you may need. In large cities there are also parts supply houses and distributors who carry a wide selection of radio and TV parts.

In addition, there are distributors scattered throughout the country who handle various popular makes of receivers. Exact duplicate parts for these receivers can be obtained through these distributors You will find the names and addresses of the distributors located in the classified section of your telephone directory or the telephone directory of the nearest large city. They are listed under the headings of radio distributors and also television distributors.

Collecting Service Data. All servicemen collect whosesale parts catalogs, both to locate sources of supply and to get information on the electrical and physical characteristics of different parts. Be sure to collect all the volume-control guide booklets, vibrator replacement guides, transformer replacement guides, tube charts, and other service data available from your local distributors or supply houses. Many of these are free; others are sold for just a few cents.

While we are on the subject of collecting information—try to get all possible information on radio and TV receivers themselves. You will find that your parts distributor will help you get service manuals.

Many set manufacturers publish their own manuals, which are kept up to date by supplements, or come out in yearly editions. You may find it desirable to get those covering any particular brands of receivers that predominate in your locality. Contact the local distributor of the particular brand in which you are interested to see about being put on his mailing list for service information. Often this information is free or relatively inexpensive.

In addition to the service sheets on their receivers, many radio and TV manufacturers also publish change sheets that list production changes in circuits, parts values, tubes, etc., according to the serial numbers in which the changes were made. It is a good idea to keep the change sheets with the rest of the service information for each set. Sometimes the production changes give a clue to defects to look for in sets of the same model that do not have these changes.

Let us turn now to certain specific radio and TV parts and learn more about the problems of obtaining the proper replacement and installing it quickly.

Iron-Core Transformers and Chokes

The great majority of radio receivers manufactured before 1940 were ac-operated receivers that used power transformers. However, almost all radio receivers manufactured for home use today are ac-dc table model receivers using transformerless power supplies. Therefore, the problem of replacing power transformers in radio receivers is not nearly as great as it was a few years ago. However, you will still find some new console radio receivers that use power transformers. Many pre-war receivers are also still in operation, and you will probably be called on to service them. You may have to replace a power transformer in one of these sets.

Besides many pre-war receivers and a few recent ones, practically all automobile receivers use power transformers. Most television receivers and high-fidelity sound systems also use power transformers. Therefore, it is almost unavoidable that once you start doing service work you will service some pieces of equipment in which the power transformer is defective, and you will have to replace it.

You will also have to replace other types of transformers, in addition to power transformers. Both radio and television receivers use transformers to couple the output stage to the loudspeaker. These output transformers frequently break down. Television receivers also use output transformers to couple the horizontal and vertical sweep systems to the deflection yoke. These transformers also break down.

In this section of the lesson, we will discuss the various types of transformer replacement jobs you are likely to have. We will tell you how to select a suitable replacement, and give you information that will help you to install the replacement transformer with a minimum amount of difficulty.

POWER TRANSFORMERS

As we pointed out previously, you will find power transformers in most pre-war radio receivers, a few modern radio receivers, in most automobile and television receivers, and in high-fidelity equipment.

There are only two defect that are likely to occur in power transformers. The transformer winding may short-circuit, or one of the windings may open. When there is a short in a power transformer, the transformer will overheat. However, this does not mean that all transformers that overheat are shorted; overheating also can be due to overload. Often a transformer can be overloaded and overheated so that you would assume, from all outward appearances, the part had been destroyed. Yet, after you remove the overload, the transformer will still be in good condition.

When you discover a power transformer that is overheating, your first step should be to find out whether the overheating is due to a defect in the transformer or to an overload that is being caused by a defect somewhere else in the equipment. It is comparatively easy to find out which of the two is causing the trouble. Simply remove the rectifier tube from its socket. If the receiver uses a selenium rectifier, disconnect the leads from one of the rectifier terminals. If the transformer stops overheating, there is a short or a defect in the B supply that is drawing excessive current from the transformer. When you eliminate the defect, the chances are that the transformer will operate satisfactorily without overheating.

If the transformer continues to overheat after you have removed the rectifier tube, remove the rest of the tubes from the receiver, plug the set into the power line, and see if the transformer still overheats. A cathode-to-heater short in one of the tubes may be placing a short across the filament winding of the power transformer. If it continues to overheat, check the leads from the transformer to be sure that none are shorting together. If none of the leads are shorting together, the transformer is defective.

As we have said, another possible defect is that one of the windings might be open. You can check the continuity of each power transformer winding with an ohmmeter. When checking the continuity of a filament winding, you must remove the tubes from the receiver; otherwise there will be continuity through the tube heaters, even though the filament winding on the power transformer is open.

It is usually easy to get a suitable replacement for a defective power transformer. Most large transformer manufacturers make a complete line of replacement transformers. You should get catalogs from one or more transformer manufacturers in which they list replacement power transformers for the most popular receivers. You can find the replacement number by looking up the receiver you are working on by the receiver manufacturer's name and the model number.

Often it is possible to get an exact replacement power transformer. Contact your local distributor of the particular brand of receiver you are repairing to find out if a direct replacement is available.

When a direct replacement transformer is not available and there is no universal replacement transformer listed in the transformer manufacturer's catalog, you can often select a suitable replacement by studying the receiver and the schematic diagram. First, you should find out how many windings there are on the original transformer and as closely as possible determine the ratings of the original windings. This is not too difficult.

Power transformers usually have a primary winding and about three secondary windings. The primary winding is designed to operate on the power line voltage, which is from 115 to 120 volts. Two of the secondary windings are almost always filament windings; one winding is usually a 5-volt winding for the rectifier tube filament, and the other is usually a 6.3-volt winding for the other tube filaments. You can tell the current rating of the rectifier filament winding simply by looking up the rectifier tube in a tube manual. Tubes such as the 5Y3 are rated at 5 volts and 2 amp. Thus, if the receiver uses a 5Y3 rectifier, you know that the 5-volt winding on the power transformer should be rated at 2 amp. Many television receivers, on the other hand, use larger rectifier tubes, such as the 5U4G which is rated at 5 volts and 3 amp. Obviously the power transformer in a receiver using this type of tube should have a rectifier filament winding rated at 3 amp.

You can find the current rating of the 6.3-volt filament winding by looking up the current required by each tube, and then adding these currents together. For example, suppose you have a radio receiver using six tubes. Five of the tubes each require 6.3 volts at .3 amp (a total of 1.5 amp), and the sixth tube requires 6.3 volts at 1 amp. Thus, by adding the currents together you find that the 6.3-volt winding of the replacement transformer should be capable of supplying 2.5 amp. You can find the current rating required of the 6.3-volt winding in a television receiver using a large number of tubes in the same way.

Determining the voltage and current ratings of the high-voltage secondary winding of the power transformer is a little more difficult, but you can usually figure out what the ratings should be if you have a schematic diagram of the set. Use the operating voltages listed on the diagram as a guide. For example, if you are replacing the power transformer in a television receiver, and the B

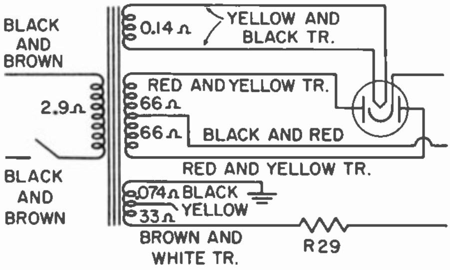


FIG. 1. A typical example of a transformer that is not color-coded according to the RETMA code. Only an exact duplicate transformer can be used to replace this one.

supply is 300 volts, you will be entirely safe if you get a power transformer designed to supply a dc output voltage from the filter of 300 volts at about 225 to 250 milliamperes.

The B supply voltage of most television receivers is usually between 300 and 350 volts at between 200 and 250 milliamperes. Most power transformers designed for TV replacements will supply voltages and currents somewhere within this range. Most radio receivers that use a power transformer operate on a B supply voltage of about 250 volts, and usually draw a current somewhere between 100 and 150 milliamperes.

The old power transformer can often be helpful in selecting a new transformer. The replacement transformer should be about the same physical size as the old one. A smaller transformer will probably run hot. A larger transformer will not overheat, but you may have difficulty mounting it on the chassis if it is much larger than the original.

Replacement power transformers for automobile receivers are also listed in transformer manufacturers' catalogs. In many cases, direct replacements are also available from the distributor of the receiver you are servicing. When replacing power transformers in automobile receivers, you should get either an exact duplicate replacement or a universal replacement designed for use in the receiver you are servicing. This will keep the possibility of running into problems such as excessive noise from the power supply to a minimum.

Sometimes you will run into transformers that have special windings. For example, some of the older receivers using automatic tuning systems had special transformer windings from which the tuning system was operated. When these transformers break down, you must get an exact duplicate replacement. A schematic of the power supply of a receiver using a transformer of this type is shown in Fig. 1.

Installing the Replacement. The leads on most universal replacement transformers are identified by a standard RETMA color code. This color code for power transformers is shown in Fig. 2. When you install a replacement, be sure to refer to any information that the manufacturer may have supplied with the power transformer. All manufacturers do not follow this color code; if the manufacturer has used a color code other than the RETMA code, you should follow it. Direct replacements manufactured by or for the original set manufacturer often do not follow this color code.

In many cases the transformer can be mounted in exactly the same position as the original transformer. However, when using universal replacement transformers, sometimes a slightly different mounting arrangement is required. Universal replacement power transformers are usually supplied with mounting brackets. Some typical replacement power transformers are shown in Fig. 3. A, B, and C show the same one mounted three ways.

When you are connecting the replacement transformer, if it is necessary to lengthen any leads by splicing, make sure that you use a suitable wire size. When the filament leads are spliced, the wires should be as large as the filament lead on the power transformer. All spliced joints should be taped so that the connection cannot short to the chassis or to other terminals. Double-check your wiring to be sure that you have the replacement transformer wired correctly.

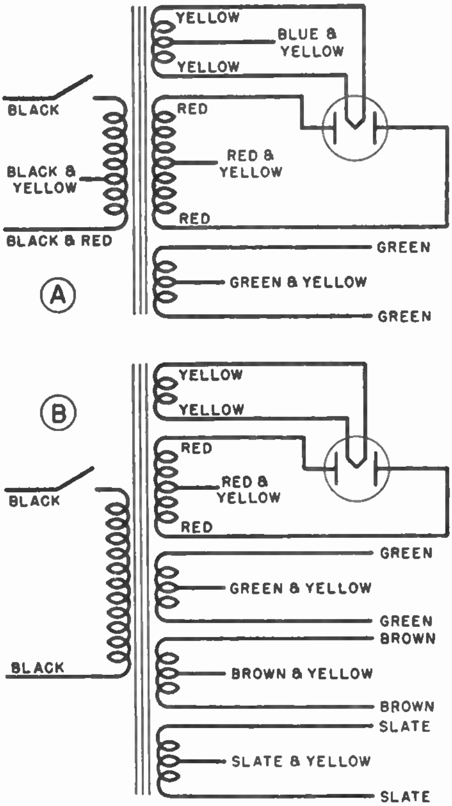
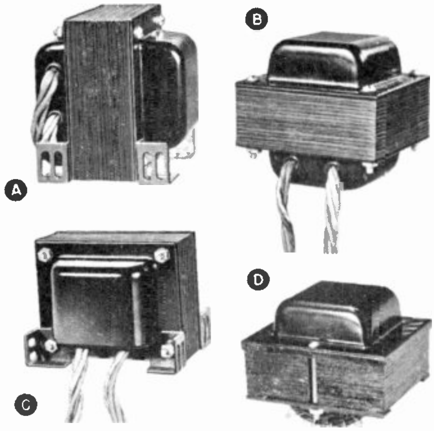


FIG. 2. The RETMA standard color code for power transformer leads. Not all transformers have their leads colored according to this code, so watch for those having different arrangements.



Courtesy Thordarson Elec. Mfg. Co.

FIG. 3. Typical replacement power transformers. The style shown at A, B, and C is a universal type; it can be mounted in many positions by moving the mounting feet to the proper corners. The style at D is called a "half-shell" transformer, which is mounted so that the lugs pass through a large cut-out in the chassis.

Checking the Receiver. Before you put a receiver into operation after replacing the power transformer, you should find out why the old power transformer burned out. A transformer seldom burns out without cause. In most cases a burned-out power transformer is due to a short in the B supply circuit that has placed a heavy load and a high current drain on the supply. The overload could be due to a shorted or leaky filter capacitor, a shorted rectifier tube, a gassy output tube, or in the case of an automobile receiver, a defective vibrator. Defects of this type must be eliminated; otherwise, the replacement power transformer will also overheat and burn out.

AUDIO OUTPUT TRANSFORMERS

The audio or sound output transformer is used to couple the loudspeaker to the plate circuit of the output tube. Universal replacement audio output transformers are readily available. To replace an audio output transformer in most radio or TV receivers, all you need to do is get a universal replacement with a primary impedance to match the output stage of the receiver, and since practically all modern radio and television receivers use loudspeakers with a voice-coil impedance of about 3.2 ohms, follow the manufacturer's instructions for using it to connect a 3.2-ohm voice coil to the plate circuit of the output tube.

Sometimes, instead of listing the output tubes that the transformer will match, by number, the data sheets supplied with the transformer list the load impedance of the primary winding. You can find the rated load impedance of the tube used in the receiver you are working on by referring to a tube manual.

If the loudspeaker voice-coil impedance is not 3.2 ohms, and you do not know what the impedance is, the easiest way to hook up the transformer is to assume a value for the voice-coil impedance and try it out. You can start at 3.2 ohms, and hook up the transformer following the instructions given by the manufacturer. If the receiver sounds satisfactory, the job is completed. On the other hand, if the output is distorted, the speaker impedance may be higher than the impedance of the transformer secondary tap that you are using. In this case you should refer to the manufacturer's information supplied with the output transformer and try the connections for a higher impedance speaker. For example, hook the speaker up assuming that its voice-coil impedance is 8 ohms, and see how this arrangement works out. Usually with a little experimenting, you can find out which tap on the secondary winding to use.

In ordering a replacement audio output transformer you should specify whether it is for a single-ended or a push-pull output stage. The push-pull output stage is capable of supplying more power than most single stages, and as a result, a larger transformer is required. Obtaining a suitable replacement audio output transformer has become such a routine job that you can usually go to the wholesaler, tell him the output tubes used in the receiver and the voice-coil impedance of the speaker, and he can select a suitable replacement from stock for you.

High-Fidelity Systems. The situation is somewhat different when the audio output transformer to be replaced is in a high-fidelity system. These transformers are designed with considerably more care than the output transformers in the average radio or television receiver. The output transformer in a high-fidelity system is a critical part, and unless an exact duplicate replacement is used, the frequency response of the system will probably be altered.

The simplest way to avoid difficulty in high-fidelity systems is to get an exact duplicate replacement transformer from the distributor of the particular high-fidelity system you are repairing. Universal replacement transformers are also available for some high-fidelity systems. These transformers, which have been specially designed for use in high-fidelity systems, will usually give results as good as the original transformer.

INTERSTAGE AUDIO TRANSFORMERS

A few older radio receivers and some TV receivers use transformer coupling between audio stages. In most cases the transformer is simply a 1-to-2 or a 1-to-3 audio transformer. If it is used with a push-pull audio stage, the secondary of the transformer is center-tapped. Universal replacement transformers are available that will give satisfactory results in most applications. The standard RETMA color code shown in Fig. 4 is used to identify the leads on most audio output and interstage transformers.

A few of the older receivers used class B audio output stages. With this type of stage, the interstage audio transformer is much more critical than in the usual class A output stage. Therefore, to avoid difficulty in replacing transformers of this type, refer to the schematic diagram to see what type of output stage is used.

Interstage transformers in high-fidelity systems also may present a problem. As with the output transformer, if the interstage audio transformer is defective, always try to get an exact duplicate replacement. However, if an exact replacement is not available, refer to the transformer manufacturer's catalogs to see if they have a transformer listed for the particular system you are working on. If you cannot find a replacement listed, refer to the manufacturer's list of general replacement transformers for high-fidelity systems, and try to find one designed for use between the particular tubes used in the high-fidelity amplifier you are repairing. However, wherever possible, when replacing the transformers in a high-fidelity system, use exact duplicate replacements. You can never be sure what results you will get when you use standard replacement transformers, except by actually installing the transformer in the equipment. Frequently, unless an exact duplicate is used, the operation of the system will be seriously impaired.

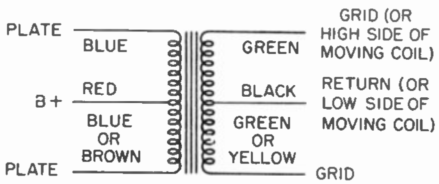


FIG. 4. The RETMA color code for audio transformer leads. The upper half is the code for an interstage transformer.

VERTICAL OUTPUT TRANSFORMERS

The vertical output transformer is used in a television receiver to couple the vertical coils in the deflection yoke to the plate of the vertical output tube. It is basically an impedance-matching device similar to the audio transformer used to couple the speaker to the plate of the sound output tube.

There are many types of tubes used as vertical output tubes in television receivers; also, different deflection yokes have different coil impedances. Therefore, as you would expect, there are a large number of vertical output transformers available.

When you have to replace the vertical output transformer in a TV receiver, the easiest thing to do is to refer to a transformer manufacturer's catalog and look up the replacement transformer recommended for the particular set according to the set manufacturer and the model number. Fortunately, most transformer manufacturers keep their catalogs as up to date as possible, so if a replacement is available, it is usually listed. However, sometimes you will find a new receiver with a defective vertical output transformer. The transformer manufacturers may not have had time to list this receiver in their catalog. This does not present a great problem because the distributor of the receiver usually carries exact duplicate replacements for the newer receivers.

In installing a replacement vertical output transformer, you must be sure to connect it in exactly the same way as the original. When you replace an audio output transformer, reversing the two primary leads or the two secondary leads will not cause any trouble. However, if you accidentally reverse either the primary or the secondary leads of the vertical output transformer in a television receiver, the picture will be upside down.

Vertical output transformers can be divided into two types. One has two separate windings, as shown in Fig. 5A, and the other is made like an auto transformer shown in Fig. 5B.

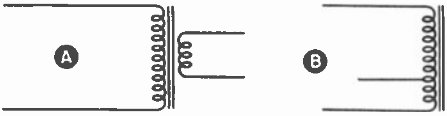
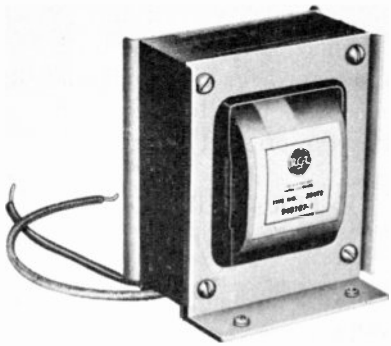


FIG. 5. A vertical output transformer may have two separate windings as shown in A, or it may be an auto transformer like the one shown at B.



Courtesy RCA

FIG. 6. A typical vertical output transformer.

Make sure that the replacement transformer is of the same type as the original. When a transformer of the type shown in Fig. 5A is used, retrace blanking circuits are sometimes connected to the secondary winding. If you try to install an auto transformer in the receiver as a replacement, you will connect the B+ voltage to the retrace blanking circuit. This may burn out other components. A typical vertical output transformer is shown in Fig. 6.

We do not expect you to understand the operation of TV receivers at this time. However, you will start to study television in the next lesson, so we have included information on replacing TV parts in this lesson so you will have all this information in one convenient place.

HORIZONTAL OUTPUT TRANSFORMERS

The horizontal sweep output transformer in a television receiver performs a task similar to that performed by the vertical output transformer. It couples the horizontal coils in the deflection yoke to the plate of the horizontal output tube. In addition, it has extra turns on the primary winding so that it can be used to generate the high voltage required to operate the picture tube. You will study this type of circuit in considerable detail later.

Since the horizontal output transformer in a television receiver is used for two purposes, it is even more important for the replacement transformer to have characteristics similar to those of the original transformer. Again, replacement transformer manufacturers list suitable replacements for most receivers in their catalogs. By consulting these catalogs, you can usually find a suitable replacement for any transformer. A typical example is shown in Fig. 7. Sometimes when a universal replacement is not available, you can obtain an exact duplicate replacement from the distributor of the receiver.

Incidentally, in selecting any replacement transformer, always refer to the service information on the receiver, because it may list suitable replacement transformers made by different manufacturers. This information is invaluable when it is necessary to replace a transformer, such as the horizontal output transformer in a television receiver.

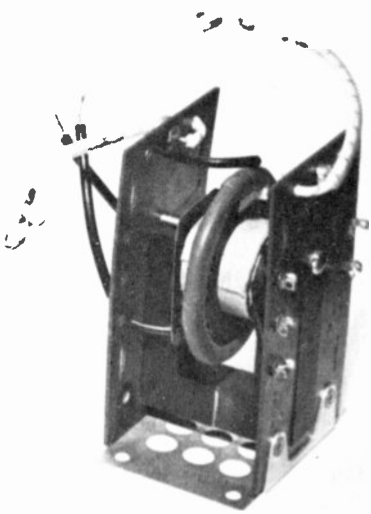


FIG. 7. A typical horizontal output transformer.

Installation. In installing the replacement horizontal output transformer, try to install the part in exactly the same spot as the original. Sometimes when installing universal replacements, you will have to drill new mounting holes. Be careful when you do this that you do not damage any nearby parts.

The lead dress on the horizontal output transformer is particularly important. Before you remove the old transformer, notice how the leads to it are run, and try to keep the leads to the replacement transformer in the same positions. Keep the lead to the high-voltage rectifier and the lead to the plate of the horizontal output tube away from other leads and away from each other. There will be an extremely high voltage pulse on these leads, so if you place other leads too close to them or place them too close together, there will probably be arcing.

The leads from the coils on the horizontal output transformer are usually of very fine wire. When mounting the transformer and soldering connections to it, be careful not to accidentally hit and break any of these leads.

IRON-CORE CHOKES

The only iron-core chokes you are likely to find will be filter chokes in receiver power supplies. Most transformer manufacturers also make choke coils, because the construction of choke oils and transformers is similar. The choke, like the transformer, is wound on a steel stack and has a winding similar to transformer windings. Therefore, manufacturers list choke coils in their catalogs along with replacement transformers. You can usually find a suitable replacement choke listed.

If there is no substitute listed, use a choke having an inductance and a current rating at least as high as the inductance and current rating of the original choke. For example, if you are replacing a choke rated at 3 henrys and 200 milliamperes, you might use a choke rated at 4 henrys and 250 milliamperes. The higher inductance will result in better filtering, and the higher current rating will mean that the choke will run slightly cooler.

The dc resistance of the replacement choke is not very important, but it should not differ too much from the resistance of the original choke. A large change in dc resistance may result in a substantial change in the operating voltages throughout the receiver. This could cause poor sensitivity if the voltages are too low. On the other hand, if the resistance of the replacement is much lower than that of the original choke, the resulting higher supply voltage might cause oscillation or cause some other parts to break down.

RF and I-F Transformers

I-F transformers used in radio receivers require replacement much more frequently than those used in TV receivers. The i-f transformers in a television receiver seldom break down, because the coils are wound with a fairly heavy wire. On the other hand, fine wire is used in winding the i-f transformers in a radio receiver.

RF transformers in radio receivers do not break down as often as the i-f transformers. However, sometimes the oscillator coil in a radio receiver must be replaced because the Q of the coil drops, and the oscillator fails to work.

I-F TRANSFORMERS

Practically all receivers designed for broadcast-band reception use an intermediate frequency of approximately 455 kc. Some of the older receivers and a few modern automobile receivers use a 262-kc i-f, and you may also find a few very old receivers that use a 175-kc i-f.

Selecting a suitable replacement i-f transformer usually presents little or no problem. All you need to do is find the i-f, and find out whether it is an input i-f transformer, an interstage i-f transformer, or an output i-f transformer. When ordering a replacement, specify which type it is and its frequency.

There are universal replacements available for use either as input or output i-f transformers that give satisfactory results in most applications. When using a replacement of this type, you need not specify whether it will be used as an input or an output transformer.

A few old radio receivers designed for broadcast-band reception used special i-f transformers with a third winding on them. Receivers of this type have not been manufactured for several years, and you will probably not be able to find an exact replacement for this type. However, a standard replacement i-f transformer will usually work satisfactorily.

Most FM receivers use an i-f of 10.7 mc. Standard replacement i-f transformers for FM receivers are available from most parts wholesalers.

Combination AM-FM Transformers. Some AM-FM receivers use a combination i-f transformer having both a 10.7-mc and a 455-kc transformer in the same container. Universal replacements suitable for use in this type of receiver can be obtained from any large wholesaler. Many manufacturers offering a complete line of replacement transformers list this type in their catalogs. Usually a universal replacement can be installed with little or no trouble. However, before ordering a replacement, you should check the circuit and also the replacement transformer to see whether or not it is suitable for use in the receiver you are working on.

You may be able to get an exact duplicate replacement transformer from the distributor of the receiver you are working on. This is particularly true of the newer receivers. Most distributors stock replacement parts of this type for two or three years after the receiver has been manufactured. However, if it is an old set, there is little likelihood that you'll be able to obtain exact replacement i-f transformers.

There are a few old AM-FM receivers around that used an FM i-f other than 10.7 mc. You must get an exact duplicate transformer if you have to replace the i-f transformer in one of these receivers.

TV I-F Transformers. Most TV receivers use i-f systems operating either in the 20-mc region or in the 40-mc region. Therefore, in replacing i-f transformers in a television receiver, you must first find out which i-f is used in the receiver. Many of the older television receivers used a sound i-f of 21.25 mc and a video i-f of 25.75 mc. Later television receivers use a sound i-f of 41.25 mc and a video i-f of 45.75 mc. The sound i-f in television receivers using intercarrier sound is 4.5 mc. Replacements for both sets of frequencies are available.

As we pointed out previously, the i-f transformers used in television receivers are wound of comparatively heavy wire, and you will seldom find trouble with them. The transformers are of two types. The example shown in Fig. 8 has a single winding, while the type in Fig. 9 contains a single winding and a trap. Notice in the illustration that the latter type can be either shielded or unshielded. Uni-

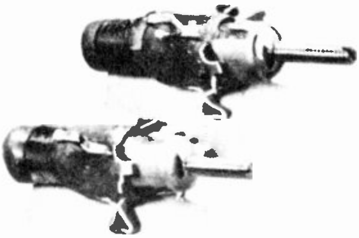


FIG. 8. Single-winding TV i-f coils.

versal replacements are available for both video i-f transformers if you need one for replacement.

Some television receivers use i-f transformers with two windings on them similar to the i-f transformers used in radio receivers. In radio, the coupling between the two coils is not nearly as important as it is in television. The i-f transformer coils used in TV receivers must be overcoupled to give the wide band width required in the video i-f system. Very often a television receiver manufacturer will use two or three i-f transformers of this type, which are identical except that different degrees of coupling are used between the coils. Therefore, when you must replace this type of transformer in the video i-f section, try to get an exact duplicate. If an exact replacement is not available, you have no choice but to use a universal replacement. This can lead to considerable difficulty in getting the receiver aligned properly, but fortunately video i-f transformers seldom require replacement.

The sound i-f transformers in a television receiver require replacement more frequently than the video i-f transformers. Fortunately sound i-f transformers are fairly standard. Most modern TV receivers use intercarrier sound, and the sound i-f in these sets is always 4.5 mc. A few of the older sets used a separate i-f of about 21.25 mc, but the sound i-f transformers in these receivers seldom cause trouble. Universal replacements can be used successfully in almost every case. However, if an exact duplicate replacement is available from the set manufacturer, by all means use it. It will lessen the possibility of unusual results or unforeseen difficulties.

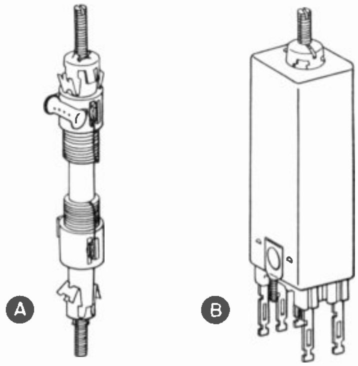


FIG. 9. A video i-f coil and trap. A shows the unshielded type; B the shielded type.

RF COILS

Many older radio receivers were designed for use with an outside antenna, and many of these receivers used an rf stage in front of the mixer stage. The antenna was coupled to the rf stage by means of an rf coil, called an antenna coil. The coupling between the rf stage and the mixer was usually accomplished by means of another rf transformer. These coils were designed to work together so that tuning could be accomplished by means of a ganged tuning capacitor. It is almost impossible to get exact replacements for these rf coils. When it is necessary to replace one, you will have to use a universal replacement.

Many universal replacement rf coils are made with an adjustable slug. The slug can be adjusted in conjunction with the trimmers on the tuning capacitor gang to get the best possible tracking over the broadcast band. You simply order a slug-tuned, broadcast-band replacement antenna coil for the coil used between the antenna and the rf stage, and a slug-tuned broadcast-band rf coil for the coil used between the rf stage and the mixer stage.

Some late model console receivers use an rf stage, but most of these receivers are designed for use with a loop antenna instead of an outside antenna. It is unlikely that you'll run into an open loop, but if the loop should open, you can usually locate the defect and repair it. If the rf transformer used between the mixer and rf stage breaks down, you may be able to get an exact duplicate replacement from the distributor. If an exact duplicate is not available, you will have to use a universal replacement.

After replacing an rf or i-f transformer in a radio or television receiver, you should check the alignment. Not only will the replacement coil itself affect the alignment, but also the lead dress may have a considerable effect, particularly in the i-f sections of a television receiver.

Generally speaking, rf coils in TV tuners are not available for replacement because in most cases it is impossible to get into the tuner to make the necessary replacement. However, some tuners are made with the various coils made up of a series of removable strips mounted on a drum, usually two strips for each TV channel. If the coils on either strip are damaged, replacement strips can be obtained.

OSCILLATOR COILS

The oscillator coil in a radio receiver may open, a short may develop, or there may be no apparent defect and the oscillator will simply fail to oscillate. When this happens, and all other components in the oscillator circuit are good, the chances are that the Q of the oscillator coil has decreased because of moisture absorption. In any of these three cases, the obvious remedy is to replace the oscillator coil.

As with the antenna and rf coils, an exact duplicate replacement is better than a universal replacement. If you can get an exact duplicate replacement and install it carefully, you probably won't have any difficulty in getting the receiver to track. However, if you cannot get an exact duplicate replacement, use a universal replacement. When ordering an oscillator coil, specify the frequency range and also the i-f of the receiver. Oscillator coils are available with an adjustable slug. This type of coil provides one additional adjustment that is often useful in getting the receiver to track over the band.

Oscillator coils in FM receivers seldom cause any trouble. These coils stand up better than those in the broadcast receiver, simply because they usually have only a few comparatively large turns.

In the rf and mixer stages of a television receiver, the oscillator is a part of the tuner. Again it is usually impossible to get at any of the oscillator coils to replace them. However, since they are wound with a reasonably large size wire, the coils themselves seldom cause trouble.

Replacing Capacitors

You may have to replace all kinds of capacitors—even tuning condenser gangs. However, you will usually carry only an assortment of paper, ceramic, and electrolytic, and perhaps a few fixed mica capacitors in stock. Let's take up capacitor replacements according to type. As you know, capacitors are also called condensers, so we will use both terms interchangeably so you'll be used to hearing both.

PAPER CAPACITORS

The most important ratings for any condenser are the capacity and the working voltage. The rating of the original part usually can be found from the schematic diagram or from the capacitor label, but an exact duplicate replacement is seldom needed for a defective paper capacitor. A wide variation in capacity is usually permissible in repairing AM and FM receivers, but in TV and high fidelity systems, you should try to use a replacement having the same capacity as the original part.

If you don't know the original capacity, use .01 mfd to .1 mfd for rf and i-f bypassing in AM and FM receivers, .25 mfd to 1 mfd for af bypassing, .002 mfd to .05 mfd for af coupling condensers, .05 mfd to .25 mfd for video coupling, and .001 mfd to .05 mfd for buffer condensers. This gives a clue to the sizes you should stock. A few each of .001, .005, .01, .05, .1, .25, and .5 mfd will be adequate for practically all bypass and coupling purposes.

A more important factor is the capacitor working-voltage rating, *which should always be greater than the voltage across the terminals to which the capacitor is connected.* Many servicemen never use a paper capacitor with less than a 600-volt rating (space permitting) even if it is to be used in a low-voltage circuit. It costs only a few cents more and is excellent insurance against a call back. Buffer condensers in vibrator power supplies should be rated at 1600 volts or more.

Sometimes one end of a tubular paper condenser will have a black ring on it and be marked "outside foil" or "ground." The foil connected to the lead at this end of the condenser is the final outside layer that surrounds the rest of the condenser. If a condenser goes either directly to gound or through a low impedance path to ground, this ground connection should be made to the outside foil end of the condenser. The outside foil then acts as a grounded shield and prevents undesirable coupling between the condenser and other circuits. This is more important in TV than in radio. If the original condenser has the outside foil marked, connect the replacement in the same way.

ELECTROLYTIC CAPACITORS

Electrolytic capacitors are often puzzling to newcomers in the service business. When replacements are to be made, many questions about capacity, working voltage, and types come up.

Let's consider capacity first. When replacing an electrolytic condenser in a receiver, the capacity of the replacement should not be much below the capacity of the original. The maximum value that can be used depends upon where the condenser is connected in the circuit. For example, a 10-mfd *output* filter condenser should not be replaced by one smaller than 8 mfd, but a much larger condenser can be used to give better filtering. However, do not replace an *input* filter condenser with one of substantially larger capacity. The peak current through the rectifier tube may increase to the point where the tube will be damaged. Small variations in the size of the input filter should not cause any trouble.

In replacing electrolytic bypass condensers, never use a capacity lower than the original; a larger capacity will give better results. In replacing condensers used across the filament strings of three-way receivers, stick to the original capacity if possible. Also, when replacing electrolytics in the video amplifiers of TV receivers, use the same capacity as those originally used in the set. These condensers are used to improve the low-frequency response. Changing their size may change the response.

Here is a good rule to remember about working voltage. *The working voltage of the replacement must be at least as high as the original;* if it is higher, there will be less chance that the new condenser will break down. If you are in doubt about the voltage applied to the condenser, check it with a dc voltmeter. When the set is first turned on, the voltage may be considerably higher than when the tubes start drawing current. It is this initial high voltage that the condenser must withstand. A working voltage of 150 volts is standard for filter condensers in ac-dc sets, (voltage doublers use 300 volts), while 450 volts is standard for those used in ac receivers. Cathode bypass capacitors are usually rated at 25 or 50 volts.

The type of can or container used with an electrolytic capacitor has nothing to do with replacements. For example, a condenser in an aluminum can may be replaced by a tubular paper electrolytic with similar ratings; however, you may find it somewhat more difficult to mount the tubular than the can type.

If there are a number of condensers in a case and one is bad, it is best to replace them all, since the others will not last as long as the new one. However, in an emergency or as a temporary repair, you can disconnect the lead to the defective section and connect a single-section replacement unit outside the case in the place of the defective section.

When you replace the whole unit, not only must it contain the correct number of sections, but also their leads must be arranged so that they can be properly wired into the circuit. For example, look at Figs. 10A and 10B. Each dual condenser contains the same value condensers and each has three leads. Yet the two cannot be interchanged—the one in Fig. 10A has a *common negative* lead for both condensers, while the one in Fig. 10B has

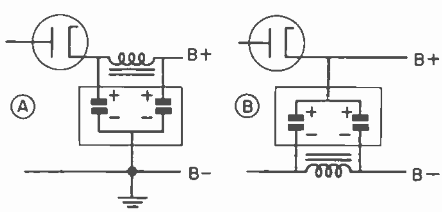


FIG. 10. Two styles of dual filter capacitors. These are NOT interchangeable, so be sure you get the proper replacement.

a *common positive* lead for both condensers. If any of the leads in a multiple unit condenser are common to two or more condensers, say so when you order a replacement. Two separate condensers, or a dual condenser with separate positive and negative leads, could be used to replace the condensers in Figs. 10A and 10B.

MICA CAPACITORS

Mica capacitors rarely become defective; when one does, it is best to use a replacement of the same capacity. Because different color codes are often used on micas, it is usually easiest to identify the proper size from the wiring diagram. If you have no service information, examine the original. You may find the capacity value is stamped on the condenser, or it may be marked according to the standard color code (see Fig. 11). Remember, *private* color codes are sometimes used, so if you read the colors according to the standard code, and come out to some unreasonable capacity value, the marking is probably *not* the standard code.

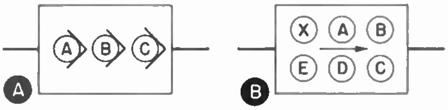


FIG. 11. How mica capacitors are color-coded. In each case, color A is the first figure of the capacity value, B is the second figure, and C is the number of zeros after the second figure (the decimal multiplier). In B, there are three additional dots. If X is white, the resistor is color-coded according to the 1947 RETMA color code. If X is black or silver, it is color-coded by the JAN (Joint Army-Navy) and AWS (Army War Standard) codes. Color D indicates the tolerance, and color E indicates characteristics of significance only to the manufacturer. The numerical values indicated by each color are as follows:

Black	**0**	**Green**	**5**
Brown	**1**	**Blue**	**6**
Red	**2**	**Violet**	**7**
Orange	**3**	**Gray**	**8**
Yellow	**4**	**White**	**9**

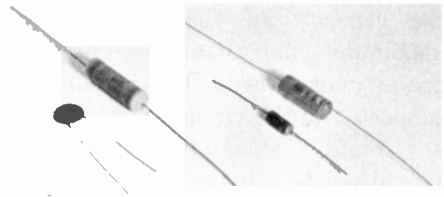


FIG. 12. Ceramic capacitors compared to paper ones. At the left is a disc type, and at the right a tubular type.

CERAMIC CAPACITORS

Ceramic capacitors are used both as coupling and as bypass condensers. Typical ceramic condensers are shown in Fig. 12. Coupling condensers used in the video- i-f stages of a television receiver are usually ceramic capacitors. In replacing these condensers, it is very important to get a replacement having the same capacity as the original because changes in capacity will affect the receiver alignment. When replacing the coupling condenser in the video i-f stages of a TV receiver, it is almost always necessary to realign the receiver. The ceramic capacitors used in coupling circuits are almost always tubular, and you should use only tubular capacitors as replacements.

Disc type ceramics are used as bypass condensers in video i-f stages. When replacing a ceramic bypass condenser, use one having a capacity at least as high as the capacity of the original part. Usually a larger capacity replacement can be used without running into any difficulty. Most disc ceramics available for replacement purposes are rated at 500 volts, but condensers with higher rated voltages are available where needed.

GANG TUNING CAPACITORS

In modern receivers the tuning capacitor gang seldom becomes so defective it cannot be repaired. Even badly bent plates usually can be straightened with a thin putty knife. However, if they are beyond repair, the shaft is bent, or the bearings are damaged, a new gang should be installed.

If the set is reasonably new, try to get an exact duplicate from your local distributor of the brand of receiver you are servicing. If the set is several years old, you will have to use a standard replacement. In some older sets, the sections of the tuning condenser were identical; in others, specially shaped plates were used in the oscillator section. Note which type the set you are working on uses, and install a similar replacement.

Replacing Resistors and Potentiometers

Resistors fall into several classifications: fixed, semi-variable, and variable types. They may have carbon, a metallic deposit, or resistance wire as the resistive element. Let's take up each type in turn.

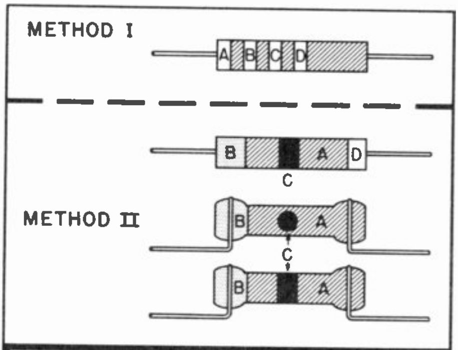
FIXED RESISTORS

You're usually safe in suspecting excess current when a metallized or carbon fixed resistor becomes defective, particularly if the resistor has a burned or charred appearance. (Wire-wound resistors rarely burn out—electrolysis at the junction of the terminal lug and the resistance wire is the usual trouble.) Look carefully for the cause of this excess current before installing a new resistor. A check from the low-potential end of the resistor to the chassis with an ohmmeter will show whether a broken-down capacitor or some other short burned out the resistor. If the resistor has not changed in appearance and no short can be found, the element is probably cracked.

After you have repaired the short, or made sure there is none, determine the proper size for the replacement.

Resistance values are not critical, so a variation of 20% is of little importance. You can find the value of the original resistor from the schematic diagram, or from the color code markings, if it follows the standard code. The color code for resistors is shown in Fig. 13.

If you are unable to find a diagram of the receiver you are working on, try to find a similar circuit using the same tube and see what value resistor is used. The chances are that a resistor of the same value will work in the circuit you are repairing. With a little experience, you soon learn the approximate resistances used in many circuits. This information will be helpful to you.



COLOR A GIVES FIRST FIGURE OF RESISTOR VALUE.
COLOR B GIVES SECOND FIGURE OF RESISTOR VALUE.
COLOR C GIVES THE NUMBER OF CIPHERS FOLLOWING THE FIRST TWO FIGURES.
COLOR D GIVES THE TOLERANCE:
GOLD BAND INDICATES ±5%
SILVER BAND INDICATES ±10%
NO BAND INDICATES ±20%

COLOR	FIGURE
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9

EXAMPLES:

A	B	C	VALUE
RED	RED	BLACK	22
RED	RED	BROWN	220
RED	RED	ORANGE	22,000
GREEN	BLACK	ORANGE	50,000
YELLOW	VIOLET	ORANGE	47,000
BLUE	GRAY	GREEN	6.8 MEG

FIG. 13. The RETMA color code for resistors. Method I is used on practically all modern resistors. Method II may be found on resistors in old receivers.

Always use a replacement resistor with a wattage rating equal to or higher than that of the original—*never lower*. Otherwise, the replacement will burn out. You can use the physical size of the resistor as a guide, if the replacement is the same type (carbon, metallized, or wire-wound) as the original. The replacement should be the same physical size, or larger.

The wattage rating of carbon resistors should always be twice the actual power they must handle, because the resistance of a carbon resistor will increase when it is overheated, and often will not return to its original value after it has cooled. The resistance of a wire-wound resistor, on the other hand, will return to its original value even after the part has been very hot. Therefore, the wattage rating of these units can be somewhat less than the computed wattage.

If carbon resistors used as bleeders or voltage dividers are defective, replace them with 10- or 20-watt wire-wound resistors.

When sections of a tapped unit fail, it is generally best to replace the entire unit with a duplicate or with individual wire-wound units. You can use the old unit and simply shunt a suitable replacement across the defective section if the section is open. However, if the resistor is a metal encased type, the entire unit should be replaced.

Your stock of resistors should include a kit of carbon resistors in ½-, 1-, and 2-watt sizes. You will usually find that values of 220, 470, 1000, 4700, 22,000, 47,000, 100,000, 220,000, 470,000 ohms, 1 meg, 2.2 meg, 3.3 meg, and 10 meg are used most. It is not worthwhile to stock large wire-wound resistors. There are so many different sizes and wattage ratings used, the best thing to do is buy replacements as you need them.

VOLUME CONTROLS

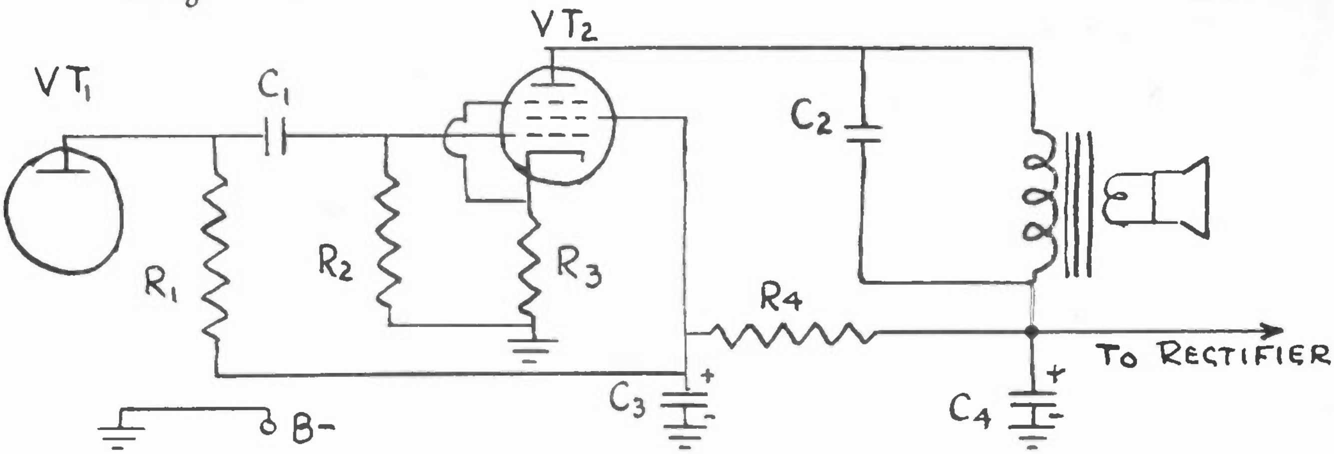
In the pre-television era, when the serviceman repaired only radios, replacing a potentiometer was a comparatively simple task. Potentiometers are used in radios as volume controls and also as tone controls. They are used for the same purposes in television receivers, but in addition, potentiometers are used to control the brightness, contrast, horizontal

National Radio Institute

3939 WISCONSIN AVE., N.W, WASHINGTON 16, D.C.

ESTABLISHED 1914

Dear Student:
Here's a service hint you may find valuable — Distortion is often caused by a gassy tube or a leaky plate-to-grid coupling condenser. Such a defect results in a positive control grid voltage and this is the cause of the distortion.



If a dc voltmeter connected across R_2 shows the control grid of VT_2 to be positive, coupling condenser C_1 is leaky, VT_2 is gassy or both conditions are present. To find the exact trouble, unsolder one lead of C_1. Be sure to have R_2 connected between the grid of VT_2 and B−. If the voltage across R_2 disappears, C_1 is leaky. If the voltage across R_2 does not change, C_1 is not leaky but VT_2 is gassy. If the voltage across R_2 decreases but does not disappear with C_1 disconnected, both the tube and coupling condenser are defective and both should be replaced. In a normally operating stage, no dc voltage should be present across R_2.

Sincerely yours

J. B. Straughn

TAC-27F-1

and vertical hold, height, vertical linearity, width, focus, etc. Many different sizes and shapes of poteniometers are used. Some potentiometers are single units, others are actually dual controls on concentric shafts.

In some of the old receivers, the volume control is a combination antenna and C bias control. As the control is rotated from the minimum volume position to the maximum volume position, the amount of signal applied to the first stage is increased, and at the same time the bias on one or more rf stages is decreased. Thus, both the signal fed to the rf stage and the gain of the stage are increased.

It is important in replacing this type of control to choose a replacement having characteristics similar to those of the original part. The exact resistance is not very important, but you should try to get a control reasonably close to the resistance of the original. However, it must be designed for use as a combination antenna-C bias control if smooth control over the receiver volume is to be achieved.

Another common type of control used in older receivers is a C-bias control. This type of control varies the bias on one or more rf stages and thus changes the gain of the rf stage. Again, the exact resistance of the control used as a replacement in this type of circuit is not very important, but it is important that it be designed for use as a C-bias control. This type of control has a right-hand taper.

Practically all television receivers and most modern radio receivers use an audio type of control. This type of control has a logarithmic taper and is used to vary the amplitude of the signal fed to the first af stage. The human ear is much more sensitive to small changes in volume at low volume levels than it is at high volume levels. The taper of the control is designed to follow the characteristics of the ear closely. Thus, as the control is rotated from minimum volume toward maximum volume, the increase in the amount of signal fed to the stage is actually comparatively slow at first. As the point of maximum volume is approached, the amount of signal fed to the first audio stage increases more rapidly. Although the signal amplitude varies considerably, the response of the ear is such that the increase in the sound output seems to be linear throughout the range of the control.

As in the case of the volume control discussed previously, the exact resistance of the replacement control is not important. However, when the control is located in the grid circuit of the first audio stage, it is important to use an audio type of control as the replacement. This type of control usually has a resistance somewhere between .1 meg and 1 meg.

TONE CONTROLS

There are many different types of tone controls used in radio and TV, but the majority are comparatively simple. Most tone controls are simply a capacitor in series with a potentiometer. The capacitor bypasses the higher audio frequencies, and gives an apparent increase in the low-frequency response of the receiver as the resistance of the potentiometer is reduced. When the control is turned toward the maximum resistance position, the added resistance in the circuit reduces the effectiveness of the capacitor as a high-frequency bypass, and the higher audio frequencies receive normal amplification.

The resistance of this type of control is not particularly critical, but you should try to stay as close as possible to the resistance of the original. Most controls of this type have a linear taper.

Hi-Fi Systems. Most high-fidelity systems have elaborate tone-control systems. There may be several potentiometers used in the tone-control circuits. Needless to say, the only sure way of avoiding difficulty when replacing one of these potentiometers is to use a control having characteristics identical to those of the original.

TV CONTROLS

With the exception of the volume control in a TV receiver, the controls usually have a linear taper. In other words, the change in resistance for a given amount of rotation is the same regardless of whether the shaft is near the maximum counter-clockwise position, in the center, or in the maximum clockwise position.

In replacing a control in a TV receiver, you should try to get a control having a resistance the same as the resistance of the original. Sometimes it is not possible to do this, but if you try to come as close to the same value as you can, the replacement will usually be satisfactory. Except for the horizontal and vertical hold controls, the values of the controls in a set usually are not critical. Even the hold controls can be varied somewhat without causing any trouble.

Selecting Replacements. One of the problems in selecting a suitable replacement is to get a control that will work with the knobs originally used on the TV receiver. There are many different styles of knobs and most knobs cannot be used on all the various shafts available. Some manufacturers supply the potentiometer and shaft as separate units so that the serviceman can purchase the desired value potentiometer and the required shaft. The shaft is simply inserted in the potentiometer and gently tapped into place. Sometimes it is necessary to shorten the shaft by cutting it with a hacksaw to the required length.

Concentric controls, in which two or more potentiometers are on concentric shafts, are used in TV receivers in many cases. Often exact duplicate controls can be obtained from the distributor of the particular brand of receiver you are working on. If an exact duplicate is not available, concentric shaft control kits can be obtained, and in most cases these can be assembled to form a suitable replacement. The serviceman simply assembles two units having the desired resistance values, and then attaches the correct type of shaft to the unit. Universal replacements of this type also can be obtained from any large parts wholesaler or mail-order establishment.

High-Wattage Units. Some TV receivers use a potentiometer in series with the focus coil to control the current flowing in the focus coil, and hence the focus. In most cases this potentiometer is a rather large unit having a high wattage rating. If it is necessary to replace the focus control in a TV receiver, you should consult the manufacturer's service information to determine the resistance of the original control and also its wattage rating. Try to get an exact duplicate replacement control from your distributor; but if an exact duplicate is not available, you will have to use a standard replacement. If you cannot get a standard replacement having the same wattage rating as the original, use the next higher wattage rating available, if there is room for it in the receiver.

Replacing Other Parts

Now let us take up some of the other radio and TV parts you may be called on to replace from time to time.

LOUDSPEAKERS

Practically all modern radio and TV receivers designed for home use use PM dynamic speakers. You will find a few receivers using electrodynamic speakers, but few manufacturers have used them except in automobile receivers, for several years.

Replacement speakers are relatively inexpensive in most cases. In years past, speakers were expensive and servicemen would often re-cone defective speakers. However, today usually the simplest thing to do is to install a new speaker rather than try to repair the old one.

To order a replacement speaker, you should know the cone diameter of the original speaker and the voice-coil impedance. If the speaker is an electrodynamic one, you must also know the field-coil resistance. Manufacturers of most radio and television receivers have standardized on a voice-coil impedance of 3.2 ohms. The manufacturer usually lists the voice-coil impedance in the service information for the receiver. If this information is not available and the set has been manufactured within the last ten years, the chances are that the voice-coil impedance is 3.2 ohms. If the speaker is an electrodynamic type, and the field coil is still in good condition, you can determine the field resistance by measuring the resistance of the old field with an ohmmeter.

You may have some difficulty obtaining an electrodynamic speaker for use as a replacement in an old receiver. In many old receivers, the speaker field is used as a filter choke in the B supply. In this case you can usually use a permanent magnet dynamic speaker and substitute a filter choke in place of the speaker field of the original receiver. You should check the service information for the receiver to determine the resistance of the original field coil, and try to obtain a filter choke having approximately the same dc resistance. Usually a choke having an inductance anywhere from 3 to 8 henrys will be suitable for this substitution.

Sometimes you will find a speaker field connected across the supply as shown in Fig. 14. The speaker field serves no useful purpose when it is connected in this way. A permanent magnet dynamic speaker can be used as a replacement, and the connections to the original speaker field can be removed completely from the circuit.

Some of the early model TV re-

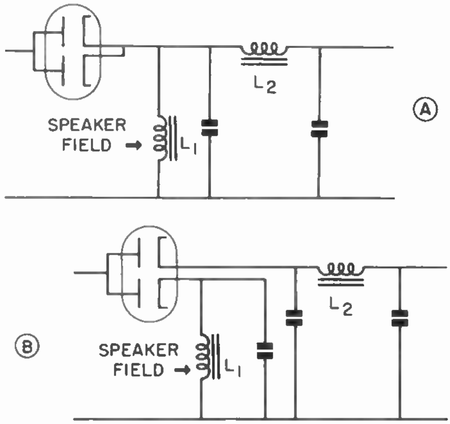


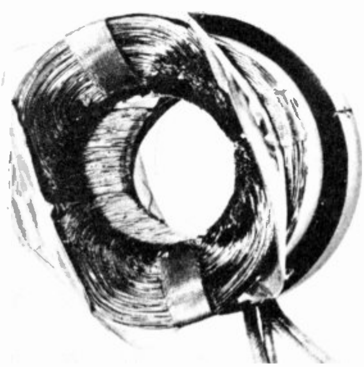
FIG. 14. Two methods of connecting speaker field coils that are used in universal ac-dc sets.

ceivers used electrodynamic speakers. The field resistance on these speakers is quite low, usually 68 ohms. You must use a similar speaker with a low resistance field or a PM speaker and a filter choke. A speaker with a 300- or 400-ohm field would soon burn out because of the high field-coil current.

Auto Receivers. Many automobile receivers use electrodynamic speakers. The field is energized by connecting it directly across the automobile's electrical supply. PM speakers can be used in these sets with no changes in the circuit, except to remove the lead that was used to connect the field coil to the supply circuit. Using a PM speaker will reduce the current drain on the battery considerably.

Re-coning Speakers. Some large wholesalers operate a speaker re-coning service. When it is necessary to replace a large speaker, it is sometimes worthwhile to take advantage of this service. Often the speaker can be re-coned for less than it would cost you to buy a replacement. Contact your local wholesaler to find out if this service is available through him. When it is necessary to replace a 10- or 12-inch speaker, find out from him the cost of a new speaker and also the cost of repairing the original. From this information, you can decide whether or not it would be worthwhile to have the original speaker re-coned. It is not worthwhile to try to re-cone speakers yourself, unless you intend to specialize in this type of work; nor is it economical to re-cone the 5- and 6-inch speakers. It usually costs more to re-cone them than to buy a replacement.

High-Fidelity Speakers. The speakers used in high-fidelity systems are extremely expensive, and you should exercise great care when handling them. It would be extremely unfortunate to let a screwdriver slip and puncture the cone. Usually, if the speaker in a high-fidelity system is defective, to obtain satisfactory results, you will have to obtain a replacement speaker designed for use in a high-fidelity system. Sometimes an exact duplicate is available. If you cannot get an exact duplicate, you may be able to install a speaker having the same voice-coil impedance and the same physical size in the original speaker enclosure and obtain satis-



Courtesy Merit Transformer Corp.

FIG. 15. The deflection yoke of a TV receiver.

factory or better results than with the original speaker.

Most owners of high-fidelity systems have studied speaker characteristics and have fixed ideas as to what types of speakers give the most satisfactory results. If you should service a high-fidelity system and discover it is necessary to replace the speaker, find out if the owner has any preferences as to the type of replacement speaker to use.

TV PARTS

There are a number of parts found in television receivers that you will not find in radios. In this last section of the lesson, we will discuss several of these parts.

Tuners. The tuner in a television receiver contains the rf, mixer, and oscillator stages. It is assembled on a small chassis and wired as a complete unit, which is then mounted on the main TV receiver chassis. Because of the compact method by which the tuners are assembled, it is usually impossible to do anything other than to make minor repairs. If a serious defect develops, the chances are you will have to replace the entire tuner. Information will be given in a later lesson on the repairs that can be made to a tuner.

When you need to replace a tuner, you can usually get a suitable one from the distributor of the receiver you are working on. Also, local parts wholesalers stock replacement tuners. One manufacturer may make tuners used in several different brands of receivers. Once you start doing TV service work, you will soon learn how to recognize these tuners.

Deflection Yokes. The deflection yoke in a TV receiver is the circular coil that fits over the neck of the picture tube. A typical yoke is shown in Fig. 15. It is used to deflect the electron beam over the face of the tube. There are two pairs of coils in a deflection yoke, a vertical set and a horizontal set.

When replacing a deflection yoke, you must obtain a replacement having the correct electrical characteristics. Yokes are designed for a particular deflection angle. The replacement must be designed for the same deflection angle as the original yoke. Most yokes are designed for deflection angles of 55 degrees, 70 degrees, 90 degrees, or 120 degrees. In addition to having the correct deflection angle, the replacement yoke must have coils with the same impedance as the coils used on the original yoke. In other words, the impedance of the vertical coils in the replacement yoke must be the same as the impedance of the vertical coils in the original, and the horizontal coils in the replacement must have the same impedance as the horizontal coils in the original.

Most transformer manufacturers make deflection yokes, and you will find deflection yokes listed in their catalogs. Look up the receiver by the manufacturer's name and model number to see if a replacement is available. If the set is new, get an exact duplicate replacement from your local distributor.

If there is no exact duplicate available, and the yoke is not listed in the catalogs you have, your local wholesaler may be able to help you select a suitable replacement. You also can check the service information on the receiver to see if the impedance of the coils is available and

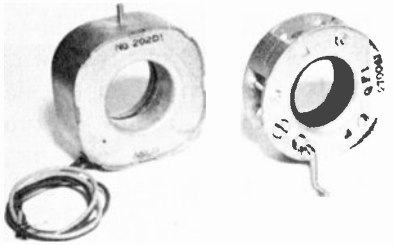


FIG. 16. A typical focus coil is shown at the left, and a permanent-magnet focusing device at the right.

check your tube manual to find the deflection angle of the picture tube used in the receiver. With this information, look through the catalogs you have, and select a replacement having characteristics closest to those of the original.

Focus Coils. A typical focus coil is shown in Fig. 16. Later you will find out when you study picture tubes that many of them use a coil of this type to focus the electron beam to a fine spot on the face of the picture tube.

The focus coil is usually connected in the B supply so that the current drawn by the entire receiver flows through it. When replacing the defective focus coil, you should try to get an exact duplicate replacement. However, if an exact duplicate replacement is not available, you can often use a universal replacement having a dc resistance approximately the same as that of the original coil. Small changes in the dc resistance should not appreciably affect the performance of the receiver, but large changes will.

Some focus coils actually consist of a permanent magnet plus a coil. The permanent magnet provides part of the field required, and the coil provides the rest of the field. Replacements for this type of coil should be obtained from the distributor of the particular receiver you are servicing. Give the distributor the manufacturer's name and model number, and if available, the part number of the original focus coil to be sure that you get a suitable replacement.

Peaking Coils. There are two types of peaking coils used in TV sets. One type has inductance only, and the other type has the inductance shunted by a damping resistor of from 22,000 ohms to 39,000 ohms. When these coils must be replaced, an exact duplicate is required. The wrong size will alter the video amplifier response. However, standard sizes are generally used, so you can get exact replacements from a parts wholesaler. Fig. 17 shows some peaking coils. If an odd size is used, you will have to get a replacement from the manufacturer of the receiver in which it is used.

Ringing Coils and Horizontal Oscillator Transformers. Both of these coils are used in the horizontal oscillator circuit. Universal replacements will work in most cases. Fig. 18 shows schematic drawings of the two. If the coil has an extra winding, or is different from the standard in some way, you will have to get a replacement from the receiver manufacturer.

Linearity Coils. The linearity coil controls the linearity of the horizontal

FIG. 17. Typical peaking coils.

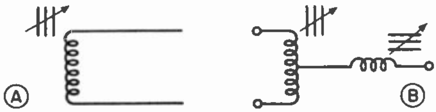


FIG. 18. Schematic drawings of (A) a ringing coil, and (B) a horizontal oscillator transformer.

sweep. Many different values of inductance are used. These coils seldom cause trouble, but if they must be replaced, you can often get an exact replacement. There is also a wide range of universal replacements available. One that covers approximately the same range as the original can be used.

Width Coils. The width coil controls the width of the picture in a TV receiver. There are many different values used. As with the linearity coil, exact replacements and a wide range of universal replacements are available.

SPECIAL PARTS

There are other miscellaneous parts that you might find in both radio and television receivers. An example is the band-change switch used in older receivers having short-wave bands and in some of the more modern AM-FM receivers. Also, television receivers have been made in which you can turn the set on and off, change channels, etc., by means of relays. When these parts require replacement, you can often get an exact duplicate replacement from the distributor of the receiver you are servicing. If an exact duplicate replacement is not available, sometimes you can get a standard replacement part that will work satisfactorily.

There are a number of mechanical parts in a TV set, such as support brackets and straps to hold the picture tube in place. If these parts are broken, you can usually make something that will do the job satisfactorily. The serviceman is often called upon to use his ingenuity in making repairs using the materials he has available.

Sometimes it is impossible to return the receiver to its original operating condition. In a receiver designed to operate on the short-wave bands as well as the broadcast band, if you cannot obtain a band-change switch or if one of the short-wave coils is defective, you may find it necessary to do away with the short-wave section and solder the broadcast band coils permanently into the circuit. The set owner will then be able to use the set on the broadcast band, and the receiver will not be entirely useless. Of course, when it is necessary to make a repair of this type, you should consult the set owner, explain the situation to him in detail, and find out whether or not he is willing to accept this type of repair.

SUMMARY

The radio and TV serviceman can get most of the parts he is likely to need from a parts wholesaler or from a large mail-order firm. Most of these firms stock a complete line of universal replacement parts. Exact duplicate replacement parts can be obtained from the distributor of the particular brand of receiver that you are working on. If you do not know the distributor's name and address, look it up in the classified section of your telephone directory of the nearest large city. When in doubt as to whether a universal replacement or an exact duplicate should be used, use the exact duplicate replacement if it is available. Of course, if an exact duplicate replacement is not available, then you have no choice but to use a universal replacement. Usually a universal part will give satisfactory results in all but the most critical circuits.

Parts such as capacitors and resistors are usually standard, and there is no need to obtain exact duplicate replacements. However, in replacing parts such as the horizontal output transformer in a television receiver, or the deflection yoke, you should get an exact duplicate replacement or else a universal replacement designed for use in the particular receiver you are servicing.

Do not forget to get catalogs such as those put out by transformer manufacturers. Many of these catalogs contain lists of the various radio and TV receivers. The lists are arranged by manufacturer's name and model number. The list will show the universal replacement part for such components as the power transformer, filter chokes, output transformers, etc. Catalogs of this type are extremely useful to the serviceman; they will save him a great deal of time and money.

In making repairs in radio and TV receivers, you will have to use all the fundamental information you learned in your earlier lessons, and often just plain common sense in choosing suitable replacement parts. We cannot give you the solution for all the replacement problems you are likely to meet in servicing. However, the questions at the end of this lesson are designed to give you some indication of the types of problems you will have to solve. The more repair work you do, the better able you will be to select the proper replacement part.

Lesson Questions

Be sure to number your Answer Sheet 47B-1.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of lessons before new ones can reach you.

1. If the power transformer in a radio or TV set continues to overheat after you remove the rectifier tube from the socket, would you assume that the transformer is defective without making any additional tests?

2. What must the current rating be of the 6.3-volt filament winding on the power transformer used in a receiver with 6 tubes, not including the rectifier, in which four of the tubes are rated at 6.3 volts at .3 amp each, and two of the tubes are rated at 6.3 volts at 1 amp each?

3. What will happen if you reverse the leads to the primary winding of the vertical output transformer in a television receiver?

4. Can you use a choke coil having an inductance of 8 henrys at 200 ma to replace one having an inductance of 8 henrys at 100 ma?

5. Is a .05-mfd, 400-volt capacitor a suitable replacement for a .05-mfd, 600-volt capacitor?

6. In replacing a 30-30 mfd dual electrolytic capacitor in an ac-dc receiver, which would you normally use, a capacitor rated at 150 volts or one rated at 450 volts?

7. What is the resistance and tolerance of a resistor color coded like the resistor shown in Method 1 of Fig. 13, where band A is white, band B gray, band C yellow, band D silver?

8. Can a 1-meg volume control be used to replace a .5-meg control?

9. Can a PM type dynamic speaker be used satisfactorily as a replacement for an electrodynamic type of speaker in an automobile radio?

10. In addition to the deflection angle, what other electrical characteristic is important in selecting a replacement deflection yoke?

YOUR REPUTATION

Success in business depends on a number of things, but your reputation is probably the most important of these. Your sense of "fair play," and of honest dealing will determine your reputation, whether you operate a store or work as a serviceman. To help you get started properly, here are a few of the business rules you should memorize well:

Keep your promises. **Be careful to make only promises which you are reasonably sure you can keep.**

Keep accurate records. **Only records can show what your profits are, what your costs are, and what your tax bill is. Adequate records are needed to show you how to adjust your charges so that you can be fair to both yourself and your customer.**

Be honest in all your dealings. **Honesty goes far beyond "dollars and cents"—it includes fairness to your employees; telling the truth in your advertising; guaranteeing your work and your merchandise; and reasonableness in dealing with your suppliers.**

Yes, a *good* reputation is certainly to be desired. With it, you are well on the road to success!

THE TELEVISION SIGNAL

48B

RADIO-TELEVISION SERVICING

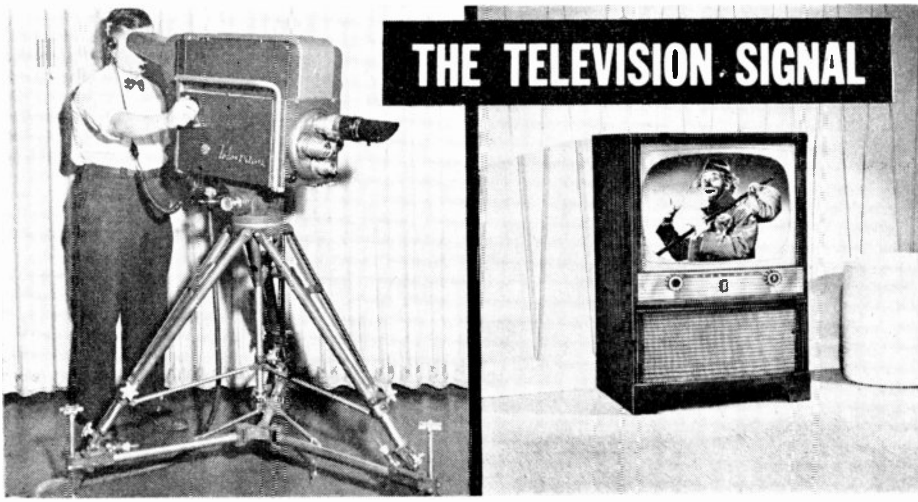
NATIONAL RADIO INSTITUTE
WASHINGTON, D. C.
ESTABLISHED 1914

STUDY SCHEDULE NO. 48

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

FM3M1260 **1960 Edition** Printed in U.S.A.

THE TELEVISION SIGNAL



THIS is your first lesson in a series dealing exclusively with television. You have already learned the functions of most of the components used in television receivers, and you have acquired a good fundamental knowledge of the electronic principles that make television possible. Now you will learn to apply this knowledge to the field of television servicing.

In this lesson and succeeding ones, you will find the important principles underlying all phases of modern television systems presented in a simple, logical, and understandable manner. After mastering these lessons, you will find it easy to understand the operation of any TV set. Then you will learn how to service TV sets. You will learn the basic techniques, and the difference between servicing radio receivers and servicing TV receivers. You will also learn how to make installations and how to instruct the customer in the operation of his set.

Fig. 1 is an over-all picture of a television system. You are already familiar with the sound half of this system. That is, you know how sound is converted into electrical signals by

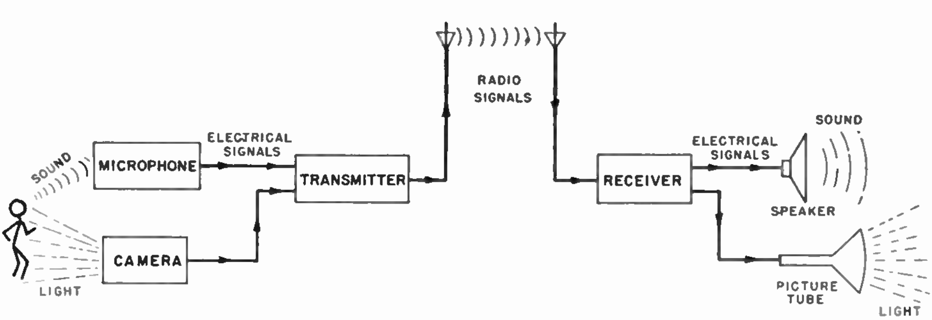


FIG. 1. A video (television) system of transmission and reception is similar to a sound (radio) system.

a microphone, amplified, and converted into radio signals by a transmitter, how the radio signals are re-converted into electrical signals by the receiver, and how these electrical signals are converted into sound at the loudspeaker. In a television system, light must go through the same series of conversions and re-conversions. The camera and the picture tube perform the same functions in the conversion of light as the microphone and speaker do in the conversion of sound.

The diagram at Fig. 1 is an over-simplification, because the differences in the characteristics of light and of sound make their conversion into electrical signals considerably different. We might say that sound is received by the microphone in series. That is, each impulse of sound follows the next so that it can be directly converted by the microphone into an ac voltage of varying frequency.

On the other hand, light is received by the camera in parallel. Each degree of light contained in a complete scene reaches the camera lens at the exact same instant of time. Therefore, it is necessary for the camera to break up the image it receives in the form of light into a series of impulses similar to those received by the microphone before it can produce a usable electrical signal to modulate the transmitter. To accomplish this, the television camera looks at the scene along one line at a time, in essentially the same way as you are reading this column.

As the camera scans along one line of the scene, it converts the light along that line into a series of electrical impulses, the amplitude of which is proportional to the intensity of the light

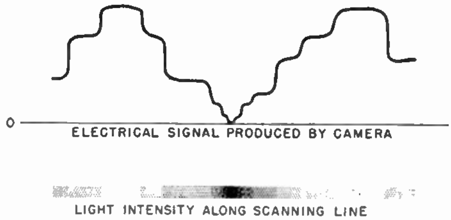


FIG. 2. As the camera scans a line of the scene, it produces an electrical signal proportional to the intensity of the light along the line.

along that line. This produces a series of electrical impulses that can be used at the transmitter to modulate a radio-frequency signal. Fig. 2 shows a line of a scene with light of varying intensities, and the type of electrical signal the camera would produce as it moved along that line.

The process of looking at a scene, moving along one line at a time, is called *scanning*. The system of scanning accounts for the fact that the picture you see on your television screen is composed of a series of horizontal lines.

THE TV CARRIER SIGNAL

The process of scanning, which breaks up a televised scene into successive signal elements, results in a frequency range for picture signals of from zero to more than 4,000,000 cycles (4 megacycles, abbreviated 4 mc) per second. Thus the television signal for one channel covers more space in the radio spectrum than the entire broadcast band. Only very-high-frequency carriers are suitable for transporting through space a signal that has a frequency range of over 4 megacycles.

With standard amplitude modulation, such as is used in the broadcast band, both sidebands are transmitted. Consequently, the total channel width needed is twice the highest modulating frequency (at least 4 x 2, or 8 mc wide in this case). To save spectrum space, TV stations use special filters that partially suppress one sideband so that the transmitted picture signal has a band width of 5.25 mc. In addition to the picture signal, allowance must be made for the FM sound signal, a guard band to avoid interference between adjacent channels, and some room for future picture improvement. Therefore, a band width of 6 mc is allowed for each television channel. A graphic illustration of how this band width is utilized is shown in Fig. 3.

Consistent television reception at greater-than-line-of-sight distances is now definitely a reality. This once was considered impossible by most engineers. The theory was that the signals traveled in a straight line like light and that once line-of-sight distances had been exceeded, signals dropped off in strength so rapidly that they were not usable.

The fact that these signals travel in a straight line is correct, but the point that was generally overlooked is that refractions (bending of the signals) occur and that it is possible to use these refracted signals to produce satisfactory pictures at distances of two or three times that of line of sight. These refracted signals are a normal occurrence and are frequently present at distances up to 125 miles, depending upon the height of the transmitting and receiving antennas.

When actual practice proved that long-distance television reception was possible, the Federal Communications

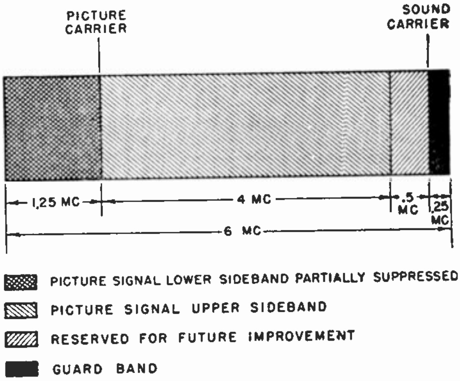


FIG. 3. How picture and sound signals are contained in a 6-mc channel.

Commission found it necessary to stop all television station construction permits to study the situation, because stations were interfering with each other. This interference caused black lines running through the picture, commonly referred to as "venetian blinds," and also garbled the audio.

An FCC order set new geographic spacings, and stations can again be built, not only on the VHF channels, but also in the ultra-high frequency (UHF) spectrum between about 470 mc and 890 mc.

UHF stations using the same channel may be located closer together than VHF stations, because at UHF the signal acts more like light so that there is less chance of interference.

The Federal Communications Commission originally allocated thirteen VHF channels to television, extending from 44 megacycles to 216 megacycles. Channel No. 1 was eliminated, so at the present time there are twelve VHF channels, designated by their original numbers, 2 to 13. The ultra-high frequency band contain channels 14 to 83 inclusive. The TV channel allocations are shown in Fig. 4.

CH.	FREQ. (MC)
	VHF
2	54-60
3	60-66
4	66-72
5	76-82
6	82-88
7	174-180
8	180-186
9	186-192
10	192-198
11	198-204
12	204-210
13	210-216
	UHF
14	470-476
15	476-482
16	482-488
17	488-494
18	494-500
19	500-506
20	506-512
21	512-518
22	518-524
23	524-530
24	530-536
25	536-542
26	542-548
27	548-554
28	554-560
29	560-566
30	566-572
31	572-578
32	578-584
33	584-590
34	590-596
35	596-602
36	602-608
37	608-614
38	614-620
39	620-626
40	626-632
41	632-638
42	638-644
43	644-650
44	650-656
45	656-662
46	662-668
47	668-674
48	674-680
49	680-686
50	686-692
51	692-698
52	698-704
53	704-710
54	710-716
55	716-722
56	722-728
57	728-734
58	734-740
59	740-746
60	746-752
61	752-758
62	758-764
63	764-770
64	770-776
65	776-782
66	782-788
67	788-794
68	794-800
69	800-806
70	806-812
71	812-818
72	818-824
73	824-830
74	830-836
75	836-842
76	842-848
77	848-854
78	854-860
79	860-866
80	866-872
81	872-878
82	878-884
83	884-890

FIG. 4. VHF and UHF TV channel allocations.

TV IS AN EXTENSION OF RADIO PRINCIPLES

Between the camera and the picture tube we find a great many familiar radio circuits. At the television transmitter there is a master oscillator that generates the rf carrier, rf power amplifiers, a modulator, linear rf power amplifiers, and a transmitting antenna. At the receiver the television signals are picked up by an antenna, and are amplified and selected in the preselector. Since the superheterodyne circuit is used, the receiver will have an rf amplifier, a mixer first detector, a local oscillator, an i-f amplifier, a second detector, and a picture-signal amplifier, all of which prepare the received signal for the picture-producing device.

The sound accompanying the television program is handled in essentially the same way as in FM program broadcasting. However, in television the frequency deviation of the sound signal is limited to ±25 kc.

In a television receiver you will find tubes, coils, resistors, capacitors, transformers, etc., just as in ordinary broadcast receivers. In many instances, as you will learn later, the parts do not have the same physical appearance, but many are identical. Some television circuits are almost identical to radio circuits, but there are others, that have been developed to meet the special requirements of picture reception, which may be entirely new to you.

We have already mentioned that the picture is converted into an electrical signal by the camera, which scans the picture line by line. At the television receiver the picture must be reassembled in the same order that it was scanned at the transmitter. In other words, when the camera is scanning the top line of the picture, the receiver must be reproducing the top line. In addition, both the camera and the receiver must be at the same point on the line. For example, if at a given instant the camera is scanning the center of the top line, the receiver must be reproducing the center of the top line.

In the process of scanning the picture, the camera starts at the top left corner and scans across the first line. The receiver must be kept in step with the transmitter so that it starts at the top left corner and moves across the first line at the same rate of speed as the camera does. To do this, the circuit that controls the scanning at the television camera must also control the scanning process at the receiver. This act of controlling the receiver scanning system so that it is in step with the picture camera is referred to as *synchronization*, and the signals that do this are known as synchronizing signals. (They are commonly referred to as sync signals.) The sync signals are produced by special oscillator circuits and are sent out on the same carrier as the picture signals.

In color television an additional sync signal is sent to synchronize color signals, which are transmitted on a separate sub-carrier within the 6-mc channel. At the receiver, the sync signals are separated from the picture signals by special circuits that are not found in the usual radio set. In the final analysis, however, all these special circuits are based upon extensions of well-known radio principles.

Once the requirements of a television system are recognized, the special circuits will seem quite natural rather than something strange and new. By studying the process of scanning first, giving special attention to the sync signals, and the circuits that handle these signals, we can make television circuits seem just as logical and understandable as ordinary radio circuits. This lesson is primarily intended to acquaint you with the important problems in television, and later lessons will go into details on the various circuits and the actions that take place in them.

Image Scanning in Television

Television is the transmission of intelligence that reaches our brain through our eyes. First, let us consider what the eye sees when it looks at an object. Ordinarily, it looks at reflected light, made up of electromagnetic waves; occasionally, it looks directly at light sources such as electric lamps, a fire, or the sun. The eye sees color because the electromagnetic waves in the visual band have different frequencies, each frequency or group of frequencies giving, through the action of the brain, a color sensation.

The human eye contains a complicated lens (much like the lens in a camera), which projects these electromagnetic light waves onto the retina, a surface at the back part of the eye. The retina has millions of nerve endings, each of which is connected to the brain. These nerve endings interpret the strength of each electromagnetic wave that hits them (determined by the brightness of the object) and they also interpret the frequency of the wave (the color of the object). Each nerve ending "sees" only a tiny portion of the entire scene; the brain reconstructs the over-all picture by assembling all the nerve impulses. Thus, the eye breaks up the scene into elements, each of which is transmitted over a separate nerve channel to the brain.

The television camera is like a human eye with only one nerve ending scanning the image projected on the retina a line at a time and sending the information to the brain (transmitter) in sequence rather than all at once as the human eye does.

TV SYSTEMS

Television takes advantage of an eye characteristic known as persistence of vision—the ability of the eye to retain an impression of an object for a short time after the object has disappeared from view. This makes it possible to send a portion of a scene at a time; just so the entire scene is transmitted before the eye has had a chance to "forget" the first part of it. Thus, although the picture you see on your television screen is sent a line at a time, you see it as a complete picture. In effect, an "eye" in the camera travels over the top edge of the scene from left to right, swings quickly back to the left-hand side, moves down slightly, travels horizontally over the scene again, and repeats the process until the whole scene has been scanned. As you no doubt know, or have guessed, this "eye" is really a light-sensitive surface that converts the light received from the scene into an electric current, which of course varies as different parts of the scene come into view of the scanning eye, is then transmitted by radio to the receiver. At the receiver, the process is reversed, and the original scene is traced out line by line.

This is a highly simplified explanation of how a television system works, but it will serve to show you the basic idea of its operation. Right now, the important fact for you to grasp is that a scene is televised bit by bit, and not as a whole.

Fig. 5 illustrates the general effect produced when a scene is scanned. Suppose we wish to televise a picture like that shown in Fig. 5A. After it has been scanned by the camera, transmitted to the receiver, and reproduced

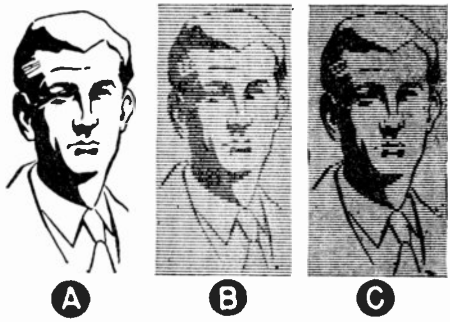


FIG. 5. The drawing at A is reproduced as a series of lines at B and C. Greater detail is obtained by using more lines, as at C.

on the receiver screen, it will appear as shown in Figs. 5B and 5C. That is, it will consist of a series of lines; these lines will vary in brightness along their length, and so make up the picture we see. The more lines we have in a given area, the greater the detail of the final picture. Fig. 5C, which has 120 lines, exhibits more detail than Fig. 5B which has only 60 lines.

Note that as you move the illustrations in Fig. 5 farther and farther away from you, a point is reached for each illustration where the details seem to blend into a complete and nearly perfect reproduction of the original. This brings out an important fact about television: if a reproduced picture is made larger without increasing the number of lines, the picture will have to be viewed from a greater distance to give a satisfactory eye impression. When you are close to the screen, operating the controls of the receiver, you will see the individual lines. If you move back a few feet, the lines will blend together and give good definition.

SCANNING AND REPRODUCTION METHODS

Before considering the technical details of breaking up a scene into a number of lines, it will be valuable to get a clearer idea of how a scene is taken apart or scanned, and how a scene is reproduced.

Mechanical Scanning. Even though mechanical methods of scanning are considered inadequate today, we will study them first, since they are easier to understand and will help you to understand electronic scanning methods.

Punch a hole with a pin in the center of a small business card and hold the card up to one of your eyes so that you can look through the hole. Turn to some object or scene. Notice that you can see only a small part of the scene through the tiny hole. Now move the card horizontally from left to right; you see all the portions of the scene along the line that you are scanning, Move the card back and forth horizontally while shifting it vertically downward a little at the end of each line and your eyes will see the entire scene, piece by piece.

The Scanning Disc. In place of this card-scanning device we could use the system shown in Fig. 6A, in which

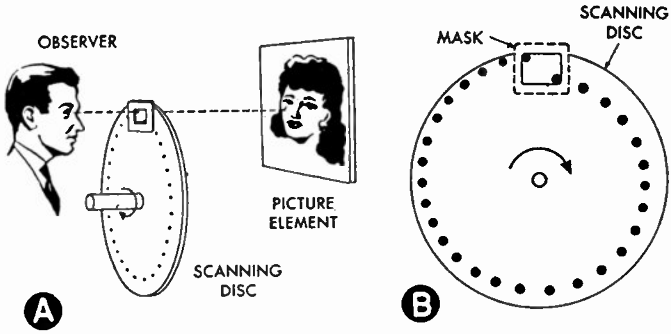


FIG. 6. This diagram shows an elementary mechanical scanning-disc system. If the disc is rotated rapidly enough, the observer will be unconscious of its presence, as persistence of vision will apparently allow him to see the entire scene, although he is actually viewing only a tiny spot at a time.

a large number of holes are arranged in a spiral fashion on a rotating disc called the scanning disc. This disc really replaces the card that we used in our previous example. One complete revolution of the disc gives one complete scanning of the entire picture, because each hole in the disc scans one line. If the disc is revolved fast enough, the visual sensation is the same as though the entire picture were being seen at one time.

The exact arrangement of the holes on the scanning disc is shown more clearly in Fig. 6B. The observer is viewing the scene through the mask, a rectangular opening in a piece of black cardboard. As the disc is rotated, each hole moves across the opening in the mask, the outermost hole in the spiral moving across the top of the opening and each succeeding hole moving across one line down. Finally, when the innermost hole has moved across the bottom of the opening, the outermost hole again scans the top line and the entire scanning process starts over again.

A Mechanical TV Camera. If the observer in Fig. 6A is replaced with a light-sensitive cell, this cell will deliver a varying electric current that is at all times proportional to the amount of light that is reaching the cell, and therefore proportional to the shade of lightness or darkness of the element of the picture that is being scanned at a particular instant. This arrangement gives us a means of converting a picture or scene into a varying electrical current. This current, or picture signal, can be amplified and placed on a radio carrier for transmission through space. At the receiver, the carrier can be demodulated and the picture signal amplified sufficiently to operate a picture reproducer.

Mechanical Reproduction. In early experimental television receivers, the amplified picture signal was fed to a neon glow tube like that shown in Fig. 7A. This lamp consisted of a wire anode and a rectangular flat metal piece (the same size as the reproduced picture) that served as a cathode. These elements were enclosed in a gas-filled envelope. A red glow of light formed on the plate when sufficient

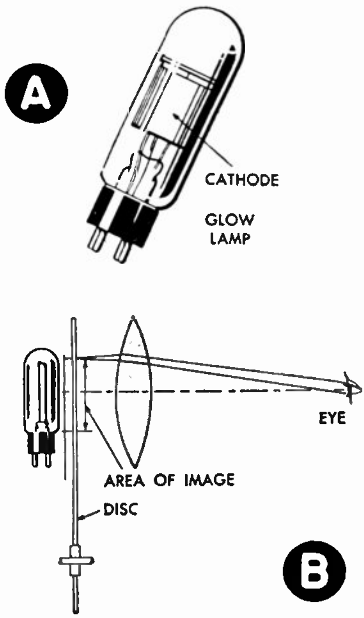


FIG. 7. An early type of mechanical television reproducer.

voltage was applied between the electrodes; the intensity of this glow varied with the applied voltage. The amplified picture signal was made to change the applied voltage, thus changing the intensity of the glow.

A pin-hole scanning disc was rotated in front of the glow lamp in such a way that the holes scanned the glowing plate. The transmitter and the receiver were synchronized so that when the scanning disc at the transmitter started to scan the top line of the scene, the receiver scanning disc likewise started to scan the top line. Line-by-line scanning discs were kept in step (in synchronization), so that the intensity of the glow lamp at any instant corresponded to the intensity of the light reflected from that same element on the actual scene. The arrangement of the scanning disc and the glow lamp is shown in Fig. 7B. The lens shown is a magnifying glass used to enlarge the image to three or four times the size of the glow lamp plate.

Electronic Scanning. Although present-day methods of scanning and picture reconstruction differ greatly from the method just described, the principle of scanning the picture a line at a time is still used.

There are several types of electronic camera tubes used to perform the same function as the scanning-disc and photoelectric cell arrangement just described. At present, the most popular of these is the *image orthicon.* A diagram illustrating the operation of the image orthicon is shown at Fig. 8. In operation, the camera lens projects an image of the scene to be telecast onto a photoelectric surface. This light-sensitive photoelectric surface consists of millions of tiny light-sensitive spots, each insulated from the others, and each scarcely larger than the point of a pin.

The effect of light upon this photoelectric surface is to drive out a number of electrons from each of these tiny spots. The number of electrons driven from the photoelectric surface depends on the amount of light striking that

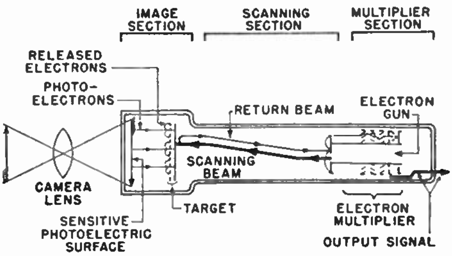


FIG. 8. Diagram of an image orthicon camera tube.

particular cell—the more light, the more electrons. The electrons driven from the photoelectric surface strike the target surface directly behind it. When an electron strikes the target, it dislodges several more electrons from the target surface, creating a positive charge at the point on the target that it strikes. Thus, the visual image that was projected on the photoelectric surface is converted to an electrical image on the target. Where high intensity light strikes the photoelectric surface, there is a high positive charge on the corresponding portion of the target, and where lower intensity light strikes the photoelectric surface, there is a lower positive charge on the target.

The target is scanned a line at a time by a beam of electrons. This beam is produced by the electron gun and swept back and forth across the target by the magnetic force of coils placed around the outside of the tube. As the electron beam is swept back and forth across the target, the positive potential areas of the target absorb enough electrons from the beam to neutralize them. The rest of the electrons are reflected back to the electron multiplier section. The subtracting process creates a return beam, the intensity of which varies in inverse proportion to the intensity of light along the line being scanned.

The effect of the multiplier is to amplify the variations created in the return beam. An ac signal whose magnitude is proportional to the amount of light along the scanning lines is taken from the electron multiplier, amplified, and used to modulate the transmitter.

The details of operation of the electron gun and the deflection coils, along with explanations of other types of electronic scanning devices will be given later. Here it is sufficient for you simply to understand the general method of operation.

Color Camera. In the reproduction of color pictures, all colors can be produced from combinations of red, green, and blue. (You may have learned in mixing paint that the primary colors are red, blue, and yellow, but when mixing light they are red, green, and blue.) In a color television camera, three image orthicon tubes, one for each of these primary colors, are used. Fig. 9 shows some of the major components used in the optical system of an RCA color television camera. Note that there is one image orthicon tube for each of the three primary colors, red, green, and blue. Light traveling through the various lenses and correctors goes through two *dichroic mirrors*. These mirrors are so designed that they will reflect only one basic color, and pass the others.

The first mirror reflects all of the blue light contained in the image; this light is directed to the blue image orthicon tube. All light frequencies except blue pass through the first mirror to the second one.

The second mirror reflects all of the red light; this is delivered to the red image orthicon tube. The remaining

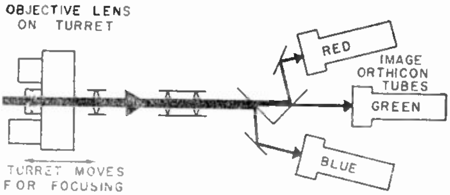


FIG. 9. Some of the basic components used in a color television camera.

light that passes through the second dichroic mirror is green, and is delivered directly to the face of the green image orthicon tube.

All of the colors in the spectrum can be developed from combinations of these three basic colors. Therefore, the sum of the electrical outputs of these three image orthicons should be equal to the electrical output of a single monochrome (black and white) image orthicon.

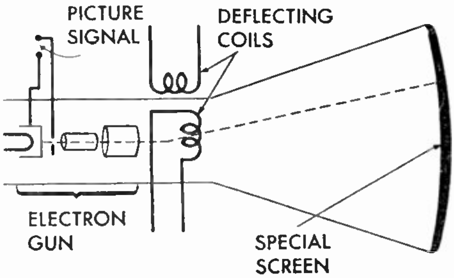


FIG. 10. A simplified diagram of an electronic picture tube.

The electrical signal from the image orthicon or other television camera tube is amplified and used to modulate a high-frequency radio signal, which is then broadcast so that it can be picked up by the television receiver. The carrier frequency must also be modulated with a synchronizing pulse at the end of each line and at the end of each picture *field* (one series of lines from the top to the bottom of the picture). These signals are used at the television receiver to keep the picture that is reproduced by the picture tube synchronized with the one being scanned by the camera.

The Electronic Receiver. Fig. 10 shows a simplified diagram of a typical electronic picture reconstructor. It has an electron gun and two sets of electromagnetic deflecting coils. Special oscillators generate the current pulses that flow through these coils; the oscillators are controlled by the synchronizing pulses sent out by the transmitter.

A spot of light appears on the fluorescent screen at the end of the tube when it is hit by the electron beam that is produced by the electron gun; the brilliance of the spot increases with the number and speed of the electrons in the beam. The picture-signal voltage controls the number and speed by means of a special grid electrode, and the deflecting coils carry the current that controls the scanning of the beam across, and up and down, the screen. The combined action is such that while the beam is sweeping across the screen, its intensity is changing continually in accordance with the picture signal, giving the effect of "painting" light on the screen.

During the transmission of a television signal, the horizontal sync pulse exists for an instant after each line has been scanned and the vertical sync pulse exists for a longer period after each field has been scanned. It is not necessary for the video signals to exist while sync pulses are being transmitted, and, as a matter of fact, the video (picture) signals are stopped entirely during the transmission of sync pulses.

There is sufficient difference between the horizontal and vertical sync pulses so that they may be readily separated at the receiver by R-C filters and applied to the proper control circuits. This separation can easily be accomplished, because the vertical sync pulse lasts a much longer time than the horizontal sync pulse, and by allowing the sync pulse voltages to build up across a condenser, it is possible to use capacities of such size that they will definitely discriminate in favor of either the horizontal or the vertical sync pulse. This, too, will be described in detail later on.

The three basic components in a monochrome television signal (the picture or video signal, the horizontal sync pulses, and the vertical sync pulses) are transmitted as shown in

three times as long as the time for one line. The black level is 75% of the maximum television signal amplitude.

Notice that points 1, 2, 3, 4, and 5 along the video signal, corresponding to elements along a line of the picture that is being scanned, are for increasing values of brightness, with point 1 corresponding to a black elemental area on the picture, points 2, 3, and 4 for gray areas, and point 5 for a white area. When increases in brilliancy

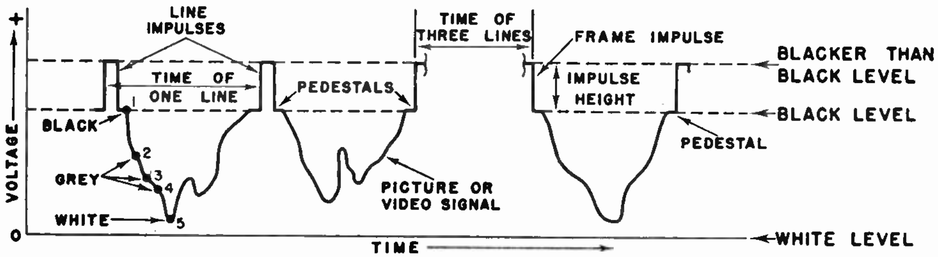


FIG. 11. This diagram shows the three essential components of a television signal—the video signal, the horizontal sync pulse, and the vertical sync pulse. This is a modulated dc signal. Since the picture signal swings in a negative direction with increases in line brilliancy, we have what is known as a negative picture phase.

Fig. 11. In color television, a color sync signal and chrominance (color) signals are added to these three. The rf carrier will be considered later and hence is not shown in this diagram.

First of all, notice that this television signal is a pulsating dc signal with all its components above the zero voltage line, which is known as the white level. The video or picture signal is contained between the white level and the black level. The sync pulses are all between the black level and what is commonly known as the blacker-than-black level. In other words, signals that swing above the black level do not cause any lines to become visible on the face of the picture tube.

The vertical sync pulse lasts about make the picture signal voltage swing in a negative direction in this manner, we say that the picture has a negative picture phase.

The sync pulses are kept in the region that is never occupied by the video signal in order to make possible the use of either a biased triode or a diode for sync separation of these pulses from the video signal. You will also notice from Fig. 11 that before and after each sync pulse the television signal voltage remains constant for a short interval of time. These constant voltage components are known as "pedestals."

In AM radio broadcasting, large carrier currents correspond to loud sounds, and low carrier currents correspond to weak sounds. Exactly the opposite is true in sight transmission. When the rf carrier is modulated with a television signal as shown in Fig. 11, the white components of the television signal will exist as low carrier currents and the sync pulses will exist as large rf carrier currents. This type of modulation is known as negative modulation. Negative modulation is used in broadcasting television programs in this country because when it is used, the sync pulses are less affected by noise pulses.

The Cathode-Ray Picture Tube

In modern home television receivers, the video counterpart of the loudspeaker is the cathode ray tube or "picture" tube.

You have already studied and are familiar with cathode ray tubes of the type used in oscilloscopes. Many of those used in earlier television sets with seven or ten-inch screens are of the same general type as those used in oscilloscopes. These tubes use deflection plates within the glass envelope to deflect the electron beam. This system is called *electrostatic* deflection.

The cathode ray tubes used in modern large-screen television sets operate on the same principle, but have a different method of deflecting the beam, known as *electromagnetic* deflection.

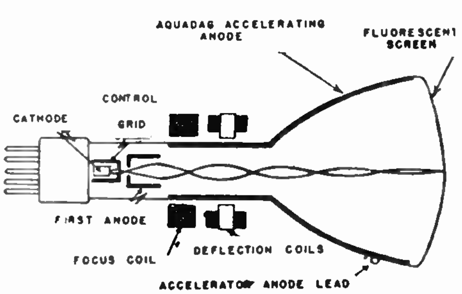


FIG. 12. A cathode-ray tube using electromagnetic deflection.

This type of tube is illustrated in Fig. 12.

PARTS OF THE PICTURE TUBE

A brief description of the function of the various parts of the tube and of their effect on the electron beam is given here so that you will understand the general method of operation. A later lesson will be devoted entirely to the study of picture tubes.

Cathode. The function of the cathode in the cathode ray tube is essentially the same as that of the cathode in any other tube. That is, it emits electrons. The cathodes used in picture tubes are indirectly heated by a heater wound in a spiral in such a manner that it will create no magnetic field that might affect the electron beam. As shown in Fig. 13, the cathode is cylindrical in shape, and the electron-emitting oxide coating is on the

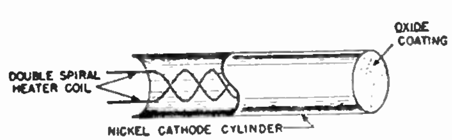


FIG. 13. The cathode of a modern picture tube.

end of the cylinder, so that the electrons will be emitted in the right general direction to be beamed toward the fluorescent screen.

Control Grid. The control grid serves two purposes. First it concentrates the electrons emitted from the cathode into a beam, and second, it controls the flow of electrons so that the rate of electron flow through it is in direct proportion to the intensity of the light at the particular point being scanned by the camera tube at the transmitter. The control grid is cylindrical with one end completely open and a small hole in the center of the other end.

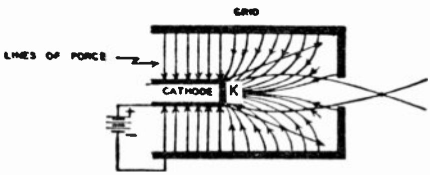


FIG. 14. An electrostatic field between control grid and cathode concentrates electrons into a beam.

Fig. 14 shows how the control grid concentrates the electrons into a beam. The arrows represent the electrostatic lines of force that are set up by the difference of potential between grid and cathode. The grid is negative with respect to the cathode, and consequently has the general effect of repelling electrons. However, the hole in the end of the grid leaves a gap in this repelling field, offering the path of least resistance, which the electrons are most apt to take.

In addition to concentrating the electrons into a beam, the control grid in effect modulates the stream of electrons with the picture signal.

The picture signal that is impressed upon the control grid varies the difference of potential between cathode and control grid. The more negative the control grid is made with respect to the cathode, the greater will be the density of the electrostatic lines of force, so that it is possible for them to close up the hole in the end of the grid, preventing the escape of electrons. Thus, it is possible by means of the video (picture) signal to control the rate of flow of electrons through the aperture in the end of the grid.

First Anode. The principal function of the first anode is to accelerate the electrons in the electron stream. In other words, it boosts them along the path toward the fluorescent screen. The first anode is at a relatively high positive potential with respect to the grid, so it attracts the electrons being emitted from the hole in the end of the grid.

The first anode is similar in shape to the control grid in that it is cylindrical, has a small aperture in one end, and is open at the other end. However, it is turned around to face in the opposite direction. From Fig. 12 you can see that the electron stream is shaped by the grid so that most of the electrons will enter the small hole in the lefthand end of the first anode. Since the first anode is at a relatively high positive potential, it is reasonable to wonder why the electron stream passes through it rather than simply being attracted to it and causing plate current to flow, just as in an ordinary triode vacuum tube. The answer is that the anode tries to attract the electrons to the sides of the cylinder, as you can see from the shape of the electron stream in the diagram at Fig. 12, but it has also, in attracting electrons from the control grid aperture, speeded up the flow of electrons to the point where they are able to pass through the first anode cylinder before they can be attracted to the walls of that cylinder. Also, the second or accelerating anode is at a higher potential than the first anode and it tends to pull the electrons away from the first anode.

Focus Coil. The focus coil is used to concentrate the electron beam again after it has passed through the first anode and undergone some dispersion, by creating a magnetic field within the neck of the tube, which again forces the electrons to travel through a narrow path of least resistance. This is possible because each electron is surrounded by a magnetic field of its own, and if magnetic fields are set up in opposition to it, they will tend to repel electrons.

Physically, the focus coil is doughnut shaped. It is basically nothing more than a coil of wire wrapped around the neck of the tube. By varying the direct current flowing through this coil, the intensity of its field and hence the focus of the electron beam can be varied. Fig. 15 is a cross-sectional diagram of the focus coil, showing the effect of its magnetic field on the electron beam.

Some receivers use permanent magnets to achieve the same focusing action by mechanically varying the strength of the magnetic field.

Deflection Coils. In order to sweep the beam back and forth in a series of horizontal lines from the top to the bottom of the picture tube, the modern television receiver uses a system of

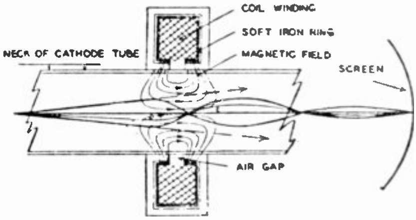


FIG. 15. The focus coil sets up a magnetic field, which concentrates the electron beam.

electromagnetic deflection. Two pairs of coils are placed around the neck of the picture tube as shown diagrammatically in Fig. 16. When current flows through these coils, magnetic fields are set up through the neck of the picture tube as indicated by the arrowheads in Fig. 16. The electron beam is deflected at right angles to the magnetic lines of force, so the horizontal deflection coils are placed above and below the neck of the tube, creating a vertical magnetic field, and the vertical deflection coils are placed one on either side of the neck of the tube, creating a horizontal magnetic field. The direction

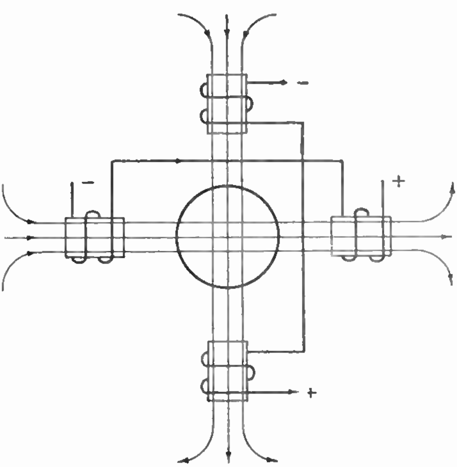


FIG. 16. Two pairs of coils set up magnetic fields which create horizontal and vertical deflections.

that the beam is deflected is reversed by reversing the polarity of the magnetic field. For instance, as shown in Fig. 16, the top coil is a north magnetic pole and the bottom one a south magnetic pole with the magnetic lines of force running from north to south. Assuming that the direction of electron flow is toward you, this would tend to deflect the beam to the left. If the current through the coil were reversed, the magnetic polarity would also be reversed and the beam would be deflected to the right. The left-hand coil is another north pole and the right-hand coil another south pole, so the tendency of the vertical deflection coil field is to deflect the beam downward. A reversal of polarity in the vertical deflection coils would deflect the beam upward.

Each coil is saddle-shaped so that it will fit the neck of the tube. All four coils are assembled into a single ring-shaped yoke which slides onto the neck of the tube. There is some overlapping of coils within this assembly, but this has little effect on their magnetic fields.

Second Anode. The second anode is a conductive coating on the inner glass walls of the forward part of the picture tube. It serves two purposes. Its primary purpose is to serve as an accelerator. It speeds the electron beam on its way to the fluorescent screen. To accomplish this it is always at an extremely high positive potential, in many cases from 15,000 to 20,000 volts.

Its secondary function is to collect free electrons knocked off the fluorescent screen by the beam striking the screen.

Fluorescent Screen. The fluorescent screen is a chemical coating called a phosphor on the inner glass surface of the face of the picture tube. The chemical composition of this coating is such that the screen will light up in proportion to the number and speed of electrons in the beam striking it. Therefore brilliance could be controlled either by the control grid, which controls the number of electrons, or by the second anode, which controls the speed. Because of the extremely high voltage that exists at the second anode, it is generally much easier to control brilliance at the control grid.

The fluorescent screen on color picture tubes contains three different phosphors, one for each of the three basic colors. Each of the three phosphors glows with a brilliance that is in direct proportion to the amplitude of the signal sent for its basic color.

THE PICTURE TUBE IN ACTION

Keeping in mind the function of the various components in the picture tube just described, let us now take a look at the effect of the television signal on these various components. The cathode, the focus coil, and the first and second anodes are relatively stable components. That is, they are kept at a constant potential and are not affected by the television signal. Their main function is simply to deliver the electron beam to the fluorescent screen with the proper focus to create a spot on the screen.

The control grid and the deflection coils are the two elements affected by the television signal. These two elements serve to vary the intensity of the beam, and hence the brilliancy of the spot, and to sweep the beam back and forth across the face of the picture tube, turning one spot into a series of lines. Thus, they literally paint the picture on the screen.

The television signal, including the sync pulses, is applied to the grid of the tube after it has been detected (separated from its carrier) in the receiver. The pulses come at the end of each line and at the end of each field. They reduce the intensity of the beam to the point where it does not produce any visible brilliance on the screen.

Between the sync pulses, the video signal varies the intensity of the beam so that it will produce light intensities ranging from white through all the shades of gray to black. The sync pulses contained in the television signal also have their effect on the deflection coils. They are used to trigger oscillators, which in turn provide the current for the vertical and horizontal deflection coils.

You will recall from your study of electrostatic cathode ray tubes that sweep is obtained in them by applying a sawtooth voltage to the horizontal deflection plates. In electromagnetic deflection systems, a somewhat different situation exists. Here, magnetic force rather than electrostatic force is used, and since the intensity of a magnetic field depends on current rather than voltage, we need a sawtooth current in the deflection coils. Therefore, the voltage output of the vertical and horizontal oscillators is not a true sawtooth voltage, but it takes a wave shape that will produce a sawtooth current in the deflection coils.

Now let us follow the movement of

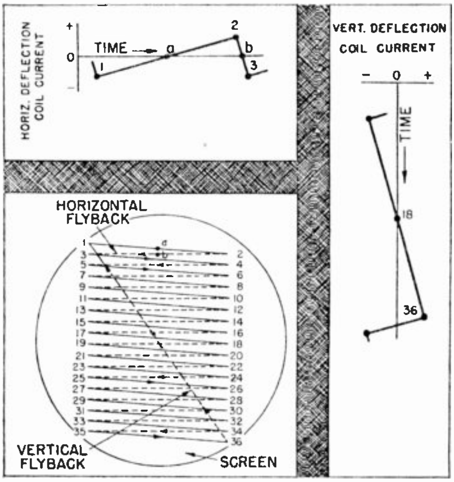


FIG. 17. Under the influence of horizontal (top) and vertical (right) sweep currents, the electron beam follows the zig-zag path shown in the lower left. In actual practice there are 525 lines instead of the 18 shown here.

the spot on the screen of a picture tube as it is swept back and forth and up and down by the sync-pulse controlled sweep circuits.

When the beam is under the control of the horizontal and vertical sweep currents, we can consider its starting point to be point 1 in Fig. 17, at the upper left-hand corner of the screen. Here the beam has been bent far to the left. From this point the horizontal sweep current gradually decreases, allowing the beam to "unbend" or return to the center of the top line. As the current in the horizontal deflection coil passes zero and increases in a positive direction, the beam is gradually bent to the right until the spot reaches the right-hand edge of the screen. While this action occurs, the vertical sweep current is gradually moving the spot in a downward direction, a distance equal to the spacing between two lines.

At point 2 a horizontal sync pulse arrives from the transmitter, causing the horizontal sweep to move the spot almost instantly back to the left-hand side of the screen along the dotted line path 2-3. This return motion is very rapid and if a trace is made it could not be seen as such, but sometimes, if the receiver is not properly adjusted, it will produce on the screen a faint haze or glow instead of a line. Points 1, a, 2, b, and 3 in the sawtooth waveform at the top of Fig. 17 indicate relative values of horizontal sweep current for corresponding points on the screen shown below.

The process just described continues for each line until the spot is swept to point 36 at the end of the last line. At this time the vertical sync pulse arrives from the transmitter and stops the gradual building up of the vertical sweep current, causing the spot to move back up to the top of the screen. The vertical sweep current drops back to its starting value at a rapid rate, but the change takes more time than is required for a complete horizontal sweep. As a result, the spot actually takes a zig-zag path from side to side as it is being returned to the top of the screen. For simplicity the vertical retrace is shown as a straight-line path, 36-1, in Fig. 17. Actually, if the receiver is misadjusted, you will see a number of diagonal lines, across the screen, which is the vertical retrace.

When either the horizontal or the vertical sync pulse is being sent by the

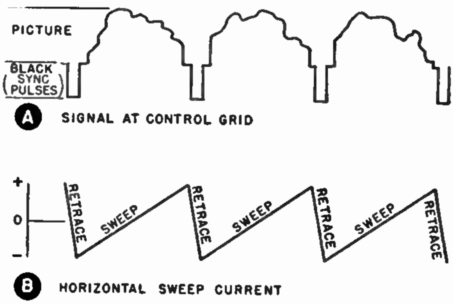


FIG. 18. When sync pulses are applied to the control grid (A) retrace current flows in the horizontal deflection coils (B) so that retrace lines do not show on the picture tube.

transmitter, no television picture signal exists and the appearance of retrace lines would only cause diagonal streaks in the picture, marring reproduction. Fig. 18 shows the relationship between the signal voltage at the control grid and the sweep current flowing in the horizontal deflection coils. The sync pulses are applied to the control grid of the picture tube in the receiver in such a way that they drive the grid highly negative, causing almost complete cut-off of the electron beam and thereby preventing retraces from showing.

Picture Detail, Brightness, And Contrast

Up to this point you should have a good general concept of how the television picture is picked up by the camera, transmitted, received, and reproduced at the picture tube. Now we will consider some of the television signal characteristics that determine the quality of the reproduced picture.

IMAGE DETAIL

A consideration of the processes of scanning and reproduction described in the preceding section should make it clear to you that the video signal exists only while the spot is traveling from left to right along the line. At all other times the television transmitter is sending out pedestals with synchronizing signals.

The changes in the intensity of the video signal from one instant to another produce the essential picture detail. The more changes there are per line for an actual given scene that is being scanned, the greater will be the amount of detail in the reproduction.

The more frames (complete pictures) there are per second, the better they blend and the less chance there is for the eye to see them individually. If too few are transmitted, flickering results. Increasing the number of frames per second reduces flicker.

Greater detail can be obtained by increasing the number of lines per frame. Both the number of frames per second and the number of lines per frame contribute to high definition, or high-fidelity reproduction. However, there are definite limits to the number of lines and frames that can be handled economically. Let us first examine the factors that determine the maximum numbers.

All television equipment must be designed to handle the maximum frequency of the picture signal current. To calculate the maximum frequency of a signal it is assumed that the picture being scanned consists of a checkerboard pattern of black and white squares, as shown in Fig. 19, with the sides of each square equal to the thickness of a scanning line. Since each of these is the smallest part of the scene the camera can see, they are called picture elements. The signal current is said to go through one cycle each time the electron scanning beam passes over one light and one dark picture element as shown in Fig. 20, because the signal current goes through a maximum

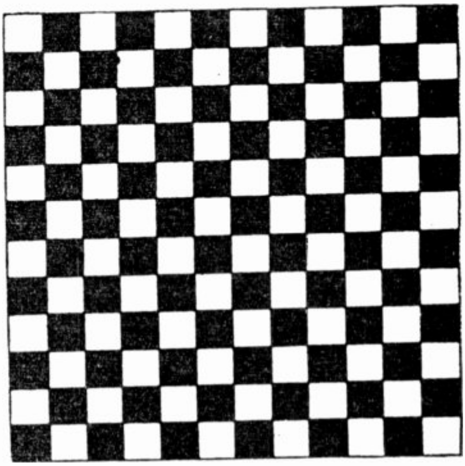


FIG. 19. The photoelectric plate can be visualized as a checkerboard of dark and light squares.

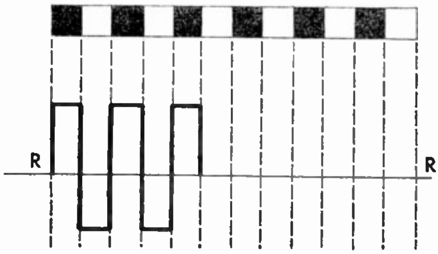


FIG. 20. The signal goes through one cycle each time the beam passes over one dark and one light element.

and a minimum value each time this happens.

To find the maximum frequency of the picture-signal current, all we have to do is compute the number of picture elements that are scanned per second and divide by two, since one cycle consists of two elements.

If each picture element is considered to be as high as it is wide, it is easy to compute the number of elements in one complete picture. For example, in a square picture with N lines there will be N picture elements per line, or N times N picture elements in the complete square picture, which is known technically as one frame. For example, at present the television standards call for a 525-line picture. Hence, in a square picture there would be 525 times 525 or 275,625 picture elements. For ordinary calculations, 276,000 elements will be sufficiently accurate.

Aspect Ratio. The pictures that are commonly involved in television are not square, however. They are wider than they are high, as shown in Fig. 21. *The width of a picture divided by its height is called the aspect ratio* which, in order to conform to motion picture standards, has been standardized at 4/3 or 1.33. This means that the number of elements in each line has been increased by the aspect ratio which we will designate as A. Now the number of picture elements per frame, or picture, will be N times N times A. For the example just considered, the total number of elements will therefore be 276,000 times 4/3, or 368,000.

Frame Frequency. The number of pictures sent per second is the frame or picture frequency. It is designated as F. By multiplying the number of elements in a frame by the frame frequency, we get the total number of picture elements per second. This total number of elements per second is N times N times A times F. Since it takes two picture elements to make a cycle, we get the maximum number of cycles per second by dividing this formula by two. The standard frame frequency is 30. In our example, then, we get the frequency involved by multiplying 368,000 by 30 and then dividing by 2. The result is 5,520,000 cycles per second.

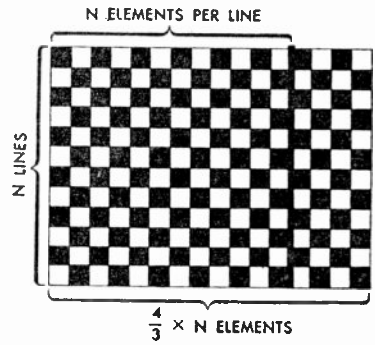


FIG. 21. When the picture is changed to the rectangular form shown here, the elements of a square picture are multiplied by 4/3.

Synchronizing Pulses. In practice, the picture is scanned only about 85% of the time. The remainder is used for horizontal and vertical sync pulses.

This increases our maximum picture frequency because it crowds our elements into 85% or 85/100 of a second. We, therefore, multiply our computed value by 1.17 (because 1 ÷ .85 = 1.17), which makes the maximum theoretical picture frequency required 1.17 times 5,520,000, or approximately 6,460,000 cycles.

Practical Frequencies. In our analysis of the theoretical maximum frequency we have assumed that there is always a sharp contrast between adjacent elements of a scene. This is not true in practice. Several adjacent picture elements may reflect the same or nearly the same amount of light. Also, in moving scenes, it is not necessary to transmit slight variations between adjacent elements. This is illustrated roughly in Fig. 22. Actually, the picture would be broken up into much smaller elements, but even here with the relatively large squares, you can see that in many instances there is practically no change from one square to another. The average scene thus requires considerably less than the maximum frequency. Practice has shown that apparatus capable of sending about 60% of the maximum theoretical frequency is satisfactory. Since the maximum number of cycles was assumed in our example, we multiply 6,460,000 by .6 and get about 3,900,000 cycles or 3.9 megacycles, as the actual frequency. Any increase in this frequency up to the limit of the 4.5 megacycles that is permitted within a television band gives a definite improvement in fidelity.

Monotones Require Very Low Frequencies. The upper part of an outdoor scene, like the sky, as shown in Fig. 23, is usually bright, while the lower part is considerably darker. The picture elements in such a scene vary in light intensity at a high level for the upper half of the picture, and at a low level for the remainder. This gives one cycle of change from light to dark for each scanning. Transmitting these changes properly, calls for a low frequency corresponding to the vertical

FIG. 22. Not all the neighboring spots on a line vary in shade. This reduces the necessary maximum frequency.

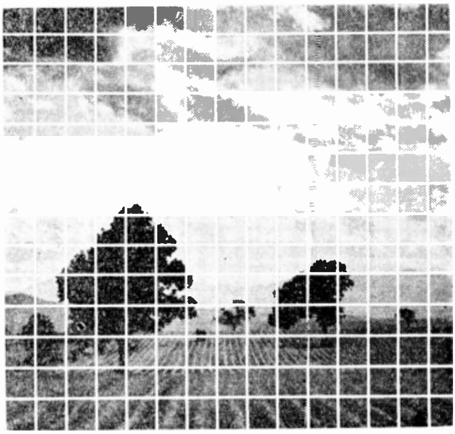


FIG. 23. Changing from a bright sky to a dark foreground once each frame, as in a scene like this, would require a 30-cycle frequency. Others with less variation could require frequencies as low as 10 cycles.

scanning frequency (the frame frequency). However, within the background, satisfactory reproduction of the slow changes in intensity requires frequencies down to at least 10 cycles. Therefore, for a 525-line picture with an aspect ratio of 4/3 and a frame frequency of 30, the picture frequency ranges from 10 cycles to about 3.9 megacycles.

Flicker. The human eye is sluggish in its response to moving objects. It continues to see an object even after the object has disappeared. Motion pictures depend upon this persistence-of-vision characteristic of the human eye. In a motion picture projection, twenty-four separate still pictures per second are flashed upon the screen in sequence, but the eye sees a continuous action rather than a series of separate pictures. The eye can detect individual views up to a rate of about 10 pictures per second, but above this rate the scenes blend together, accompanied by pulsating light impressions which give the effect of flicker. At about 20 pictures per second the blending of pictures into motion is almost perfect, but flicker is still not entirely absent. Even at 24 pictures per second, the standard in the motion picture industry, flicker can still be noticed. For this reason motion picture projectors have a shutter in front of the lens that breaks up each still picture into two separate views, giving the effect of 48 pictures per second, although only 24 of them are different. As you will see shortly, much the same thing is done in television.

In television the frequency of the available ac power has considerable effect upon the choice of a frame frequency (number of pictures transmitted per second). Since the power line frequency in the United States is standardized at 60 cycles, ripple voltages at this frequency or some multiple of it will get into the video signal and the sweep voltages, tending to cause ripple effects, wobbling of the picture, and random movement of bright bands on the image if the number of pictures is increased to 48, or even 72, in order to eliminate flicker. By using a frame frequency equal to some sub-multiple of 60 (such as 30 or 20) or some multiple of 60 (such as 60, 120, or 240), these ripple effects can be removed or at least made stationary so that they will be less objectionable.

Frame frequencies of 20 or 30 are still too low to eliminate flicker entirely. On the other hand, a frame frequency of 120 pictures per second would increase the maximum required frequency of the video signal to an extremely high value. There is left then, a scanning rate of 60 complete frames per second, which imposes quite a burden upon the transmitting system, insofar as maximum frequency range is concerned. With a 525-line image being scanned 60 complete times each second, the upper frequency limit for high definition becomes about 7.8 megacycles. Therefore, if a 60-cycle frame frequency were used, a channel width of 8 or 9 mc would be required. This problem is overcome in television in much the same way as it is in moving pictures. A frame frequency of 30 complete pictures per second is used but a method of scanning that breaks each picture into two separate views, just as the shutter on the motion picture projector does, eliminates flicker.

INTERLACED SCANNING

To avoid increasing the frequency requirements of TV systems and to eliminate flicker, a simple scanning trick is used that makes the maximum video signal frequency correspond to that of a 30-picture-per-second transmission while still keeping the scanning rate at 60 pictures per second. In this system, known as *interlaced* scanning, only half of a picture is transmitted during one complete scanning. The other half is transmitted in the next complete scanning. The first, third, fifth and all other odd lines are covered during one scanning, and the second, fourth, sixth and the other even numbered lines are covered during the next scanning. Two complete scannings are therefore required to cover every elemental dot area on the scene that is being televised.

At the receiver there must likewise be two complete scannings to give a complete reproduction of the image. With interlaced scanning, the frame or picture frequency is 30 cycles per second, since that is the number of complete pictures transmitted. For each complete picture, the scene is scanned twice, so the vertical sweep frequency (field frequency) is 60 times per second. 30 *complete* pictures (frames) are sent per second, but it takes two scannings from top to bottom (fields) to make one complete picture.

In referring to a field we mean the area covered during one vertical sweep of the scene. In non-interlaced scanning the field is the entire scene, but in interlaced scanning the field is only half of the scene. By the frame we mean one complete scanning of every elemental area in a scene.

For interlaced scanning of a given number of lines per second at a given frame frequency there are two requirements: 1, an odd number of lines per picture; 2, a vertical scanning rate that is twice the frame frequency.

This automatically gives scanning of the odd-numbered lines during one vertical sweep and of the even-numbered lines during the next vertical sweep, with odd and even line scanning alternating automatically.

Just how this may be done is best illustrated by an example, but instead of using a 525-line image that would be too cumbersome, we will use a lower number of lines to illustrate the principles involved.

Suppose we divide our picture into ten lines as shown in Fig. 24A, and that we scan this complete scene ten times per second, which gives a vertical sweep frequency of 10 per second. This means that one complete scanning of the scene, starting at point 1, proceeding to 2, 3, 4, 5 . . . 17, 18, 19, 20 and then returning to point 1, will take 1/10 of a second. Assuming flyback time to be negligible in these examples, we see that it will take 1/100 of a second to scan one line, moving from point 1 to point 2 and back to the starting point of the next line at point 3.

Now suppose that we scan the scene, which has an even number of lines, 20 times per second by doubling the vertical sweep frequency. We will still be scanning the same total number of lines per second, and it will still take 1/100 of a second to scan one line. But now only five lines will be covered in one field (complete scanning from top to bottom). Referring to

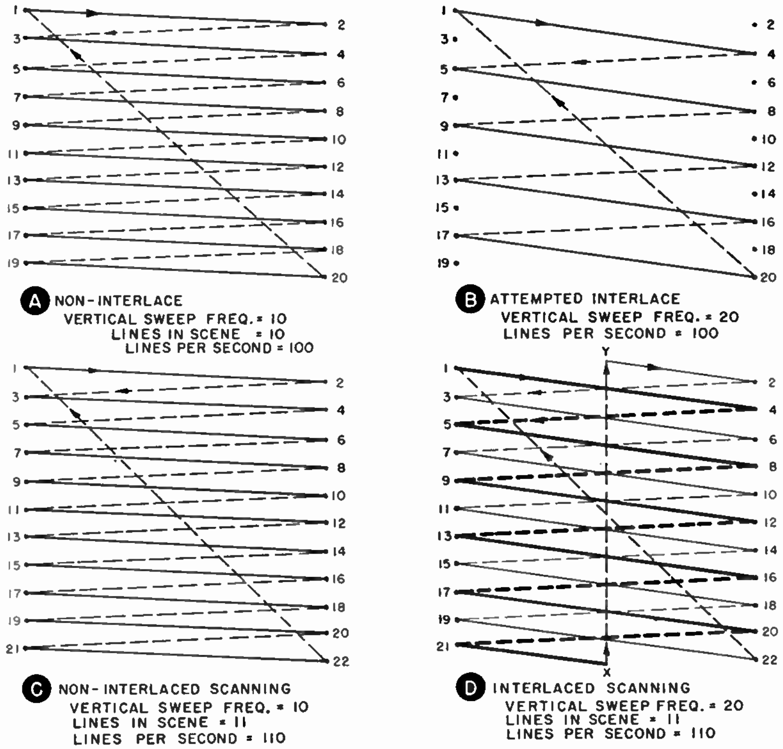


FIG. 24. Interlace cannot be achieved by doubling the vertical sweep frequency when an even number of scanning lines are used (A & B), but it is achieved with an odd number of lines (C & D). The heavy lines in D represent the first field in the frame, and the light lines the second.

Fig. 24B, the scanning path starts at 1 and goes to points 4, 5, 8, 9, 12, 13, 16, 17, and 20 during one complete scanning of the scene. Vertical fly-back now brings us back to point 1 at the upper left-hand corner, and we cover exactly the same scanning path for the second scanning of the scene. This shows that a television system using an even number of lines per picture could not secure interlaced scanning by doubling the vertical sweep frequency. It would only scan half the number of lines twice in each frame.

Now let us take an example in which we have an odd number of lines (11) per picture, and use a vertical sweep frequency of 10 per second as indicated in Fig. 24C. All eleven lines are covered in one complete scanning, and vertical fly-back takes us directly from point 22 back to the starting point at 1.

Next, suppose we double the vertical sweep frequency, giving 20 scannings of the picture per second without changing the total number of lines transmitted per second. This doubles the speed at which the scanning spot is moved downward, so that we arrive at point x in Fig. 24D (at the bottom of the picture) in exactly the same time it took to reach the middle of the picture in Fig. 24C.

In Fig. 24D, however, we have scanned only half the lowest line when vertical fly-back moves the spot up to point y for the second scanning. This time we scan along path y, 2, 3, 6, 7, 10, 11, 14, 15, 18, 19, and 22. From point 22 the spot goes back to point 1 to start the next complete scanning. We are thus securing interlaced scanning of the complete scene. Fig. 24D represents a complete frame (all lines scanned). The first field (one half of the lines scanned) is shown in heavy lines and the second field in lighter lines.

Interlacing, as illustrated in Fig. 24D, is standard practice. To secure this without changing the total number of lines scanned per second, which would change the picture detail, the vertical scanning frequency must be twice the frame frequency and there must be an odd number of lines per frame.

Let us now consider interlaced scanning in terms of the standards in use for television. With 525 lines per frame, a vertical scanning frequency of 60 per second, and interlaced scanning, the total number of lines scanned per second must correspond to that of non-interlaced scanning with a frame frequency of 30 per second. Multiplying 525 by 30 gives us 15,750 as the total number of lines scanned per second. This means that the frequency of the horizontal sweep is 15,750 cycles per second and that the vertical scanning sweep has a frequency of 60 cycles per second.

The detail in the image will correspond to that of 30 complete scannings per second of all lines in the 525-line image. Interlace only eliminates flicker, it does not increase the amount of possible detail.

Actually a few lines at the top and bottom of each picture are blanked out by the blanking system associated with the vertical sync pulses for reasons that will be taken up later. The sync pulse itself prevents vertical fly-backs x-y and 22-1 in Fig. 24D from being visible.

BRIGHTNESS AND CONTRAST

The television signal that is fed between the control grid and the cathode of the picture tube must be pulsating dc and it must be applied to the tube in such a way that sync pulses will cause darkness, and picture signals will give various degrees of spot brightness. Another requirement for faithful reproduction of a scene is that the pedestals all line up with each other at the input of the picture tube despite any variations in the brightness of a scene. An example of this is shown in Fig. 25, where you will note that the pedestals in Fig. 25A have no more amplitude than those shown in Fig. 25B, although the video signal of Fig. 25A is far brighter than that of Fig. 25B.

Now let us see how signals such as those shown in Fig. 25 affect tube spot brightness when the pedestals are lined up with each other. Remember that the electron beam is focused to a small spot on the screen and that the negative voltage applied to the control grid of the tube determines the brilliancy of the spot.

The control that this grid has upon the spot brilliancy is fairly linear with

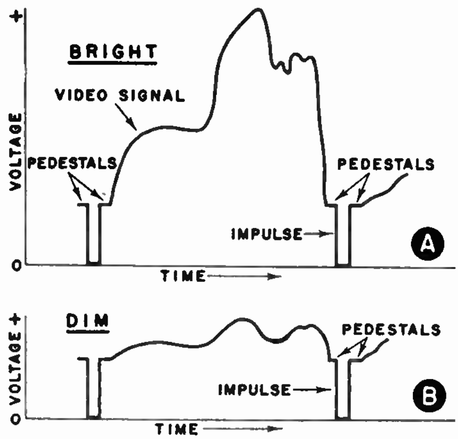


FIG. 25. The pedestal voltage level must remain constant regardless of variations in picture signal amplitude.

respect to the applied grid voltage, except that complete cut-off or darkening of the spot occurs at a definite high negative bias voltage.

This is clearly illustrated in the curve shown in Fig. 26. Note that as the video signal drives the grid of the picture tube in a positive direction, the spot brilliancy will increase. Points 2, 3, 4, and 5 are increasingly brilliant and correspond to increasingly positive control grid voltages. This grid-voltage-brilliancy characteristic curve shown in Fig. 26 is quite similar to the grid-voltage — plate-current (Eg-Ip) characteristic curve of the average vacuum tube.

The negative bias on the grid of the picture tube must be chosen so that the pedestals in the applied television signal will be at the brilliancy cut-off point (point 1 in Fig. 26) on the characteristic curve of the tube.

With the picture tube bias properly adjusted, the video or picture signal will swing the grid more positive than cut-off, giving various degrees of brightness, and the sync pulse signals will drive the grid more negative than cut-off, so that the spot is darkened to the point where it cannot be seen. This is shown as the blacker-than-black region of the characteristic curve.

When the video portion of the signal shown in Fig. 26 is acting on the grid-cathode circuit of the picture tube, the instantaneous control-grid voltage will vary between points 1 and 5 on the curve, and spot brilliancy will vary over the region indicated as B. The sync pulses associated with this signal will swing the grid beyond visual cut-off at point 1, and hence cannot produce a spot on the screen. As long as the pedestals line up with the cut-off

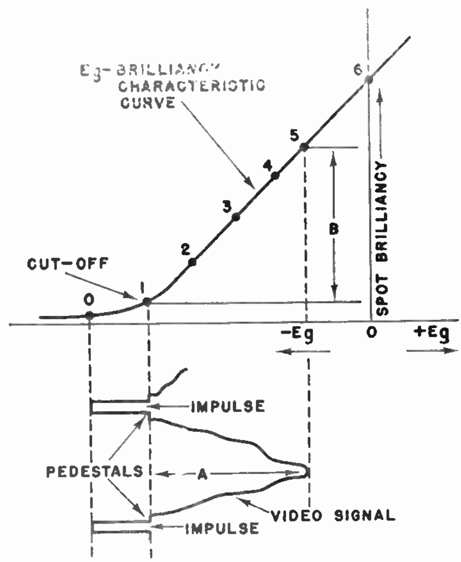


FIG. 26. Typical grid-voltage-brightness characteristic curve for a cathode-ray tube in a television receiver. Point 1 is considered the brilliancy cut-off point for the tube, as it corresponds to a spot brilliancy weak enough to be indistinguishable to the human eye.

point, the pulses cannot produce a visible spot even with a weak video signal, and a weak video signal, corresponding to a dim line or a dark scene, will cause the brilliancy to vary in the desired manner over the lower portion of the characteristic curve, such as between points 1 and 2.

However, suppose that the television signal in Fig. 26 were applied in such a way that the pedestals lined up with point 2. The video signal would swing the grid voltage positive from point 2 up along the curve to point 6, which is perfectly all right since the various shades of brightness would appear, but the sync pulses would swing only a small amount below cut-off and would not darken the spot completely. As a result, vertical retraces would be clearly visible as shown in Fig. 27. Such a condition would not give a picture that is satisfactory. Horizontal retraces are not seen as lines because their time duration is too short to result in a trace visible to the eye.

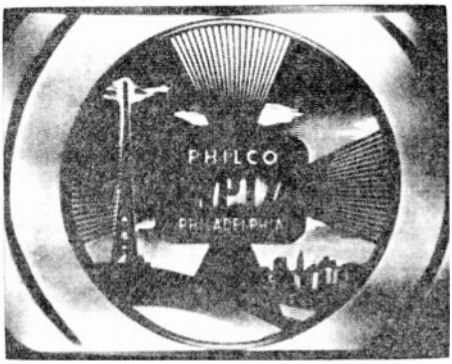
Another undesirable condition occurs when the pedestals are beyond cut-off and line up with point 0 on the characteristic curve in Fig. 26. Under this condition, portions of the video signal will swing into the dark region beyond cut-off, causing dimly lighted portions of the scene to appear black instead of gray, as shown in Fig. 28. This condition is just as undesirable as that illustrated in Fig. 27.

The operating point on the Eg-brilliancy characteristic curve of a picture tube may be shifted in two different ways in order to make the pedestals line up with the black level (cut-off point) of the tube. One method involves adjusting the fixed C bias of the picture tube; the control in a television receiver that changes this bias is called the brilliancy control because its most noticeable effect is a change in the brilliancy of the reproduced image.

It is also possible to shift the pedestals in one direction or the other to make them line up with the cut-off point by changing the amplitude of the picture signal that is applied to the

Courtesy Philco Corp.

FIG. 27. When the pedestal voltage is above the cut-off point, vertical retrace lines become visible.



Courtesy Philco Corp.

FIG. 28. When pedestals are below the cut-off point, some of the grays will become black. Overamplification (too much contrast) of the picture signal may proproduce a similar effect.

picture tube. The amount of signal that reaches the grid of the picture tube depends upon the amplification of the receiver, and by changing the gain of one or more stages through which the television signal passes, we can vary the amount of signal that will reach the picture-tube input. The receiver control that changes the gain is called the contrast control, because its most noticeable effect is a change in the amount of contrast between bright and dark areas of the reproduced image.

If the picture appears as shown in Fig. 28, we can reduce the contrast control to restore the proper relationship between the bright and dark areas. On the other hand, if the receiver amplification is too low, giving us a flat gray picture with insufficient contrast, the amplification may be increased until the desired light and dark relationship is obtained.

One point should be mentioned here that will be gone into in greater detail later. If the contrast is adjusted too high on a strong local station, some of the pedestals may be clipped by overloading the amplifier stages in the receiver and it will then be impossible to obtain proper synchronization of the picture due to the loss of the sync pulses.

Another requirement for a clear image is that the electron beam be focused to a clearly defined spot of the correct size on the screen. Improper adjustment will result in a fuzzy picture in which the lines are not clearly defined. An adjustable control, called the focus control, is provided to correct for errors in focusing due to the natural aging of the picture tube or to changes in part values. Where electromagnetic focusing is used, the focus control changes the amount of dc flowing through the focus coil.

The main adjustable controls for the sight section of a television receiver are the brilliancy control, the contrast control, the focus control, and the tuning control. Additional controls, that will be described later, are also used but they do not often require adjustment.

The controls mentioned above must be adjusted to give an image that has the proper brilliancy and the correct contrast between elements along the line, with no vertical retrace visible. In general, when the brilliancy control is adjusted, the contrast control will also require resetting since there is some interaction between these controls.

Television Signal Standards

For a television system to be successful, the receiver must be easy to adjust, the cost of the receiver must be relatively low, and the transmitter must have as much control as possible over the receiver. This last requirement means that the receiver and the transmitter must be interlocked and synchronized. Furthermore, the type of transmission must be standardized to a certain extent—otherwise radical changes in the method of transmission might make all existing television receivers obsolete.

At the same time, it would not be advisable to set up standards in such a way that it would be impossible to make improvements in the transmitting and receiving circuits. Standards are essential for a successful television system, but these standards must be sufficiently broad to permit future improvements that might make interlace and synchronism more reliable, or increase the definition of the reproduced scene.

You are already familiar with the general characteristics of the television signal. The specific standards set by the FCC for television transmission are summarized below:

1. *Television Channel Width; Channel Allocations.* The present standards provide for essentially single side-band transmission and reception (partial suppression of one set of side frequencies results in *vestigial side-band transmission*), for with this method of operation, sufficient detail for a satisfactory image along with the accompanying sound can be transmitted in a definite channel width of 6 megacycles. The channel frequency allocations as made by the FCC are shown in Fig. 4. A number of micro-wave channels have been allocated for television relay purposes, such as linking the television studio to the transmitter by radio, linking the remote pick-up point to the transmitter by radio, or linking together television stations in different cities and towns to form a network. Most present-day receivers are designed for reception of only the twelve VHF channels. To pick up UHF transmissions, a converter is required.

2. *Video and Sound Carrier Spacing.* The audio and video signals that make up a television program cannot be modulated on the same rf carrier; each must have its own carrier. *The sound carrier must be exactly 4.5 megacycles higher in frequency than the picture carrier.* To prevent interference between adjacent television channels or between a television carrier signal and services operating on adjacent carrier frequencies, there must be a .25-megacycle wide guard band at the high-frequency end of each television channel. These facts are illustrated by the chart in Fig. 29, that shows a typical distribution of signals in one 6-megacycle wide television channel.

3. *Frequency Relation Between Video and Sound Carrier.* An example

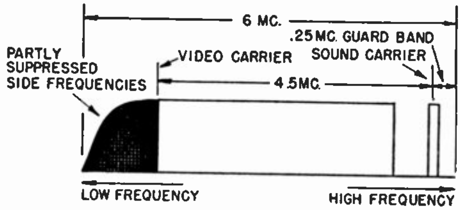


FIG. 29. Distribution of signals in a 6-megacycle wide television channel.

will best illustrate the frequency relationship in a television channel. Suppose that the 76- to 82-megacycle channel is assigned to a particular television station. To keep the FM sound transmission well within the allotted 6-mc band, the audio signal carrier must be placed at 81.75 megacycles. According to the standards, the video carrier must be 4.5 megacycles lower, or at 77.25 megacycles. It is not practical to remove all of the side frequencies below the frequency of the video carrier, so a portion of the channel must be provided for those frequencies that cannot be removed. This portion is indicated by the dark portion in Fig. 29. With this arrangement of a 6-megacycle channel, the frequency range of television equipment can be improved up to a maximum of about 4.25 megacycles without making existing television equipment obsolete.

4. *Type of Modulation; Black Level.* Negative modulation of the picture carrier signal is standard for the United States. As we have already pointed out, negative modulation means that *bright elements of a picture are transmitted at low carrier levels, and dark elements at high carrier levels.* The standards further specify that the black level or pedestal level at the transmitter shall be at a definite carrier level that remains fixed regardless of variations in sync pulse signals or in video signals. The black level at any one point in a television system is the voltage that must exist at that point to give a just barely visible spot on the screen of a properly adjusted receiver.

5. *Sync-Pulse Amplitude.* Both horizontal and vertical sync pulses must be transmitted as carrier values higher than the unmodulated carrier level (black level). These pulses extend from 75% (black level) to 100% of the peak carrier amplitude. The video signals may vary in amplitude from the black level down to 15% of the carrier level or lower. The general appearance of a typical modulated video carrier signal as it is fed into the television transmitting antenna is shown in Fig. 30. When there is no modulation, the rf carrier will have amplitude A, corresponding to the black level. Any increases in carrier amplitude must be

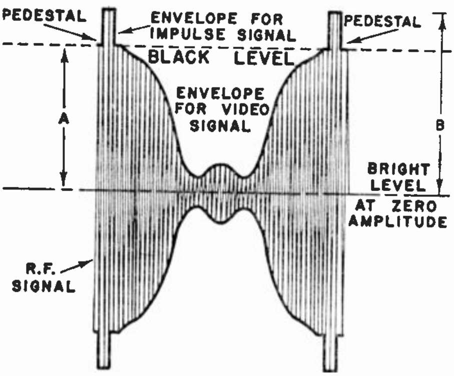


FIG. 30. Modulated rf carrier signal, with the amplitudes varying in accordance with a television signal. A is the unmodulated, and B the peak carrier level. This entire figure represents the transmitted side band. The vestigial side band (not shown) is much smaller in amplitude and would be somewhat distorted.

for the synchronizing pulses; any decreases in carrier amplitude must be for the video signals.

6. *Horizontal, Vertical, and Frame Frequencies.* The establishment of standard values for these three frequencies was based upon the need for high-image definition with a minimum of flicker. The vertical scanning frequency (field frequency) is 60 times per second, for this value minimizes any trouble due to 60-cycle power ripple. (In England, where 50-cycle power lines are used, the field frequency has been standardized at 50 vertical scannings per second.) Since interlaced scanning is used in the United States, two field sweeps are required to analyze all of the details once in a particular scene; these two vertical or field sweeps constitute a frame (one complete transmission of the picture), and consequently the standard for the frame frequency is 30 frames per second. As we have already seen, there are 525 lines per frame; this means that there are 262½ lines per field. With a 525-line picture being sent 30 times each second, the horizontal frequency becomes 525 times 30, or a total of 15,750 lines per second.

7. *Aspect Ratio.* This ratio has been standardized at 4/3, corresponding to existing motion picture standards and giving a width-to-height ratio of 4 to 3.

8. *Synchronizing and Equalizing Pulses; Blanking.* The ability of a television transmitter to control the reproduced picture at the receiver depends entirely upon the synchronizing pulses. Many years of research have been spent on this problem, and many different forms of pulse signals have been tried. The standard synchronizing pulses shown in Fig. 31 have been found best suited to present and future requirements of television in this country. Note that dimensions for pulse widths, etc. are given in terms of "H," which is the time required to scan one horizontal line including one horizontal sync pulse and pedestal.

Pattern A shows, among other things, the sync pulses recommended for the end of a frame; these will move the spot up to the top of the picture along the retrace path for the beginning of a new frame.

Pattern B shows the impulse signal sequence recommended for the end of the first half-frame (field); this moves the spot from the bottom to the top of the picture for the beginning of the second interlaced field scanning. A careful study of the diagrams in Fig. 31 will reveal five outstanding characteristics of a television signal:

I. The horizontal sync pulse that is transmitted at the end of each line is not exactly rectangular. The enlarged diagram in Fig. 31D shows the exact shape of this synchronizing signal.

II. The video signal is blanked out for a short interval before and after transmission of the horizontal sync pulse at the end of a line, in order to insure blanking during the horizontal retrace. The total time for this horizontal blanking is about 18% of the time from the start of one line to the start of the next line (this is designated as .18H at the right in Fig. 31D). Note that the horizontal pulse occupies about half of this blanking time, and that the front (leading) edge of the pulse is near the start of the horizontal blanking. The two portions of this blanking signal that are on each side

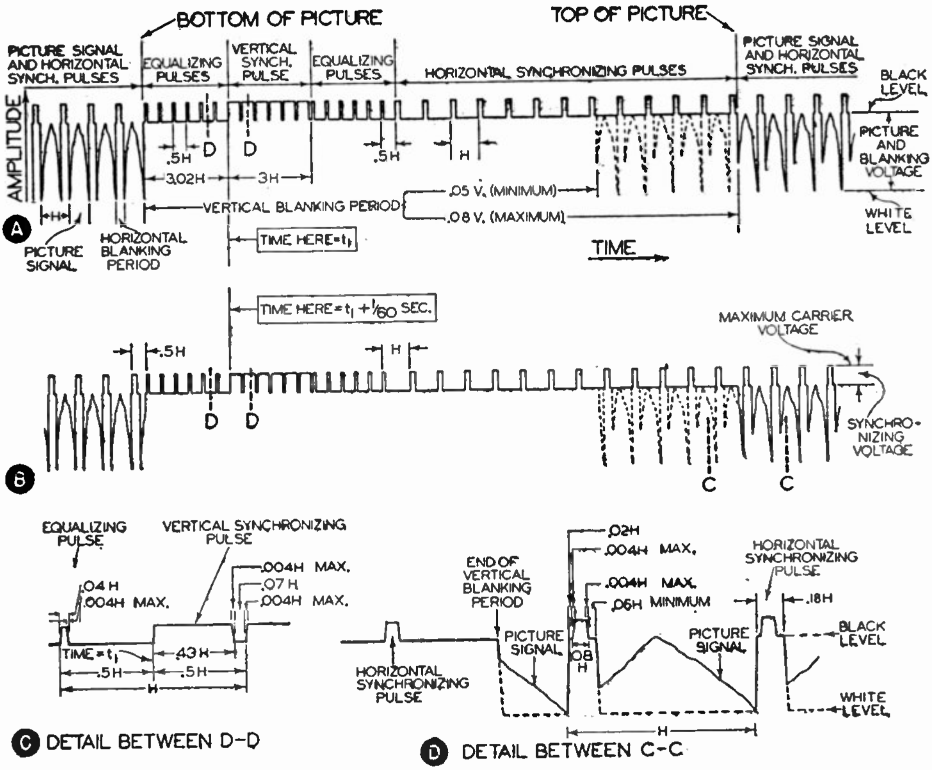


FIG. 31. Specifications for the standard television signal for 525-line pictures transmitted at the rate of 30 frames per second with double interlaced scanning, giving 60 fields per second. In these diagrams H is the time from the start of one line to the start of the next line, and is equal to 1/15,750 second. The time from the start of one field to the start of the next field (V) is 1/60 second.

Diagrams A and B show blanking and synchronizing signals in regions of successive vertical blanking pulses. The black level is about .75 of the synchronizing pulse amplitude.

***Horizontal dimensions in these diagrams are not drawn to scale.* The receiver vertical retrace will be complete at the end of about .07 V during the vertical blanking period. The length of the vertical blanking period produced by the transmitter may vary between .05 V and .08 V. The leading and trailing edges of both the horizontal and the vertical blanking pulses have slopes (not indicated in A and B), which should be kept as steep as possible.**

Diagram C is an enlarged detail view, drawn accurately to scale, of the signal between points D-D in diagrams A and B.

Diagram D is an enlarged detail view, drawn accurately to scale, of the signal between points C-C in diagram B.

of the horizontal sync pulse are known as *pedestals,* and are originally at the black level.

III. The vertical sync pulse exists for an interval of three lines, but this pulse is divided into six small pulses, each acting for half a line. This serrated pulse is shown in Fig. 31A. Each vertical pulse is divided into six small pulses or serrations in order to maintain horizontal sync pulses at all times. These serrations will be explained in detail later.

IV. Six equalizing pulses precede and six follow each vertical pulse period. The purpose of these will also be covered later.

V. The vertical blanking period starts slightly ahead of the first equalizing pulse and extends considerably beyond the last equalizing pulse; this vertical blanking period should take between 5% and 8% of the time for one vertical sweep. Note that horizontal sync pulses are transmitted during the latter portion of the vertical blanking period.

Explanation of Standards. As long as we have 60 vertical sweeps per second, interlaced scanning will continue automatically throughout a transmission. The vertical fly-backs or retraces will be 1/60 of a second apart; they may occur either near the beginning or near the end of the vertical sync pulse interval, but must occur at the same point in each pulse (this point is controlled by the design of the receiver).

Although the leading (left-hand) edge of the vertical sync pulse in Fig. 31A is directly above the leading edge of the vertical sync pulse in Fig. 31B, these actually occur 1/60 of a second apart due to interlacing. For this reason, the horizontal pulses at A and B in Fig. 31 are not in line.

Experience has shown that no matter what happens, the horizontal sync pulses must not stop even for a single line. If the vertical sync pulse were made three lines long without breaking it up, no horizontal pulses would exist for this period. To avoid the situation, the vertical pulse is serrated or separated into six smaller pulses.

To visualize why the vertical sync pulse must be broken up, let us first assume that it is broken up into three pulses as shown in Fig. 32, and see what happens. For the moment we will forget about the equalizing pulses.

Pattern A in Fig. 32 shows the last horizontal sync pulse (just before the bottom of the picture) as being one whole line ahead of the start of the vertical blanking period, and pattern B shows this last horizontal pulse as only half a line ahead of the vertical blanking period; these are actual conditions for successive field sweeps, so we must consider them in Fig. 32. Horizontal sync pulses must exist for the entire vertical blanking period; this means that there should be horizontal sync pulses at points 2, 3, 4, and 5 in Fig. 32A. At each of these points there is a break or serration in the vertical pulse; since the leading edge of a pulse or serration is sufficient to control the horizontal sweep in the receiver, this will give adequate control of the horizontal sweep.

When we turn to pattern B in Fig. 32, however, we find that horizontal sync pulses should occur at points 2, 3, and 4. There are no steep leading edges at these points to control the line sweep, and consequently three serra-

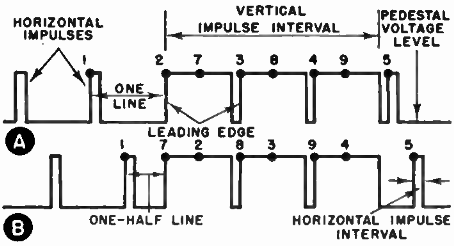


FIG. 32. These diagrams tell why the vertical synchronizing pulse signal must be broken up into six smaller pulses.

tions in the vertical impulse are not adequate for pattern B, which occurs for every other scanning of the picture. If the vertical impulse is divided into six parts as shown in Figs. 31A and 31B, we secure the desired steep front at points 2, 3, and 4 in pattern B in Fig. 32.

The vertical synchronizing pulse is chopped into segments by the application of a special signal having a rate twice that of the horizontal synchronizing signal. Because of the difficulty of synchronizing this signal exactly with the vertical pulse, this twice-normal signal exists somewhat before and after the vertical pulse as a series of horizontal synchronizing pulses at half-line intervals. Then, it is sure to cut up the vertical pulse properly. In Fig. 31A, these additional pulses are labeled "equalizing pulses." A pulse one-half a line from the proper one is ignored at the receiver; the sweep oscillator responds only to the pulse that occurs at the proper time to maintain the horizontal synchronization.

The value of this information will become apparent when you study sync circuits and methods of observing wave shapes with an oscilloscope. At that time you will find a review of this information helpful.

THE COLOR SIGNAL

In order to achieve practical transmission and reception of color television, it was necessary for engineers to evolve a system of transmitting and receiving color information that would keep the color signal within the same 6-mc channel width as the monochrome signal. It was also considered necessary for the color television system to be *compatible*. By compatible we mean that the color signal must be such that it can be received and reproduced as a black and white picture on a monochrome receiver, and conversely the color receiver must be capable of receiving and reproducing the signals from monochrome transmitters.

Any system that was incompatible would not have been acceptable because it would have made all present monochrome receivers obsolete if broadcasters changed to a color system. The details of how color information that would fit into the 6-mc band without interfering with monochrome signals, and how color systems are made compatible, will be taken up in later lessons. Here it is only necessary for you to learn the general nature of the color signal.

Color information is transmitted on what is known as a "sub-carrier." A process known as *interleaving* makes possible the transmission of this sub-carrier along with monochrome signals. A complete explanation of interleaving is not necessary here. It is sufficient for you to know that this process takes advantage of certain gaps that exist in a monochrome video signal; the color information fills in these gaps without interfering with the monochrome signal.

To make interleaving possible, a color sub-carrier frequency of approximately 3.58 megacycles has been selected. Fig. 33 shows the location of the color sub-carrier within the allotted 6-mc television channel. Note that the upper side band of the color or chrominance sub-carrier is suppressed so that it takes only .5 megacycles,

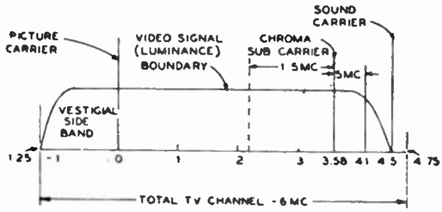


FIG. 33. A 3-58-mc color sub-carrier is transmitted along with the regular picture carrier within the allotted 6-mc band.

but the lower side band takes 1.5 megacycles.

In addition to the color sub-carrier, a color sync signal must also be sent. This signal is sent on the "back porch" of the horizontal sync pulse pedestals as shown in Fig. 34. The nature of this synchronizing burst is such that it will not normally be detected by the monochrome receiver, but will serve its intended function in the color receiver.

Color Information. There are three types of color information that must be sent in the color television signal. These correspond to the three characteristics of any color: brightness, hue, and saturation.

Brightness is the intensity of the color. It has the same meaning for color television as it has in mono-

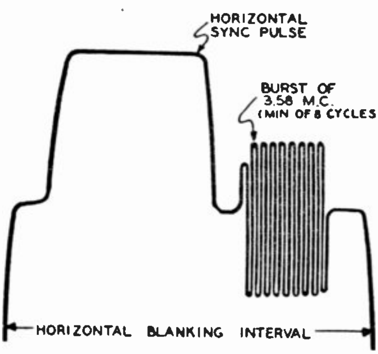


FIG. 34. The color sync signal is transmitted on the "back porch" of the horizontal sync pulse pedestals.

chrome television, and it is determined by the amplitude of the normal mono-chrome video signal. Brightness is a characteristic that is commcn to both color and monochrome television and it can therefore be included in the same signal for either.

Hue refers to the color itself. In other words, red is one hue, green another. The color signal must contain information that will enable the receiver to distinguish between hues. The phase of the sub-carrier signal determines the hue that will be visible at the receiver screen. Hue depends upon the difference between the phase of the color sync burst and the phase of the color sub-carrier signal.

Saturation describes the amount of white light mixed with the particular hue or color in question. Zero percent saturation would indicate a totally white light; 100% saturation would represent a hue containing no white light. In a color television system, saturation is determined by the amplitude of the chrominance sub-carrier signal.

The color signal for one horizontal scanning line is shown at Fig. 35. Here the primary and secondary colors ranging from black to white are being transmitted for equal lengths of time. All colors are shown with 100% saturation. The numbers on the left from zero to 100 represent percent modulation. Therefore, with 100% saturation you can see that green, cyan, and yellow would extend beyond the zero percent modulation level. However, this does not present any great problem because fully saturated colors are rarely telecast.

The heavy stair-step line represents

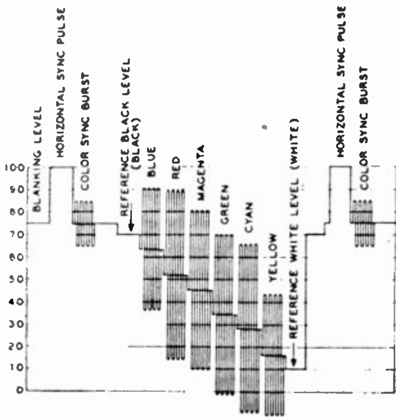


FIG. 35. The color signal for one horizontal scanning line.

the brightness information. It is this portion of the signal that will be detected by the monochrome receiver and appear on the television screen as shades of gray ranging from black to white.

You are not expected to have a full understanding of the color television signal from the foregoing explanation. However, the concept of its general nature and the familiarity with some color television terms that you have attained here will be of assistance to you in your study of later lessons on color television.

Lesson Questions

Be sure to number your Answer Sheet 48B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. Why is it that a TV picture signal does not require a channel band width equal to twice the modulating frequency?

2. What process is used to convert a scene into a succession of signal intensities?

3. What characteristic of the eye makes it possible to send a picture signal a portion at a time, and yet have the resulting picture appear as a complete scene?

4. What is the purpose of the sync pulses sent out by the transmitter?

5. In what way does interlaced scanning improve picture quality?

6. What is the advantage of using negative modulation of the picture carrier signal?

7. What two functions does the control grid of the picture tube perform?

8. In Fig. 26, what would be the effect on the picture if the pedestals lined up with point 2 on the Eg-Brilliancy curve? Point 0?

9. What is the frequency of (A) the vertical scanning, and (B) the horizontal scanning?

10. What three types of color information must be contained in the color television signal?

SELF-EDUCATION

"The best culture is not obtained from teachers when at school or college—but by our own diligent *self-education* when we have become men."

This quotation has been proved true many, many times. Let's take a few outstanding examples. President Ulysses Grant was often called "Useless" by his mother because he showed so little promise as a young man. General Stonewall Jackson was noted for his slowness while a pupil at West Point. Watt—who invented the steam engine—was notoriously dull in school. Sir Walter Scott was outstanding in school *only* for his readiness to pick a fight—and was not known as an author until he was over forty.

To again quote, Gibbons said, "Every person has two educations. One which he receives from others—and one, more important, which he gives to himself."

You are now busy *giving yourself* education in Radio and Television which can and should be the most important education of your entire career.

J. M. Smith

BASIC TV RECEIVER CIRCUITS

49B

RADIO-TELEVISION SERVICING

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 49

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. Tracing Signals Through a Television Receiver ..... Pages 1-7

Sound and picture signals are traced through a typical television receiver.

☐ 2. Signal Reception, Amplification, and Conversion .. Pages 8-14

Here we take up the receiving antenna, the rf amplifier, and the oscillator and mixer-first detector.

☐ 3. Video I-F Amplifier and Detector .... Pages 15-18

In this section you study typical circuits of a video i-f amplifier and of a video detector.

☐ 4. Video Amplifier and DC Restorer .... Pages 19-25

A video frequency amplifier stage is analyzed, and the problem of realigning pedestals is taken up.

☐ 5. Forming the Picture .... Pages 26-33

The cathode-ray tube, sync circuits, and sweep circuits are discussed.

☐ 6. Automatic Gain Controls .... Pages 34-36

Here you learn how automatic gain control compensates for variations in signal strength.

☐ 7. Answer the Lesson Questions.

☐ 8. Start Studying the Next Lesson.

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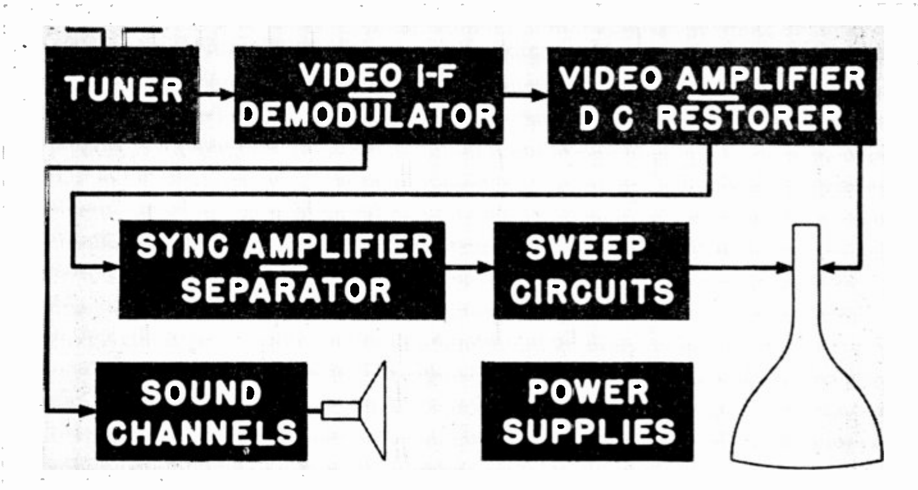


BEFORE we analyze in detail the various circuits that may be used in a TV receiver, let us trace the sound and picture signals, through typical receivers.

A Television Channel. Let us assume that the receiver is tuned to the 54 to 60-mc channel, shown in Fig. 1. The rf carrier center frequency for the audio signal will be 59.75 mc. The rf carrier for the video signal will be 4.5 mc below this, at 55.25 mc.

The antenna intercepts the 59.75-mc frequency-modulated audio rf carrier, causing a constant rf current, varying in frequency, to flow down the transmission line to the first section of the receiver. This same antenna also intercepts the 55.25-mc video rf carrier, along with its side frequencies extending down to 54 mc and up to about 59.25 mc, and sends down the transmission line an rf signal current. Notice that the antenna intercepts two signals that are 4.5 mc apart.

Television Receivers. A block diagram of a television receiver is shown in Fig. 2. Notice that the sound and video signals are separated at the output of the mixer-first detector. The video signal is fed to the video i-f am-

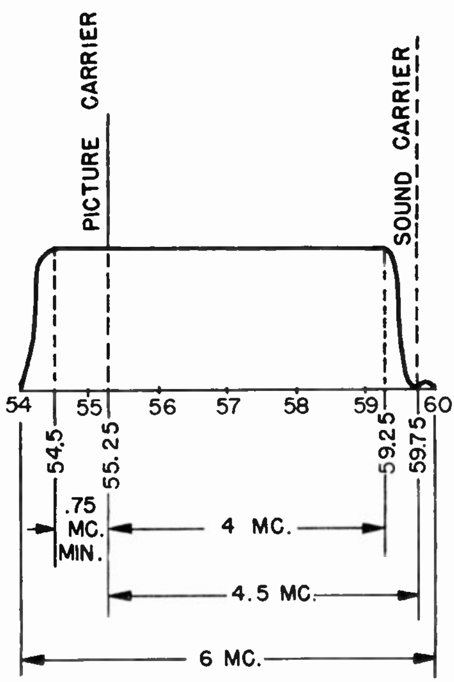


FIG. 1. Idealized picture transmission amplitude characteristic.

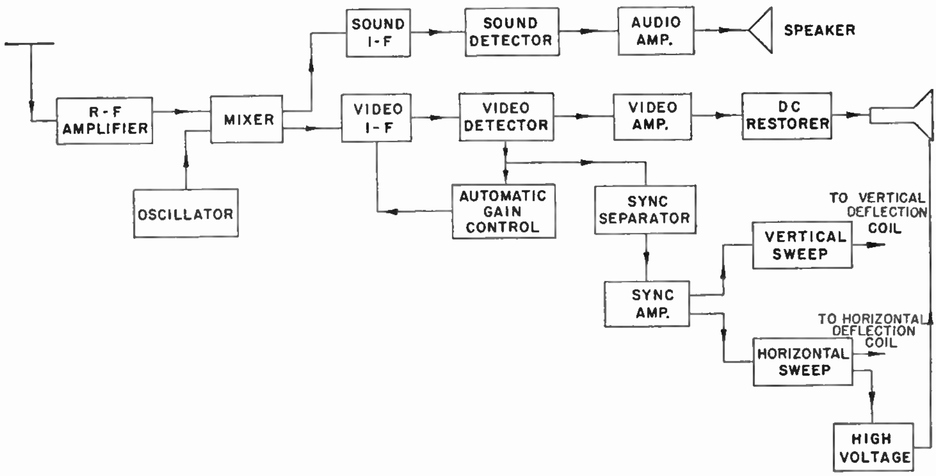


FIG. 2. Block diagram of receiver using a separate sound i-f.

plifier and the sound signal to the sound i-f amplifier.

In some receivers, the sound and the video signals, instead of being separated at the output of the mixer-first detector, are separated after they are passed together through one or more of the video i-f amplifier stages.

Another block diagram is shown in Fig. 3. In this receiver the sound and video signals are amplified simultaneously by the video i-f amplifier and fed into the video detector together. Here the two signals beat together to produce a 4.5-mc signal that will be both amplitude and frequency modulated. The frequency modulation contains the sound information. The 4.5-mc signal is then amplified by the sound i-f amplifier and detected by an FM detector. The audio signal developed by the detector is then amplified

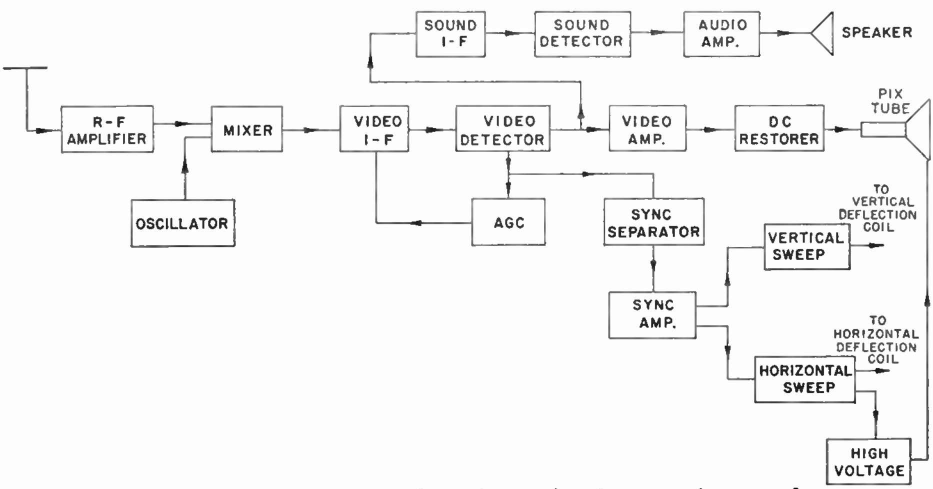


FIG. 3. Block diagram of receiver using inter-carrier sound.

by the audio amplifier and fed to the speaker.

RF Amplifier. The first section of a television receiver is the rf amplifier. This section increases the amplitude of both the sound and the video rf signals without changing their characteristics in any way, and hence must have a pass band of 54 to 60 mc (in the case of a channel 2 station). In addition, the rf amplifier must reject any carrier frequencies (outside the 54- to 60-mc channel) which might cause interference.

Local Oscillator and Mixer-First Detector. The amplified sight and sound rf signals are fed into the mixer-first detector section, where they are combined with the unmodulated rf signal produced by the local oscillator to produce the sound and video i-f signals. A video i-f value of about 25.75 mc was used in the older TV sets, but most modern sets use 45.75 mc.

Let us assume that the video i-f in this receiver is 25.75 mc. This means that the local oscillator frequency will be 55.25 + 25.75, or 81 mc. If the video i-f were 45.75 mc, the local oscillator would have to operate at 55.25 plus 45.75 or 101 mc.

I-F Values. We have already mentioned that 25.75 mc (or a frequency close to this value) is frequently used as the video i-f in older TV receivers. With this i-f, the local oscillator would operate at 81 mc and beat with the 55.25-mc video rf carrier and its side frequencies to produce a video i-f carrier signal of 25.75 mc along with side frequencies ranging down to 21.75 mc and up to 27 mc.* At the same time, the 81-mc local oscillator signal will beat with the 59.75-mc sound rf carrier to produce a 21.25-mc sound i-f signal which can vary 25 kc above and below this value. These i-f signals have essentially the same characteristics as the original signals.

Sound I-F Amplifier. This i-f amplifier section must pass the complete 50-kc deviation of the sound i-f carrier. In addition, if the receiver has a separate sound i-f system, its bandwidth must be sufficiently wide to permit passage of the entire sound i-f signal despite normal frequency drift of the local oscillator circuit.

The Limiter. Some of the older television receivers may use a limiter between the sound i-f amplifier and the detector to remove any amplitude variations which would be reproduced as "noise." Limiters will seldom be found in modern receivers.

The Audio Detector. Some of the older television receivers used an FM discriminator as the sound detector. However, practically all modern TV receivers use a ratio detector.

Audio Amplifier. The signal at the output of the sound detector will be a typical audio signal having a maximum frequency of about 15 kc. This audio signal is fed to a conventional audio amplifier, where it undergoes

*Frequency conversion reverses the relationship of the desired side frequencies to the carrier. The desired band of side frequencies is above the video rf carrier in the rf amplifier, but is below the carrier in the video i-f amplifier. Thus, when the highest side frequency (59.25 mc) for the original video rf signal beats with the 81-mc oscillator signal, we get 21.75 as the lowest video i-f side-frequency value. The side frequencies extending from 25.75 mc to about 27 mc correspond to the partial lower side band in the original signal, for as yet these undesired side frequencies are not completely eliminated at the transmitter.

voltage and power amplification before being converted into sound.

Video I-F Amplifier. If the video i-f frequency is 25.75 mc, the video i-f amplifier should have a pass band from about 21.75 mc to 25.75 mc and have a frequency response characteristic that will suppress the undesired side frequencies. If the receiver uses a separate sound system as shown in Fig. 2, the video i-f response must suppress a 21.25-mc sound carrier. On the other hand if the intercarrier sound system is used as in Fig. 3, the sound signal must pass through the video i-f amplifier.

If the higher i-f is used, the video amplifier should have a pass band of from about 41.75 to 45.75 mc.

Video Detector. The amplified video i-f signal passes into the video detector, where its envelope is "stripped" from the carrier. The video detector circuit usually has a diode tube or a germanium crystal for rectification, followed by a condenser-coil filter circuit which rejects all i-f components while passing the entire television signal ranging from 10 cycles to 4 mc.

The demodulated television signal, consisting of the synchronizing pulses and the video signal, is actually a pulsating dc signal. The signal voltage across the load resistor of the diode video detector in a television receiver is therefore a pulsating dc voltage with the pedestals all lined up at one dc voltage value and the sync pulse peaks lined up at another dc voltage value. If the intercarrier sound system is used (Fig. 3) the 4.5-mc beat signal which contains the sound intelligence will also be present at the output of the video detector.

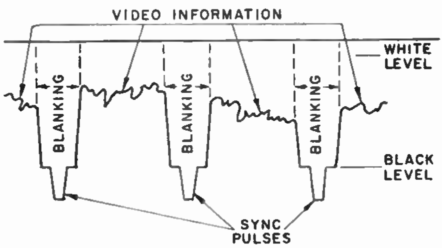


FIG. 4. Video signal with the sync pulses swinging negative.

Automatic Gain Control. The sync pulse level in the received television signal is independent of picture brilliancy; synchronizing pulses are therefore utilized to actuate the automatic gain control (agc) section of a television receiver. A portion of the output of the video demodulator may be fed into the agc section through a network of parts which is so designed that only the pulses are effective in producing an agc voltage for biasing purposes.

In many modern receivers a form of amplified agc is used. In this type of circuit a portion of the output of the video detector is fed to the agc amplifier, and the output of the amplifier is used to control the gain of the rf and i-f stages.

In some of the earlier television receivers, the gain of the video i-f amplifier was controlled manually, and agc was not used at all.

Video Amplifier. The video signal applied to the picture tube must be of the correct phase, otherwise a negative picture will be produced. If the signal is fed to the grid of the tube the sync pulses must swing negative as shown in Fig. 4, and if the signal is fed to the cathode of the picture tube the sync pulses must swing positive as in Fig. 5 to cut off the electron beam during the retrace period.

The video amplifier may use resistance-capacitance coupling or direct coupling. A direct-coupled amplifier will pass both the ac and dc components of the television signal, but a resistance-capacitance coupled amplifier will pass only the ac component.

Video-frequency amplifier stages must amplify equally well over a range extending from about 10 cycles to about 4 mc. Furthermore, these stages must not introduce phase distortion, for any distortion of this type would cause elemental* impressions of gray, white, or black to be shifted either ahead of or behind their proper positions along a line.

DC Restorer. Removal of the dc component throws the pedestals of a television signal out of line, giving the ac signal shown in Fig. 6. This means that when resistance-capacitance-coupled video amplifier stages are used, a dc restorer section must be used to restore the dc component and realign the pedestals. This section adds to the ac television signal a dc voltage that varies from instant to instant in exactly the proper manner to make the pedestals line up again. The restored television signal will look like Fig. 5.

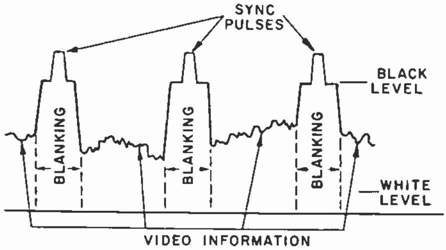


FIG. 5. Video signal with the sync pulses swinging positive.

Kinescope. Modern kinescopes, or picture tubes as they are most commonly called, can be divided into two types, electrostatic focus and magnetic focus. In the electrostatic type the anodes serve to focus the electron beam to a point on the screen. In the magnetic type a magnetic field, which may be produced by a permanent magnet or by an electro magnet is used to focus the beam.

The application of a television signal to either the grid or the cathode of

*Elemental impressions is the term used to describe the minute element or areas of white, black, or gray, which comprise the picture.

the tube serves to modulate the beam, thereby varying the brightness of the spot on the screen. The sync pulses and the blanking level prevent retraces from being visible during the fly-back period.

While the electron beam is being modulated by the television signal, it is simultaneously being swept back and forward both horizontally and vertically by magnetic fields produced in the deflection yoke. In accordance with present standards the horizontal frequency will be 15,750 cycles per second and the vertical sweep will have a frequency of 60 cycles per second.

Synchronization. Each horizontal and vertical sweep in the receiver must start at exactly the same instant that the corresponding sweep starts at the transmitter. Sync pulses are sent along with the video signal for this purpose. These pulses must be separated from the video signal, after which the horizontal and vertical pulses must be separated from each other. Finally, each type of pulse must be made to control the start of its own sweep circuit.

Sync Separator. If we pass the demodulated television signal shown in Fig. 5 through a triode tube which has a high negative bias, only the positive peaks of the signals (the pulses) will cause variations in plate current. We thus have only the pulses in the plate circuit of this triode; since this separation of pulses from video signals is dependent upon the amplitude of the television signal, the section containing this tube is the clipper or sync limiter. The signal at the output of this section will appear as in Fig. 7. As you can see, it now contains only the horizontal (line) pulses, the serrated vertical or field pulses and any equalizing pulses transmitted along with these.

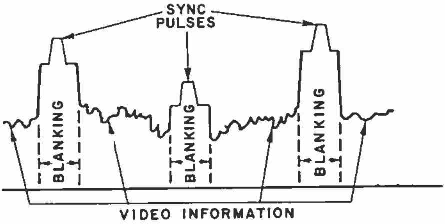


FIG. 6. Unrestored video signal.

The next problem is the separation of the serrated vertical pulses from the line and equalizing pulses. This is accomplished by the use of differentiating and integrating circuits.

Sweep Circuits. The separated pulses are fed into the vertical and horizontal sweep oscillators, where they control the starting times of the sweeps. The vertical sweep circuit normally consists of an oscillator and a sweep amplifier. The horizontal sweep circuit also contains a sweep generator and an amplifier, but it also contains a damper used to damp out undesired oscillations that would occur.

High-Voltage Supply. The high voltage required to operate the picture

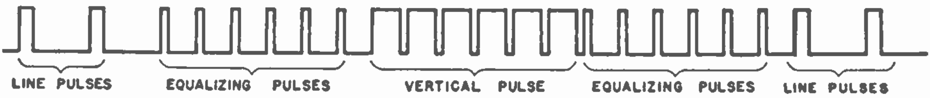


FIG. 7. Output of sync separator.

tube is usually obtained from the horizontal sweep circuit by means of a high-voltage winding on the horizontal output transformer. Some older TV receivers used rf power supplies and a few receivers were made using iron-core, 60-cycle, high-voltage supplies.

Low-Voltage Power Supply. The low-voltage power supply can be omitted in this brief analysis of a complete television receiver, for even though it is a necessary part of any system employing vacuum tubes, it is conventional in design; this circuit is considered elsewhere in the course.

Having traced the television signal through the different essential sections of the receiver, let us now study a typical circuit for each section, to see just how it performs its required duties.

Signal Reception, Amplification, and Conversion

The Receiving Antenna. Practically all modern television receivers have a built-in antenna and in primary signal areas will usually give an acceptable picture on this antenna alone. However, in some installations even in primary signal areas, an outside antenna will be necessary, and in practically every case it will improve the picture quality.

An ideal television antenna would receive all channels equally well and reject all external noise. Unfortunately there is no such antenna; therefore, in selecting an antenna some compromise must be made. A dipole or a folded dipole will usually give satisfactory results in a primary signal area. To improve the directivity of these antennas, a reflector is frequently placed in back of the antenna. Both the dipole and the folded dipole are fairly broad and usually one antenna will give satisfactory results on a number of channels.

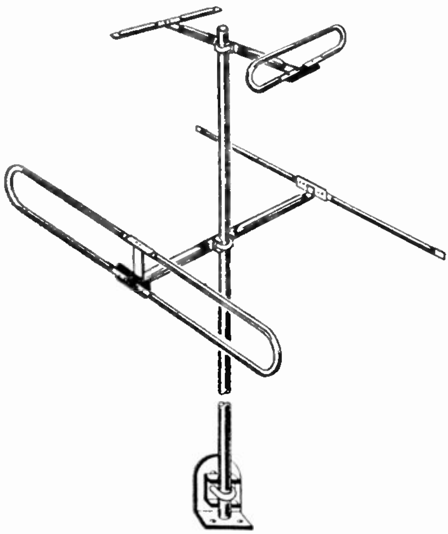


FIG. 8. A typical VHF TV antenna installation.

A typical VHF antenna is shown in Fig. 8. Actually the antenna consists of two separate antennas connected together by a suitable length of transmission line. The larger antenna (the lower of the two) is used for channels 2 through 6 and the smaller antenna for channels 7 through 13. An antenna of this type will give satisfactory results in an area where a reasonably strong signal can be picked up.

In weak signal areas more elaborate antennas are needed. Frequently a high-gain antenna such as the Yagi is used. Antennas of this type have high gain, but comparatively narrow frequency response and, therefore, can normally be used on only one channel. A typical Yagi antenna is shown in Fig. 9.

Dipoles and folded dipoles are also used for UHF reception. In primary signal areas an antenna of this type is normally all you will need. A corner reflector antenna is also frequently used in UHF reception. This type of antenna is shown in Fig. 10.

Two types of transmission line are in common usage. More common is the so called "twin lead." This type of transmission line consists of two parallel conductors supported and held apart by a plastic insulating material. The transmission line has a characteristic impedance of about 300 ohms and is therefore ideal for use with television receivers having a 300-ohm input impedance.

Coaxial line is also frequently used in TV installations. Co-ax is more difficult to work with than twin lead, and it is more expensive, but since the outer conductor is grounded, the problem of noise pickup on the transmission line

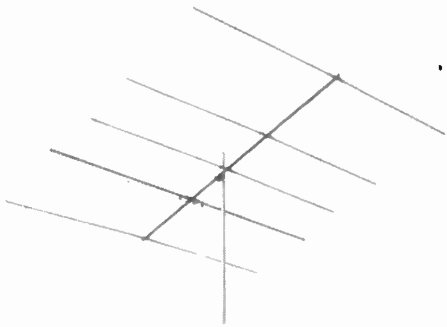


FIG. 9. A typical Yagi antenna.

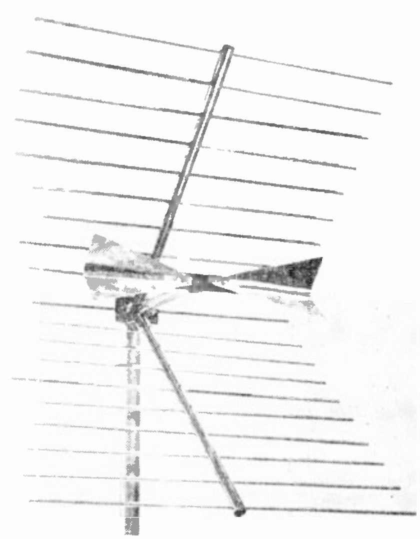
is eliminated when it is used.

When 300-ohm twin lead is used, the lead should be twisted about one turn per foot of lead. The twisted transmission line will result in less noise pickup than an untwisted line.

TUNERS

RF Amplifiers. The preselector or rf amplifier has two important functions. It must amplify all signal components in the television channel to which it is tuned, and it must exclude signals outside this channel which produce interference. Unfortunately, the rf amplifier usually does neither of these jobs very well. The gain of most rf stages is usually comparatively low. In addition, since the rf amplifier must pass a 6-mc signal, it must be made broad and therefore it will usually pass strong signals outside of the television channel. FM interference and interference from other radio services is not uncommon in TV receivers.

There are a number of different types of rf stages in use in TV receivers. A pentode rf amplifier is shown in Fig. 11. Notice that this rf stage is basically quite similar to the rf stage that might be found in a radio receiver. The secondary of the input coil is loaded to give a wide band width so that the amplifier will pass the entire channel. The rf amplifier is switched from one channel to another by switching the desired coils into the circuit.



Courtesy Tele-Tech

FIG. 10. A "Bow-tie" antenna with corner reflector for UHF reception.

An rf amplifier stage of this type normally used a high-gain tube, but because of the loading and the fact that the operating voltages on the tube are comparatively low, the stage gain is seldom much better than 10.

Another rf amplifier is shown in Fig. 12. This circuit is called the cascode

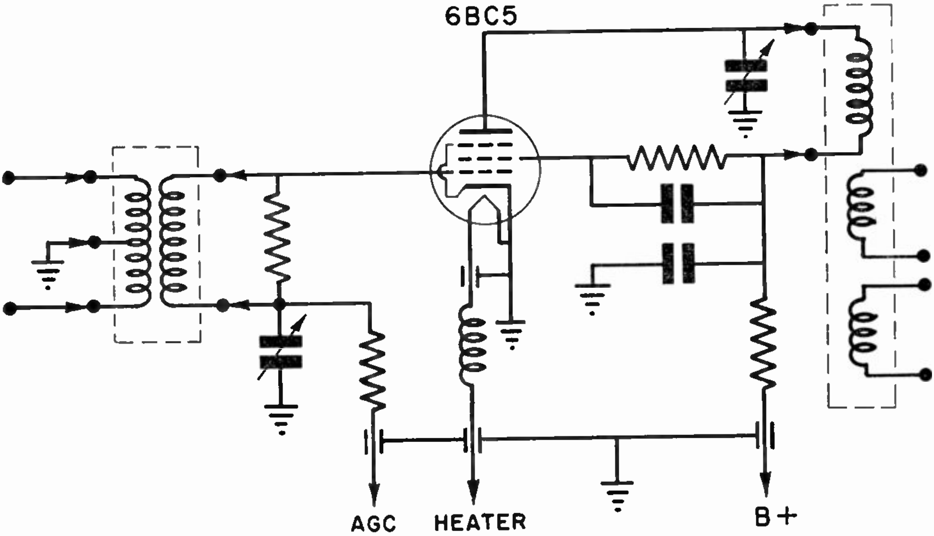


FIG. 11. A pentode rf amplifier.

circuit and is used in many modern TV receivers. Since it differs somewhat from the type of rf amplifier used in radios, a brief explanation of its operation will be helpful.

The signal applied to the grid of the first triode is amplified by this stage, and the amplified signal is fed from the plate of the triode to the cathode of the second triode. A portion of the signal is also fed back through a condenser to the lower end of the grid

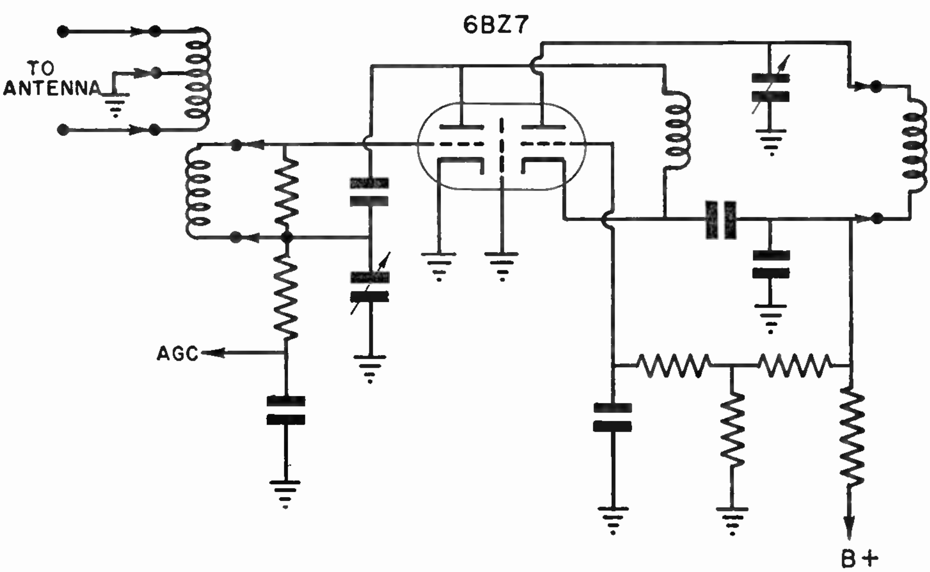
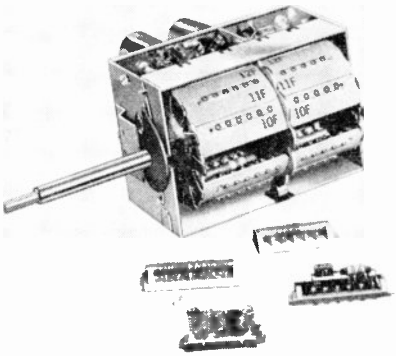


FIG. 12. A cascode rf amplifier.

coil. This signal is fed back to the grid circuit of the first stage to neutralize the stage. (A triode used in an rf stage will oscillate unless it is neutralized.) The second triode is used as a grounded-grid amplifier. Instead of feeding the signal to the grid of the tube, the signal is fed to the cathode and the grid of the tube is grounded through a condenser. The grounded grid then acts as a shield between the input and output circuits much as the screen grid of a pentode tube does. The signal fed to the cathode of the tube causes the grid-cathode potential to vary, and the effect is more or less the same as feeding the signal to the grid and grounding the cathode. The amplified signal is fed from the plate through a coil that is inductively coupled to the coil in the grid circuit of the mixer stage which follows.

The cascode rf amplifier has two big advantages over a pentode rf stage. The gain of the stage is normally higher than that of a single pentode rf stage, and the noise generated by the tube is lower than the noise generated by a pentode; therefore the tuner will give better signal-to-noise ratio especially on weak signals.

RF amplifiers are usually used in tuners designed for VHF reception. However, at UHF the rf signal is seldom fed to an rf amplifier because of the difficulty of handling the high frequencies involved. The normal procedure in UHF receivers and converters is to feed the signal directly to a mixer in order to convert the signal to a lower frequency that can be more conveniently handled.



Courtesy Standard Coil

A turret-type tuner with one set of strips removed. In place of the VHF strips removed, which are shown nearer the tuner, strips for one of the UHF channels may be installed, these are shown in the foreground.

The Oscillator and Mixer. As you already know, the process of frequency conversion involves mixing the unmodulated constant-voltage output of a local oscillator with the incoming modulated carrier signal. This process is basically the same in TV receivers as in radio. However, because we are dealing with very high frequencies and ultra high frequencies, precautions must be taken to prevent degeneration and to prevent shifting of the oscillator frequency. These difficulties were eliminated in early television receivers by the use of a separate oscillator tube. However, the trend in modern receivers designed for VHF reception is to use a single dual purpose tube to perform the functions of mixer and oscillator. A typical mixer-oscillator is shown in Fig. 13. Notice that one half of a 6J6 tube is used as the mixer and the other half as the oscillator. The internal coupling between the two sections of the tube is sufficient to inject the oscillator signal into the mixer section. The plate circuit of the mixer is tuned to resonance at the i-f frequency. A suitable low-impedance path is provided in the plate circuit for the rf signal reaching the plate of the mixer to avoid the possibility of oscillation in the mixer. In the tuner from which this circuit was taken, the coils are mounted in a turret that is rotated as you change from one channel to another and new coils are inserted in the circuit. The tuner is normally supplied with 12 sets of coils on separate strips, one for each channel. Each of the coils is removable, so they can be replaced individually or removed for the insertion of UHF strips. The mixer circuit operates at the frequency of the incoming signal and the oscillator operates at the incoming signal frequency

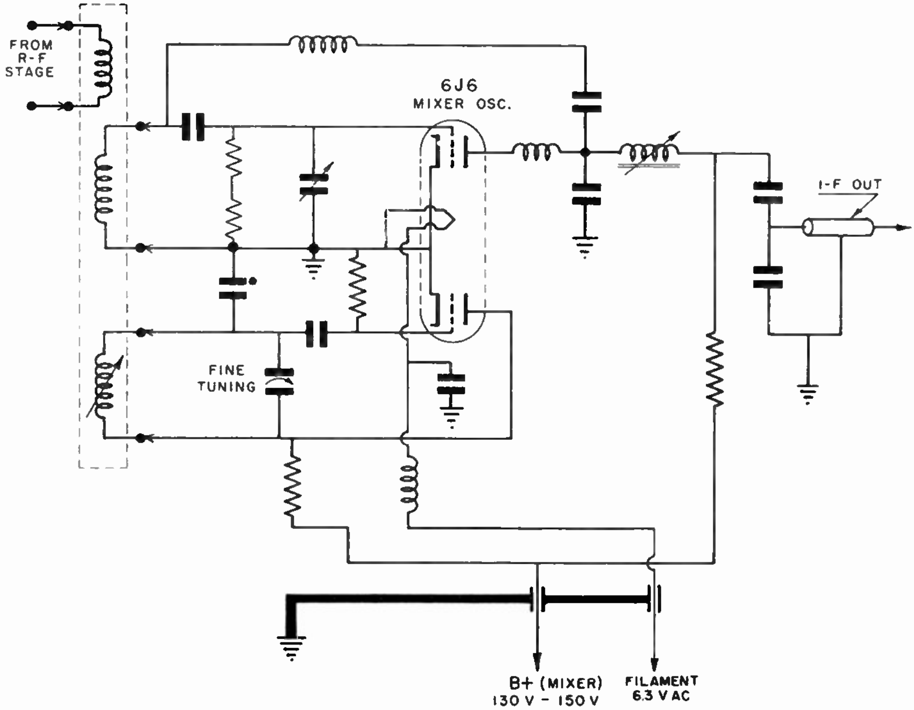


FIG. 13. A typical mixer-oscillator.

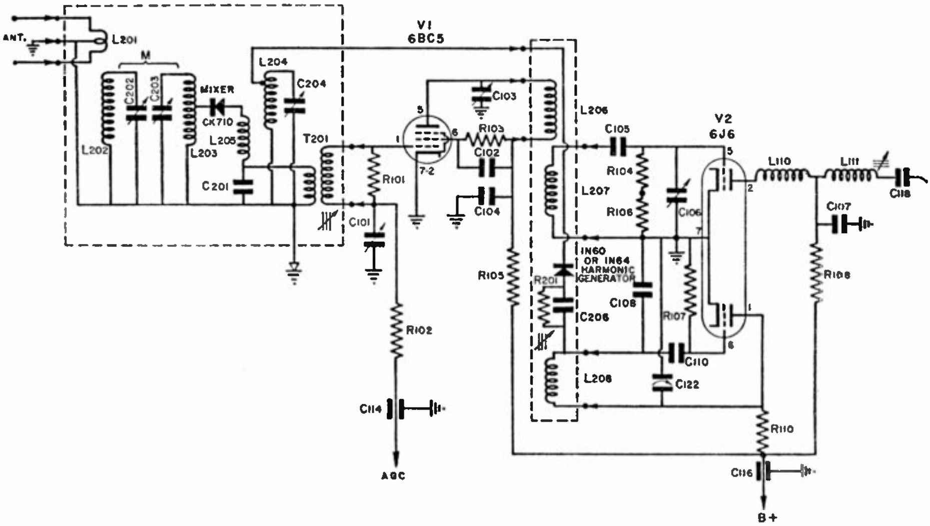


FIG. 14. Schematic of a turret-type tuner with UHF strips in place.

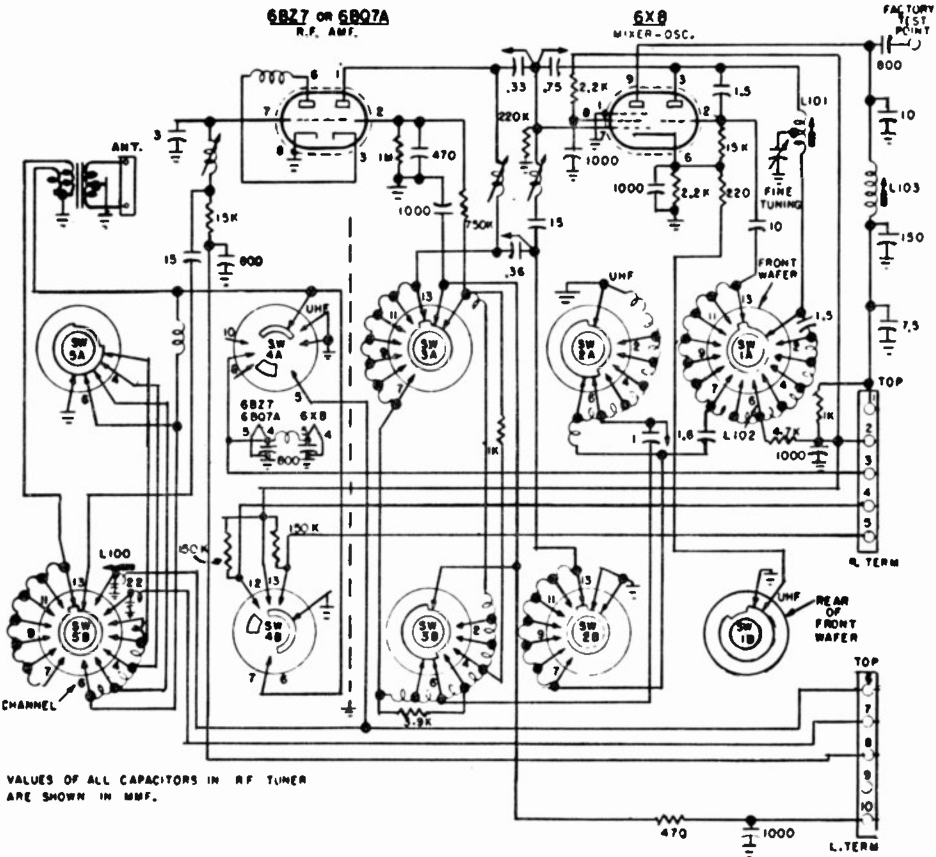
plus the i-f frequency.

When this tuner is used on a UHF channel, the oscillator output is fed to a crystal harmonic generator, and the output of the harmonic generator is then fed to another crystal where it is mixed with the incoming signal. Instead of converting the signal to the i-f frequency, it is changed to a frequency that can first be amplified by the rf amplifier. The signal is then fed to the mixer, where it is mixed with the oscillator fundamental to convert it to the i-f frequency. A complete turret tuner using a pentode rf stage and with a set of UHF coils in place is shown in Fig. 14.

Pentodes are sometimes used in mixer circuits. A typical tuner using a pentode mixer and a triode oscillator both in the same envelope is shown in Fig. 15. In this tuner, instead of changing the coils each time you change from one channel to another, a series of coils connected in series is used. The coils are connected between adjacent terminals of a selector switch so that when you change from channel 13 to channel 12, you simply add a coil to the circuit. If you then switch from channel 12 to channel 11, you add another coil in series with the inductance already in the circuit.

Notice the section of the channel selector switch marked 5B (in the lower left corner of the diagram). The switch is shown in the channel 13 position. When you switch to channel 12, the switch moves in a counter-clockwise direction and adds the first coil to the inductance already in the circuit. Similarly when you move the switch to the channel 11 position you add the next coil in series with the inductance already in the circuit. You continue this until when you tune to channel 2 all of the coils are connected in series.

Tuners of this type are difficult to align. Adjustments are usually pro-



Courtesy Westinghouse

FIG. 15. A typical VHF tuner with a pentode mixer.

vided for channels 13 and 6. You align the tuner on the highest channel first and work towards the lowest channel. In some tuners a slug is provided in each coil, but in others you must vary the spacing between the turns of each coil or the shape of the coil to align the tuner. When you must adjust this type of tuner, you should obtain the manufacturer's alignment instructions.

Video I-F Amplifier and Detector

The process of frequency conversion produces in the receiver, video i-f and sound i-f signals, separated by 4.5 mc. If the video i-f frequency is 25.75 mc, video i-f signals will range from 25.75 mc down to about 21.75 mc, and the sound i-f signals will extend about 25 kc on either side of 21.25 mc. If the receiver has a 45.75-mc i-f, the video i-f signals will range from 45.75 mc all the way down to 41.75 mc and again the sound i-f signals will extend about 25 kc on either side of 41.25 mc.

The video i-f amplifier must have a reasonably flat over-all response so it will uniformly amplify the most important video i-f components. If the sound and video signals are separated before they reach the video detector and a separate sound i-f is used, the response curve will be similar to Fig. 16. Notice that the video carrier is about half-way down on the response curve, and the sound carrier falls in a dip on the response curve so that the output at the sound i-f frequency will be essentially zero. This dip is produced by a trap inserted in the video i-f amplifier and tuned to the sound i-f frequency.

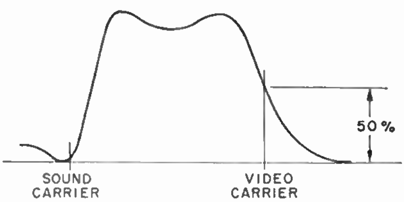


FIG. 16. Typical video i-f response curve for receiver with separate sound i-f.

If intercarrier sound is used, both the sound and video signals must reach the video detector. However, the sound i-f signal must be kept well down on the response curve, otherwise the resultant 4.5-mc beat signal produced will be so strong it will produce a grain effect in the picture. A typical video i-f response curve for a receiver with intercarrier sound is shown in Fig. 17.

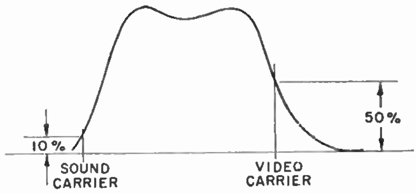


FIG. 17. Typical video i-f response curve for receiver with inter-carrier sound.

VIDEO I-F AMPLIFIER

Video i-f amplifiers can be divided into two general types depending upon the method used to obtain the desired pass-band. One method is to have a series of i-f coils that are heavily loaded, each tuned to a different frequency so that the result is an i-f amplifier having a response that is essentially flat over the desired pass-band. The other method is to use i-f transformers that are both over-coupled and heavily loaded so that the response of each transformer is quite broad. The transformers are adjusted to give the desired band-pass.

An i-f amplifier using a series of coils tuned to different frequencies is called a stagger-tuned i-f amplifier. A

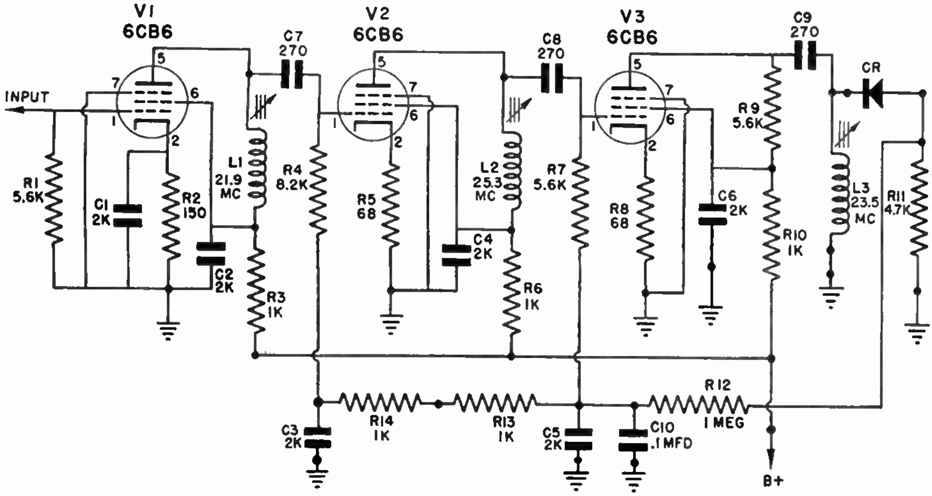


FIG. 18. A stagger-tuned video i-f amplifier.

typical example is shown in Fig. 18. Notice that each of the coils is adjusted to a different frequency. Also notice that instead of two windings on each of the i-f coils as on the i-f transformers in a radio receiver, each i-f coil has only a single winding. The coil in the plate circuit of V1 is loaded by the resistor in the grid circuit of V2. Similarly the coil in the plate circuit of V2 is loaded by the resistor in the grid circuit of V3, and the resistor in the plate circuit of V3 loads the coil following it. The net result of staggering the frequencies to which the coils are tuned, and loading the coils heavily is a broad-band i-f amplifier.

Notice that the coils have no capacitors connected in parallel with them as in a radio receiver. Actually, the output capacity of the tube is in parallel with the coil, and at the high frequency used, this capacity is all that is needed in the resonant circuit.

A schematic diagram of an overcoupled video i-f amplifier is shown in Fig. 19. In this i-f amplifier, the i-f transformers have both primary and secondary windings, and either the primary or the secondary winding of each of the transformers is loaded with a resistor to lower the Q and broaden the response.

The video i-f amplifier shown in Fig. 19 is in many respects similar to the i-f amplifier in a radio receiver. However, again there are no condensers in parallel with the coils, and traps are used in the circuit.

In the input to the first video i-f amplifier is a trap tuned to 39.25 mc. This trap is an adjacent-channel picture trap. Its purpose is to prevent interference by the video signal from the channel immediately above the channel to which you are tuned. The trap is inserted because the video carrier frequency of the adjacent channel is only 1.25 mc above the upper limit of the channel to which the receiver is tuned.

In the circuit between the first and second video i-f stages, there is a series resonant trap tuned to 41.25 mc

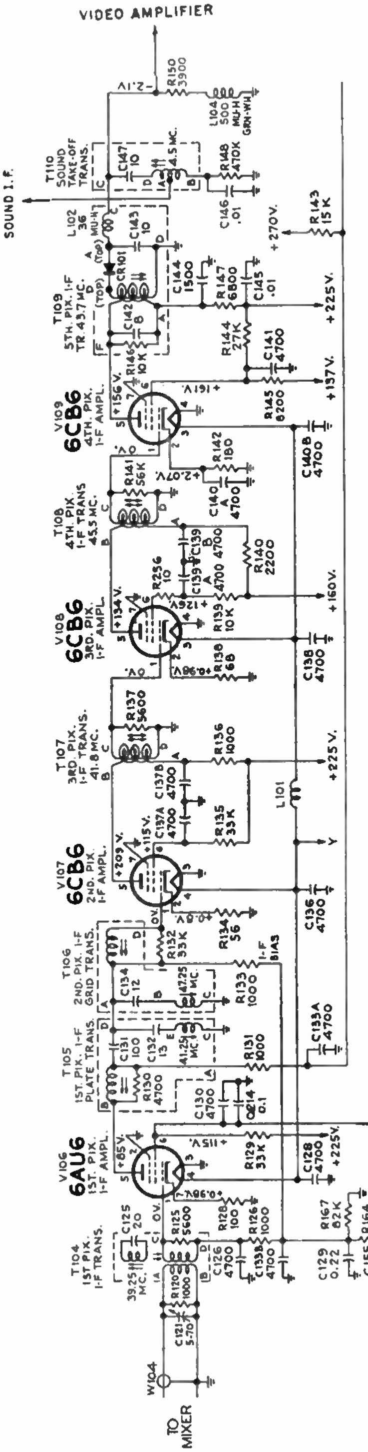


FIG. 19. A typical video i-f amplifier, using a 45.75-mc i-f.

Courtesy RCA

and one tuned to 47.25 mc. The 41.25-mc trap is used to keep the sound carrier down on the response curve as shown in Fig. 17. (The receiver from which this circuit was taken uses intercarrier sound). The 47.25-mc trap is an adjacent channel sound trap. This trap is used to eliminate interference from the sound of the channel immediately below the one to which the receiver is tuned.

THE VIDEO DETECTOR

The television signal at the output of the video i-f amplifier is an rf signal with the modulation containing the video signal and the synchronizing pulses. The signal is normally fed to the video detector, which is almost always some type of diode detector. A typical diode detector is shown in Fig. 20. The signal is fed to the cathode of the tube so the detector conducts only on the negative half of the rf cycle. The output signal obtained from the detector will be like Fig. 21B. This type of connection is frequently used so that the dc voltage developed across the diode load resistor will be negative with respect to ground and can therefore be used either as agc or to control the agc amplifier. The resulting video signal has a positive picture phase.

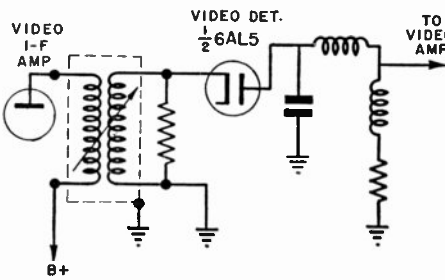


FIG. 20. A typical diode detector.

The polarity of the video signal can be reversed by reversing the connections to the diode. The video signal will be like the one shown in Fig. 21A. With the detector reversed, the sync pulses and the video signal information reverse in polarity, and the video signal is said to have a negative picture phase. Notice this important difference between the detector in a radio receiver and the video detector in a television receiver. In radio we are unconcerned about which half of the rf signal we rectify, but in television, reversing the polarity of the detector reverses the polarity of the output signal.

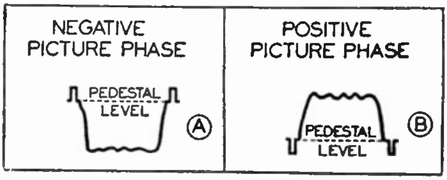


FIG. 21. When a diode video detector is connected as in Fig. 20, the output signal has a positive picture phase. If the diode connections are reversed, the output signal has a negative picture phase.

Many modern television receivers use a germanium crystal as the video detector. A typical example of this type of circuit is shown in Fig. 22. The operation of this circuit and the video signal produced in the output are the same as in the circuit in Fig. 20. The crystal will pass current in only one direction and therefore its operation is similar to that of the diode tube. Again, reversing the connections to the diode would reverse the polarity of the video signal.

The coils shown in the video detector output circuit are peaking coils. These coils are used to improve the high-frequency response of the detector output circuit. They do this by resonating with the detector output capacity and the distributed capacity in the circuit at a frequency above the normal high-frequency cut-off of the circuit. This reduces the shunting effect of the capacities and improves the response at high frequencies.

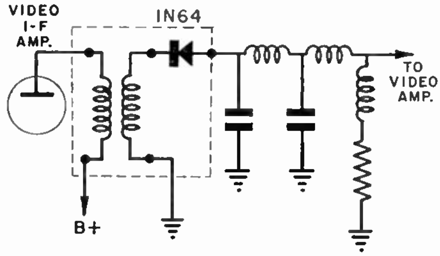


FIG. 22. A typical video detector using a germanium crystal as the detector.

Video Amplifier and DC Restorer

VIDEO AMPLIFIER

The video amplifier in a television receiver can be compared to the audio amplifier in a radio receiver. The rectified signal at the output of the video detector is fed to the video amplifier where the signal is amplified to obtain the signal amplitude needed to drive the picture tube. In an audio amplifier the output stage is normally a power amplifier that supplies power to the loudspeaker. In a video amplifier, the output stage is a voltage amplifier designed to provide a high-voltage signal to control the picture tube beam current.

A typical resistance-coupled amplifier stage is shown in Fig. 23. The amplifier shown is suitable for use as an audio amplifier where it must amplify signals over a limited frequency range. A video amplifier, however, must amplify frequencies from about 10 cycles per second to 4 mc. Let us consider what would happen if we tried to use a circuit similar to Fig. 23 as a video amplifier. At frequencies within the audio range the amplifier would function satisfactorily. However, on low video frequencies below about 50 cps, the reactance of the coupling condenser C2 would become appreciable (the reactance of a condenser increases as the frequency decreases). Therefore at the low video frequencies condenser C2 and resistor R4 would form a voltage divider, and only a portion of the signal developed by the tube would be available as useful output voltage. Another disadvantage would be that at low frequencies there would be an appreciable phase shift. Remember that the voltage and current are 90° out of phase in a capacitive circuit. In a circuit consisting of capacity and resistance, the phase displacement will be somewhere between 0 and 90°, depending upon the ratio of resistance to reactance in the circuit. As the frequency of the video signal goes down, the output will decrease, and the signal will undergo a phase shift. At very low video frequencies, the reactance of the capacitor may be so large that there is little or no signal available in the output. A loss of the low-frequency

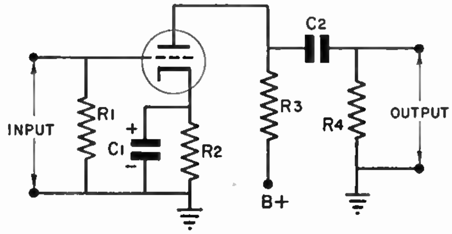


FIG. 23. A resistance-coupled amplifier stage.

video signals and the accompanying phase shift will result in smearing of large objects in the picture.

The cathode by-pass condenser C1 will also affect the low video frequencies. Unless a large capacity condenser is used, the cathode resistor R2 will not be effectively by-passed at the low frequencies and as a result there will be considerable degeneration. This will result in a further falling off of the output signal at low video frequencies.

This circuit will also prove unsatisfactory at the high video frequencies. Remember that in a vacuum tube, there are interelectrode capacities. The capacity from the plate of the tube to the cathode will be several mmf. The plate-to-cathode capacity will in effect be placed directly in parallel with the load resistor R3. In addition, distributed capacities in the circuit will also shunt R3 and R4. As the frequency increases, the capacitive reactance of a condenser decreases. Therefore at the higher video frequencies the shunting capacity plus the output capacity of the tube will act as a low reactance in parallel with the tube load. Therefore at the high video frequencies, the effective value of the plate load will decrease and the gain will be less than it is at low and middle frequencies.

From the preceding discussion you can see that a resistance-coupled amplifier such as is used as an audio amplifier would be totally unsuitable as a video amplifier. However, we can modify the circuit as shown in Fig. 24 and obtain satisfactory results from it. Let us look at Fig. 24 and compare it with the resistance-coupled amplifier in Fig. 23. The cathode by-pass condenser C1 is usually larger in a video amplifier than in an audio amplifier. This will reduce low-frequency degeneration. Another way of eliminating this problem is to omit C1 entirely, and then there will be some degeneration at all frequencies which will tend to flatten the amplifier response, because if the gain increases, the degeneration will also increase.

The coupling condenser C2 will also be made larger than in the audio amplifier. The larger coupling condenser will have a lower reactance at low frequencies. C2 and R4 will still continue to act as a voltage divider at low frequencies, but if the capacity of C2 is made large and the resistance of the grid resistor made as large as possible, the reactance of the condenser will be so small even at low video frequencies

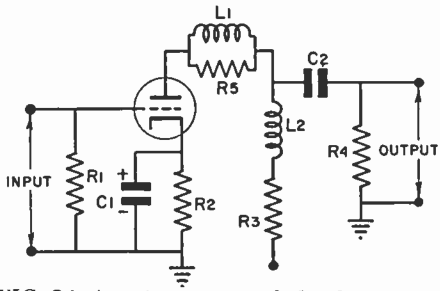


FIG. 24. A resistance-coupled video amplifier.

(in comparison with the resistance of the grid resistor), that very little voltage will be lost across the condenser, and the phase shift introduced will be negligible.

Coils L1 and L2 are peaking coils. These coils are added to the circuit to improve the high-frequency response of the amplifier. Remember that at the high video frequencies the plate load is shunted by the output capacity of the tube plus the distributed capacitance in the circuit. As the frequency increases, the reactance shunting the load decreases, and the gain will therefore fall off. One way of keeping this effect at a minimum is to use a low value of plate load resistance. If the load resistance is already low, then the low reactance of the shunting capacities will have less effect on the gain of the amplifier. The coils L2 and L1 are then inserted to resonate with the shunting capacity and form a circuit that is resonant at the higher frequencies. The resonant circuit produced has a high impedance and at the higher frequencies eliminates the shunting effect of the output capacity.

The peaking coils will have the effect of keeping the gain of the stage constant up to a higher frequency than could be obtained without the coils. However, at frequencies above the resonant frequency of the peaking coils and circuit capacities, the gain will fall off rapidly.

The component values in a resistance-coupled audio amplifier stage usually are not too critical. Although any change will have some effect on the gain and frequency response of the stage, in most cases a small change in a part value will not have any noticeable effect on the performance of the stage at audio frequencies. In a video amplifier, however, the component values are much more critical and a change in a part value will frequently affect the performance of the stage very noticeably. As a matter of fact the peaking coils and the coupling condenser are usually mounted some distance away from the chassis to keep the distributed capacity in the circuit at a minimum. Simply pushing the peaking coils and the coupling condenser next to the chassis will usually reduce the high-frequency response of the amplifier appreciably.

The video amplifier shown in Fig. 25 is a direct-coupled stage. The video signal at the output of the video de-

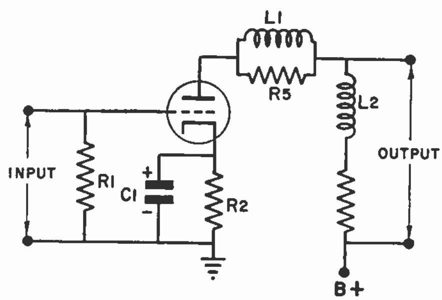


FIG. 25. A direct-coupled video amplifier.

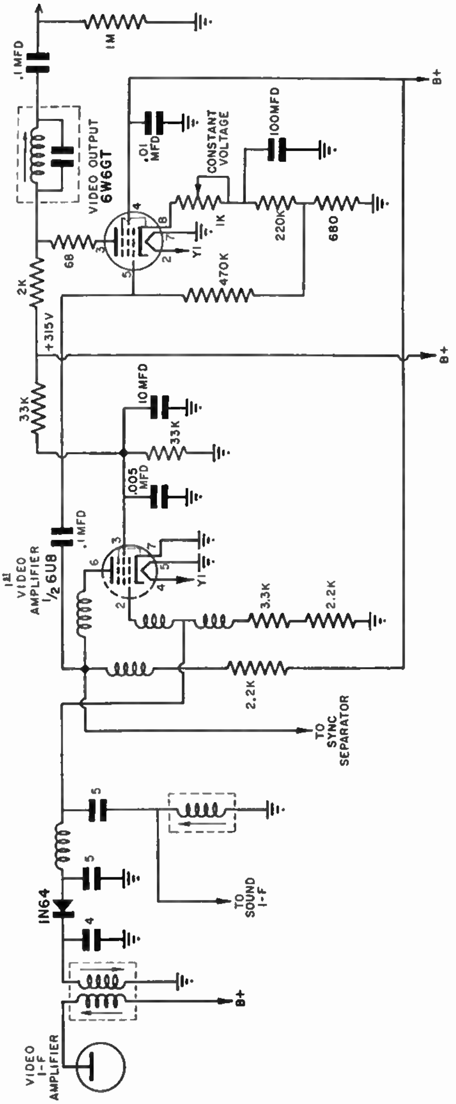


FIG. 26. A typical video detector followed by a two-stage video amplifier.

tector is actually a pulsating dc signal. When this signal is applied to an amplifier similar to Fig. 24 the dc component of the signal will not be passed by the coupling condenser C2. This difficulty, plus the undesirable effect of C2 at low frequencies, can be overcome by the use of a direct-coupled video amplifier. In this type of amplifier the coupling condenser C2 is omitted and the signal at the output of the amplifier will contain both ac and dc components. Direct-coupled video amplifiers are sometimes used in television receivers, but since the output of the amplifier is coupled directly to the picture tube, changes in signal level will frequently have a noticeable effect on picture brightness and the brightness control may require adjustment when switching from one channel to another. In addition, any change in the current flowing through the video amplifier will have a noticeable effect on picture brightness. In general, although this type of circuit may present some advantages it is not as flexible as the resistance-capacity coupled type of amplifier.

Typical Video Amplifiers. A typical video detector and two-stage video amplifier is shown in Fig. 26. Notice that peaking coils are used in the plate circuit of the first video amplifier and in the video detector output circuit to improve the high-frequency response of the amplifier. A 4.5-mc trap is used between the plate circuit of the video output stage and the grid of the picture tube to keep the 4.5-mc sound signal from the picture tube. (The receiver from which this circuit was taken uses intercarrier sound and the 4.5-mc sound signal is present in the video detector output).

The signal at the output of the video detector has positive picture phase. This means that the sync signals swing negative. As you know, a resistance-capacity-coupled stage reverses the signal phase 180° and therefore at the output of the first video amplifier we will have a negative picture phase. The signal then undergoes an additional 180° phase reversal in the video output stage so that at the output of this stage we again have positive picture phase. The signal is then fed to the grid of the picture tube so that the sync signals swinging negative will cut off the beam, driving the tube to cut off during the retrace period. The video signal will vary from zero in the white elements in the picture to a high negative signal in the black portions of the picture.

Another typical video detector followed by a single video amplifier stage is shown in Fig. 27. The coils L1, L2, L3, L4, and L5 are peaking coils used to improve the high-frequency response. Both R1, the detector load resistor, and R2, the amplifier load, are comparatively low resistances to keep the effect of the shunting capacities at a minimum.

At the output of the video detector we have a positive picture phase and the signal undergoes a 180° phase reversal in the video amplifier so that at the output of the video amplifier we have a negative picture phase and the sync pulses swing positive. If we apply this signal to the grid of the picture tube, the sync pulses would drive the tube into the conducting region instead of into the cut-off region. The video signal representing the dark signal areas would have a maximum positive value which would cause a high beam current and produce a bright area on the picture tube. Similarly, the signal representing the bright area would be reversed, and the light areas would be reproduced dark. In other words we would have a negative picture. This difficulty can be overcome quite simply by feeding the video signal to the cathode of the tube instead of to the grid. The sync pulses swinging positive simply make the cathode positive with respect to the grid and blank out the tube during the retrace period. Similarly the

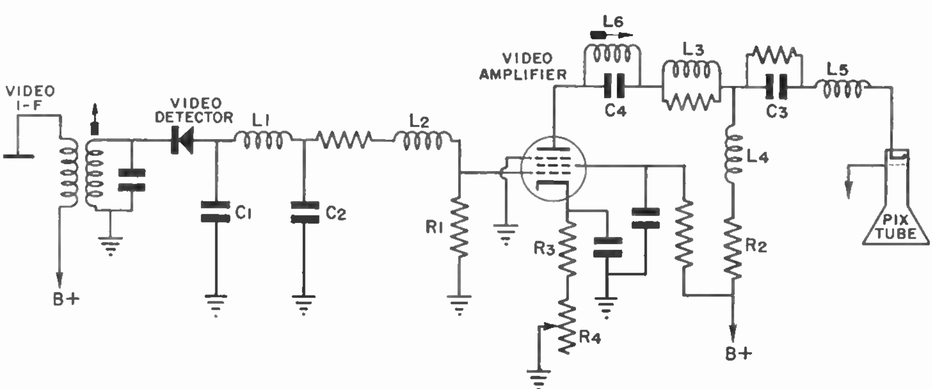


FIG. 27. A typical video detector followed by a single-stage video amplifier.

dark areas of the picture, which are produced by the maximum amplitude of the video signal will drive the cathode positive, reducing the beam current.

If we want to feed the video signal to the grid of the picture tube, we can reverse the picture phase simply by reversing the connections to the video detector. We already mentioned that reversing the video detector reverses the polarity of the video signal. You can see now why the polarity of the signal at the output of the video detector is important, whereas in radio the polarity of the signal at the output of the sound detector is unimportant.

THE DC RESTORER

The dc component of a television signal will be lost in a resistance-capacitance coupled video amplifier because the coupling condenser will not pass dc. We can restore the dc component simply by eliminating the fixed bias on the last video stage and allowing the sync pulses that are applied to the grid of the tube to develop their own bias by means of rectified grid current flow through a grid resistor of high ohmic value. Of course, in order to restore the dc component by this method, the signal applied to the grid of the last video amplifier must have negative picture phase so that the sync pulses drive the grid positive and cause grid-current flow.

A typical video output circuit which reverses the phase of the signal and at the same time restores the dc component in the correct manner to make the pedestals line up is shown in Fig. 28. Although a triode tube is shown in the circuit, a pentode tube could be used

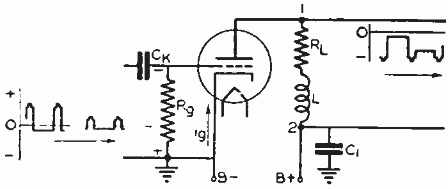


FIG. 28. Video output stage designed to restore the dc component and align the pedestals.

just as well. When an ac signal of the form shown at the left in Fig. 28 (having a negative picture phase) is applied to the circuit, the output signal will be of the form shown at the right with pedestals all lined up to give proper restoration of the dc component and with the positive picture phase required if we are to feed the signal to the grid of the picture tube.

The grid resistor Rg plays an important part in the dc restoration process. The resistor normally has a high value, generally somewhere between .5 and 1 megohm. The operation of the circuit is comparatively simple. Notice the first two pulses shown (on extreme left). The amplitude of these pulses is considerably greater than the amplitude of the two pulses next to them. Because of the greater amplitude of the two pulses on the left, the grid will swing highly positive and an appreciable grid current will flow. The grid current will develop a high bias, which in turn will reduce the gain of the stage. With the two pulses having the smaller amplitude, the grid will not be driven so far positive, the bias will not be as great, and the gain of the stage will be greater. The net result is that the pedestals will all be lined up in the output as shown in the signal to the right of the circuit. The alignment is not perfect, but it is near enough for all practical purposes. The operating bias on the output stage will shift with each change in line brightness so that the instantaneous grid bias will depend on the average brightness of a line. Since the average brightness ordinarily does not change from line to line, the time constant of the resistance and capacitance in the grid circuit of the stage can be made fairly large so that the dc level will remain essentially constant for a given line.

Early television receivers almost always used a dc restorer. Some used a diode for dc restoration and others an arrangement like Fig. 28. However, the trend in later sets was to omit the dc restorer or use the picture tube for dc restoration.

Forming a Picture

As you already know, in television the picture is sent by scanning it line by line. You can compare this action to the process that your eye goes through in reading this page. You do not glance at the page and extract all the information at one glance, but rather you read the page line by line. When you reach the bottom of the page your eye moves quickly to the top of the next column and you read it line by line. In transmitting a picture, the same procedure is used. The picture is focused on the camera tube and then is scanned one line at a time starting at the top and working toward the bottom. The picture is broken up into a total of 525 lines. Instead of scanning the first line and then the second and then the third etc. the camera scans the first line, then the third, then the fifth etc. until all odd numbered lines have been scanned. The electron beam is then moved back to the top of the tube and the even numbered lines are scanned. Therefore, for every complete picture, the vertical sweep must go through two cycles, and the horizontal sweep 525 cycles.

The standard in use in this country calls for 30 complete pictures per second. To accomplish this, the vertical oscillator must operate at 60 cycles per second and the horizontal oscillator must operate at 15,750 cycles per second.

In order to reproduce the picture being picked up by the camera, the sweep oscillators in the television receiver must keep in step with the sweep oscillators in the television camera. In other words the oscillators must not only operate at the same frequency, but when the horizontal oscillator in the television transmitter starts the electron beam traveling from the left to the right, the sweep oscillator in the receiver must also start the beam moving from the left to the right. Similarly the vertical sweeps must be kept in exact synchronization.

The simplest way to keep the sweep oscillators in the television receiver in synchronization with the oscillators at the transmitter is to transmit synchronizing pulses to control each oscillator. A horizontal synchronizing pulse is transmitted at the end of each line, and a vertical synchronizing pulse at the end of each field.

In the television receiver these pulses must be separated from the video information and then separated from each other and used to control the oscillators.

In addition to controlling the oscillators to keep them in synchronization with the oscillators in the transmitter, the bias on the picture tube must be adjusted to a value which will make the pedestals in the television signal line up with the cut-off point on the grid voltage-brightness characteristic curve of the picture tube. The sync pulses will then drive the tube into the blacker-than-black regions so that the tube will be cut off during the retrace period. The video signal will vary the grid voltage between cut off and a minimum value so that brightness will vary in accordance with variations in the video signal.

THE CATHODE-RAY TUBE

There are several circuits that can be used to control the bias and hence the brightness of the picture tube. If direct coupling is used between the video output stage and the cathode-ray tube, a circuit like Fig. 29A may be used. In this circuit when the tube is conducting there will be a voltage drop across the load resistor and the plate end of the resistor will be negative. This means that if the potentiometer is rotated all the way to point 4, the cathode will be positive with respect to the grid. As the potentiometer is rotated towards point 3, the positive voltage on the cathode of the tube is reduced until when the control is rotated all the way to point 3 the cathode and grid will be at approximately the same potential. The resistor in the cathode circuit of the picture tube is inserted to protect the picture tube. If the grid should become positive with respect to the cathode (it might during the warm-up period), the resistor in the cathode circuit will limit the tube beam current.

Often the video signal is fed to the cathode of the picture tube instead of to the grid. When this arrangement is used a circuit similar to Fig. 29B can be used to control the bias on the picture tube. The grid might be connected directly to ground as shown in the diagram or in some cases it can be connected to the dc restorer output. The restoration voltage is then applied to the grid of the tube and the video signal to the cathode.

It is important to have a variable bias on the picture tube. By varying the bias, the brightness of the picture tube can be changed. If the bias of the tube cannot be varied over a suitable range, the pictures obtained will have either too much or too little contrast. In a few receivers, automatic brightness control circuits were used, but these circuits have in general disappeared in favor of the manually operated brightness control, that give improved control.

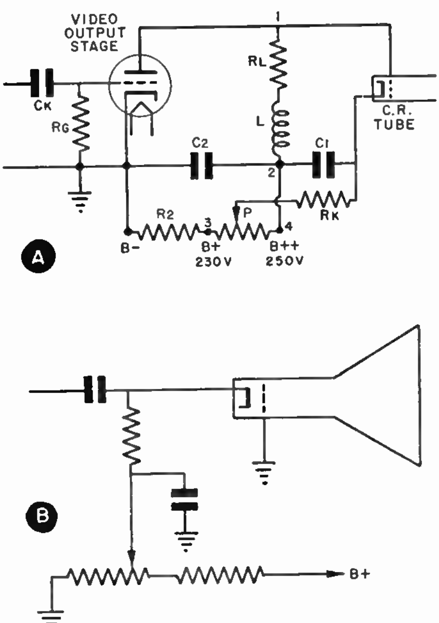


FIG. 29. The circuits shown provide a means for inserting an adjustable positive bias in series with the video signal applied to the grid and cathode of the picture tube. In the circuit at A, direct coupling is used. In B, resistance-coupling is used.

SYNC CIRCUITS

We have already mentioned that synchronizing pulses are transmitted in order to keep the horizontal and vertical oscillators operating at the correct frequency. The horizontal sync pulses are sent at the end of each line, and the vertical sync pulses at the end of each field. We have already shown what a typical video signal looks like and you know that the sync pulses are contained in the composite video signal. To control the oscillators, the sync pulses must be separated from the video signal so that only the pulses are fed to the oscillators.

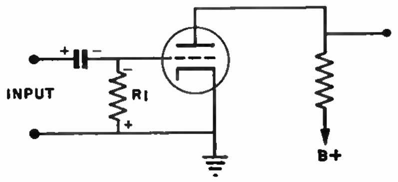


FIG. 30. A typical sync separator.

The composite video signal containing the sync pulses and the video information may be taken off anywhere between the video detector and the picture tube and fed to the sync separator. If the signal at the video detector has negative picture phase, it can be fed directly to the sync separator. However, if the signal at the output of the video detector has positive picture phase, it must be inverted. The simplest way to accomplish this is to take off the signal at the output of the first video amplifier. Remember that an amplifier inverts the picture phase.

Since the amplitude of the sync pulses is not the same as the amplitude of the video signal, it is comparatively simple to separate the sync pulses from the video information. A typical sync-separator is shown in Fig. 30. The grid resistor R1 is usually a rather large resistor. The tube is operated with a low plate voltage; and the sync pulses applied to the input of the separator must be positive pulses and drive the tube into the grid current region to bias the separation.

When the sync pulses swing positive, the tube will conduct heavily, and it will draw grid current, charging the grid condenser. A pulse identical to the sync pulse, but reversed in phase will appear in the output. After the sync pulse has been transmitted, the coupling condenser will begin the discharge through the large value of grid resistance, placing a high negative bias on the tube. The tube will be cut off so that the video information will not appear in the output.

It is usually impossible to effect complete separation with a single separator; however, in most cases the separation is good enough. If more complete separation is desired, two sync-separators may be used. Often the second stage is designed primarily as an amplifier so that in addition to improving the separation of the sync pulses from the video information, the pulses will receive considerable amplification.

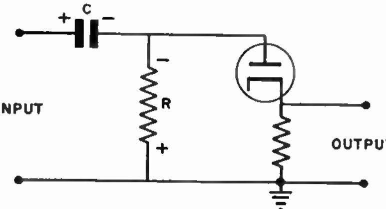


FIG. 31. A diode sync separator.

A diode may also be used as a sync separator if the circuit shown in Fig. 31 is used. When this circuit is used, the sync pulses drive the plate of the tube positive, causing the tube to conduct and charge the condenser C. After the sync pulse is transmitted, the condenser discharges through R, which is

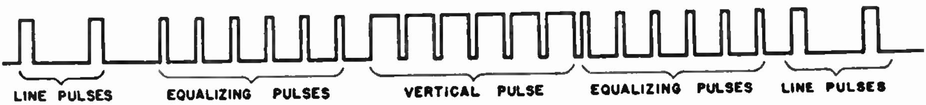


FIG. 32. The line-equalizing vertical sync pulse in a TV receiver.

usually quite large, and a voltage having the polarity shown is developed across the resistor. This voltage biases the tube so that it will not conduct while the video signal is being transmitted.

The triode sync-separator shown in Fig. 30 reverses the phase of the sync pulses 180° but the diode shown in Fig. 31 produces sync pulses having the same phase in the output as the pulses applied in the input. Of course, the output of the triode will be greater than the output of the diode. A diode sync separator is almost always followed by a suitable sync amplifier.

At the output of the sync chain, both the vertical and horizontal sync pulses are present. If the pulses are fed to an integrating circuit, only the vertical sync pulses will be present in the output. If the pulses are fed to a differentiating circuit, only the horizontal pulses will appear in the output.

The sync pulses at the output of the sync chain can be fed directly into an integrating circuit and then to the vertical oscillator. The vertical synchronizing pulse transmitted is shown in Fig. 32. Notice that instead of one big pulse a serrated pulse is transmitted. The serrations are needed in order to maintain control of the horizontal oscillator during the vertical blanking interval (the period during which the vertical sync pulse is transmitted).

At the output of the sync separator the serrated vertical sync pulse is fed to an integrating circuit like Fig. 33 which *adds* the serrated vertical pulse, and produces a single pulse in the output. The pulses can then be used to control a vertical sweep oscillator.

The schemes used to control the horizontal oscillator are usually more complicated than those needed to control the vertical oscillator. This is due to the fact that the horizontal sweep operates at a much higher frequency. Since the horizontal sweep control is so completely tied in with the horizontal oscillator, we will discuss these circuits together.

SWEEP CIRCUITS

Some of the early television receivers used picture tubes with electrostatic deflection. However, this type of tube has practically disappeared, and practically all TV receivers use picture tubes with magnetic deflection. We will

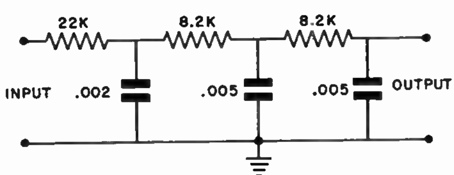


FIG. 33. An integrating circuit.

therefore consider only sweep circuits designed for magnetic deflection tubes.

To deflect the electron beam linearly, the current through the deflection yoke must be a saw tooth, such as the one shown in Fig. 34. To produce a saw-tooth current, a trapezoidal wave shape like that shown in Fig. 35 must be applied to the deflection yoke. This type of wave shape can readily be obtained either from a blocking oscillator or from a multivibrator. Both oscillators are suitable for use in television, not only because they can be made to produce the required wave shape, but also because

FIG. 34. The current in the deflection yoke must be a sawtooth current.

their frequency can readily be controlled.

A typical blocking oscillator is shown in Fig. 36. Transformer T in the circuit provides the feedback from the plate circuit to the grid circuit. Transformer connections are such that when the circuit is in operation, the feed-back voltage drives the grid positive, just as in a conventional oscillator. The resulting flow of grid current through the grid resistor and potentiometer produces across these resistors a voltage drop which drives

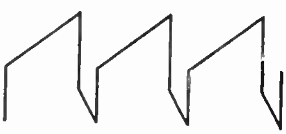


FIG. 35. A trapezoidal voltage wave must be applied to a practical coil to produce a sawtooth current.

the grid highly negative and at the same time charges condenser C. This charging action lasts only a very brief interval equal to the time required for the negative grid to stop all electron flow in the circuit. Condenser C then begins discharging through the grid resistor and potentiometer at a rate determined by the values of both. When the charge at C has leaked off enough to lower the negative C bias on the grid sufficiently to allow plate current to flow again, feed back then occurs again, driving the grid positive and causing a repetition of the entire cycle.

The frequency of the oscillator shown in Fig. 36 is controlled by varying the resistance of the potentiometer in the grid circuit. The potentiometer should be adjusted until the

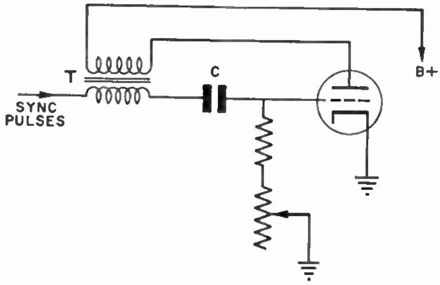


FIG. 36. A blocking oscillator which can be controlled by synchronizing pulses.

oscillator is operating at approximately the correct frequency. The signal on the grid of the blocking oscillator will be like Fig. 37. Notice the curved portion which represents the time during which the condenser C is discharging to the cutoff point through the resistance in the grid circuit. If we adjust the oscillator so that it is operating slightly below the correct frequency and then feed a positive sync pulse into the grid circuit, the sync pulses will show up in the grid curve as shown in Fig. 38. Therefore, the condenser discharges through the grid resistance lowering the grid bias, when the grid voltage has almost reached the cutoff point at which the tube would conduct again, the sync pulse arrives and immediately drives the grid into the conduction region. The tube will then conduct, feedback occurs again, driving the grid positive and causing a repetition of the entire cycle. With this arrangement, the sync pulses will con-

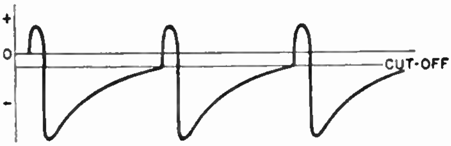


FIG. 37. Blocking oscillator grid curve.

trol the oscillator frequency and keep it in synchronization with the oscillator in the transmitter.

With the circuit of Fig. 36, the output of the blocking oscillator will be a saw tooth, but the deflection yoke current will not be a saw tooth. By modifying this circuit slightly and adding a condenser and resistor in the output as shown in Fig. 39 we can obtain the wave shape needed to drive the sweep output tube so that a sawtooth current will flow in the deflection yoke.

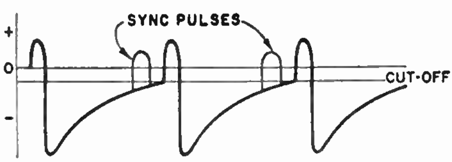


FIG. 38. Blocking oscillator grid curve showing when the synchronizing pulses appear.

Blocking oscillators are frequently used in the vertical sweep circuit of a television receiver. The method we have discussed is entirely suitable for use in controlling the frequency of an oscillator at the vertical sweep frequency of 60 cycles per second.

Multivibrator circuits are also often used as sweep oscillators. They are particularly suitable for use in the horizontal sweep circuit. A typical multi vibrator is shown in Fig. 40. In this circuit a parallel resonant circuit is used in one stage of the multivibrator circuit. The circuit resonates at 15,750 cps and is used to adjust the oscillator to approximately the correct frequency. The potentiometer in the grid circuit of the other section of the multivibrator is a fine-frequency control and is used to bring the oscil-

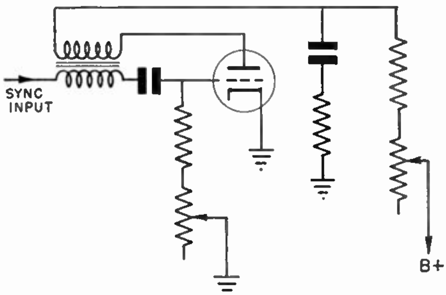


FIG. 39. A blocking oscillator that will produce a trapezoidal wave in the output.

lator to the correct frequency after a coarse adjustment has been made by means of the resonant circuit in the other stage of the multivibrator.

The output of a multivibrator is normally a series of rectilinear pulses, but by means of a discharge circuit consisting of a condenser and a resistor in series between the plate (pin 5) of the tube and ground, a trapezoidal wave may be obtained.

The complete horizontal sweep circuit of a television receiver is shown in Fig. 41. Notice that the multivibrator circuit shown in Fig. 40 is used.

The horizontal sync pulses are fed

to a sync amplifier that splits the sync pulses and provides the pulses of opposite polarities in the output. The pulses are fed to a phase detector and compared with a pulse fed back from the output of the horizontal sweep circuit. As long as the pulse fed back from the horizontal sweep output is of the proper frequency and phase relationship to the sync pulses, there will be no voltage developed by the phase detector. However, if the frequency or phase should vary, a volt-

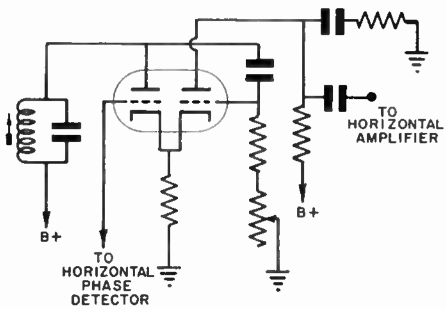
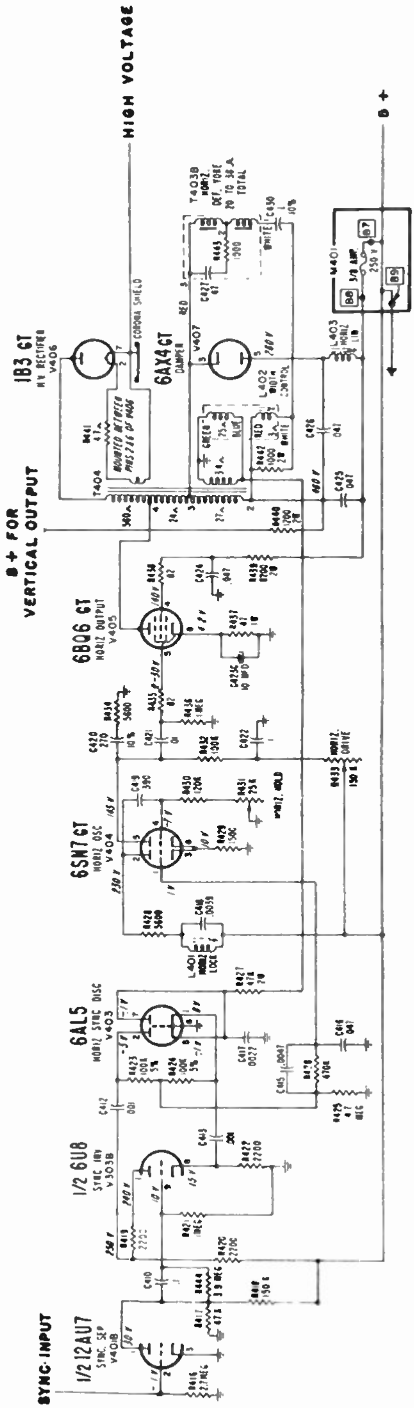


FIG. 40. A multivibrator for use as the horizontal sweep generator.

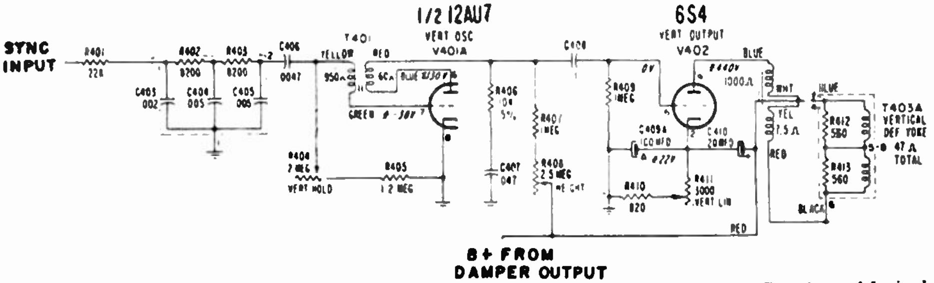
age will be developed by the phase detector that is fed to the grid of the horizontal oscillator. This voltage will shift the horizontal oscillator frequency to lock it in with the sync pulses.

The horizontal sweep output tube is usually a tube with a high current capacity. A saw tooth current having a high amplitude is developed in the output of this stage and fed to the horizontal deflection yoke through the horizontal output transformer. At the end of a horizontal line, the grid of the horizontal output tube is driven sharply negative causing the plate current in the tube to drop to zero



Courtesy Admiral

FIG. 41. A complete horizontal sync and sweep system.



Courtesy Admiral

FIG. 42. A complete vertical sweep circuit.

almost instantly. The field in the deflection yoke and the horizontal output transformer must collapse almost instantly. Actually, when the plate current in the horizontal output tube is cut off, the horizontal deflection yoke begins to oscillate. The yoke is permitted to oscillate through one half cycle to move the electron beam rapidly from the right side of the picture back to the left side to start the next line. As the deflection yoke starts to go through the next half cycle of the oscillation, the plate of the damper becomes positive and the tube conducts and damps out the oscillation. The plate current in the horizontal output tube will begin to increase and the next line will start.

We mentioned that when the electron beam reaches the right side of the tube the plate current in the horizontal output tube is cut off almost instantly. The field in the deflection yoke and horizontal output transformer must collapse almost instantly. A high-voltage winding is wound on the horizontal output transformer, and the rapid collapse of the field induces a high voltage in this winding, which is fed to a rectifier, rectified, and used as the high voltage to operate the picture tube.

This circuit is typical of the horizontal sweep circuits in use in modern television receivers.

A typical integrating circuit, blocking oscillator and vertical sweep output is shown in Fig. 42. Notice that the voltage applied to the blocking oscillator is applied to a potentiometer which is used to control the amplitude of the output signal. This control is used as a "height" control.

A resistor is inserted in the cathode circuit of the vertical output tube so that the tube bias can be adjusted to operate the tube on the linear portion of its characteristic curve. This control is therefore called a linearity control.

In the output of the horizontal sweep circuit, a damper tube is used to damp out the oscillations that would occur in the deflection yoke. Oscillation is not such a problem in the vertical sweep and it can be damped by means of damping resistors placed in parallel with the deflection yoke.

Many variations of these circuits can be found in television receivers. However, the basic principles of operation are similar to those discussed.

Automatic Gain Control

Automatic gain control, abbreviated agc, corresponds to automatic volume control in a radio receiver. Agc is necessary in order to obtain satisfactory contrast as the receiver is switched from one channel to another and also to compensate for any variations in signal strength in the signal being received.

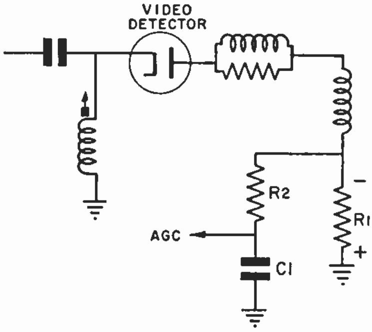


FIG. 43. A simple method of obtaining agc from the video detector.

In some television receivers comparatively simple agc circuits are used. A simple diode detector is shown in Fig. 43. The incoming rf signal produces a current flow from the cathode to the plate of the diode through the peaking coils and through the plate load resistor R1, producing a voltage drop across it having the polarity shown. This voltage will depend upon the amplitude of the signal reaching the diode.

By using a suitable R-C filter such as R2 and C1, the pulsating dc present across R1 can be filtered and a dc voltage suitable for use as agc will be available across C1. This voltage can be fed to the grids of the rf amplifier and the video i-f tubes through suitable isolating networks.

Circuits of this type will give satisfactory results providing the variation and signal strength is not too great. When the signal varies over wide limits, an agc system similar to Fig. 44 will be more satisfactory. This type of circuit is called a keyed agc circuit.

In this circuit, the cathode of the tube has a high positive voltage placed on it to bias the tube. The plate of the tube is returned to ground through a special winding on the horizontal output transformer and a series of resistors. The pulses picked up in the special winding on the output transformer are applied to the plate of the tube and when the plate is driven positive with respect to the cathode, the tube will conduct, providing the grid bias is not too high. With the cathode connected to a high positive voltage, the bias is too high; therefore, this action alone will not cause plate current to flow in the tube. However, notice that in addition to the pulses fed to the plate of the tube, the sync pulses are also fed to the grid. The sync pulses drive the grid in a positive direction, reducing the bias on the tube so that the tube will conduct during the sync pulse interval.

Now let's stop and consider what the effect of this action will be on the voltage developed across resistors R1, R2, and R3. If the signal is strong, the sync pulse amplitude will be high and the grid will be driven far enough in a positive direction for a high plate current to flow. This will produce a high agc voltage across R1, R2, and R3, reducing the gain of the agc-controlled stages. On the other hand, if the signal is weak, the sync pulses will not drive the grid as far positive and the plate current will be less, with the result that the agc voltage developed will be less and the gain of the agc-controlled stages higher. The agc voltage developed will therefore depend on the amplitude of the sync pulses and the setting of R2. R2 is made variable so the receiver sensitivity may be adjusted for best results in either fringe areas where the signal is weak or in primary areas where a strong signal is picked up.

This type of circuit will give much better results than the simple agc circuit shown in Fig. 44. The circuit will respond very rapidly to change in signal amplitude and will not only automatically adjust the gain of the receiver when tuning from one channel to another, but also can in most cases take care of rapid signal fading such as might occur when the signal is being reflected by an airplane flying between the transmitter and the receiver.

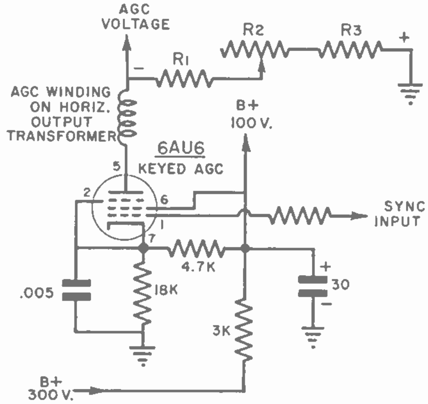


FIG. 44. A keyed agc circuit.

SOUND SYSTEM

We have not made a detailed analysis of the sound system because it is similar to the sound system in an FM receiver. Narrow band FM is used, and the maximum signal deviation is 25 kc. Many early TV receivers used two i-f stages and sometimes a limiter before the sound detector. However, most modern receivers use only a single sound i-f stage and a ratio detector.

The audio amplifier in a television

receiver generally consists of a single voltage amplifier stage followed by a power amplifier to drive the loudspeaker and is identical to the sound systems used in AM and FM receivers.

REVIEW OF LESSON

In reviewing this Lesson, try to visualize the frequency conversions that occur as the television signal progresses through the receiver. Learn the frequency ranges that are handled by each stage and section, and above all, try to visualize the characteristics of the television signal at each stage or section. Furthermore, keep in mind that in television the terms picture signal, video signal, image signal, and sight signal are used interchangeably. The terms sound and audio are likewise used interchangeably.

Lesson Questions

Be sure to number your Answer Sheet 49B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next Lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of Lessons before new ones can reach you.

1. What is the frequency separation between the sound carrier and the video carrier frequencies?
2. What is the frequency of the sound i-f amplifier in a receiver using inter-carrier sound?
3. Is the sound i-f signal at the output of the mixer higher in frequency or lower than the video i-f signal?
4. Why must the pass band for the sound i-f amplifier in a receiver using a separate sound i-f system be greater than the 50-kc value required for an FM system of 25-kc deviation?
5. Are the pedestals lined up in the signal voltage whicn exists across the load resistor of the diode video detector in a television receiver?
6. Should the video i-f carrier appear at the peak, the bottom, or half-way down on the video i-f response curve?
7. What change can be made in a diode video detector circuit in order to reverse the phase of the picture signal at the output of the video detector?
8. What phase should the picture signal have at the input to the picture tube if the signal is to be fed to the grid?
9. What effect does a resistance-capacitance-coupled video amplifier stage have upon the phase of the picture signal?
10. Will the sync pulses at the output of a diode sync separator be in phase or 180° out of phase with the sync pulses at the input to the separator?

BE PREPARED

Here is an old, old quotation—a warning—which has helped many a man avoid trouble, gain success, in personal and business affairs:

> **"It's too late to learn to swim when the boat begins to sink!"**

In other words, if you believe certain difficulties and troubles may be in the offing—*do something* NOW to get ready to handle them.

And along the same line of thought—if you see future opportunities coming up—*prepare* NOW to take advantage of them.

Foresight is a wonderful thing IF you *do something* about the conditions you see ahead.

J. M. Smith

PRACTICAL TRAINING IN TV SERVICING

ANALYZING TYPICAL TV RECEIVERS

REFERENCE TEXT 49BX

PIONEER HOME STUDY RADIO-TV SCHOOL
NRI

NATIONAL RADIO INSTITUTE
WASHINGTON, D. C.
ESTABLISHED 1914

STUDY SCHEDULE 49BX

This text is not intended as a regular study lesson—it outlines a Practical Training Plan for getting practical experience in television servicing. We recommend that you follow this plan if you expect to do TV service work.

FM3M1060 **1960 Edition** Printed in U.S.A.

ANALYZING TYPICAL TV RECEIVERS

TELEVISION servicing is a highly competitive business. Only the man who can find trouble and then locate and replace defective parts quickly can hope to succeed.

A knowledge of individual circuits is not enough. You must understand the receiver as a whole, and the relationship of its separate parts. To tell whether a receiver section is defective, you must know first what it is meant to do; then you must know how it does it.

The ability to repair a receiver quickly and surely comes with experience. It takes time to gain that experience. This Practical Training Plan has been designed to help you get that experience quickly.

You will be shown how to approach each repair job systematically, using the time-tested methods developed by experienced and successful servicemen.

To get this training and experience, you must have a standard TV receiver. Using this receiver you will learn to use the picture tube, the sound, and the receiver controls to apply effect-to-cause reasoning to find the bad section of the receiver. You will learn to analyze circuits and to locate the various sections and parts of a receiver from the schematic diagram. Later you will introduce defects and apply standard servicing methods to localize and find the cause of the trouble. In this way, through actual experience, you will learn the best and quickest servicing methods. Your ability as a serviceman will depend on your ability to locate trouble quickly using effect-to-cause reasoning, and on your proper use of test equipment. Once the trouble has been located, anyone who can handle a soldering iron can repair the set.

If you carefully follow the methods we outline, and study the sample circuits, you will gain as much experience as you would get in a year of service work.

In summary, the steps of this plan are:

1. Get a suitable receiver of the type recommended in this book.
2. Get the manufacturer's manual on the set so that you will have complete service information on it.
3. Check the operation of the set and learn just what all the controls are for.
4. Learn how to locate sections, stages, and parts in the set from the circuit diagram.
5. Analyze the circuit diagram to find out how the set works.
6. Follow a step-by-step procedure to introduce defects in the set.
7. Observe the effect of each defect on the operation of the receiver, and see how effect-to-cause reasoning can be applied.
8. Use each of the basic methods of localizing defects (such as signal tracing, signal injection, stage blocking, voltage measurements, etc.) to see which one is best for a particular defect.

This work book is intended to cover the first five steps, and another will give the rest of this Practical Training Plan.

Of course, you are not *required* to carry out this plan, but we strongly advise you to do so to get the greatest good from your course. Also, to get the most out of this instruction in TV servicing, you should first have carried out the corresponding plan on a radio. A radio is simpler to work on than a TV set, so you can learn how to service the radio much more easily. Then, once you have learned how the various service techniques are applied to the radio, it will be far easier to apply similar methods to a TV set.

Now that you have an understanding of the basic plan, let's go on to details for each of these steps.

OBTAINING RECEIVER

Your test receiver should be one of standard make, using electromagnetic deflection. Also, it should use either an rf oscillator or a flyback type of high-voltage power supply. There are no other restrictions on what set you use. Although you may be able to find an old 7-inch set using electrostatic deflection that will cost you little or nothing, much of the practical experience you would get from working on it would be of no value because such sets used circuits different from those usually encountered by the serviceman.

You can get your test receiver from your local radio store, from mail-order or local wholesale supply houses, or by purchasing one from a neighbor. If you already have a satisfactory set, you can use it; the Practical Training Plan will not damage it.

It is not necessary for you to buy a *new* receiver. A used set is perfectly all right. *It is essential, however, that the set be in good condition.* Otherwise, when introducing a defect, you would not be sure whether the results were due to the defect that you introduced or to some other defect already in the set. If the set is not in good condition, check the tubes and look for obvious defects such as burnt or charred resistors. If you cannot repair the set, take it to some reliable TV serviceman and have him put it in first-class shape. Once you have completed the Training Plan, you will be able to handle the more difficult repair jobs yourself.

Then, be sure that your set is correctly installed so that it is working well on at least one local TV channel. Your set should be working at least as well as other receivers in the locality. If you cannot get help in making this possible, wait until you master the lessons on TV receiver installation before carrying out the Training Plan.

SERVICE MANUALS

Most manufacturers publish a service manual for their sets which contains the schematic diagram, sometimes a pictorial layout, a tube location chart, and pictures showing the location of the various adjustments and controls. Detailed instructions are usually given for adjusting the controls and for setting up the receiver. These service manuals are very valuable to the service technician.

You must get the manufacturer's service manual, or at least a schematic diagram, for the receiver that you are going to use. To attempt to service a TV set without a schematic diagram is like driving through a strange section of the country without a road map. You will waste a lot of time in trying to locate parts and trace out circuits. If you cannot get a diagram or service manual from the set manufacturer, his local distributor, or one of the diagram services, you can order one from NRI.

GENERAL PRECAUTIONS

Now, if you have a suitable TV set, you are ready to proceed to experiment with it. Before you start, let us go over certain precautions that you should take when working with any set.

First, remember that there are two dangerous power supplies in a TV set. One is the high-voltage supply used for accelerating the electron beam (voltages usually in excess of 10,000 volts); the other is the "normal" B voltage supply. Although the B supply voltage may be only about 300 volts or so, it is as dangerous as the high-voltage one, because the low-voltage supply in most TV sets (and in ordinary radios too) can deliver a fairly high current. Thus, there is danger not only of shock, but even of electrocution. With the high-voltage supplies, there is danger of a severe shock, but because the power supplies have, in most instances, a high internal impedence, there is less danger of its being fatal.

Because of the possibility of shock, you must be extremely careful while working on a TV set. When working on a "hot" set, make it a practice to *keep one hand in your pocket* so that there is less danger of making a complete path through the body. Also, when you first turn off the set, wait some time before working on it, so that the capacitors will have time to discharge. You should discharge the high-voltage and power-supply capacitors by shorting them with a screwdriver.

Do not work on your TV set while standing on a concrete basement floor or on a damp floor. Some sets have the chassis connected to one side of the power line. Do not touch a radiator, a cold-water pipe, or any other ground while working on such a set. When servicing these sets, you should use a 400-watt, 1:1 isolation transformer between the ac outlet and the receiver. This is necessary to reduce shock hazard and to protect your ac-operated test equipment.

There are also certain precautions to follow when handling the picture tube. First, remember that the picture tube is a large glass bulb, and is rather delicate. Also remember that there is a very high vacuum in the picture tube. Because of this, if you break the tube, there is danger if "implosion". The glass will fly all over the room.

Handle the picture tube with extreme care—do not scratch the surface of the picture tube, as this will weaken it; do not strike or bump the tube, and do not put any strain or pressure upon it. You should always wear shatter-proof goggles and heavy gloves when handling picture tubes. Many servicemen use thick vests or heavy canvas shop aprons also.

Notice that a picture tube has a very narrow neck. This neck is comparatively weak and the tube should *not* be handled by it. Handle the tube by the funnel and the edges; touch the neck only to guide the tube into position.

When placing a tube in a TV receiver, do not force it into position. If it does not slip into place easily, find the obstruction and remove it.

Most of the glass electromagnetic tubes have an outer coating of conductive material called "Aquadag". This outer "Aquadag" coating is grounded by means of a spring contact, generally at the yoke assembly. There is also an inner coating of similar conductive material. The capacity between the inner and outer coatings is used as the output filter capacitor for the high-voltage supply. Because of this, even when the tube is disconnected, there may be a considerable charge between the inner and outer coatings. This charge may be held for a long time and may not be completely removed even by momentarily shorting between the high-voltage terminal and the outer coating (because of dielectric hysteresis).

Although such a charge is not usually enough to be dangerous in itself, it might give you enough of a shock to cause you to drop the tube and break it. Whenever you are removing a tube from a set, after disconnecting the high-voltage terminal, use a test lead to short between the outer coating and the high-voltage terminal as a safety move. Make connection to the outer coating first and then to the high-voltage terminal. Make the connection directly to the coating; do not trust the spring connection between the coating and the chassis. Hold the test lead in place for several seconds, break contact, and short again for some time to be sure of discharging it.

Follow this procedure even on a new tube before handling it. They are tested at the factory, and may come to you with a charge still on them. Hence, be careful when unpacking a new tube not to touch the high-voltage terminal until you have discharged it.

Finally, when working with a TV set, remember that some of the parts get very hot and you may be burned if you touch them. This is particularly true of rectifier tubes and bleeder resistors.

When unpacking a new set, be sure to check all shipping tags and labels for special instructions.

GENERAL INSTRUCTIONS

Once you have installed your experimental receiver, the next step is to become thoroughly familiar with its operation. After that you will study its physical construction so that you will know how to take it apart. After you are thoroughly familiar with the operation and construction of your set, you will analyze its circuits.

Of course, the limitations of space prevent us from giving instructions for each make and model of receiver that you might use. However, we will give instructions for typical examples that will cover most of the types of construction and circuits that are used.

Although you will naturally concentrate on the sections of this book that cover your set, you should also study the other sections. In this way you can become familiar with other commercial sets.

The technical details in this text are brief, because the complete details of circuit operation can best be covered in your study lessons. If you do not understand the details of one of the circuits now, remember to restudy this book after you have finished the lesson on that section of the TV set.

Receiver Controls

As soon as you have installed your set, you will naturally want to try it out. In doing this you can learn much about the various controls and their effects on receiver operation. Therefore, the next step in your Practical Training Plan is to find all the external controls on your receiver and move them, watching the effect on the operation of the receiver. Adjusting the controls is a very important part of the serviceman's daily work. You must adjust these controls whenever you install a new set and after any repair job that you do. The effect on the picture or sound of varying the controls will often help in effect-to-cause reasoning. Therefore, you must know exactly what effect each of the controls should have on the set.

TYPES OF CONTROLS

The controls may be divided into three general types: operating, semioperating, and nonoperating. The operating controls are those that the set owner must adjust for normal operation. They are usually conveniently located and equipped with knobs. The semioperating controls include those that require less frequent adjustment but can be set by the average person for best picture quality.

The nonoperating controls include all those that rarely require adjustment after the set has been installed and properly adjusted. To adjust them properly, you need a technical knowledge of their purpose. Therefore, under normal circumstances they should not be touched by the set owner.

Operating Controls. The following controls are generally considered operating controls:

Tuning or Channel Selector. On most sets this is a twelve-position switch. Some older sets used a continuous tuner to select channels.

Fine Tuning. Used with switch type tuners, this control is adjusted for best picture and sound.

On-Off Switch and Volume Control. This control serves the same purpose as the one on a standard radio receiver. The switch may be a separate control or it may be combined with another control such as brightness instead of volume.

Tone Control. Some television sets include this control, which works the same as the tone control on an ordinary radio receiver.

Contrast Control. This control, often labeled "picture", is used to get the most pleasing degree of contrast between the light and the dark parts of the television picture. It is frequently grouped with the semioperating controls rather than with the operating controls.

Semioperating Controls. The following semioperating controls may occasionally require adjustment and can be safely adjusted by the set owner. They usually have knobs or knurled potentiometer shafts and are reasonably convenient to reach.

Brightness or Brilliance Control. On some sets this may be included in the operating controls, but since it rarely requires readjustment once it is set to a level of brightness that is satisfactory to a set owner, it is usually considered as semioperating.

Focus Control. This is used to adjust the picture to the point of sharpest definition. In some cases it is a potentiometer adjustment and in others it is a screw that moves the focus coil or magnet on the neck of the picture tube.

Horizontal Hold Control. When the picture loses horizontal sync, it can sometimes be brought back into sync by adjusting this control. It works as a fine adjustment of the horizontal sweep frequency.

Vertical Hold Control. This control serves the same purpose for vertical sync as the horizontal hold control does for horizontal sync.

Nonoperating Controls. The following nonoperating controls require adjustment only upon installation of a new set or after repairs have been made to a set. They seldom require any other adjustment, and since the adjustment of some of them is critical, they are usually located where it would be inconvenient for the set owner to touch them. Some of them are potentiometer shaft adjustments, but they rarely have knobs attached to the shaft; others are screwdriver or lever adjustments.

Width or Horizontal Size Control. As its name states, this control can be used to adjust the width of the picture.

Height or Vertical Size Control. This control is used to adjust the height of the picture.

Horizontal Linearity Control. This control changes the shape of the sawtooth waveform used for horizontal deflection, thus eliminating picture cramping on one side or the other.

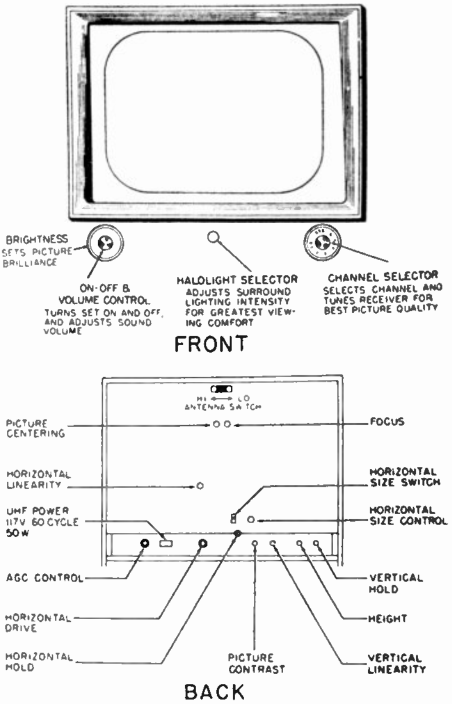
Vertical Linearity Control. This control adjusts the shape of the vertical deflection sawtooth waveform to eliminate cramping at the top or the bottom of the picture.

Horizontal Drive Control. This control varies the amplitude of the sawtooth waveform applied to the horizontal output tube and so has some effect on picture size. It also affects the linearity of the picture and in some sets the brightness.

Horizontal Frequency, Horizontal Lock, Horizontal Locking Range, or Ringing Coil. Some sets have both a horizontal frequency and a horizontal lock or locking range control. Other sets have one or the other of these but not both. All of these controls set the coarse frequency range of the horizontal oscillator and require readjustment when the picture cannot be brought back into horizontal sync with the horizontal hold control.

AGC Control. Many sets have some means of controlling the operation of the automatic gain control. This may be only a switch marked "local-distant" or it may be a knob on a potentiometer shaft labeled to indicate that it should be adjusted for unusually strong or weak signals.

Many manufacturers do not label this control, or the following one, plainly. The name is frequently



Courtesy Sylvania

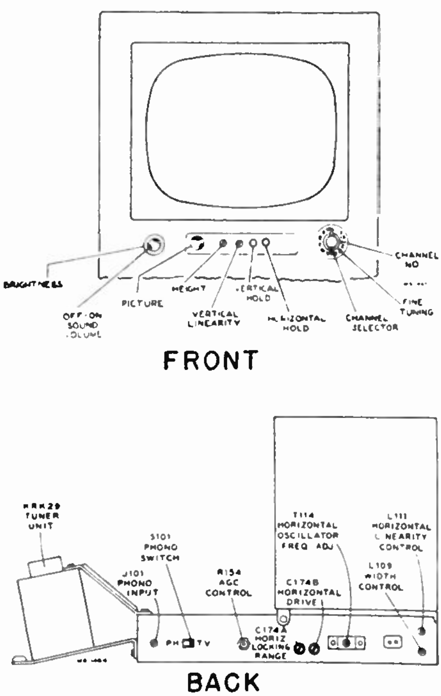
FIG. 1. Operating and nonoperating controls on a typical television set.

"dressed up" so that it may be a more effective advertising and sales feature.

Sync Stability Control. Some sets have a control that can be adjusted to eliminate the effects of noise on sync circuits in weak or noisy signal areas.

Ion Trap. Although this is not actually a control in the sense that it has a knob or a screwdriver adjustment, the ion trap magnet must be adjusted for maximum brightness on installation to prevent damage to the picture tube that might be caused by ion bombardment.

Picture Positioning Control. All sets provide some means of changing the magnetic fields at the neck of the tube to position the picture on the face of the picture tube.



Courtesy RCA

FIG. 2. Operating, semioperating and nonoperating controls on a typical TV receiver using semioperating controls.

Deflection Yoke. Here again, there is no actual control, but if the picture on the face of the tube is tilted, the deflection yoke must be turned to straighten it.

Your test receiver will probably not have all of the controls listed here. However, all of the controls it does have should be listed. Find all of the controls on your receiver. After you have located all of them, turn on your receiver and turn the various controls to study the effects of their misadjustment on the picture.

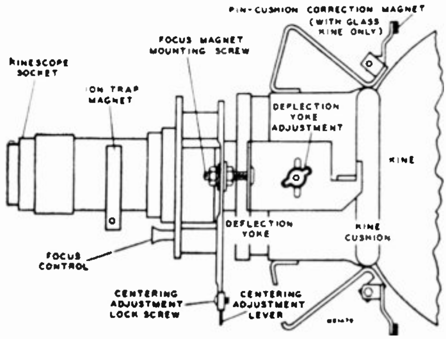
LOCATION OF CONTROLS

If you can get complete manufacturer's service data on your set, it will probably include diagrams showing the exact location of all the controls on that set, and you will have no trouble finding them. However, if your data does not include such diagrams, the information given here may help you to find them. Even if you have complete information for your own particular set, you should study this section in order to become familiar with the general location of controls in other sets.

There are two general plans for placing controls, one or the other of which is usually used in a TV set.

The first, shown in Fig. 1, has only the operating controls on the front of the set and all other controls at the back. This eliminates the classification of semioperating controls, because all of the controls that are not definitely operating controls are in the back and inconvenient for the set owner to operate.

A second arrangement of controls that is more popular is shown in Fig. 2. Here, the semioperating, as well as the operating controls are at the front of the receiver. In many cases the semioperating controls are hidden under a hinged decorative cover on the front of the set.



Courtesy RCA

FIG. 3. The location of controls on the neck of an electromagnetic-deflection picture tube.

Fig. 3 shows a typical assembly on the neck of the picture tube. Adjustments, except on the focus control, are made here by loosening the various parts when necessary and repositioning them on the picture tube neck. The focus control shown here has a screwdriver adjustment that moves the focus magnet back and forth as necessary.

You may find that your set, instead of having controls on the front, has the operating controls at the side of the cabinet and all other controls on the back. Look your set over carefully and find all the controls that you can without taking off the back of the set or removing the set from its cabinet. Once you have become familiar with the location of the various controls on your set, you are ready to see what effect they have on the picture.

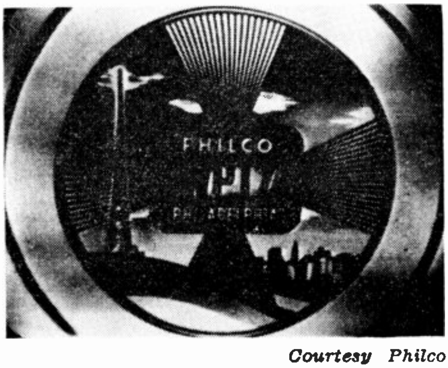
EFFECT OF ADJUSTMENTS

To study the effect of adjusting the various controls, first turn the set on, and adjust the operating controls for a good picture. Undoubtedly you already know how to do this, because you tried the set out before buying it to make sure it was in good operating condition. However, a brief review is given here, just to refresh your memory.

Turn your set on and tune to some channel on which a local station can be received. Allow the set a few minutes to warm up. Turn the volume up until the sound is audible. Adjust the fine tuning for best picture, and the sound volume control for comfortable listening. If there is a disturbing buzz in the sound, you may have to make a compromise between best picture and good sound. Once you have adjusted the tuning control for the best picture possible, adjust the contrast and brilliance controls.

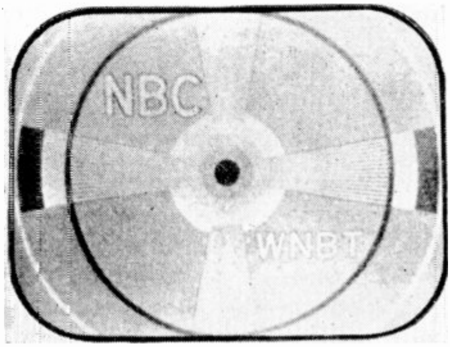
Contrast and Brightness. Turn the contrast control to its limits in both directions and watch its effect on the picture. In one direction you should get a picture with most of the gray tones missing. Everything will be either black or white as shown in Fig. 4. When the contrast control is turned in the other direction, the whole picture will be gray without definite blacks and whites. See Fig. 5. Experiment with the brightness or brilliance control in this same manner. The effects of too much and too little brightness are shown in Fig. 6.

The contrast and brightness controls interact, and the best setting for both of them depends on the amount of room light striking the face of the tube. Watch the black portions of the picture when setting the bright-



Courtesy Philco

FIG. 4. Too much contrast.



Courtesy RCA

FIG. 5. Too little contrast.

ness. Turn this control down until detail in the darkest portion just disappears, then advance it slightly. The contrast control should be turned up until detail just disappears in the lightest portion of the picture, then back down slightly. You may get the best picture by adjusting contrast and brightness alternately.

After you have tuned in a station and adjusted the operating controls for a good picture, you are ready to experiment with the other controls. Since most of the remaining controls are usually on the back of your set, you may find it somewhat difficult to adjust a control and watch the effect of the adjustment on the picture at the same time. To overcome this difficulty, use a mirror in front of the set. Any mirror that you can hang on the wall or prop up against a chair on the floor where you can see the picture while you make adjustments on the back of the set is satisfactory. If you have a good picture on your set and have set up some mirror arrangement so you can see the picture, proceed to experiment with the controls as follows:

Focus. There are two ways in which focus may be controlled. One way is to have a potentiometer that controls the current flow through the focus coil and hence the intensity of the magnetic field which focuses the electron beam in the tube. The other method is to have a focus coil or permanent magnet that can be moved back and forth on the tube neck. Where a potentiometer is used, you may find the focus adjustment on the front of the set, but where the second method is used, it will invariably be on the back of the set. Turn the focus adjustment in either direction and observe the change in picture quality. The picture should become fuzzy and lacking in definition as shown in Fig. 7.

The simplest and quickest adjustment of the focus control can be made by observing the line structure of the raster. Adjust the focus control for the sharpest lines.

Vertical Hold Control. This controls the natural frequency of the

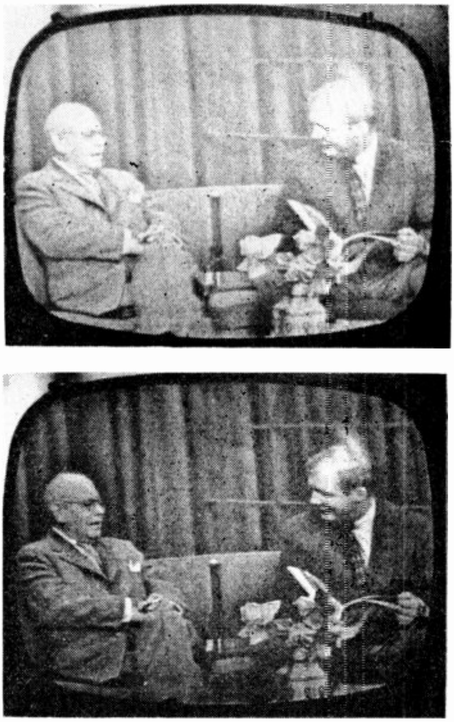
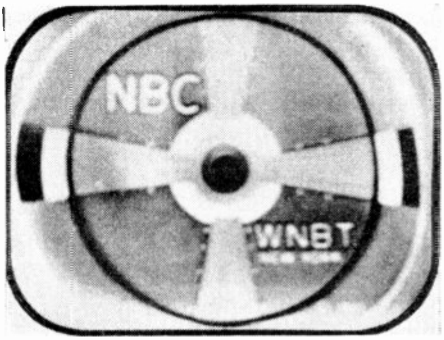


FIG. 6. Too much brightness (above), and too little brightness (below).



Courtesy RCA

FIG. 7. Out-of-focus picture.

vertical oscillator. Try turning this control while watching the picture. The first noticeable effect will be a movement of the picture up and down on the face of the tube as shown in Fig. 8. The direction of movement will depend upon the direction that the control was turned from its original position. At the extreme ends of the control range, the movement will probably be so fast that the picture is unrecognizable. After you are through experimenting with this control, reset it for a stationary picture.

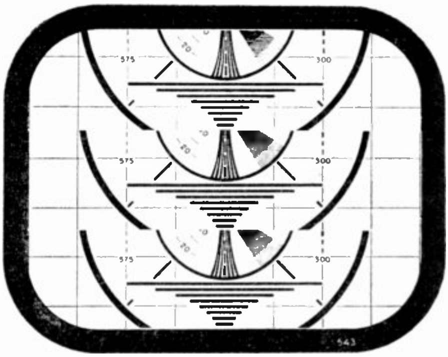
Horizontal Hold Control and Horizontal Frequency and/or Lock. Every set has a horizontal hold control and either a frequency or lock control and some sets have all three. The appearance of the picture tube when these controls are incorrectly set may be seen in Fig. 9. The high frequency of the horizontal oscillator makes its frequency adjustment quite critical. Therefore, both coarse and fine adjustments are provided. The semioperating horizontal hold control is used as the fine adjustment and the frequency or lock control is the coarse adjustment.

Try adjusting the horizontal hold control first. It may not be possible to cause the picture to lose sync by moving this control. Next, make trial adjustments of the frequency or lock control. If both of these controls are present, one will probably change the frequency and the other will shift the phase. Whenever the frequency or lock control must be adjusted to sync the picture, first set the hold control to the middle of its range and bring the picture into sync with the coarse control.

After making these trial adjustments of the horizontal sweep frequency, reset the controls for normal picture.

Height and Vertical Linearity Controls. The height control is used to adjust the vertical sweeps so that the picture just fits the mask. Fig. 10 shows the results of poor adjustment of this control. Adjustment of the height control usually results in a non-linear picture. Therefore, when changing the height of the picture, the vertical linearity control must also be adjusted. As you vary these controls for the first time, you will see that one control has greater effect on the top of the picture and the other on the bottom. These two controls should be adjusted alternately in order to get the correct height and at the same time give a linear picture.

An example of vertical non-linear-



Courtesy Belmont

FIG. 8. Misadjustment of the vertical hold produces a picture like this that runs up or down at a rate that depends upon how severe the misadjustment is.

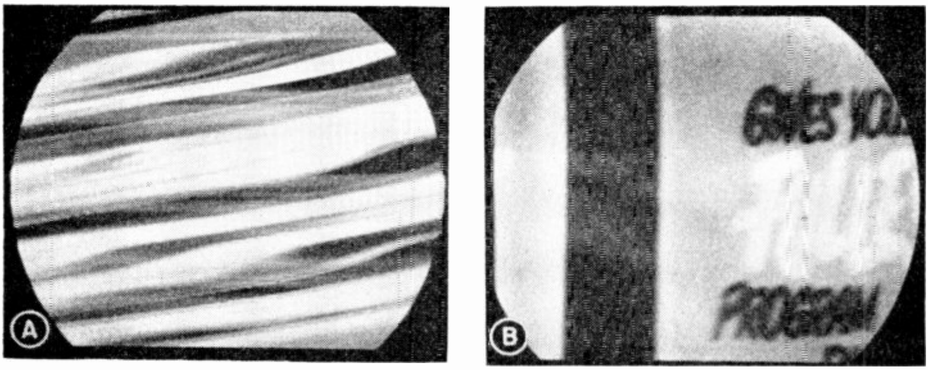
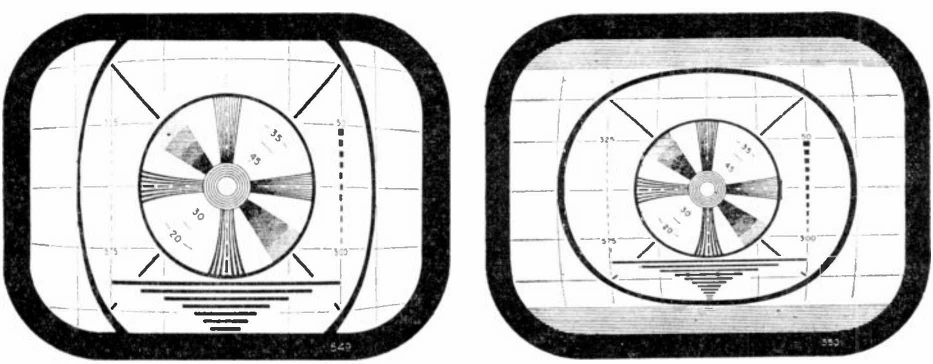


FIG. 9. Two forms of horizontally unsynchronized picture: (A) horizontal frequency off; (B) out of phase.

ity is shown in Fig. 11. In this picture, the top is compressed and the bottom stretched. The opposite condition, stretched top and compressed bottom, is just as likely to occur.

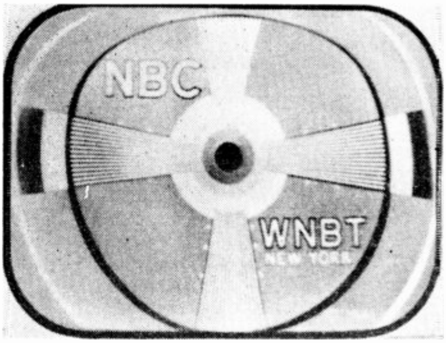
In some sets, changes in the height control will change the frequency and cause the picture to roll. This is corrected with the vertical hold control.

Horizontal Drive, Horizontal Linearity and Width Controls. These controls are grouped together for discussion since they interact in operation. Vary these controls, one at a time, both ways from their normal position. In most sets you will find that the drive control has the greatest effect on picture size. This control varies the amplitude of the signal fed to the horizontal output tube. Since this stage may also provide the high voltage for the picture tube, as the picture increases in width it may become brighter. The drive should be set as high as possible for greatest brilliance. The practical limit in the adjustment of this control is shown in Fig. 12. When the white line appears in the picture, the drive control should be backed down until the line disappears. As you change the drive control, you will notice that it stretches one side of the picture more than the other. This is shown in Fig. 13. This non-linearity is corrected with a horizontal linearity control. After you have correctly set the drive and linearity controls, the picture size



Courtesy Belmont

FIG. 10. Misadjusted height control



Courtesy RCA

FIG. 11. Vertical non-linearity.

is adjusted with the width control so that it just fits the mask on the picture tube.

Automatic Gain Control. All but the very oldest sets have some form of automatic gain control, but on many there is no means of adjusting the agc voltage. Therefore, you may not find this control on your set. This control affects the gain of the rf and i-f stages of the receiver, and misadjustment of it will have the effect of giving either too strong or too weak a signal. Since the effect of varying the agc adjustment depends upon signal conditions, and its range of adjustment is limited, you may not be able to see any definite effect from changing its setting. Experiment with this control and observe its effects, but do not be alarmed if it has very little effect on the picture. Readjust it for best picture quality.

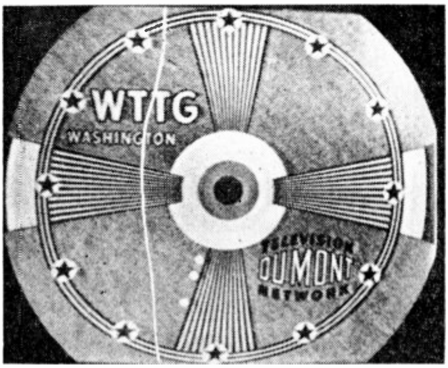
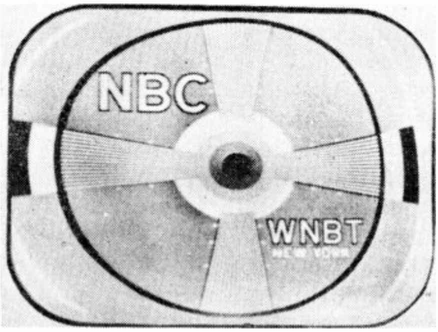


FIG. 12. Too much horizontal drive.

Sync Stability Control. It is quite likely that your set does not have this control, but if it does, you will probably find that the effect of its being out of adjustment is to throw the picture out of sync. This control is used to improve sync by suppressing noise peaks that would cause the sweep oscillators to be unstable. If it is turned up too far when a normal picture signal is received, instability will result. After experimenting with this control, turn it down (usually counter-clockwise) as far as is necessary to receive a picture of satisfactory quality.

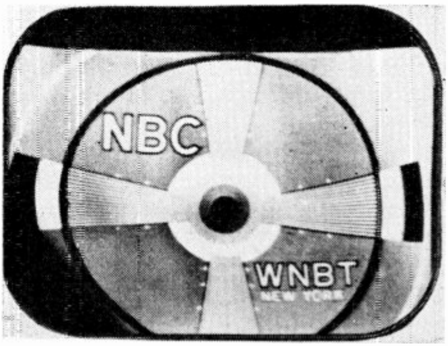


Courtesy RCA

FIG. 13. Horizontal non-linearity.

The rest of the adjustments with which you will experiment are on the neck of the picture tube. Some of them may have mechanical couplings extending through the back cover of the set, others will not. If you are not sure how to get the back cover off the set, and still retain power, wait until you have read the next section before experimenting with these adjustments. Some of these adjustments are easier to make with the set out of the cabinet.

Ion Trap. Note the position of the ion trap on the neck of the picture tube before experimenting with its adjustment. Mark its original posi-



Courtesy RCA

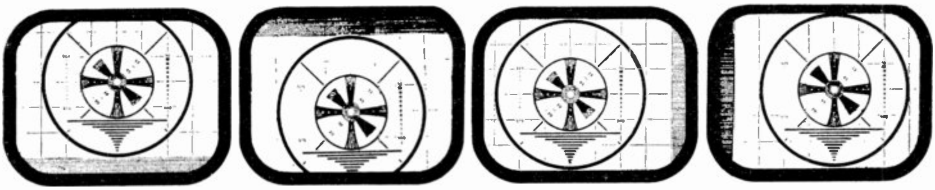
FIG. 14. Misadjustment of the ion trap magnet.

tion on the neck of the tube with a crayon or wax pencil. Now move the trap forward on the neck of the tube. The picture should lose some of its brilliance. If the trap is moved far enough forward, no raster will be visible at all. Return the trap to its original position and again move it; this time rotate it around the neck of the tube. Again you will find the picture loses its brilliance. A poorly adjusted ion trap often results in shading of the picture corners as shown in Fig. 14. After you have noted the effects, return the trap to its original position, adjusting it until you get maximum picture brightness. When adjusting the ion trap, always keep the brightness turned down as far as you can and still see a raster. Do not operate the set too long with the trap out of adjustment, or you may damage the picture tube.

Several different methods are in use to position the picture on the face of the tube. All of these methods are alike in that they vary the strength or position of a steady magnetic field at the neck of the tube. One of the oldest methods, but one still frequently used, is to pass a controllable direct current through the deflection yoke. Other sets change the picture position by changing the tilt of the focus coil or magnet. A common method on the newer sets is to use separate permanent magnet centering devices.

Before experimenting with this adjustment, adjust the height and width controls so that all four edges of the picture are visible. This will make it easier for you to center the picture after experimenting with its adjustments. Now move the picture-positioning controls and note the direction in which the picture moves. Experiment with these controls until you know how to move the picture in all four directions, and then re-center the picture and readjust the height and width controls. Fig. 15 shows the effect of misadjusted positioning controls.

Deflection Yoke. The deflection yoke is rigidly mounted and does not usually need any adjustment if it has been properly set on installation. However, if the picture is tilted or has shaded corners, it may sometimes be necessary to readjust the yoke. Refer to Figs. 3 and 21 for pictures of typical yoke mountings. Study



Courtesy Belmont

FIG. 15. Pictures that are off center like those shown above may be corrected with the positioning control.

the mounting of the deflection yoke and then loosen any screws so that you can rotate it. Rotate the yoke slightly and observe the picture. Note that the picture is now tilted. Readjust the yoke so that the picture is square in the mask and tighten the nuts. The yoke should be tightened down as far forward on the neck of the tube as possible, or corners of the picture may become shaded.

It is possible, although not likely, that there may be some controls on your set that are not labeled and that you cannot identify from the service information you have. If this is the case, note the setting of the unidentified control and mark it in some way so that you can return it to its original position. Then experiment with the control to see its effect on the television picture. Compare the picture with the illustrations in this book for some clue to the purpose of the control. Later, when you analyze the circuit of your receiver. you will undoubtedly find out its exact purpose.

Once you have become familiar with the adjustment of all the controls on your set, you are ready to remove the set from its cabinet and learn more about what goes on inside. Before you remove the set from the cabinet, study the following section on physical construction so that you will be able to take the chassis from the cabinet without damaging it.

Physical Construction

It is very important for you to be thoroughly familiar with the construction of TV sets. When you remove a chassis from its cabinet, you should know just where to look for all of the screws that hold the chassis and you must know what precautions to take to avoid damaging any of the parts or the cabinet. Valuable time can be wasted in looking for the right screws in order to take the set apart or in trying to remove the set without first removing all obstructions.

Fig. 16 shows front, bottom, side and rear views of a typical TV cabinet. Inspect your set and locate, but do not remove, the screws that hold the chassis in the cabinet. If your set is a console model, there will probably be no cover on the rear lower half of the cabinet. The chassis will be in the upper half, and the screws that hold it in the cabinet can be reached from the open lower half.

The next step in your study of construction is to remove the screws that hold the back cover on the cabinet. There are usually at least four screws, one in each corner. When you have the screws removed, remove the cover by pulling it straight out from the back of the set. Do not attempt to slide it up or down because often the neck of the picture tube extends through the back cover and is protected by a special cover attached to the back cover. Also, there will be some form of interlock arrangement that cuts off the power to the set when the back cover is removed. This is usually a line cord connector permanently attached to the back cover that is pulled out of the chassis receptacle when the cover is removed. In order to operate the set with the cover removed or the chassis out of the cabinet, you will have to get a replacement line cord with connector or else remove the line cord connector from the cover.

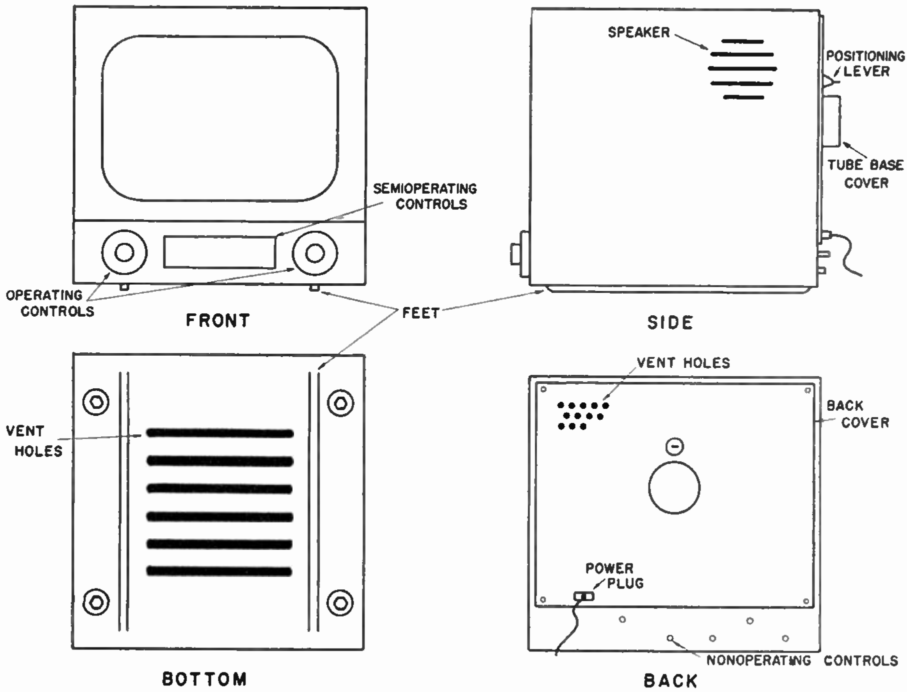


FIG. 16. Four views of a typical TV cabinet.

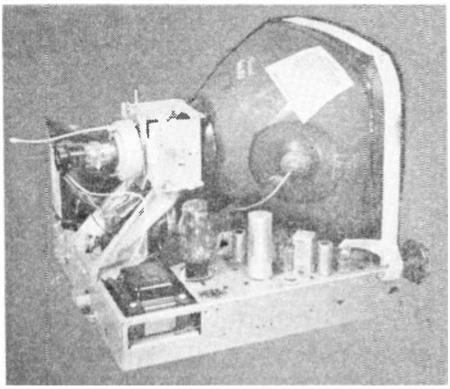
REMOVING CHASSIS

Before you attempt to remove the chassis of your set from its cabinet, study how the picture tube is mounted. There are three possible ways. You must see which of these is used and decide how to remove the chassis and tube with the least danger of damage to any of the parts.

The Picture Tube. The usual method in modern TV sets is to mount the tube directly on the chassis so that the tube will come out with the chassis. There is no mechanical connection between the picture tube and the cabinet. Fig. 17 shows a chassis with the tube mounted in this way. The neck of the tube is supported by the deflection yoke assembly and the front of the tube is held to the chassis by means of an adjustable trap. When removing this type of chassis, hold it so that the picture tube cannot slip out. The picture tube may not be securely fastened.

Another method is to mount the tube, along with the deflection yoke and coil assembly, separately in the cabinet. To remove the chassis from this type of set, you must disconnect the leads from the picture tube assembly to the chassis, and then remove the chassis. Plug-in connections from the picture tube and deflection coil assemblies are often made to the chassis so that disconnecting them is no problem.

The third and least used method of mounting is one in which the tube is connected both to the cabinet and to the chassis. With this method, the face of the tube is usually clamped to the front of the cabinet, and the neck is supported by the deflection yoke assembly on the chassis. This is probably the most difficult of the three types of mounting to remove.



Courtesy Admiral

FIG. 17. TV tube mounted completely on the chassis.

When this type of mounting is used, cabinet construction is usually such that the tube can be removed through the front. If this is the case, you must disconnect the tube and remove it before removing the chassis. If the tube cannot be removed through the front of the cabinet, you must disconnect the leads from chassis to tube, and remove the chassis first, giving such support as you can to the tube neck while removing the chassis, and then remove the picture tube.

The Speaker. Speakers are almost always mounted on the cabinet. In some cases electrical connections to the chassis are made through a plug. If so, and the speaker is mounted so that it will not interfere with the chassis removal, you need only disconnect the plug before removing the chassis. In many cases, even though electrical connections to the speaker are made through a plug, you will find that the speaker is in the way if you try to slip the chassis or the picture tube out of the cabinet. Therefore, the speaker must be removed first. If the speaker is permanently wired to the chassis assembly, the speaker must be taken off the cabinet and removed at the same time as the chassis.

If you have studied the methods used to mount the picture tube and speaker in your set, you are now ready to remove the chassis. If the manufacturer's service information gives instructions on removing the tube and chassis, study them before you start. A step-by-step procedure is given here for removing the chassis, that will assure maximum safety both for yourself and for the parts of your receiver.

1. *Provide Space for Chassis on Bench or Table.* Before you begin to remove the chassis from your set, make sure to clear space on your bench for it. The chassis is heavy, and if you should have to hold it with one hand while attempting to clear the bench with the other, you might easily drop it and damage a number of parts.

2. *Remove Knobs.* All knobs on the front of the cabinet should be taken off and put in a safe place where they will not be lost. These knobs will usually slip off when pulled straight out from the set, but in some cases there may be set screws holding them to their shafts.

3. *Disconnect Antenna.* Before attempting to remove the chassis, disconnect the antenna lead-in from the terminals on the back of the set. Make sure that the lead-in is not under foot where you might trip over it while you have your arms full.

4. *If Necessary, Remove Tube.* If your set is of the type with the tube mounted on the chassis, you can omit this step. It may also be omitted if the tube mounting is entirely separate from the chassis. In this case, the tube can be removed later after you have the chassis out. However, if the tube is attached to the cabinet in any way so that the tube and the chassis must be removed separately, disconnect the leads between the picture assembly and the chassis.

5. *Disconnect Speaker.* If your speaker is not connected to the chassis assembly with a plug, it may be easier to take the speaker from its mounting on the cabinet and take it out with the chassis rather than to disconnect the leads. The speaker must be removed first if it will be in the way when you try to slide the chassis out of the cabinet.

6. *Remove Chassis-Mounting Screws.* There are usually four of these on the bottom of the cabinet, or if the cabinet is a console model, on the bottom of the shelf on which the chassis is mounted. When removing the mounting screws from a table model receiver, do not turn the receiver on its side. Slide the corners of the set over the side of the workbench so you can remove the screws one at a time. Hold the set with one hand while you do this so it cannot slide off the bench. When these are removed, you are ready to slide the chassis out of the cabinet. Before pulling the chassis out, make sure that there are no obstructions and that all leads have been removed.

7. *Remove the Chassis.* To remove the chassis, pull it straight back out of the cabinet. If you cannot get hold of the chassis directly in order to slide it out, use the power transformer, the shield case over the high voltage supply or some other strong mechanical structure as a hand hold. Never try to move a chassis by grabbing tubes, filter capacitors or small shield cans. When carrying a chassis with the picture tube mounted on it, be careful to carry it in such a way that the picture tube cannot slip out. Observe the same care that you would in carrying a picture tube alone.

Once you have your chassis out of the cabinet, you must devise some means of setting it up so that it is convenient to work on. The exact manner in which you set it up on the bench will, of course, depend upon the type you have. It must be placed so that both the top and the bottom of the chassis are easily accessible. In doing this, do not put any strain on the picture tube or other parts that are mounted on the chassis.

If your set is of the type that has the tube mounted separately from the chassis or has the tube mounted partly on the cabinet and partly on the chassis, you will have to make some provision to mount the tube on or near the chassis.

The following paragraphs should be of help to you in mounting your chassis and picture tube securely on your workbench.

Picture Tube Mounted on Chassis. If your set has the tube mounted securely to the chassis, all you need to do is to find some way of standing the chassis on its side without danger of tipping it over and without putting any strain on the picture tube or other parts. A simple support bracket is shown in Fig. 18. Make the bracket of strap iron ¾ inch wide, 1/16 inch thick, and 28 inches long. Drill a hole at one end large enough to clear the bolts that were used to mount your chassis in its cabinet. At the other end drill a hole large enough to clear a No. 8 or a No. 10 wood screw. Bend both ends at a 45-degree angle

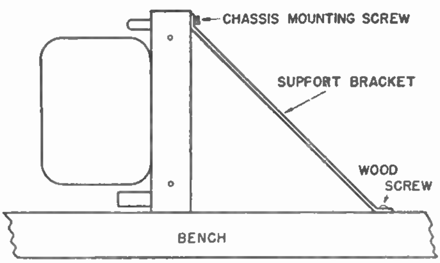


FIG. 18. Chassis support brackets can be used to hold a chassis firmly on the workbench.

as shown. Two of these brackets will hold your television chassis so that it is nearly impossible to knock it over. Fig. 18 also shows how to attach the support brackets to the chassis and the bench.

If you have a modern large-screen television set, the picture tube may be wider than the chassis. In this case, cut one or more lengths of wooden two-by-fours and place them under the edge of the chassis. These should be as long as the chassis is deep. Fasten as many of these under the edge of the chassis as you need to keep the weight of the chassis off the picture tube, and the picture tube off the top of the bench. With the blocks under the chassis, connect the support brackets as shown. Since the support brackets are soft iron, they can be easily bent to adjust for chassis of various widths.

Picture Tube Mounted Separately. If your set is of the type that has the picture tube and deflection yoke assembly separate from the chassis, support the chassis on the bench with a support bracket as just described. To mount the picture tube, you will have to make a special block to go under the front of the tube and also support the deflection yoke and other components on the neck of the tube.

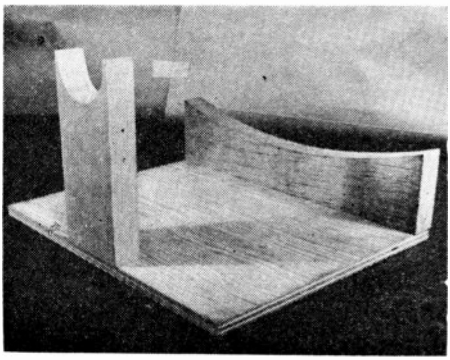


FIG. 19. Picture-tube supporting blocks.

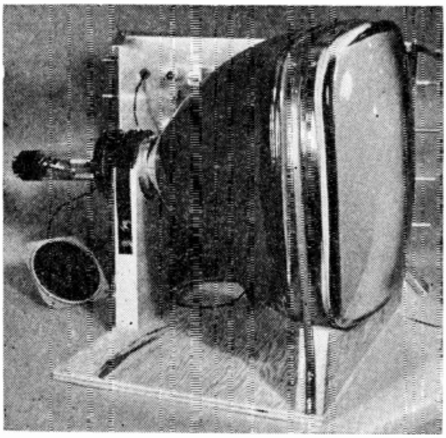
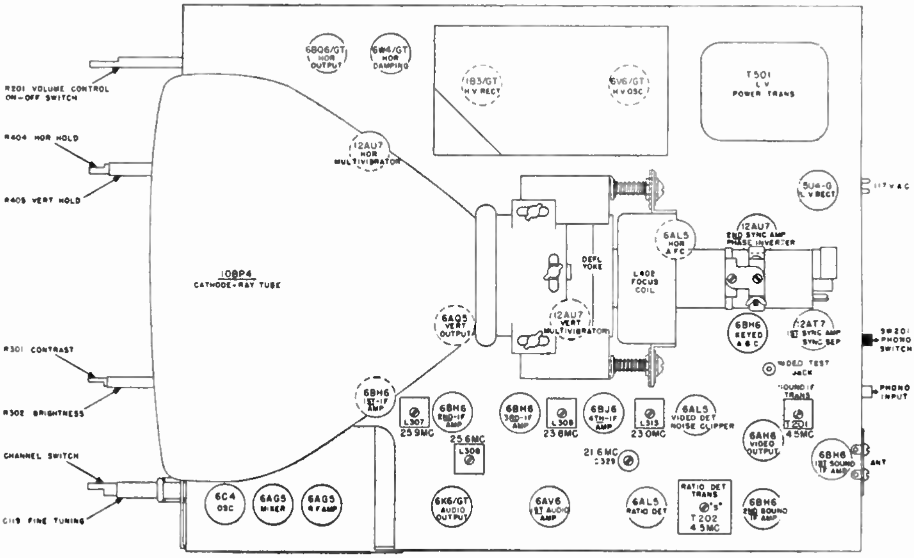


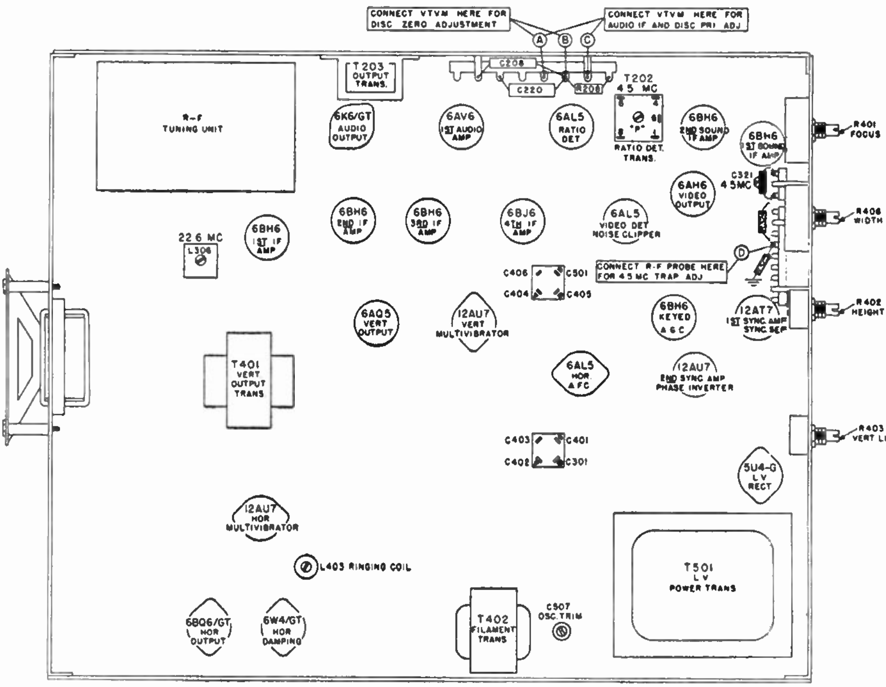
FIG. 20. Chassis with separately mounted picture tube arranged on workbench.

Blocks that can be used to support the tubes are shown in Fig. 19. The dimensions of these blocks depend upon the size and shape of the picture tube; however, we recommend that they be made of material at least one inch thick to give ample support to the tube. Fasten a strap made of canvas or 300-ohm twin lead transmission line to one side of the front block with a wood screw and a wide washer. Then put the tube in the block, stretch the strap tightly over the tube, and fasten it to the other side of the block with another screw and washer. Fig. 20 shows the arrangement of a chassis and separately mounted picture tube on the workbench. The height of the wooden block under the yoke should be carefully adjusted so that there is no strain on the neck of the picture tube where it passes through the deflection coil assembly.

Tube Partially Mounted on Chassis. It is possible that your set may have the deflection coil assembly permanently attached to the chassis and the tube attached to the front of the cabinet. Thus, the neck of the tube is supported by the chassis, but the front of the tube is supported by the



TOP VIEW OF CHASSIS



BOTTOM VIEW OF CHASSIS

Courtesy Westinghouse

FIG. 21. Typical chassis layout diagram.

cabinet. If so, you will need to make a wooden block and a strap to support the front of the tube while the receiver is out of the cabinet. This can be similar to the front part of the one shown in Fig. 19. It should fit right under the front of the picture tube. Before attaching the block to the chassis, try the tube in it, to see whether the block should go right against the chassis, or whether you will need spacers between the block and the chassis to put the block in the right position. The support block can be mounted with two long bolts going through block, spacers, and chassis, or clamped to the chassis with "C" clamps. If you must drill holes in the chassis to mount the support block, be very careful when drilling so that you do not damage any parts under the chassis.

LOCATION OF PARTS

Now that you have the chassis out of the cabinet, you should study it carefully and practice locating the various parts. If you have been able to obtain complete manufacturer's service data on your receiver, you will have a chassis layout diagram similar to that shown in Fig. 21. If you do not have such a diagram, you should make one for your set. At this time, you may not know the purpose of all of the parts that appear on the top of the chassis, but you can make a sketch of the top view of the chassis and put in the tube types and identify such parts as you can at this time. Later, when you study the schematic and analyze the circuits of your receiver, you will be able to identify the rest of the parts. Such a diagram as this is essential in servicing. Effect-to-cause reasoning will tell you what portion of the set is defective. The chassis layout diagram shows you where the defective stages are located. A diagram of the chassis layout may also save you the trouble of removing the chassis just to replace a tube.

The chassis layout shown is typical. Note that there are definite groups of tubes. The tuner is very often a sub chassis. The rf amplifier, oscillator, and mixer tubes are mounted on this sub chassis close to each other. You will usually find that the tube closest to the antenna connection on the tuner assembly is the rf amplifier, and the one closest to the tuning control is the oscillator.

The video i-f stages are usually mounted in a straight line, with alternate tubes and i-f transformers. Once you have located the first i-f stage, you need only go down the line to find any of the succeeding stages. The tubes that handle the sound signal are usually grouped together—the sound i-f amplifier, detector, audio amplifier, and and audio output tubes. The B+ and high-voltage power supplies are easily identified and are usually mounted toward the rear of the chassis. Sync and sweep circuits are more likely to be scattered over the chassis.

Once you have become familiar with the layout of your chassis, you should study the under side and learn to locate the various parts by using a schematic diagram.

Using the Schematic Diagram. When troubleshooting, the professional serviceman observes the effect of trouble on the sound or picture, or both, and then uses effect-to-cause reasoning to decide what the possible sources of trouble are. Almost invariably, his next step is to refer to the schematic diagram for the set in question and find the points in the circuit at which he wishes to make tests or observations. Since this is an essential step in the professional troubleshooting process, it is very important for you to practice locating the various parts under the chassis by using the schematic diagram.

If you had to draw your own chassis layout diagram, you could now identify the function of each tube in that diagram by locating the tubes on the schematic. Study your schematic carefully. Note that each tube is labeled with the tube type, its function, and a symbol number. Resistors and capacitors are labeled with a symbol number beginning with R for resistors, and C for capacitors, and also the resistance or capacitance of the part. Coils are labeled with a symbol number beginning with L and may also show the frequency to which they are tuned if they are tunable. Many schematic diagrams also give the voltages that should be obtained at various points in the circuit, and possibly the wave shape that should be seen on an oscilloscope.

To find out the function of one of the tubes on your chassis layout diagram, first identify the tube type number and then look under the chassis at the connections to the socket for that tube. Notice what parts are connected to each of the tube pins. It may be helpful if you draw a diagram of the connections to that tube socket. Next, check the tubes of that type on your schematic diagram until you find one with the proper parts connected to the various pins. The label on the schematic diagram will tell you the purpose of the tube.

Whether you have a complete chassis layout diagram or not, you should follow the same procedure for each tube on your chassis for practice. You should also reverse the process. Pick out a tube on the schematic diagram and note the various parts and the value of the parts connected to it. Next, find the tube on the chassis by first looking for the type of tube and then inspecting the connections to the tube socket to find the same parts as appeared on the schematic diagram. When you have done this for every tube in your set, you will have had considerable experience in locating parts from the schematic diagram, and should be able to do this quickly in any set.

ANALYZING THE CIRCUIT

Now that you are thoroughly familiar with the physical construction of your set and can locate the various parts, you should analyze the circuit. This means that you should follow the TV signal through the various stages and note the effect that each stage has on the signal.

Fig. 22 is a block diagram of blocks representing those essential circuits found in all TV receivers. This is not a diagram of any particular receiver. The arrows between the blocks show what type of signal is fed into a given stage and what type of signal comes out of it. By tracing the signal through these variout stages, you can get a clear picture of the part each section of the receiver plays.

The signal received at the antenna is fed into an rf amplifier, which will pass both video and sound signals. These signals are fed into a mixer where they beat with a signal from the local oscillator which converts them to lower frequencies.

If the set uses a separate-channel i-f system, the sound i-f carrier would be taken off between the mixer and the video detector, as shown by the dotted arrow. However, the more economical and more common i-f system is an "intercarrier system" in which both sound and picture i-f pass through a common amplifier to the video detector where a sound i-f signal of lower frequency (4.5 megacycles) is produced by beating the picture

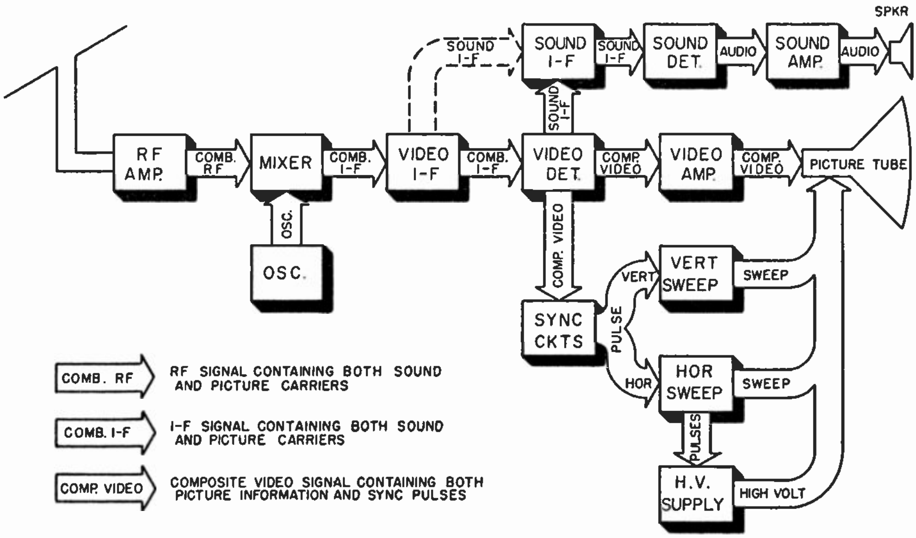


FIG. 22. A block diagram of the essential circuits in all television receivers.

carrier against the sound carrier. This sound i-f signal is fed to a sound i-f stage, or stages, then to the detector. The audio signal is amplified and fed to the speaker.

In addition to the sound i-f signal, a composite video signal is produced by the video detector. This signal contains both picture information and sync pulses. A video amplifier, which will pass frequencies from 0 to 4 megacycles, increases the amplitude of the composite video. This high level video signal modulates the beam of the picture tube to reproduce in black and white the scene before the camera.

The application of the composite video signal to the control grid circuit of the picture tube is not enough to produce a picture on the screen. Before a picture is possible, a raster must be produced. To accomplish this, the composite video signal is taken from the video detector and fed into the sync circuits.

Three things happen in the video signal in the sync circuits. First, the sync pulses are separated from the picture information. Second, the horizontal and vertical pulses are separated from each other; and third, the horizontal and vertical pulses are shaped to provide proper synchronizing action on their respective sweep circuits.

The sweep voltages developed and amplified in the sweep circuits are delivered to the deflection yoke of the picture tube where they create the necessary magnetic fields to deflect the beam and form the raster on the face of the tube. In most modern TV sets pulses from the horizontal output tube are stepped up by means of an auto-transformer, rectified, filtered, and used as the high voltage supply for the picture tube.

From this study of what happens to the TV signal in a receiver, it is obvious that the receiver circuits can be divided into a few major sections for the purpose of effect-to-cause reasoning. The first major section contains the circuits that handle both picture and sound signals: the rf amplifier, the mixer, the oscillator, and in some cases the video i-f amplifiers. The second section contains the circuits that handle only sound signals: the sound i-f, the sound detector, and the sound amplifier. The third section includes the circuits that handle the composite video signal: the video detector and the video amplifier. The fourth section contains the circuits used to produce the raster: sync circuits, vertical and horizontal sweep, and high voltage power supply. Another section, not shown here because this particular diagram is concerned only with the TV signal, contains the low voltage and filament power supplies.

Now that you have become familiar with the effects that the various sections of the TV receiver should have on the signal, you are ready to analyze the circuit of your own receiver. Lack of space prevents us from making an analysis of every receiver. However, we will analyze three typical sets, which cover most of the circuit variations in TV sets. The schematic diagrams of these sets are on a separate large sheet enclosed in this book.

To analyze the circuit of your receiver, first study all the analyses made here. After you have studied these, make a similar analysis of the circuit for your own set. The easiest way to do this is to compare the schematic diagram of your set, section by section with those shown here. For any given section of your set, find the section in one of the schematics in this book that most nearly resembles it. Your analysis will then be quite similar to the one made here.

Westinghouse H-609T10

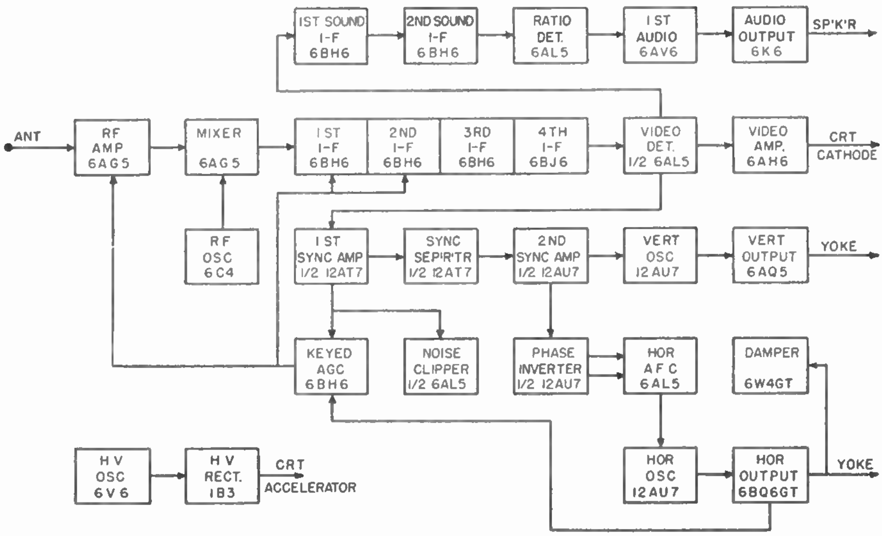
This Westinghouse Model H-609T10 uses a 10-inch picture tube with electromagnetic deflection. Its circuit is typical of television receivers that were produced several years ago when 10-inch screens were popular.

THE BLOCK DIAGRAM

The first step in analyzing any circuit is to have a block diagram of the over-all circuit. You should understand the relationship of each stage to the other stages in the circuit. A block diagram of this receiver is shown in Fig. 23. If you have complete servicing data on your receiver, you might have a block diagram. If you do not, the first thing you should do is draw one.

Let us follow the path of the signal in the diagram. The signal received at the antenna is amplified in the rf amplifier and delivered to the mixer where it beats with the output of the rf oscillator. This produces the audio and video i-f signals. These i-f signals from the mixer are delivered to the control grid of the first i-f tube.

There are four i-f stages. The output of the last i-f amplifier is fed to the video detector. The gains of the first and second i-f stages and of the



Courtesy Westinghouse

FIG. 23. Block diagram of Westinghouse Model H-609T10.

rf amplifier are controlled by the output of a keyed agc tube.

After detection the video signal is fed to a video amplifier and to a sync amplifier. The signal from the video amplifier is used to control the beam in the picture tube.

In the video detector the audio and video i-f carriers beat together to produce a new audio i-f signal at 4.5 mc. This audio signal is fed to a two-stage i-f amplifier and then to a ratio detector. The audio output of the detector is amplified and fed to a loudspeaker.

The output of the first sync amplifier is fed to the keyed agc tube, to a noise clipper, and to a sync separator. The output of the sync separator drives a second amplifier. Two outputs are taken from the second sync amplifier; one is fed to the vertical oscillator, and the other to a phase inverter.

The two outputs from the phase inverter are fed to the horizontal afc tube where they are compared with a signal from the horizontal output tube. The output signal from the horizontal afc is fed to the horizontal oscillator. The sweep signal generated by the horizontal oscillator is fed to a horizontal output tube. This horizontal output tube drives the deflection yoke of the picture tube and a damper tube from one output; a second output from the horizontal amplifier is fed back to the keyed agc tube.

The vertical oscillator drives a vertical output tube which in turn drives the deflection yoke for the picture.

High voltage for the picture is developed in a high voltage oscillator and rectified in a 1B3 rectifier.

Now that you have the block diagram of this receiver in mind, let us look at the complete schematic diagram shown in Fig. 24 on the large sheet, and see what the actual circuits look like.

ANALYZING THE SCHEMATIC

The schematic shown has been divided into five major sections: rf, sound i-f and audio, video, sweep, and power. Having the diagram thus divided simplifies the analysis of the circuit somewhat in that you can study it section by section.

RF Section. As indicated by the dotted line surrounding it, the rf section or tuner is a separate sub-chassis. The rf amplifier, mixer, and oscillator circuits are included on this chassis. The tuning coils which form the resonant circuits in this section are wired on wafer-switch sections. As the selected channel frequency is lowered, more coils are added in series in each tuned circuit, lowering the resonant frequency of the circuit. This type of front end is called an "incremental inductance" tuner.

The antenna lead-in is connected to a matching transformer, L101. A parallel-resonant circuit across the output of L101 is formed by the coils on the first wafer-switch section and the distributed capacity in the circuit. AGC bias from the main chassis is fed to the grid of the rf amplifier through R101. C101 is a dc blocking capacitor.

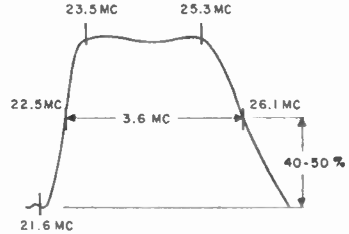
The rf amplifier is coupled to the mixer grid by a double-tuned broadband circuit. The tapped inductances on each of the next two wafer-switch sections form parallel-resonant circuits which are capacitively coupled by C110. Capacitors C106, C107 and C108 are used to increase the coupling at the lower frequencies. R103 and R104 load the circuits on the lower band and broaden the response. C128 and C111 are dc blocking capacitors.

The 6C4 oscillator tube is in an ultra-audion circuit, which is a form of Colpitts oscillator. A resonant circuit, formed by C118, C119, the distributed circuit capacities, and the coils on the fourth wafer of the wafer-switch gang, is in the grid circuit of this triode. Plate-to-grid feedback is accomplished through the interelectrode capacities of the tube. The plate is grounded for rf, and choke coil L106 raises the cathode above ground for rf while providing a dc return. The oscillator frequency can be varied slightly by means of the fine-tuning control, C119. The oscillator is coupled to the grid of the mixer through capacitor C115.

In the mixer, the signal from the oscillator beats against the audio and video carriers and their respective sidebands. Since the oscillator is tuned 26.1 mc higher than the video carrier, the i-f signal produced by the mixer is a band of frequencies which ranges from approximately 21 to 27 mc. This includes a 21.6-mc sound carrier and a 26.1-mc picture carrier signal.

I-F Section. The i-f signals produced by the mixer are fed to the video i-f section. The type of amplifier used here is called a "stagger-tuned" i-f section. It uses single parallel-resonant circuits between the various stages instead of double-tuned i-f transformers of the type found in most radio receivers. Each of these resonant circuits is tuned to a different frequency, so that the over-all response of the i-f stages is relatively broad and flat as shown in Fig. 25.

The first resonant circuit, consisting of L306 and C330, is the plate load for the mixer. This circuit is tuned to 22.6 mc. The i-f signal is



Courtesy Westinghouse

FIG. 25. Over-all i-f response.

coupled to the grid of the first i-f amplifier through C312 and a parallel-resonant circuit consisting of L301 and C302, which is used to block high frequency oscillator signals.

You will note that each of the i-f interstage coupling coils is tuned to a different frequency. Compare these frequencies with the points marked on the response curve in Fig. 25. The two coils which tune in the middle of the pass band are resistor loaded to broaden and flatten their individual response curves.

The fourth i-f stage has a trap in its cathode circuit tuned to reduce the sound i-f carrier. This trap, a parallel-resonant circuit, presents a high impedance to the sound i-f. Since the trap is in the cathode circuit, it makes the stage degenerative for the sound i-f and greatly reduces the gain of the stage at that frequency.

All of the interstage coupling coils are shunted by the tube input and output capacities and the stray wiring capacity. Since the stray capacity forms a large part of the shunt capacity, lead positioning is very important. If these leads are moved, the stage may be detuned.

Video Detector. The output of the fourth i-f amplifier is developed across plate load coil L304 and fed through C310 to the cathode of the video detector tube. A final parallel-resonant circuit tuned to 23 mc, consisting of L313 and its distributed capacity, is in the cathode circuit of the video detector.

There are two signals developed at the output of the video detector: a composite video signal that includes both picture information and sync pulses, and a 4.5-mc FM sound i-f signal. Both of these signals pass through the peaking coil L305, which serves to improve the high frequency response of the video system. The distribution point for the video and sound i-f signals is at the junction of L305 and R337, the grid resistor of the video output tube. Note that a test jack is provided at this point. From this point, the composite video signal is fed to the video amplifier and sync amplifier tubes and the intercarrier audio i-f is fed to the sound channel.

Video Output Stage. The composite video signal is amplified in the video output tube. The amount of amplification of this signal depends upon the setting of R301, the contrast control. This control varies the resistance between the cathode and ground, and hence the grid bias on the tube, and also introduces degeneration into the circuit. The degeneration obtained in this stage by omitting the cathode by-pass capacitor, holds the frequency response constant in spite of changes in bias. The video output tube is coupled to the cathode of the picture tube through a 4.5-mc trap composed of L314 and C321. This trap eliminates the sound i-f signal from the video signal. From this trap, the ac signal passes through C308 to the cathode of the picture tube; the dc component of the video signal is coupled to the picture tube through R324. The plate load of the video output tube consists of peaking coil L312, and R330. The signal applied to the cathode of the picture tube has positive-going sync pulses. It has the same effect as a negative-going signal applied to the grid of the tube. Brightness is controlled in the picture tube by varying the dc potential applied to the grid by means of potentiometer R302.

Keyed AGC Tube. The keyed agc tube is included in the video section. It is normally held at cut-off by means of high bias and low screen voltage. These voltages are set by the resistive divider string composed of R303, R340, and R341. The plate has no dc connection. The only voltage appearing on the plate of this tube is in the form of pulses from the horizontal output tube. Thus the tube can conduct only when these pulses arrive at the plate. The conduction of the tube is governed by the amplitude of the sync pulses fed to the grid from the first sync amplifier.

During conduction, capacitor C443, a length of 150-ohm twin lead, charges to a level which depends upon the conduction. Between pulses, this capacitor discharges through resistor R338 to produce a negative voltage at the plate of the tube. This negative voltage is filtered by resistor R327, and capacitors C331 and C304, and then used to control the gain of the rf and i-f tubes.

Since the tube can conduct only during the sync interval, the agc voltage will be governed solely by the amplitude of the sync pulse. Sync pulses are used to control the agc voltage because the tip of the sync pulse is at the maximum carrier level. If the average composite video signal were used to control agc, the bias would vary with the picture brightness.

Sound I-F and Audio. The sound section of this receiver does not differ greatly from an ordinary FM receiver. The 4.5-mc signal from the video detector is delivered through C207 to the grid circuit of the first sound i-f amplifier. T201 tunes the grid of this tube to 4.5 megacycles.

In an intercarrier receiver, it is necessary to prevent the audio i-f signal from exceeding 10% of the video i-f carrier. This low level of audio in the video detector requires two stages of amplification before demodulation.

The output of the ratio detector feeds a two-stage audio amplifier and loudspeaker. Trace the cathode lead of the 6K6 tube and you will find that it is connected to the plate of the horizontal damping tube through a low-pass filter. This filter is composed of C405, R412, and C424. The reason for this will be taken up when we discuss the damper tube.

The loudspeaker is of the electrodynamic type. The field coil of this speaker is used as a filter choke for the low voltage power supply. The presence of 120-cycle ripple across the field coil requires a hum bucking coil in series with the voice coil.

Sweep Section. The sweep section includes both sync and sweep-generating circuits. Its over-all purpose is to produce horizontal and vertical sweep currents that will move the electron beam across the picture tube in sync with the electron beam in the camera tube at the transmitter.

You will note that in this section of the schematic diagram the manufacturer has shown waveforms obtained on the oscilloscope at critical points throughout the circuit. Let us trace the signal through this section.

Sync Amplifiers and Separator. The composite video signal taken from the video detector output is fed to the grid of the first sync amplifier (left-hand triode of the 12AT7). This tube amplifies the composite video signal and shifts its phase 180 degrees. The cathode of this triode is connected directly to ground. A plate voltage of 50 volts is applied through R455, the plate load resistor, and a positive grid voltage is applied through R457. A noise clipper circuit consisting of C407, R456, and one-half of a 6AL5 tube is connected between the output of the first sync amplifier and ground. When noise pulses exceeding the amplitude of the sync pulses appear in the output of the sync amplifier, the noise clipper conducts, providing a low resistance path to ground. This action prevents noise pulses from affecting the sync and sweep circuits and the agc tube which are fed by this stage.

The output of the first sync amplifier is coupled to the grid of the sync separator through C441 and the series RC combination formed by R459 and C440. The sync separator is used to remove all of the composite video signal except the sync pulses. It is a self-biasing triode with low plate voltage so that plate current flows only when positive sync pulses are applied to the grid; hence the rest of the signal is clipped off and the output of the sync separator is a negative-going sync pulse.

The sync pulse from the sync separator is coupled to the grid of a second sync amplifier. Two sync signals are taken from the second sync amplifier. One is coupled through C444 to the grid of a phase inverter. The other output is taken from the cathode and fed to the vertical multivibrator.

Vertical Sweeps. The sync pulses from the second sync amplifier pass through an integrator network. This network consists of three resistors and three capacitors combined in a single unit. In the integrator, the horizontal sync pulses are greatly reduced and the vertical pulses are shaped for best triggering of the vertical oscillator.

The vertical multivibrator is adjusted so that its free-running frequency is slightly less than 60 cycles per second. However, when uncontrolled, the frequency or phase may deviate slightly. Therefore, it is necessary that it be synchronized by the incoming sync pulses. The sync pulses trigger the multivibrator, increase its operating frequency to 60 cps, and hold it in phase with the transmitter vertical sweeps.

The multivibrator consists of two triodes. The output of the first is coupled to the grid of the second through capacitor C445. The feedback coupling from the second triode to the first is obtained with a common cathode resistor.

The free-running frequency of the multivibrator is determined by the time constant of C445, R464, R465 and R405. R405 is the Vertical Hold control. This control is used to set the free-running frequency to a value slightly less than 60 cycles. The multivibrator is then pulled into step by the sync signal which is applied to the grid of the first triode section.

The output of the multivibrator is a sharp negative pulse. The amplitude of this pulse is set with R402, the height control; varying this control may cause small changes in the frequency of the oscillator. The pulse output of the multivibrator does not have the proper shape for sweeping. R421 and C409 modify it to the proper trapezoidal shape. The vertical output tube amplifies this trapezoidal wave and drives the vertical coils in the yoke assembly through an output transformer.

The vertical linearity control, R403, controls the bias on the vertical output tube so that the sweep signal will have the correct shape. This waveshaping is accomplished by operating the vertical output tube on a portion of its grid-plate characteristic which will introduce distortion to counteract the distortion in the wave shape as it appears at the grid of the tube.

The resistors, R449 and R450, connected across the deflection coil damp out the oscillation that would occur during the sweep flyback interval.

Horizontal Sweep Circuits. The horizontal oscillator is also a cathode-coupled multivibrator. The ringing coil, L403, serves as the horizontal frequency control. This coil and C434 form a parallel-resonant circuit tuned to approximately 15,750 cycles. Fine adjustment of the frequency is made with R404, the Horizontal Hold control. R426 and C432 shape the output of this multivibrator.

The horizontal sweep signal is amplified in the horizontal output tube. The gain of this stage and hence the width of the picture is controlled by R406 in the plate circuit. The deflection yoke is connected between the plate and the cathode through a dc blocking capacitor, C410. If the plate current for the output tube were allowed to flow through the yoke, the resulting magnetic field would move the picture off-center.

Horizontal sync pulses from the phase inverter are compared with a signal from the horizontal output in the horizontal afc diode. If the horizontal output signal differs in frequency or phase from the sync pulse, a voltage is produced across R445. This voltage varies the bias on the grid of the first section of the horizontal oscillator to bring it into step with the horizontal oscillator at the transmitter.

The purpose of R438 and C415 is to provide a long time constant so that the voltage appearing on the grid of the multivibrator tube will be an average of the voltages that appear across R445.

This receiver does not have either horizontal drive or horizontal linearity controls.

The horizontal damping tube is connected across the output of the horizontal amplifier tube to prevent oscillations that would otherwise occur because of the sudden collapse of the magnetic field of the horizontal deflection coils during the horizontal retrace time. This tube conducts on the first negative cycle of these oscillations, thus damping any further oscillation. This damped pulse returns to ground through C424.

A polarizing voltage to control the conduction level of the 6W4 horizontal damping is obtained by connecting this tube in the cathode dc return of the 6K6 audio output tube. The cathode of the 6K6 is connected to ground only when both the 6W4 and the 6BQ6 are conducting. The 15,750-cycle pulses through this circuit are smoothed out by C405 and do not appear in the audio output.

Focus. The focus coil (L402) is energized by the plate current drawn by all tubes except the horizontal output. The amount of current that flows through the coil may be controlled to some extent by the focus adjustment R401. This, in series with R408, shunts the focus coil.

High-Voltage Power Supply. The principal components in the high-voltage power supply are the oscillator tube, the transformer T502, and the high voltage rectifier tube. C507 and one winding of T502 form a tuned circuit in the plate circuit of the oscillator. C507 is tuned for maximum dc output from the rectifier. Feedback to the grid is accomplished through the bottom winding of T502. High voltage is developed through induction across the rectifier plate winding of T502, and the rectified high-voltage dc appears at the filiment of the high-voltage rectifier. Another winding in T502 provides the necessary filament current for the high-voltage rectifier. C505, R502, and the capacity between the inside and outside coatings on the cathode ray tube provide a smoothing filter for the rectified high voltage.

Low-Voltage Power Supply. The low-voltage power supply is a conventional transformer type of power supply. 117 volts ac is applied to the primary of power transformer T501 through switch SW501, where it is stepped up and applied to the plates of the low voltage rectifier, 5U4G.

A dc voltage of 290 volts appears at the filament of the rectifier. This voltage is fed into a filter network consisting of C501, the speaker field coil, and C401, which smooths the B+ voltage for application to the plates of the various tubes. A 5-volt filament winding is provided on T501 to supply the rectifier filaments, and a 12-volt filament winding is center-tapped to supply the 6-volt filaments of the other tubes in the set. A separate filament transformer, T402, is provided to supply filament voltage to the horizontal damping tube. Having a separate filament transformer for the damper, means that its filament can be connected to its cathode. If the heater were at ground potential, the high voltage pulses at the cathode would cause cathode-to-heater shorts.

Admiral 122DX12

The Admiral 122DX12 is a modern television receiver using a 21-inch picture tube. A block diagram of this receiver is shown in Fig. 26. Notice that this diagram differs slightly from the one we have just discussed.

THE BLOCK DIAGRAM

The manufacturer has included in the blocks representing the various stages, the frequencies those stages are designed to handle.

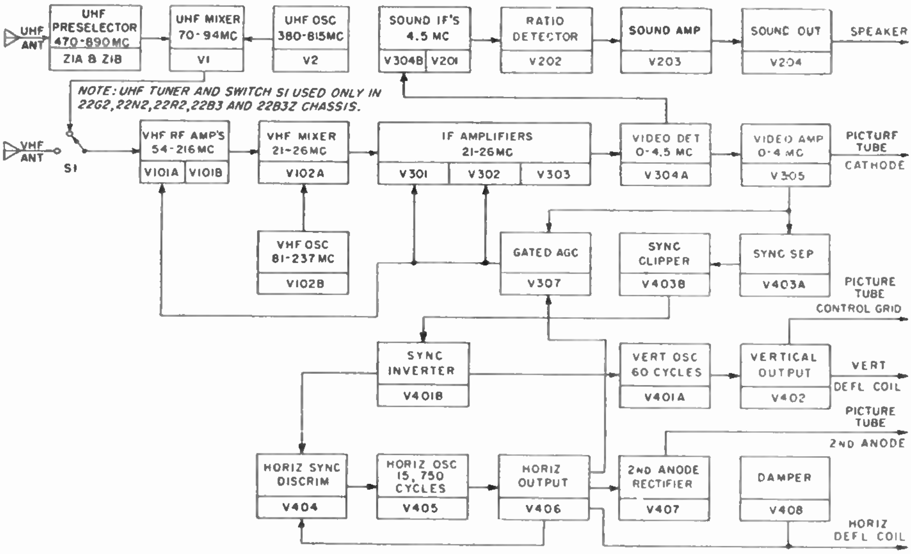
The signal from the antenna is fed into the rf amplifier section. In this case, as shown in the rf amplifier block, there are two stages, V101A and V101B. The amplified signal from the second rf amplifier is fed to the mixer. The signal from the oscillator is also fed to the mixer where the i-f signal, ranging in frequency from 21 to 26 mc, is developed.

There are three i-f amplifier stages that amplify the signal and feed it to the video detector. In the video detector, the picture carrier signal beats against the sound carrier, and an audio i-f of 4.5 mc is produced in addition to the composite video signal. The detected video signal is fed from the video detector to the video amplifier, where it is amplified and coupled to the cathode of the picture tube.

The 4.5-mc sound i-f signal is fed to the sound i-f stages where it is amplified and coupled to a ratio detector circuit. The ratio detector converts the sound i-f signal into an audio signal, which is amplified through two audio stages and fed to the speaker.

A composite video signal is fed from the video amplifier to the sync separator where the picture information is removed, leaving only the sync pulses. These pulses are coupled from the sync separator to the sync clipper; from this they go to a sync inverter. Separate outputs from the sync inverter supply the vertical oscillator and the horizontal sync discriminator.

The output of the vertical oscillator goes to the vertical output tube, which amplifies the vertical sweep voltage and applies it to the vertical deflection coils. A signal also goes from this stage to the control grid of the picture



Courtesy Admiral

FIG. 26. Block diagram of Admiral Model 122DX12.

tube to assure good vertical blanking during retrace.

Pulses from the sync inverter and feedback from the horizontal output stage are applied to the horizontal sync discriminator, which controls the sync of the horizontal oscillator. The sweep voltage developed in the horizontal oscillator is applied to the output stage, which amplifies it, and applies it to the horizontal deflection coils. A damper is connected across the horizontal output to prevent transient oscillations.

Also connected to the horizontal output circuit is the second anode (high-voltage) rectifier. This stage rectifies high-voltage pulses developed in the horizontal output stage, and applies them to the second anode of the picture tube. Pulses from the horizontal output stage are also fed to the gated agc tube. A composite video signal from the video amplifier is used for grid excitation of the gated agc tube. The output of this stage is applied to the first two i-f stages and the first rf stage of the receiver.

ANALYZING THE SCHEMATIC

Although the block diagram shown for this receiver is similar to that shown for the Westinghouse receiver, you will find that the schematic diagram shown in Fig. 27 on the large sheet is quite different. There are differences in the tuner, the i-f, the sweep and sync circuits, and the high voltage power supply.

In this receiver and the following one, we will limit our descriptions of stages to those unlike the ones you have already studied in this book.

The Tuner. The tuner of this receiver is of the so-called "turret" type. Separate sets of coils labeled L101A, L101B, L102A, L102B and L102C are used for each channel. The coils are mounted on insulating strips which make up the sides of a drum or turret. Channels are selected by rotating the turret so that the proper set of coils makes contact with the other elements of the tuner.

The two rf amplifiers contained in the type 6BZ7 tube are connected in an arrangement known as a cascode amplifier. From the standpoint of the B+ supply the two triodes are connected in series.

The first section acts as a grounded-cathode amplifier, and the second section as a grounded-grid amplifier. The common coupling coil between these stages is made very broad-band by the low impedance input to the second stage. Capacitor C120 is used to neutralize the first stage. An rf amplifier of this type is favored by many set manufacturers because of its high sensitivity and low noise.

The signal is fed from the antenna to coil L101A and coupled inductively to L101B, which is in the grid circuit of the first rf amplifier. The output of the second stage is inductively coupled to the mixer.

The resonant circuit for the rf oscillator, composed of L102C, C109, and C111, acts as the fine-tuning adjustment for the receiver. The oscillator output is coupled inductively to the coil L102B and the grid of the mixer stage.

Since both the oscillator and the rf signals are coupled to the grid of the mixer, they beat together to give the intermediate frequency of 21 to 26 mc. The mixer output is coupled to the first i-f stage through a band pass coupling arrangement consisting of L103, L309, C314, and a coupler unit. C333, C334 and L311 are tuned to 19.75 mc and form a series-resonant trap to eliminate interference from the video carrier of the channel immediately above the one to which the receiver is tuned. C336 and L313 form a series-resonant circuit at 27.25 mc used as an adjacent channel sound trap to eliminate sound interference from the channel below the one to which the receiver is tuned. L312 in parallel with the two traps forms a parallel-resonant circuit which peaks the response at 23.5 mc.

I-F Section. There are three stages of i-f amplification. Inter-stage coupling in the i-f section is by means of stagger-tuned, overcoupled transformers. This gives a wide-band i-f response. The over-all band width of the i-f section is approximately 3.9 mc. To prevent sync buzz in the sound, the sound i-f signal must be amplified much less than the video signal. To accomplish this, a 21.25-mc (sound carrier frequency) trap, composed of L310, C324, and C327 is placed in the grid circuit of the second i-f amplifier.

Since the cathode resistors in the first two i-f stages are not by-passed, they will introduce degeneration. This prevents radical changes in the i-f response curve due to changes in the agc bias applied to these stages. The output of the last i-f tube, V303, is inductively coupled through T303 to the cathode of the video detector.

Video Detector and Amplifier Circuits. The video detector tube is one-half of a 12AT7 with the grid and plate tied together so that it serves as a diode. The 4.5-mc sound i-f signal is fed from the video detector through C201 to the first sound i-f section, and the composite video signal is fed to the video amplifier. L301 and L302 are peaking coils used to improve the frequency response of the video section. C322 and L308 form a "grain" trap to prevent 4.5-mc interference from entering the video amplifier. Note that the output of the video detector is directly coupled to the grid of the video amplifier. Thus, there is no loss of the dc component of the composite video signal.

The contrast control, R316, is in the cathode circuit of the video amplifier. This control varies the bias on the tube and introduces degeneration on strong signals. The degeneration keeps the frequency response of the stage constant while the bias changes.

The output circuit of the video amplifier is designed to maintain the necessary high-frequency response of the video system. Coil L303 isolates the output capacity of the video amplifier from the input capacity of the picture tube, reducing the effects of these distributed capacities. Coil L304 increases the plate load impedance of the higher video frequencies, overcoming losses due to shunt capacity. C320 is in parallel with C307A as the screen by-pass because electrolytics are not reliable at high video frequencies. C320 alone is too small to be a good by-pass at low video frequencies. Resistors R320 and R321 are shunted across peaking coils L303 and L304 to load the coils and to prevent ringing, which is a form of oscillation that may occur in peaking coils that are shock-excited by video or sync pulses. The output of the video amplifier is coupled to the cathode of the picture tube through C309 and R324. R324 couples the dc component of the composite video signal to the cathode of the picture tube.

R343 and R326 form a voltage divider in the grid circuit of the picture tube. This allows the dc potential on this grid to be varied, controlling the brightness of the picture. Negative pulses from the vertical output circuit are also applied to the grid of the picture tube to assure good vertical retrace blanking.

The Sound Section. The 4.5-mc sound i-f signal is fed to the sound i-f amplifier through C201 and L201 which are series-resonant at 4.5 mc. C326 effectively by-passes the 21-mc i-f signals. The first sound i-f stage is a grounded-grid amplifier. The i-f signal appears across the parallel-resonant circuit L203 and C219 in the cathode circuit of the first i-f tube. L203 provides a low resistance dc path from cathode to ground, while at the same time the impedance to a 4.5-mc signal is high. C202 and L202, along with the input capacity of the second i-f amplifier, form a resonant pi-section coupler between the first and second sound i-f stages.

The output of the second i-f amplifier is connected directly to the winding of the ratio detector transformer T201. R222 is connected across this winding to broaden its response. Audio voltage is delivered from the volume control R208A, through a coupling capacitor, C209, to the grid of the sound amplifier. The first audio amplifier is of the grid-leak biased type common in AM receivers. A tone control circuit consisting of C216 and R223 is connected across the output of this stage. The sound output amplifier is of conventional design. A permanent magnet speaker is used in this set.

Sweep and Sync Circuits. The sync circuits in this receiver are similar to those in the Westinghouse receiver with two exceptions. The first is that the vertical oscillator is a blocking oscillator rather than a multivibrator. The second is that the high voltage power supply is actually a part of the horizontal output circuit rather than a separate oscillator. You will note also that the composite video signal for the sync circuits is taken from the output of the video amplifier and fed to the sync separator grid. Taking this signal from the output of the video amplifier rather than from the video detector means that a sync amplifier is not needed.

Cut-off bias developed by grid leak action in the sync separator permits only the highest positive peaks, the sync pulses, of the composite video signal to pass through this section.

The sync separator is coupled to the clipper through C409. Grid leak bias is also used on the sync clipper stage. Negative sync or noise pulse peaks drive the tube to cut-off, resulting in clipping or amplitude limiting action. The output of the clipper stage is coupled through C410 to the sync inverter. This sync inverter is practically the same as the phase inverter in the Westinghouse receiver, but the high grid leak bias provides additional clipping. Sync pulses are taken from the cathode of the sync inverter to control the vertical oscillator.

Vertical Sweep Circuits. The vertical blocking oscillator works much the same as the multivibrator in the previous set. The transformer provides the phase reversal and feedback that are obtained in the first triode of a multivibrator. The frequency of the vertical oscillator can be varied by adjusting the resistance from grid to ground with the vertical hold control, R405. The amplitude of the sweep signal output of the vertical oscillator is controlled by varying the plate load resistance with height control R408. C406 and R407 form the wave-shaping network that develops a trapezoidal voltage waveform at the output of the vertical oscillator.

The vertical output stage uses an audio-transformer for coupling to the yoke, otherwise it is the same as the stage you studied in the previous set.

Horizontal Sweep Circuits. The phase inverter and the horizontal sync discriminator circuit act exactly the same as the horizontal afc circuit in the Westinghouse receiver. The dc voltage developed from the comparison of sync signals with sweep output signals is applied across R429 and through the filter network consisting of C415, R428, and C416, to the first grid of the horizontal oscillator.

The horizontal oscillator is a multivibrator very similar to the one you studied in the Westinghouse circuit.

Compare the circuits of the two sets. Note that the wave-shaping networks, R426 and C432 in the Westinghouse, and C420 and R438 in the Admiral, have different time constants. The values of the components in these networks are determined primarily by the deflection yoke and horizontal output coupling characteristics. These components will vary greatly from set to set.

R447 varies the plate voltage of the output section of the multivibrator, and hence the horizontal drive.

The beam power tube used in the horizontal output in this receiver serves a dual purpose. It not only sets up the deflection current for the yoke, but also is used to provide the high voltage necessary for the acceleration of the beam in the picture tube. The output coupling of this tube is by means of an auto-transformer.

L402, the width control used with this stage, has two separate windings with a common core that can be moved from one winding to the other. One winding is connected across a small secondary of the output transformer, the other winding is in series with the deflection yoke and is used to control the deflection current. As the core is moved from the winding in series with the deflection yoke, the current through the yoke increases, giving a wider picture. At the same time, moving the core into the other winding increases the secondary loading of the output transformer. This maintains the over-all load on the output tube constant.

Damper Tube and B+ Boost. The damper tube in this set also does two jobs. The auto-transformer is connected in such a manner that the dc supply to the output tube and the sweep voltage are in series. When the damper tube conducts, the resulting rectified pulse adds to the dc supply voltage and raises the voltage on the horizontal output tube, on the vertical sweep tubes, and on the second anode of the cathode ray tube. This rectified pulse is partially filtered by capacitor C428, coil L403 and capacitor C427. Varying coil L403 changes the shape of the ripple voltage which appears at the plate of the horizontal output tube. This change in ripple voltage is used to control the linearity of the output tube. Before this increased voltage is applied to the vertical sweep tubes and to the anode of the cathode ray tube, it is completely filtered by resistor R415 and capacitor C438.

High Voltage Supply. The rapid collapse of the magnetic field of the deflection yokes during the flyback portion of the sweep, gives rise to a very high voltage pulse. The first half cycle of this pulse is of the same polarity as the sweep signal and therefore is not damped out by the damper tube. This first half cycle is stepped up by means of the autotransformer and applied to the plate of the 1B3 rectifier tube. This tube rectifies the pulse to give a high voltage output of about 17,000 volts, which is applied to the accelerating anode of the picture tube. Since a high frequency power source is used for this supply and since the load current is low, very little filtering is required; the capacity between the inner and outer Aquadag coatings of the picture tube is all the filter necessary. A high-voltage supply of this type is known as a "flyback supply" and is used in almost all modern TV sets.

AGC Circuit. The agc circuit in this receiver works the same as the one in the Westinghouse receiver. However, this receiver provides a non-operating control to set the agc voltage for the best picture at any given location. This adjustment is made by varying the bias on the keyed agc tube and provides control over the conduction of the tube.

Low-Voltage Power Supply. The low voltage power supply is a typical transformer type of supply using full wave rectification. The focus coil is used as a filter choke. A section of the coil is shunted by the focus control R452 which varies the current through the coil to obtain the proper focus. The input filter capacitor, C432, is a 60-mfd capacitor and the output filter, C407C, is 80-mfd.

Crosley Chassis No. 434

The circuits used in the Crosley Chassis No. 434 have allowed the manufacturer to produce a large-screen TV receiver at relatively low cost, while still maintaining good picture and sound reproduction.

THE BLOCK DIAGRAM

A block diagram of this receiver is shown in Fig. 28. The path the signal takes through this receiver does not differ greatly from that taken in the other receivers you have studied. The antenna feeds the rf signal into the tuner, where it is amplified and converted into an i-f signal containing both picture and sound carriers. These are amplified in an i-f amplifier section and fed to the second detector. The second detector develops the 4.5-mc sound i-f and produces the detected composite video signal. Both of these are fed into the video amplifier where the composite video signal is amplified and applied to the picture tube cathode, and the 4.5-mc sound i-f signal is amplified and delivered to the first sound i-f amplifier. AGC voltage is taken from the video detector and fed back to the rf and i-f amplifiers.

There are only three stages in the sound system of this receiver. In the first stage, the 4.5-mc sound i-f signal is amplified and then fed to a combination limiter-discriminator-amplifier stage. In this stage, the sound signal is limited to prevent amplitude interference, detected to produce an audio signal, and the audio signal is amplified. All of this is accomplished through the use of a special gated-beam tube. The output of the limiter-discriminator-amplifier stage is coupled to an audio output tube which drives the speaker.

A composite video signal is taken from the video amplifier circuit to supply sync pulses to the sync circuits. This signal is fed to the sync clipper. Snyc pulses from the clipper are fed to the sync amplifier, where they are amplified and distributed to the vertical and horizontal sweep circuits. Vertical pulses are fed to the vertical blocking oscillator through an integrator network. The vertical blocking oscillator develops the required trapezoidal sweep voltage, which is then fed to a vertical output tube where it is amplified and applied through a transformer to the vertical deflection coils.

Horizontal sync pulses are coupled from the sync amplifier to the horizontal afc (automatic frequency control) stage, which syncs the horizontal blocking oscillator. The trapezoidal waveform from the horizontal blocking oscillator is applied to the horizontal output tube. There it is amplified and applied through a horizontal output transformer to the horizontal deflection yoke. A flyback type of power supply is used to supply the high voltage to the second anode of the picture tube. The horizontal damper is connected across the horizontal deflection circuit to eliminate transient oscillations.

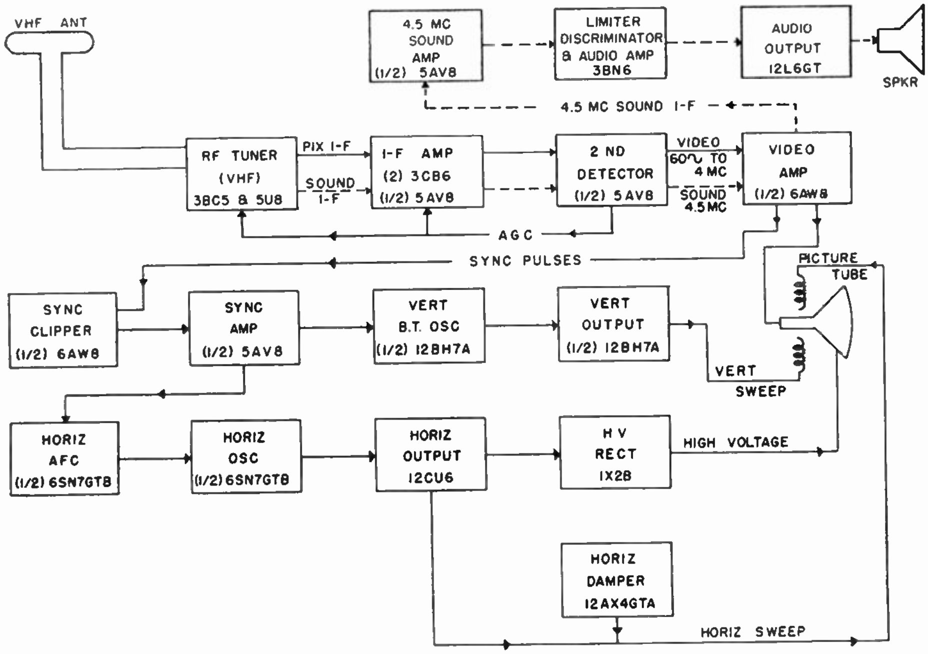
A brief study of the schematic diagram of this receiver, Fig. 29A on the large sheet, shows that there are a number of circuits different from those in the two sets that we have already analyzed. First, there is no power transformer for the low-voltage power supply, and all of the tube filaments are connected in series. There is one less tube in the audio section, the horizontal frequency control is different, and a blocking oscillator is used in the horizontal oscillator circuit instead of a multivibrator.

ANALYZING THE SCHEMATIC

A detailed circuit analysis can be made from the schematic diagram. This diagram is slightly different from the others in that the tuner section is shown on a separate smaller diagram, Fig. 29B. In the main diagram, it is simply shown as a block.

Tuner. The tuner is a conventional wafer-switch tuner similar to the one used in the Westinghouse receiver. If you compare the two circuits you will find only minor differences.

At the rf amplifier grid this tuner does not use the coils for channels



Courtesy Crosley

FIG. 28. Block diagram of Crosley Chassis No. 434.

7-12 on the low bands. Instead coil L1 replaces them and a separate secondary on the input transformer provides a better match to the antenna. AGC bias is applied to the rf tube grid.

The interstage coupling network is the same, but the oscillator is a straight Colpitts instead of an ultra-audion.

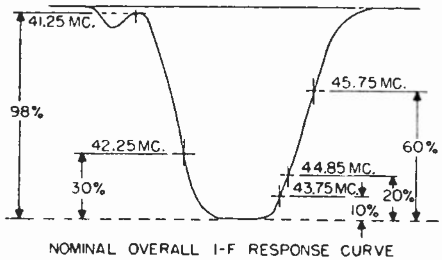
The oscillator operates at a frequency 45.75 mc higher than the video carrier frequency. This produces a band of frequencies extending from 41.25 mc to approximately 47 mc. The use of this higher i-f eliminates certain types of interference.

Note each of coils L2, L3, L4, and L5 is connected in series with the coils on one of the switch decks. These coils are provided for front-end alignment and are the only inductance in the circuit when the set is tuned to channel 13.

I-F Section. The over-all response of the video i-f section is shown in Fig. 30. This is obtained by using i-f transformers that are both over-coupled and stagger-tuned. Notice that there is a resonant tank coupled to L101. This is tuned to 47.25 mc and is an adjacent channel picture trap.

The output of the second i-f tube is coupled to the third i-f through L103. This i-f transformer is tuned to 42.25 mc and contains an absorption trap tuned to the sound-carrier frequency, 41.25 mc. The 41.25-mc trap reduces the sound carrier to a sufficiently low level to avoid interference. The first and second i-f amplifiers have automatic gain control.

The third and last video i-f stage is coupled to the video detector



Courtesy Sylvania

FIG. 30. Over-all response curve.

through T101. This transformer is tuned to 43.75 mc, approximately the mid-point of the i-f range.

The Video Section. Although the video detector tube is actually a triode, its plate and grid are tied together so that it acts as a simple diode detector. The polarity of the video detector is such that the output signal is a negative-going composite video signal, and the rectified component of the signal builds up a negative voltage across R118. This negative voltage is filtered by C114, R117, and C111, and used as the agc voltage.

Coil L104 forms a peaking circuit in the output of the video detector, which improves the high-frequency response. The output of the video detector is capacity-coupled through C113 to the grid of the video amplifier.

The contrast control R120, along with R121, forms the cathode bias resistance. By varying the amount of resistance between the cathode and ground, the bias and degeneration in the stage are varied and hence the gain of the tube is changed to control the amplitude of the video signal. The output of the video amplifier is fed through L109, where the 4.5-mc sound i-f signal is taken off. C115 connected across the primary of L109 forms a parallel-resonant circuit, tuned to 4.5 mc, in the output of the video amplifier. Since it is in series with the video amplifier output, it offers maximum resistance to a 4.5-mc signal, and therefore blocks the 4.5-mc sound signal from the picture tube circuits, while affording maximum transfer of sound i-f signals to the sound section of the receiver. The video signal is coupled to the cathode of the picture tube through C117 after going through another peaking network consisting of L105, R123, L112 and R172.

Notice that the dc component of the signal is not transmitted to the cathode of the picture tube. It is partially restored, however, by the rectifier action of the cathode and grid and the relatively long time constant in the cathode circuit. The positive dc potential applied to the cathode of the picture tube can be varied by means of R126, the brightness control. Since this controls the difference of potential between the cathode and the grounded grid of the picture tube, it controls the intensity of electron flow through the tube, and hence the brightness.

Sound Section. The secondary winding of L109 and C116 forms a parallel-resonant circuit across which the 4.5-mc sound i-f signal is developed. This is in the grid circuit of the sound i-f amplifier, V105A. The output of the sound i-f amplifier is coupled to the grid of the special limiter, detector, and audio amplifier tube through L111, which is also tuned to 4.5 mc.

V106 is a specially constructed detector tube known as a "gated-beam" detector. This tube has very sharp grid voltage-plate current cut-off characteristics and saturates easily. When properly adjusted, a grid swing of about 5 volts will drive the tube from plate saturation into plate current cut-off. This action produces

4.5-mc pulses with all amplitude variations removed.

The detecting action is brought about by the phase relationship of the signal on the first and third grids. These grids are commonly referred to as the first and second gates. Coil L106 and capacitor C125 form a high Q circuit tuned to the i-f center frequency. Shock excitation by the plate current pulses causes this circuit to oscillate. However, the voltage on the third grid lags the signal on the first grid by 90 degrees at the carrier frequency. The third grid exerts almost as much control as the first, and both gates must be open for the tube to conduct. The first gate opens and closes at a rate determined by the frequency of the incoming signal. As the frequency varies, the phase relationship between the two gates varies.

If the frequency on the first gate is lowered, the gates will be open and the tube will conduct for a longer period; if the frequency is raised, the tube will conduct for shorter periods. Since the average plate current is determined by the length of the conduction period, the plate current variations will reproduce the audio information that is on the sound carrier.

The buzz control R132 adjusts the bias on the first grid for proper limiting.

The output from the detector is coupled to the grid of the audio output through capacitor C127. The audio output circuit is a conventional power amplifier, the output of which is coupled to a permanent magnet speaker through output transformer T105.

Trace the cathode return of the audio output tube. Part of the current for the tuner, i-f amplifiers, and sync clipper and amplifier pass through this tube. This circuit arrangement uses the 12L6GT as a dropping resistor for these tubes. Using this tube instead of a resistor reduces the drain on the power supply.

Sync and Sweep Section. A composite video signal is taken from the output of the video amplifier through L105 to supply the sync and sweep circuits with the necessary sync pulses. This signal is fed through a network, C129, to the grid of the sync clipper, V104B. In this circuit, the clipper acts as both sync separator and clipper, removing the video information from the sync pulses and limiting the sync pulses to a uniform amplitude. This combined clipping and limiting action is obtained by using high bias and low plate voltage. The output of the sync clipper is fed to the grid of a sync amplifier through capacitor C130. Here the sync pulses are amplified and distributed to the vertical and horizontal sweep circuits.

Vertical Sweep Circuit. The output of the sync amplifier is coupled to the vertical oscillator in the usual manner, through an integrator network. The vertical oscillator is a conventional blocking oscillator, the output of which is fed to the vertical output tube. The vertical hold control is in the grid circuit of the vertical oscillator tube. The vertical output tube amplifies the sweep signal from the oscillator and applies it through auto-transformer T107 to the vertical deflection coil, L107A. Height control, R146, is in the grid circuit of the vertical output tube and varies the plate voltage of the oscillator. The vertical linearity control is in the cathode circuit as in the other sets.

Horizontal Sweep Circuits. The horizontal sync and sweep system differs from those we have seen before. This is an example of pulse width afc. The sweep generator is a blocking oscillator composed of V107B and the transformer T108. The frequency is controlled by varying the bias on the grid of the tube by means of R164, the horizontal hold control.

V107A acts as a phase discriminator. Its grid is biased to cut-off by grid leak action. Sync pulses from the sync amplifier combine with the output wave of the horizontal oscillator to allow conduction of this tube. The phase relationship of these pulses determines the length of the conduction interval. If the oscillator output has a low frequency or lags the sync pulses, the tube will conduct longer. If the oscillator output has a high frequency, or leads the sync pulses, the conduction period will be shorter. A correction voltage proportional to the conduction period appears at the cathode of this tube and is applied to the grid of the oscillator to correct the frequency.

The operating frequency is set with the horizontal lock and horizontal hold controls. Both these controls operate by changing the conduction time of the afc tube and hence the oscillator bias. The phase of the feedback voltage is adjusted by means of the transformer slugs. There is no provision for adjustment of the horizontal width, linearity, or drive.

The horizontal output tube is coupled to the yoke and the high-voltage rectifier with an auto-transformer. The damper tube provides B+ boost for the vertical sweep tube, the horizontal output tube and the anode of the picture tube.

Focus. The picture tube in this receiver is self-focusing. When the proper range of voltages is applied to the two anodes, the beam of the tube remains in focus on the screen for any setting of the brightness control. This type of tube is becoming very common in TV sets.

Power Supply. The power supply in this receiver is designed to eliminate the usual power transformer. The tubes are especially designed for series operation so that they can be connected in a single filament string. This accounts for the unusual filament designations in the tube types such as 3CB6 and 5AV8. The tubes used in TV series heater strings are designed so that all tubes will warm up at the same speed. This reduces burn-outs when the set is turned on. The B+ voltage is obtained from a half-wave voltage doubler using selenium rectifiers SR101 and SR102. With this arrangement, a total output voltage of approximately 280 volts is developed across C104A. L108 is the filter choke, and C132B and C140C, connected in series, act as the filter output capacitor. C140C also acts as the cathode by-pass for the audio output tube and prevents the audio signal current from modulating the i-f tubes. If this capacitor becomes open, sound bars will appear in the picture. There is 150 volts at the junction of C132B and C140C, and 260 volts at the high side of C132B.

Receiver Variations

Since it is impossible by analyzing just three TV receivers to show you all of the possible circuits that you might encounter, we will discuss here some other circuit variations.

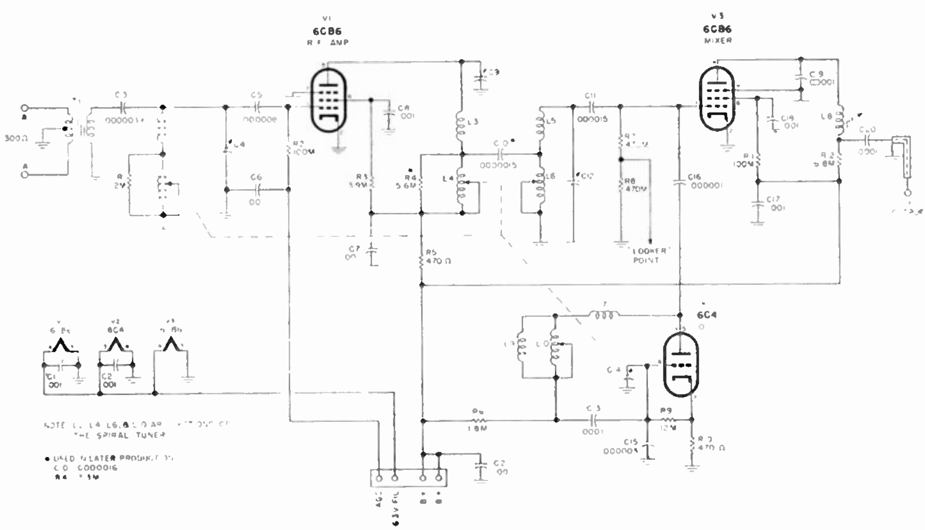
CONTINUOUS TUNER

All of the tuners that you have thus far studied, have had a switching device to select the desired channel. However, some sets have no channel selector switch, but are continuously tuned, very much like an ordinary broadcast receiver. Other receivers have a tuning switch for high and low band selection. There is one position for channels 2 through 6, and a second position for channels 7 through 13, with continuous tuning throughout each of these bands.

A schematic diagram for an rf tuner using completely continuous tuning is shown in Fig. 31. The coils used in this tuner are wound in a flat spiral and mounted on ceramic forms.

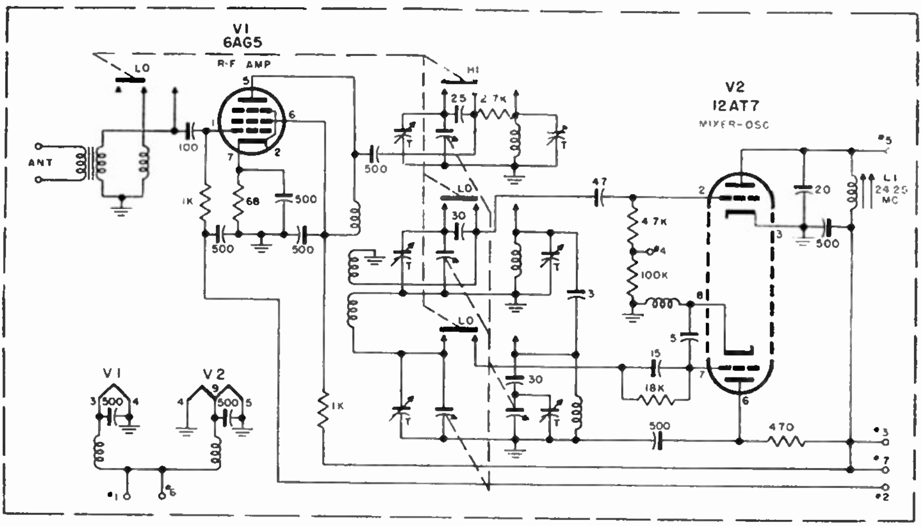
The circuit of this tuner is almost the same as that of tuners you have already studied; the differences are mainly mechanical. Tuning is done by varying L2, L4, L6 and L10 by means of a ganged control. Capacitors C4, C9, C12 and C14 are trimmers used for alignment. Resistors R1 and R4 load the coils in the rf stage to broaden the response. The resonant circuits in the plate of the rf amplifier and grid of the mixer are coupled through C10. C10 actually overcouples these stages to give a broad passband.

Fig. 32 shows a variable-capacity continuous tuner circuit. A two-position switch is used in this type of tuner so that in one position the low-band VHF channel can be tuned, and in the other position the high-band VHF channels can be tuned. Switching is automatic; as the shaft is turned, tuning the variable capacitors, it operates a switch when it passes the dividing point between channels 6 and 7. This switch changes the values of the fixed capacitors in



Courtesy Sylvania

FIG. 31. Schematic diagram of a continuous type of tuner.



Courtesy Capehart

FIG. 32. Variable capacity type of continuous tuner.

each circuit. As you can see in the schematic, the rf amplifier grid is not tuned within a band. This circuit is switched to the high band by adding parallel inductance to raise the frequency response. The outputs of both the oscillator and the rf amplifier are inductively coupled to the grid of the mixer stage. The operation of this circuit is conventional and need not be gone over again here. Only a few capacity-tuned continuous tuners have been used, and it is not likely that you will see many of them.

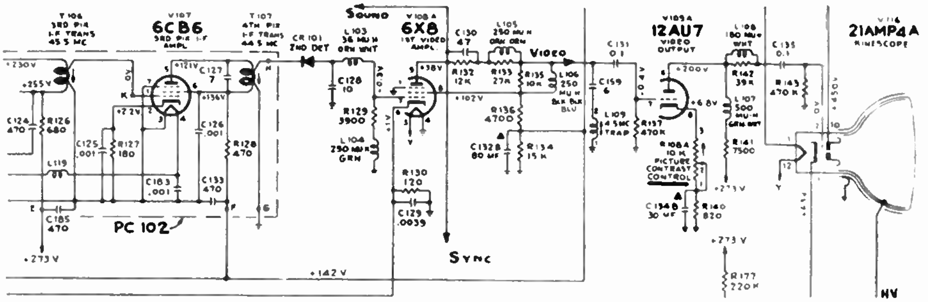
CRYSTAL DETECTORS

In the circuits that we have analyzed thus far, the video detectors have all been vacuum tubes. However, in a number of sets, a crystal detector has been used in place of a vacuum tube.

These crystal detectors have many features that make them quite popular with receiver manufacturers. They are small in size and require no heater connections or socket for mounting. They are generally mounted on terminal strips in the same way as a resistor. However, some manufacturers have placed the crystal detector in the last i-f shield can.

The schematic diagram of Fig. 33 shows the video section of a receiver with a crystal detector. In analyzing a schematic, you should remember that the bar represents the cathode and the triangle represents the plate of a crystal diode.

While crystals have a long life, they do not last forever. Their life will generally be greater than that of a vacuum tube diode. When failure of one of these diodes is suspected, it is tested with an ohmmeter. When the positive lead of an ohmmeter is connected to the plate end of the crystal, a resistance of several hundred to several thousand ohms will be indicated. When the ohmmeter is reversed with the positive lead to the cathode of the crystal detector, the resistance should be 250,000 ohms or higher in a good unit. In changing one of these diodes, take care not to overheat it with a soldering iron. It is generally best to grasp the lead of the diode with a pair of pliers between the joint and the end of the



Courtesy RCA

FIG. 33. Video section of a TV receiver using a crystal detector.

diode. As the lead becomes warmer, the heat flows into the pliers and does not damage the diode.

LIMITER-DISCRIMINATOR FM SOUND SYSTEM

In the circuits that we have analyzed thus far, either a ratio detector or a gated-beam detector has been used in the FM sound system. In some older sets, however, a sound discriminator was used which could respond to both AM and FM. In these sets it was necessary to remove all amplitude changes before detection. The schematic diagram of such a sound section is shown in Fig. 34.

The second sound i-f tube operates with no fixed bias, and with low screen and plate voltages. The stage limits in both the grid and the plate circuits to eliminate amplitude modulation.

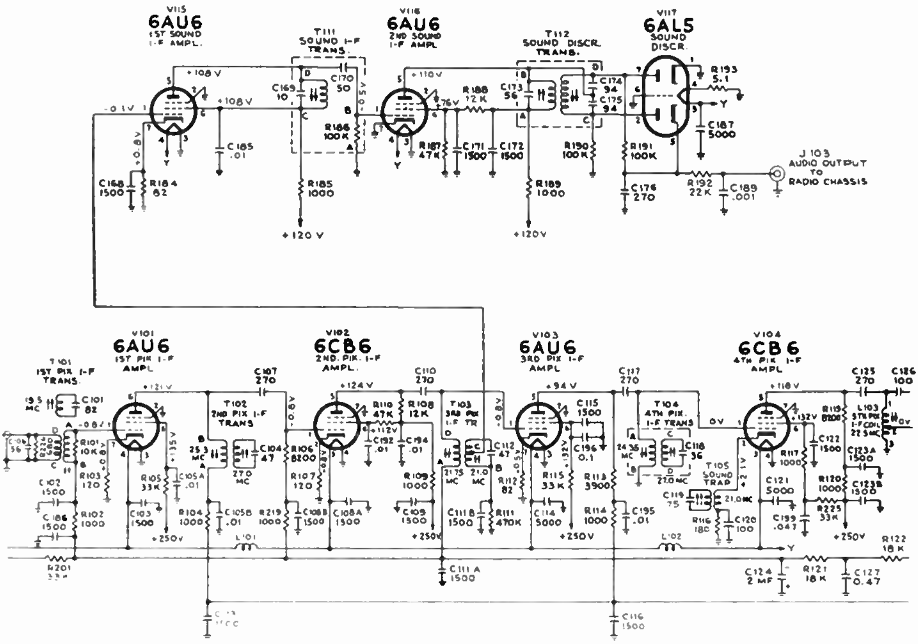
This circuit also shows an example of a separate audio i-f system. As you can see, the sound i-f is tapped off the 3rd i-f grid coil. The only sound i-f trap is in the cathode of the 4th i-f stage. Because of the high level required at the limiter grid, the sound i-f response cannot be reduced in any stage before the sound i-f take-off.

VARIATIONS IN PHYSICAL CONSTRUCTION

Although the major changes in the construction of TV sets were covered in an earlier part of this manual, there are other variations that you might meet. Among the minor variations are the large console sets which frequently are radio and TV combinations or even radio, phonograph, and TV combinations.

When servicing combination sets, you must bear in mind that the audio section of the radio is often used for the audio output of both TV and phonograph as well. Also, particularly in older sets, the speaker field is sometimes used as a filter choke. In either case, after removing the chassis for servicing, these units must be connected again before the set can work.

Fig. 35 illustrates two important types of construction which are becoming quite common. The first thing you will notice in this picture is the use of a vertical chassis with the picture tube extending through the chassis. In most sets the space behind the flare of the picture tube is wasted. The use of the vertical chassis allows the parts to be mounted in space which would otherwise be wasted. This results in considerable reduction in the cabinet size. The construction shown in this illustration leads to easy removal of both chassis and picture tube from the cabinet. In addition, all components and wiring are placed so as to be readily accessible.



Courtesy RCA

FIG. 34. Sound section of a TV receiver using an FM limiter and discriminator.

Look closely at the upper right-hand corner of the chassis. You will see there a sheet of darker material bolted to the chassis proper. All the small parts are mounted on this sheet of darker material. The leads of the individual resistors run through the base. This is an example of printed wiring construction.

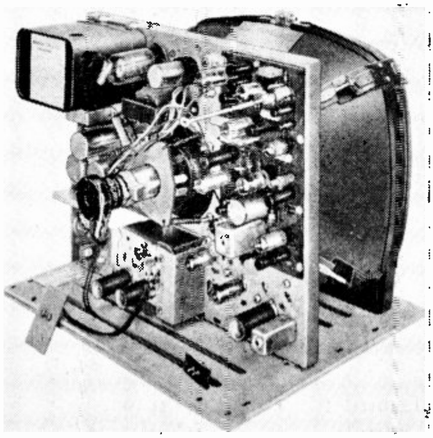
The heart of this type of construction is a phenolic board, with a thin sheet of copper cemented to it. The necessary leads for inter-connection of the parts are laid out on the copper and the rest of the copper is etched away.

Extreme care must be taken when replacing components. Small soldering irons must be used and the job must be done quickly; excess heat will loosen the copper.

LOOKING AHEAD

If you have your experimental receiver and have followed the instructions given in this manual you should now be thoroughly familiar with your set. In addition, your set should be mounted securely on your workbench in readiness for you to proceed to the second section of your practical TV training, in which you will gain experience in actually troubleshooting and repairing your set.

The experience that you have already gained covers a large part of the TV serviceman's daily work. You have done most of the mechanical part of TV servicing in removing the chassis from the cabinet and placing it securely on the bench. This is a part of every serviceman's daily routine. You have adjusted your set for best picture and sound. This is a part



Courtesy Admiral

FIG. 35. An Admiral television set using a printed circuit. This is the darker part of the chassis in the upper right-hand corner.

of every TV servicing job. You have also analyzed the circuit of your set and become familiar with typical circuits, and this is the first step in trouble shooting.

You may not fully understand the operation of some of the circuits. Do not worry about this. All of the circuits will be covered in detail in later regular lessons. No one man can hope to recognize and immediately understand all the circuit variations that are found. You must learn to use your reference material when making circuit analyses.

Television manufacturing is a constantly advancing art. New tubes, new circuits, and new circuit variations are being developed all the time. You will need to study these new features as they come out. You will be able to get information on them in servicemen's magazines and from manufacturer's bulletins.

Remember that the man who knows the most about the operation and adjustment of a set is usually the man who designed it. You will find that it is simpler, easier and more profitable to adjust a set by following the manufacturer's instructions for that set.

If you have carefully performed all the work outlined in this manual, you will have little or no trouble performing the experiments outlined in the next section of your Practical Training Course. By the time you have completed the second section, you will be able to find and correct any trouble in any TV receiver quickly.

HE WON'T LET GO!

Off the coast of New England a fishing boat was being tossed about in a rough sea. Suddenly a seaman noticed a young man clinging to the mast, lashed by the biting wind. In horror the seaman ran to the Captain and exclaimed, "*Look, Captain, your son is up there in grave danger. If he lets go he'll be dashed to pieces.*"

The Captain looked up and calmly replied, "*He won't let go.*"

Here and there we find a strong man. His problems are many and no different from those of others. But he keeps on hustling. He knows that he is master of his own destiny. Whatever his future shall be, he knows depends upon him and him alone. While others are willing to float with the tide, he is swimming upstream. He doesn't know defeat. *He won't let go.*

You've probably heard this philosophy before. But if only one man who reads this will hitch up his belt another notch and say, "I won't let go," this page has been worthwhile. Because, in time, that fellow will be a successful man. I hope it is you.

J.E. Smith

HOW THE TV PICTURE TUBE WORKS

50B

RADIO-TELEVISION SERVICING

NATIONAL RADIO INSTITUTE

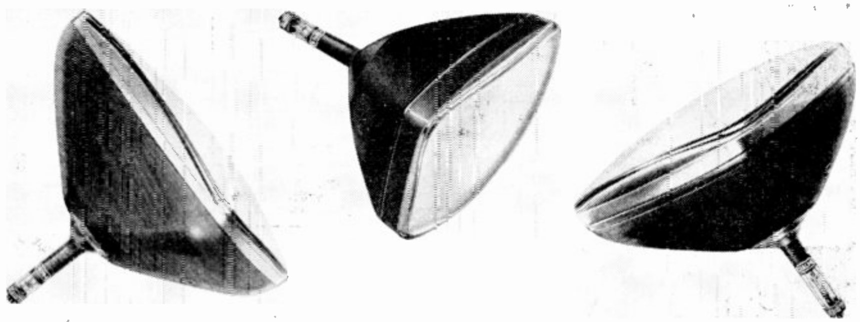
WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 50

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

FM3M360 **1960 EDITION** Printed in U.S.A.



HOW THE TV PICTURE TUBE WORKS

THE SOUND section of the television system is similar to standard FM radio. A microphone changes the sound into electrical signals that vary in amplitude. These signals are then changed into frequency variations (FM) and are sent out on the TV sound carrier. At the TV receiver, the FM signal is amplified, demodulated, and used to operate a loudspeaker.

In the sight section of the TV system, the scene to be broadcast is focused as an image on the sensitive surface of a camera tube, as shown in Fig. 1, and is then converted into electrical variations by that tube. These electrical variations are similar to the electrical fluctuations generated by a microphone, except that they occur over a much wider frequency range. These electrical variations, called the "video signal," represent the brightness distribution of the image.

Before the signal can be transmitted, it must be amplified and made to modulate a radio-frequency carrier wave. Since the video signal variations occur at much higher frequencies than sound signal variations, the frequency of the carrier must be much higher to obtain the required band width. Consequently, the television signals are transmitted in the VHF and UHF ranges.

At the receiver, the video signal is demodulated and applied, after amplification, to the control grid-cathode circuit of the picture tube. The function of the picture tube is to convert the electrical variations back into brightness changes and thus reproduce the image that was focused upon the camera tube.

The light distribution of the image on the camera tube is not transmitted as a single, lumped signal. Instead, a scanning beam in the camera tube moves across and down the image and releases *electrical variations* that correspond to the brightness changes that the scanning beam interprets. In other words, the brightness changes of an image are released in much the same manner as your eyes read across and down this page of type.

At the receiver a similar scanning beam moves across and down the pic-

Photo above courtesy RCA

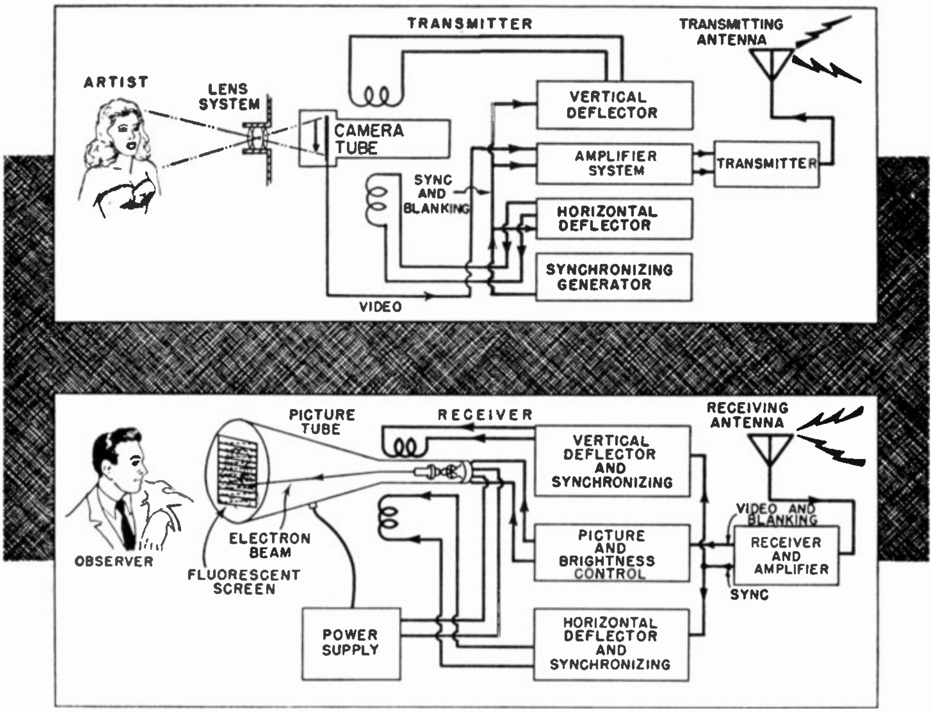


FIG. 1. The picture tube in the television system.

ture tube screen. This beam reproduces the original image by scanning across the fluorescent screen, element by element, and line by line, in accordance with the variations of the video signal arriving at the picture tube.

To obtain a true reproduction, the scanning beam of the picture tube must follow exactly the same path as that taken by the scanning beam in the camera tube in releasing the signal variations. That is, both the horizontal and vertical motions of the scanning beams must be *synchronized.* To accomplish this, two special voltage pulses are produced by a circuit, called the *sync generator,* in the TV transmitter. The signals generated in this circuit are referred to as the horizontal and vertical synchronizing pulses. The horizontal sync pulse synchronizes the horizontal movement of the electron beam in the picture tube in the receiver with the horizontal movement of the electron beam in the camera tube. The vertical sync pulse synchronizes the vertical movement of the receiver beam with the vertical movement of the camera beam.

Let us see how the signal synchronization is accomplished. Notice in Fig. 1 that the horizontal and vertical signals are supplied to the deflection circuits of the camera tube. At the same time, the same sync pulses are inserted into the video signal and both signals are transmitted to the receiver.

At the receiver, both signals are demodulated, and the sync pulses are used to synchronize the horizontal and vertical deflection circuits of the picture tube. Consequently synchronizing both the camera and the picture tube sweep circuits causes the picture tube scanning beam to follow exactly the same pattern as is taken by the camera tube scanning beam.

The demodulated video signal controls the strength of the electron beam in the picture tube. As the beam moves across the screen, it causes the elements along each line to vary in brightness in accordance with the video signal variations.

As you can see, each of the television signal components has a task to perform in reproducing the picture on the TV picture tube. When the TV receiver is operating properly, the reproduced picture will correspond exactly to the image that was focused on the camera tube screen. However, if a defect occurs in one of the signal circuits, it will be noticed immediately in the reproduced picture. Therefore, you can use the picture tube itself as the primary trouble localizer.

In this lesson, we will discuss the picture tube, and find out how the video signals are converted into a scene. Later lessons will take up, in detail, the operation of each circuit in a television receiver and the defects that occur in them. With a knowledge of how each part and circuit affects the quality of the reproduced picture, you will be well on your way to being able to localize circuit defects quickly.

PICTURE TUBE TYPES

All television picture tubes are fundamentally the same. Although they vary in type and size, all contain the following basic components:

1. A source of electron emission in the form of a cathode, which is indirectly heated by a filament.

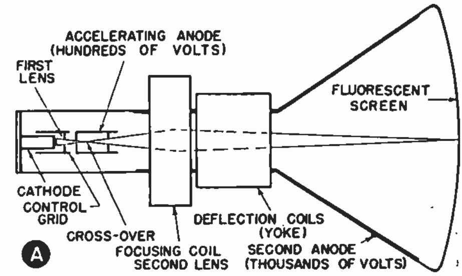
2. A control grid that varies the number of electrons that leave the cathode and strike the fluorescent screen. A change in grid voltage alters the number of electrons in the beam and therefore, the intensity of screen illumination.

3. A method of focusing the scanning beam so that it will be concentrated into a pin point at the fluorescent screen. When the focusing is accomplished by cylindrical elements mounted within the tube neck, the method is called *electrostatic focusing*. An external magnet coil surrounding the neck of the picture tube can be used instead to focus the scanning beam. This is called *magnetic focusing*.

4. A fluorescent screen, in the form of a coating on the inside of the face of the tube, that glows with the impact of the beam electrons. The intensity of illumination corresponds to the number of electrons in the scanning beam at the point of impact. Thus, by varying the number of electrons in the beam, it is possible to control the illumination.

5. A high-voltage anode system that accelerates the beam electrons toward the fluorescent screen. The high velocity impact causes the screen to fluoresce (light up).

6. A deflection system that can move the scanning beam to any part of the fluorescent screen. With the application of proper waveforms to the deflection system, it is possible to make the beam follow a prescribed pattern. The beam can be deflected by an external deflection yoke that is mounted on the neck of the tube. This is called electromagnetic deflection. When the beam is deflected by deflection plates mounted within the picture tube, it is referred to as electrostatic deflection.



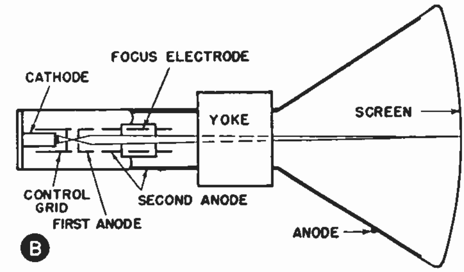


FIG. 2. Basic components of electromagnetic picture tubes. (A) A tube with electromagnetic deflection and magnetic focusing. (B) A tube with electromagnetic deflection and electrostatic focusing.

Electromagnetic Deflection. Modern picture tubes employing electromagnetic deflection (also known as magnetic deflection) may be divided into two basic types, according to the method used to focus the electron beam. If the beam is focused by an external focus coil (Fig. 2A) or by an external magnet instead of the coil, the method is called *magnetic focus.* If focusing is accomplished by the use of internal focusing electrodes (Fig. 2B), it is called *electrostatic focus.*

In a magnetic deflection picture tube that uses an external focus coil, the electron gun consists of a filament and a cathode to form an electron source, and a control grid and first anode (also called an accelerating grid or anode) to concentrate the electrons emitted from the cathode into a fine beam at a cross-over point. The focus coil then causes this electron concentration to strike the fluorescent screen as a dense pin-point of electrons (Fig. 2A).

The accelerating electrode, called the second anode, must supply the initial attraction that pulls the electrons away from the cathode and causes them to move toward the screen. The electrons must strike the fluorescent screen with sufficient impact to cause the elements to light up. This high impact is provided by greatly increasing the velocity of the electron stream through the use of a very high voltage on the final anode.

The electromagnetic picture tube shown in Fig. 2B uses electrostatic focus. Notice that there is an additional electrode in the gun. Instead of using a focusing coil or permanent magnet, the focusing of the beam is controlled by regulating the difference of potential between the focus electrode and the first anode. Precise focusing is accomplished by regulating the voltage applied to the focus electrode.

Although the focusing methods vary, the method used to deflect the electron beam is the same in both types of electromagnetic tubes. The scanning beam is deflected to all parts of the fluorescent screen by two separate magnetic fields that penetrate the glass envelope of the tube. A horizontal deflection field causes the beam to follow a prescribed path from left to right on the screen, while a vertical deflection field causes the scanning beam to move from top to bottom.

Electrostatic Deflection. A typical electrostatic focus and electrostatic deflection picture tube is shown in Fig. 3. This type was used in the earlier receivers using 5 to 7 inch picture tubes, and is also used in the

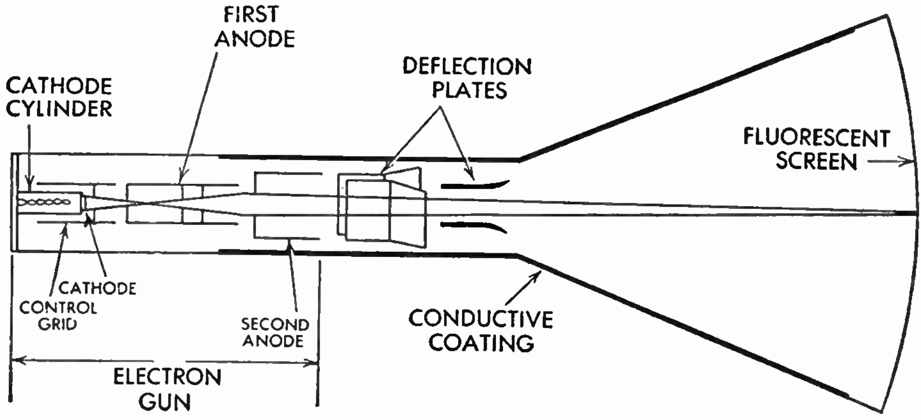


FIG. 3. Basic components of an electrostatic picture tube.

cathode-ray tube in your service oscilloscope. The electron gun section consists of a cathode, a control grid, a first anode, and a second anode. Instead of external deflection coils, two pairs of deflection plates within the tube control the deflection of the scanning beam. The deflection or movement of the beam is accomplished by varying the potential on the deflection plates.

In this gun the difference of potential between control grid and first anode focuses the electrons into a sharp cross-over point; the difference of potential between the first and second anodes focuses the very sharp cross-over point on the fluorescent screen. Often the electrodes of the picture tube that focus the beam to a cross-over are referred to as the "first lens" while the electrodes that focus the cross-over on the fluorescent screen are called a "second lens."

There are three operations taking place inside the picture tube. First, the scanning beam is generated and focused by the electron gun. Second, the deflection fields act upon the scanning beam and cause it to move in a standard pattern. Third, the focused and moving beam scans the fluorescent screen and illuminates it in accordance with the intensity variations of that beam.

Forming the TV Picture

To understand the operation of a television system, as well as the action of the picture tube, it is important that you know how the television raster is formed.

FORMING THE RASTER

The raster is composed of a series of horizontal lines on the picture tube screen. These lines are produced by the beam of electrons striking the fluorescent screen in a controlled pattern.

Deflection Plates. We can illustrate how the scanning beam traces a series of horizontal lines by studying the scanning beam movement in a picture tube using electrostatic deflection. The electron scanning beam in the electrostatic picture tube shown in Fig. 3 is deflected from left to right and from the top to the bottom of the screen by applying voltages to the deflection plates. It is the potential difference between these plates that causes the beam to move to form the raster. Fig. 4A shows what happens when the potential on all the deflection plates is the same; the scanning beam is focused in the center of the screen (in the illustration, we are looking directly into the electron gun).

When the right-hand plate is made positive with respect to the left-hand plate, the electrons in the beam are attracted by the positive plate and repelled by the negative plate. The beam is deflected, and the spot appears off-center to the right, as in Fig. 4B. When the left-hand plate is made positive with respect to the right-hand plate, the spot appears off-center to the left.

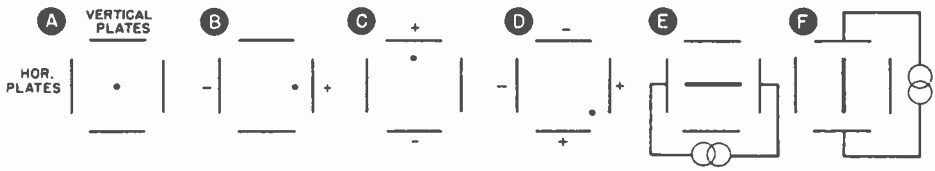


FIG. 4. The electron beam may be moved by applying different potentials to the horizontal and vertical deflection plates.

The spot can be moved vertically up the screen by making the top plate positive with respect to the bottom, as in Fig. 4C, and down the screen by making the bottom plate positive with respect to the top plate. The spot can be moved to any part of the screen by applying steady voltages across both pairs of plates. Fig. 4D shows the plate voltages that would move the spot to the lower right-hand corner.

If an ac signal is applied across the horizontal plates, the polarity of the voltage between these plates will change constantly. The beam responds to this changing voltage by moving back and forth across the screen, drawing a line as in Fig. 4E. If an ac signal is applied across the vertical plates the beam will draw a vertical line as in Fig. 4F.

The spot can be made to trace an unlimited number of patterns on the tube face by applying different ac signals across the two pairs of plates. The particular pattern that we are interested in for television is a series of horizontal lines across the face of the tube. We can get them by applying a specially shaped ac signal called a sawtooth voltage to each pair of plates.

A sawtooth voltage waveform is shown in Fig. 5A. At the beginning of the cycle, the voltage is negative; it changes in the positive direction at a steady rate, then drops very rapidly back to the original negative value. If this wave is applied to the horizontal deflection plates of a tube so that the right-hand plate is negative at the beginning of the cycle, the beam will move from the left side of the screen to the right then jump back to the left again, tracing a horizontal line on the face of the tube. The left-to-right movement is called the "trace", and the rapid right-to-left movement is called the "retrace".

Fig. 5B shows another sawtooth wave with a frequency one-quarter that of the wave in Fig. 5A. The wave in Fig. 5A goes through four complete cycles while the wave in Fig. 5B goes through one cycle. Now suppose we apply the wave in Fig.

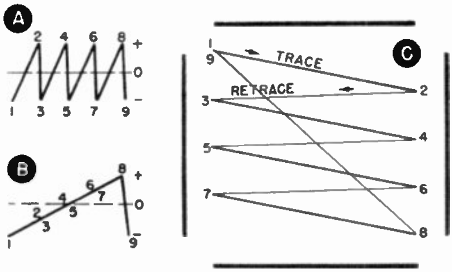


FIG. 5. Formation of a scanning raster.

5A to the horizontal plates and at the same time apply the wave at Fig. 5B to the vertical plates. When both waves are at their most negative value, the right-hand plate and the bottom plate are negative with respect to the left-hand plate and the top plate.

The beam is moved from left to right by the signal on the horizontal plates, and from top to bottom by the signal on the vertical plates. The frequency relationship between the two signals is such that the beam moves horizontally across the screen four times while it is traveling from top to bottom.

The numbers on the two waveforms in Figs. 5A and 5B show the voltages across the two sets of plates at nine different times. The numbers on the trace in Fig. 5C show the spot position at these times. In a television receiver, the beam is cut off during the retrace times, so that only the traces show on the face of the tube.

In actual practice, the frequency of the horizontal sawtooth is 262½ times as fast as that of the vertical sawtooth. This means that 262½ lines are formed during each motion of the scanning beam from top to bottom of the screen. You can see in Fig. 5 that the individual lines are tilted slightly. However, at these frequencies, the individual lines are produced at such a rapid rate that the tilt is not noticeable.

In modern TV broadcasting, a system called 1 to 2 interlaced scanning is used; that is, additional lines are interspaced between the first group of lines. Consequently, there are approximately 500 scanning lines from top to bottom.

You may see the individual scanning lines that make up the television raster by observing the face of your picture tube. The lines are particularly apparent on a large screen tube. When no video signal is applied to the tube, the scanning lines have a uniform illumination over the entire screen. You can adjust the over-all illumination by adjusting the brightness control.

Deflection Coils. The same type of scanning raster can be formed by using deflection coils mounted externally around the neck of the magnetic picture tube. To move the scanning beam, we apply a sawtooth *current* to each deflection coil. The sawtooth currents in the deflection coils form magnetic fields, which penetrate the glass envelope and control the movement of the beam generated by the electron gun.

If the sawtooth current changes linearly, it will produce a corre-

Courtesy of Admiral

FIG. 6. Picture formed by light variations along each scanning line.

sponding linear motion of the scanning beam. The principle of electromagnetic deflection will be discussed in more detail in a later section.

A picture is formed on the fluorescent screen by causing brightness changes along each individual line of the raster, as shown in Fig. 6. This is accomplished by applying the video signal to the control grid circuit of the picture tube. As the grid voltage changes, so does the density (the number of electrons in the scanning beam). Consequently, as the beam traces from left to right across the screen, the illumination changes along the scanning line.

When a dark element is transmitted, the density of the scanning beam is low, causing dim illumination of the fluorescent screen at the point of impact. When a brilliant element is transmitted, the scanning beam has much greater density. Thus, the impact of the beam at this instant causes intense illumination at this point of impact.

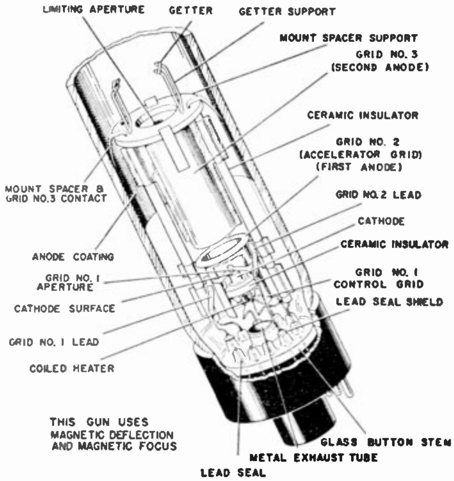
You can observe the brightness variations along a single line of a picture by looking closely at your television screen. Notice the areas of darkness, gray, and intense white along a single line. These same brightness changes along each of the 500 lines of the standard television picture reproduce the entire scene scanned by the camera tube.

FORMING AND FOCUSING THE SCANNING BEAM

The electron gun of a picture tube forms the scanning beam and focuses it on the fluorescent screen. The arrangement of the cylindrical elements in a picture tube that uses electromagnetic deflection and magnetic focus is shown in Fig. 7. The initial section of the gun consists of a heater, a cylindrical cathode, a cathode surface, and a control grid (sometimes referred to in service diagrams as grid No. 1). The rest of the gun in this tube consists of an accelerating electrode (the first anode, or grid No. 2), and the second, or final, anode (grid No. 3). In an electrostatic focus tube, an additional focus electrode is inserted between the first anode and the high-voltage second anode.

In a picture tube, the source of electrons is the emitting surface of the cathode that is heated by, but isolated from, a filament. The cathode is a cylindrical nickel cap mounted over the filament. At its end is a nickel disc upon which the emitting coating has been deposited. The composition of the oxide coating has been chosen to supply efficient electron emission with the amount of heat created by the filament. The actual cathode-emission surface is made as small as possible to permit the formation of a beam of small diameter. However, the surface must be sufficient to supply an adequate beam density.

To insure a very small diameter beam, the electrons leaving the cathode are concentrated into a cross-over



Courtesy of RCA

FIG. 7. Electron-gun structure of a picture tube.

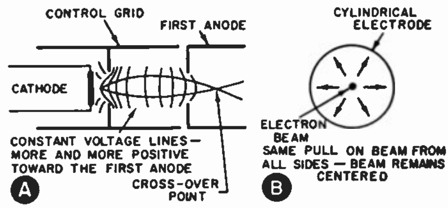


FIG. 8. Formation of cross-over point.

point. This is shown in Figs. 2 and 3. Then the electron gun regulates the density of the beam. These functions are accomplished by the cathode, the control grid, and the first anode.

The control grid, which is another cylindrical electrode, controls the amount of electron emission from the cathode surface just as the control grid in a conventional vacuum tube is able to regulate the plate current flow. As with the vacuum tube control grid, the picture tube control grid is biased negatively. Therefore, by changing the amount of negative grid voltage, either with a dc supply source or a signal, you can regulate the number of electrons that move from the cathode into the cross-over. Thus, the varying video signal applied to this electrode causes the bias voltage to vary. In turn, this produces the beam current variations that cause the brightness changes along each individual line of picture information.

The control grid electrode has a small aperture through which the electrons pass. The reason for using apertures in the various electrodes is to reduce the diameter of the high intensity beam and to eliminate all the fringe electrons. The fringe electrons are undesirable because they tend to enlarge the beam diameter without adding much to the illumination. Consequently, the fringe electrons fall on the aperture masks of the various electrodes, and are removed from the beam. This operation is referred to as *beam masking*, because it masks out all except the dense central portion of the stream of electrons.

It would be possible to arrange the electrodes in a picture tube so that the electrons traveled from the emitting surface of the cathode in parallel paths directly to the fluorescent screen. However, this would form a beam of large diameter, which would approximate the size of the cathode-emitting surface; the beam size would be too large for fine detail reproduction. Focusing the electron beam into a fine cross-over point makes the diameter of the beam much smaller than the cathode-emitting surface. The electrons are converged by means of the changing voltage levels, called "voltage gradients," between the first anode, the control grid, and the cathode surface.

The electrons, as they are emitted from the cathode surface, have like charges and therefore repel each other, and the stream of electrons begins to spread out.

The rising potential gradient between the control grid-cathode electrodes and the first anode causes the electrons that diverge from the center to take a curved path back to the center. These electrons converge at the cross-over point as shown in Fig. 8A. The curved voltage gradient lines in the illustration are referred to as constant voltage contours (same voltage at all points along contour line). The actual contours are not straight, but are curved because of the electrode construction and apertures, as well as the voltage ratios between the electrodes.

To understand the formation of the cross-over, let us consider what happens to those electrons that move down the center of the gun and those that diverge and must be brought back to the center. The electrons that move away from the center of the cathode follow a centered path down through the electron gun. These electrons do not diverge because there is an equal potential attraction for them on all sides, as shown in Fig. 8B. This equal potential attraction results from the cylindrical shape of the electrodes and prevents the electrons emitted by the cathode from landing on the actual electrodes themselves. Instead, the acceleration given to the electrons by the anode attraction causes them to move down the center of the gun and strike the fluorescent screen.

The electrons that are emitted at points other than the center of the cathode surface are located in the gun structure at a point where there *is not* equal potential attraction on all of its sides. These electrons are acted upon by two forces—the initial anode attraction as well as the attraction by the walls of the electrodes through which they pass. If the proper voltage contours were not established, these electrons would strike the positive electrode. Notice in Fig. 8A that with the proper potential difference between the first anode and the cathode, the contours can be made to fold over in opposite directions. Thus, the electron that enters the contour field on the left and is diverging from the center attempts to move toward the nearest, most positive, potential. The shape of the contour causes the beam to bend down the center instead of taking its initial divergent path. Once the electron has made the turn toward the center, the shape of the field must be changed so that it does not make a sharp twist toward the center. Rather, it must be brought toward the center gradually along with electrons from all the other possible divergence paths so that all electrons cross over at the point in the center of the gun.

The electrons that leave the cross-over point again diverge because of their mutual repulsion and their direction of motion. The second lens or focus system of the picture tube brings the electrons back to the central axis at the beam. In fact, it creates another cross-over point at the screen of the picture tube.

The focusing of the cross-over point on the screen can be accomplished magnetically or electrostatically. When electrostatic focusing is used, as shown in Fig. 9, the potential difference between the first and second anodes sets up a contour field which brings the beam to focus at the fluorescent screen. When magnetic focusing is used, an external field is generated to penetrate the envelope of the tube and bring the beam to focus at the screen as shown in Fig. 10.

Electrostatic Focusing. In electrostatic focusing (Fig. 9), the electrons in the outer segments of the beam diverge again after the first cross-over and move toward the elec-

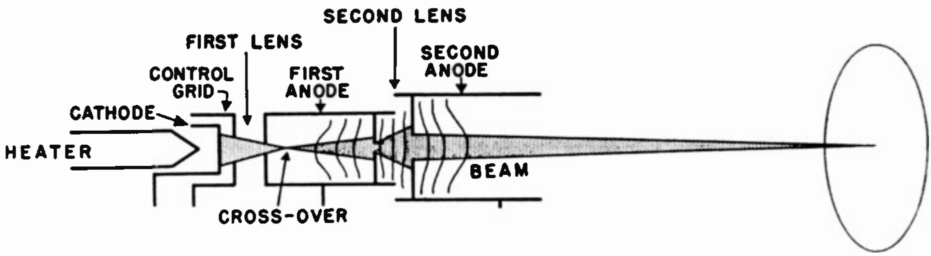


FIG. 9. Electrostatic focusing of scanning beam.

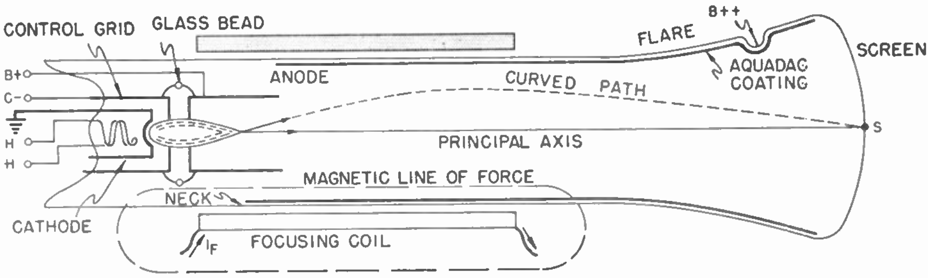


FIG. 10. Magnetic focusing of scanning beam.

trode walls. It is necessary to set up similar contours as discussed for the first lens to bring the divergent electrons back to the center. Again the proper ratio must be set up between the first and second anodes to bring about the gradual fold-over of the beam path and the long gradual swing back to the central axis. Notice in Fig. 9 that the distance between the cross-over point in the first anode (the first lens) and the screen is much greater than the distance between the cathode and the cross-over. This factor must be considered in the shaping of the focusing contours.

Apertures in the electrodes of the second lens confine the beam. The removal of the fringe electrons is also effective in removing a focus disturbance. In an electronic lens, as well as in an optical lens, it is difficult to bring the fringe electrons (marginal rays in the case of an optical lens) into focus at the same point as the centrally located electrons. Consequently, the removal of the fringe electrons makes certain that the lens system brings into focus only the highly concentrated central region of the beam.

Magnetic Focusing. When magnetic focusing is used, a magnetic field created by the focusing coil or magnet on the neck of the tube acts on the diverging electrons and causes a second cross-over point at the screen. To better understand the action of a magnetic lens, let us first consider some of the basic magnetic laws :

1. A current flow, whether through a wire or in the form of an electron beam, is surrounded by a magnetic field. These magnetic lines making up the field revolve counter-clockwise when looking in the direction of electron flow, as shown in Fig. 11A.

2. When two magnetic fields are perpendicular to each other, there is no reaction between them. Thus, if a beam of electrons moves through a magnetic field whose magnetic lines are parallel to the motion of the beam (and therefore perpendicular to the field surrounding the beam) the magnetic lines will have no influence on the beam motion, as shown in Fig. 11B.

3. When a stream of electrons diverges so that it is no longer parallel to the magnetic field, there is a force exerted on it at right angles to both the direction of current flow and the magnetic lines of the field. This is

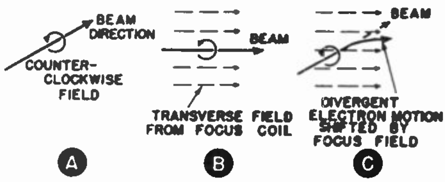


FIG. 11. Electron deflection by the magnetic field of the focus coil.

shown in Fig. 11C. In this case, interaction does exist between the magnetic fields. It is this interaction between the magnetic field produced by the stream of electrons and the magnetic field of the coil or magnet that permits the development of a magnetic lens. The focus coil or magnet that is mounted around the neck of the tube produces a magnetic field that is parallel to the center axis of the gun. This field, called a transverse magnetic field, is parallel to the motion of the electrons at the center of the gun. Those electrons moving in a straight line down the gun toward the screen are not influenced by the focus field. However, any electrons which diverge from the center axis of the gun after the cross-over are acted upon. These electrons are made to curve back to the center of the beam.

The divergent electrons are acted upon by a force that is attempting to move the entire stream of electrons perpendicular to both the direction of flow and the magnetic lines of the field. Actually, the divergent electrons would make a complete circle were it not for the original attraction applied by the anode voltage. Therefore, the high velocity of the beam, because of anode attraction, causes the electron path to follow a curved path as a result of the combined forward and circular movement. However, when the strength and position of the focus field are adjusted properly, the divergent electrons move back to the center so that the beam forms a very small, dense spot at the screen.

DEFLECTING THE SCANNING BEAM

Almost all picture tubes now being used have magnetic deflection. Electrostatic deflection is used primarily in cathode-ray oscilloscope tubes, although it was used in some of the older small-screen picture tubes. Magnetic deflection is preferred for TV picture tubes because the neck of the tube can be made shorter for a given size screen. Therefore, the over-all length of the tube can be made short enough to fit in a practical cabinet size. In addition, the spot size or beam diameter can be made smaller when using magnetic deflection, which results in improved resolution.

Electromagnetic deflection, like magnetic focusing, depends on the magnetic laws discussed in the preceding section. In *electromagnetic deflection,* however, the magnetic fields have lines of force that are *perpendicular* to the direction of beam motion instead of *parallel,* as in the case of *magnetic focusing.*

How coils can be used to deflect the electron beam is illustrated in Fig. 12. Let us assume that two coils are mounted so that one is above and the other is beneath the neck of the

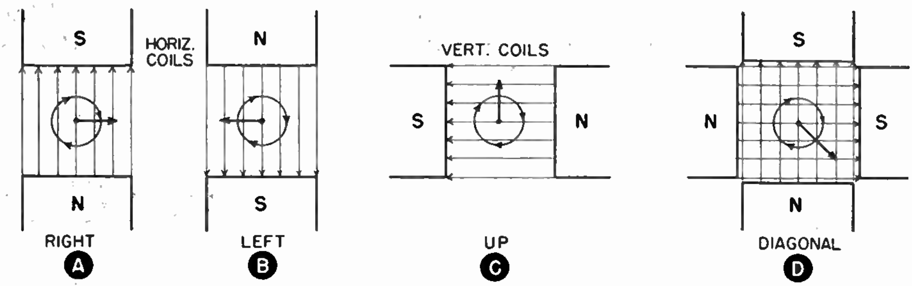


FIG. 12. Magnetic deflection of scanning beam.

tube in such a way that a horizontal magnetic field penetrates the glass envelope of the tube. If we assume also that the scanning beam is coming out of the paper, there will be a *clockwise* magnetic field surrounding the beam. This field, as shown in Fig. 12A, will *add* to the magnetic field from the coil to the *left* side, but it will *subtract* (opposite direction of field) from the same field on the *right* side of the beam. Therefore, there will be excess energy on the left side forcing the beam to the right as shown. If the magnetic field is reversed by changing the direction of current flow in the two coils, as in Fig. 12B, the beam can be deflected to the left. The left deflection occurs because the magnetic fields now add on the right side but subtract on the left.

When a pair of deflection coils are mounted on the right and left sides of the picture tube neck, it is possible to deflect the beam vertically. Thus, they are referred to as vertical deflection coils. In Fig. 12C, the horizontal lines of force add to the field surrounding the beam at the bottom but subtract at the top. Consequently, the beam is forced upward. If the direction of the field lines is reversed by changing the direction of current flow in the vertical coils, the beam can be deflected downward.

In an actual picture tube, the deflection yoke contains a pair of horizontal coils and a pair of vertical coils. Therefore, two magnetic fields are present, one with its lines vertical and a second with its lines horizontal. Since the two fields are perpendicular to each other, there is a minimum of interaction between them. The scanning beam can be moved to any part of the raster by regulating individual current amplitudes as well as the relative current amplitudes between horizontal and vertical coils. The illustration in Fig. 12D is an example of how the beam may be deflected diagonally.

The raster on a TV picture tube is formed by applying sawtooth currents (currents which rise linearly to a peak value and then drop suddenly) to the horizontal and vertical deflection coils. These currents cause the magnetic fields of the coils to change linearly, and therefore, to deflect the scanning beam in a prescribed pattern. Since the horizontal coils control the line formation of the raster, the frequency rate of the sawtooth current applied to these coils is 15,750 cps. As the beam sweeps back and forth, forming the horizontal lines, a 60-cycle sawtooth current is applied to the vertical coils to cause the beam to move from top to bottom.

For example, when the scanning beam is at the top left of the picture to begin the formation of a raster, both the vertical and the horizontal magnetic fields are at maximum strength. As a horizontal sawtooth current pulse causes the current in the horizontal deflection coil to drop to zero and then build up linearly in the opposite direction, the horizontal field decreases in intensity until it drops to zero and then builds up in the opposite direction as the current builds up. The scanning beam moves from left to the center of the screen and then on to the right side of the picture tube. When the beam reaches the far right, the direction of current flow suddenly changes, and the scanning beam returns quickly to the left to start a new line. The frequency of the sawtooth current applied to the horizontal coils is many times higher than that applied to the vertical coils. Therefore, a great many horizontal lines are formed as a single vertical sawtooth pulse in the vertical coils

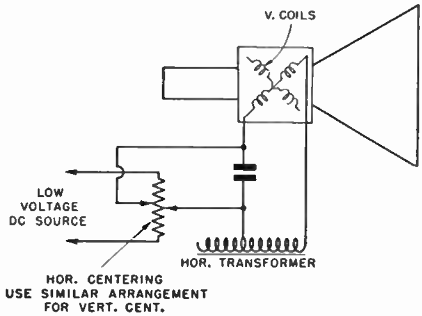


FIG. 13. Centering the scanning raster by applying a dc voltage to the horizontal and vertical deflection coils.

causes the scanning beam to move down the screen.

Now let us sum up the basic differences between electromagnetic and electrostatic deflection. When electromagnetic deflection is used, a sawtooth current and a changing magnetic field produce full deflection of the beam; when electrostatic deflection is used, a sawtooth voltage and a changing electrostatic charge produce full beam deflection.

CENTERING THE PICTURE

After forming the raster, you must have some method of properly centering it to the left or right and up or down on the fluorescent screen. One way is to insert a low-voltage dc source in the horizontal and vertical deflection coil circuits and adjust the amount and direction of the dc flow in each winding with a variable resistor. An adjustable centering circuit of this type is shown in Fig. 13. With separate potentiometers, you can adjust the amount and direction of dc flow and obtain proper centering horizontally and vertically.

The most common centering method for picture tubes with magnetic deflection involves proper positioning of the *focus coil* on the neck of the tube. Fig. 14A is an illustration of this method. Since a dc component flows in the focus coil, it can control the position of the scanning beam and thus the position of the raster. Generally, you must place the focus coil so that its own central axis does not coincide exactly with the central axis of the electron gun structure. Thus, to obtain proper centering, you will find that the focus coil must be positioned at a slight angle on the neck of the picture tube. In this position, the focus coil corrects for the dc components in the deflection coils that tend to move the scanning raster off center, and for any slight misalignment in the gun.

When electrostatic focusing is used, the most common centering

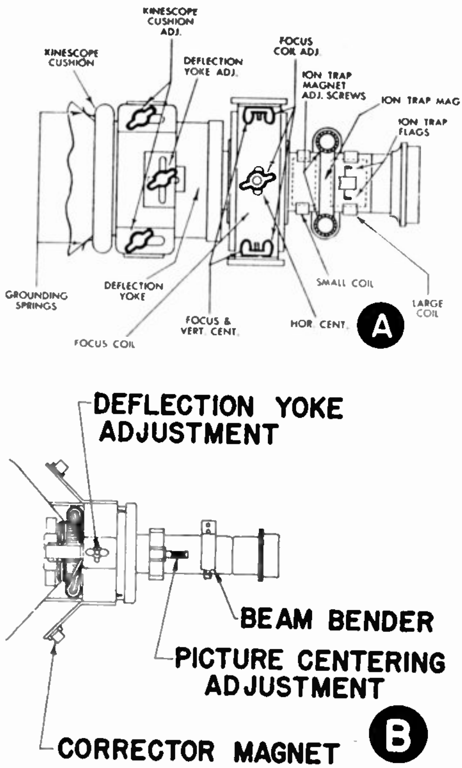


FIG. 14. Centering arrangements. In A, centering is achieved by proper position of the focus coil. In B, a centering magnet is used.

method is to use a small ring magnet on the neck of the tube near the deflection yoke. This is shown in Fig. 14B. Then, to obtain proper centering of the picture, all you have to do is rotate the magnet. Often a centering magnet of this type is used on a tube with magnetic focusing because it is easier to adjust than the focus coil.

FLUORESCENT SCREEN AND SECOND ANODE COATING

After the electron beam leaves the deflection field, its initial acceleration carries it to the fluorescent screen. The screen is made of a fluorescent material that is deposited on the inner face of the picture tube. When the material is bombarded by an electron beam, it will produce light, because the energy that the striking electrons impart to the fluorescent material disturbs its atomic structure. In returning to its normal state, the material gives off light. A material that behaves in this manner is referred to as a phosphor. The preparation of an efficient phosphor material for picture tubes is a highly specialized branch of chemistry. By properly combining different materials into a compound, it is now possible to obtain an almost white fluorescence.

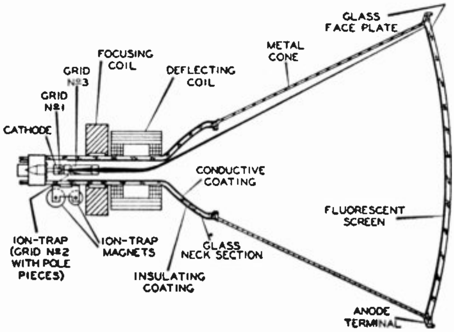
When the material is bombarded, it fluoresces and remains illuminated for a short interval after the electron beam has moved on to another section of the screen. The screen must glow long enough so that the image remains illuminated between scans, but at the same time it must not glow so long that the images overlap. A decay time (the decay time is the time required for the luminescence to decay to 1 per cent of its initial value) that will give a reduction in brilliancy to a negligible value in a few milliseconds will result in an adequate image persistence and reduction in flicker without causing the images to overlap.

When the electron beam strikes the fluorescent screen, it causes secondary electrons to be emitted. If the secondary electrons are not attracted to a positive electrode, they accumulate in front of the screen and form an electron cloud that interferes with the normal operation of the tube. To prevent this, the inside of the glass envelope in almost all picture tubes is coated with a conductive material, such as carbon or powdered graphite, called "aquadag." It extends out from the neck of the funnel-shaped part of the tube to within an inch or so of the screen. One end of the coating is connected to the second anode through spring clips, and so has a high positive potential to attract the secondary electrons away from the screen. In some picture tubes, the gun structure does not include a metallic second anode; the aquadag coating itself serves as the high-voltage anode.

On many picture tubes, the outside of the glass envelope has a conductive coating, which must be grounded. The glass between the inner and outer coatings acts as a dielectric, forming a capacitor that operates as part of the filter system for the high-voltage anode supply.

Picture tubes have been constructed using metal cones instead of glass. This type of tube, as shown in Fig. 15, consists of a large metal cone that links the face plate with the neck section. The large end of the cone is fused to a slightly curved, glass face plate, while the small end is fused to the glass neck section containing the electron gun.

The metal cone serves as the anode for the picture tube and is connected electrically to the anode section of the gun through a conductive coating



Courtesy RCA

FIG. 15. Metal-cone picture tube.

deposited on the inside of the glass neck section. The cone, being at high potential, usually is covered by a plastic insulating sleeve as a safety precaution.

SAFETY RULES

The picture tube can be the most hazardous component in a television receiver. There is danger of implosion and you may be hit by flying glass. Therefore, you must observe certain precautions each time you handle a picture tube. If you disregard these safety rules, you may be inviting disaster.

Never drop a tube even from an elevation of a fraction of an inch, and never slide a tube over any hard surface. This may scratch and weaken the tube so that at some future time a slight jar will cause it to implode. If the picture tube will not easily slide out of the television chassis, never jar or tug at it in an attempt to dislodge it. Instead, locate the cause of the difficulty. Always handle the tube carefully and gently. When a picture tube is not in use, always place it in its carton or on a rack. Never subject a picture tube to sudden temperature changes; when a tube has been operating for some time, allow it to cool before taking it outdoors.

Be careful in handling the tube so as not to receive a shock. The actual shock itself is not particularly dangerous. However, it can startle you sufficiently to make you drop or severely jar the tube, and it may result in an implosion, or at least, it may weaken the tube When handling TV picture tubes, always wear shatterproof goggles and heavy gloves for your own protection.

Almost all television receivers have a safety glass window over the viewing face of the picture tube. This window not only prevents accidental damage to the tube, but also it protects the viewer from flying glass if an implosion should occur. Therefore do not remove the protective window under any circumstances.

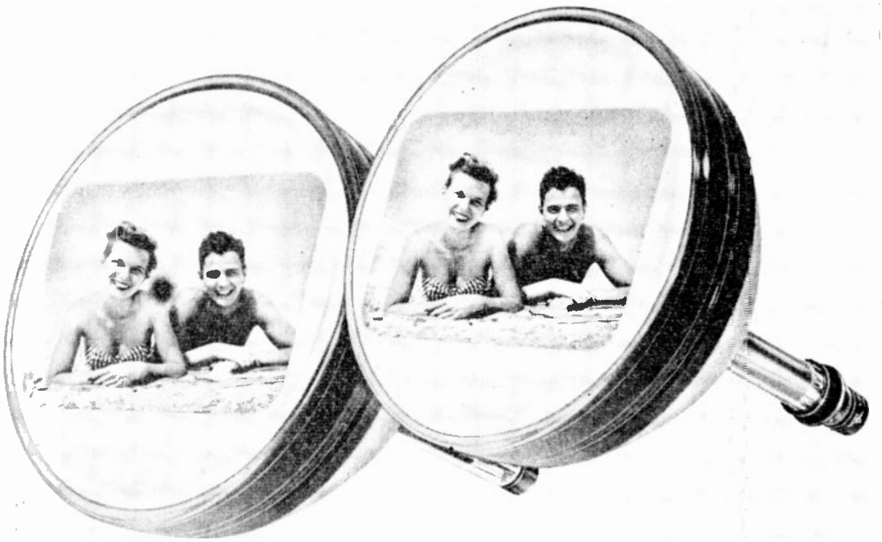
Special Features of Picture Tubes

In the previous sections, we have discussed the fundamentals and essential components of the picture tube and have explained its operation. Next, we will study some of the special characteristics, modifications, and improvements that have been made in the modern picture tube.

To produce a scanning beam of electrons that will strike the fluorescent screen with sufficient impact to illuminate the screen, we must use a very high accelerating voltage. However, this same high voltage is able to dislodge ions as well as electrons from the cathode surface. Since the ions have the same charge as electrons, they are attracted at high velocity by the high voltage of the anode. The ions have a much greater mass and are heavier than the electrons. Therefore, when they strike the fluorescent coating, they cause the screen to disintegrate. If the screen is bombarded by ions for a period of time, it will become incapable of producing very much light.

ION TRAPS

The problem of ion burns in an electrostatic deflection tube is not serious, because an electrostatic field is able to deflect the heavy ions as well as the lighter electrons. However, a magnetic field has little influence on the heavy ions; only the electrons are deflected. Thus, the ions remain in a cluster and strike a small central area of the picture tube continuously, which results in rapid deterioration of that surface. This is shown in Fig. 16.



Courtesy Sylvania Elec. Products Co., Inc.

FIG. 16. Notice ion spot in center of the face of the tube at left.

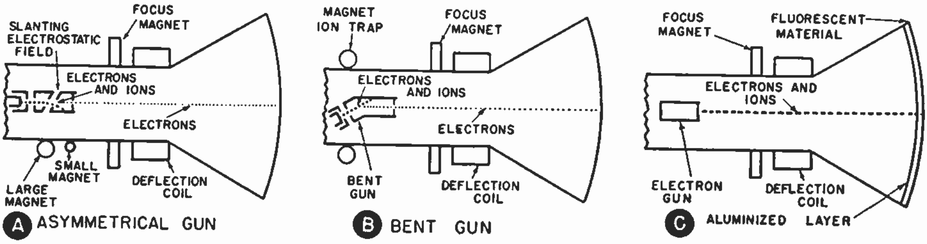


FIG. 17. Ion trap methods. A shows an asymmetrical gun; B a bent gun, and C an aluminized layer in back of the fluorescent screen.

There are several methods for preventing the heavy ions from burning the fluorescent screen. These methods take advantage of the fact that an ion is heavier than an electron and that an electrostatic field will deflect both ions and electrons equally well, but a magnetic field will deflect only the electrons. Several ion trap arrangements are shown in Fig. 17. The methods in Fig. 17A and 17B employ electron guns of special construction (either asymmetrical or bent). In the third system (Fig. 17C), an aluminum backing at the fluorescent screen prevents the ions from penetrating to the fluorescent material.

Asymmetrical Gun. The ion trap arrangement in Fig. 17A consists of an especially constructed electron gun, and a magnetic ring assembly that is placed externally around the neck of the tube. The adjacent ends of the first anode and second anode are cut at an angle rather than straight. There is a small aperture at the end of the second anode through which the electrons pass to reach the screen of the picture tube. A strong electrostatic field exists in the air gap between the two anodes, and because this air gap is slanting, the electrostatic field does not follow the normal axis of the tube, but slants. The ions and electrons that enter this electrostatic field are deflected away from the central axis toward the walls of the second anode. Thus, if no external magnetic field were employed, both the electrons and the ions would be attracted to the wall of the second anode instead of passing through the aperture and continuing on to the screen.

To separate the ions from the electrons, we utilize the principle that a magnetic field will deflect electrons but will not deflect ions. Notice in Fig. 17A that two magnets are placed on the outside of the tube neck approximately over the gap between the two anodes so that the magnetic lines cut across the neck of the tube, and the effect of the slanting electrostatic field on the electrons is neutralized. The field from the first magnet penetrates the glass neck and pulls the electrons back toward the principal axis. This is rather large because considerable strength is required to change the direction of the electron stream.

A second and weaker field is contributed by a smaller magnet, which helps to guide the electrons through the small aperture in the second anode. The heavier ions, however, remain trapped by the second anode because the magnetic fields have practically no effect on their direction of travel. Therefore, they cannot be deflected back to the principal axis of the tube.

To obtain peak performance from

the receiver, you must adjust the ion trap properly. Proper adjustment is important not only from the standpoint of ion damage to the fluorescent screen, but also because it determines the full brightness and contrast of the picture.

Bent Gun. Another method of ion removal employs the bent-gun type of construction (Fig. 17B). In this gun the actual cylindrical elements are mounted at an angle with respect to the center axis of the tube. An external bending magnet or coil is used. When the electrons and the ions emerge from the aperture at the end of the control grid, they move toward the collector wall of the next cylindrical anode. Both the electrons and the ions pass through the lines of force of the magnetic bending field. The magnetic field is of sufficient strength and of the proper polarity to return the electrons to the center axis of the picture tube structure. However, the ions, since they are not influenced by the magnetic field, strike the collecting wall and are dissipated. Both systems we have described use the same basic approach to remove the ions, except that the first type has an asymmetrical gun and the second type has a gun mounted at an angle.

Aluminized Screen. The aluminum-backed screens also eliminate damage due to ion burns. The aluminized screen, which is actually a coating placed on the gun side of the fluorescent screen, is thin enough so that the electrons can pass through it and strike the screen. However, the ions, which are of greater mass and dimension are not able to penetrate the aluminized layer. Instead, they strike the layer and are disintegrated by it.

This type of ion removal is simple because it does not require an elaborate electron gun. However, picture tubes with aluminized screens also may use ion trap magnets, depending on gun style.

Three factors that influence the brightness of the fluorescent screen and, therefore, the obtainable contrast are the second anode voltage, the luminous material, and the effective utilization of the light emitted from the screen. A higher anode voltage, of course, increases the beam current without enlarging the spot size. Also, the brightness can be improved by using a more efficient fluorescent material. However, probably the greatest improvement in the picture brightness and contrast has been accomplished with the use of aluminum-backed screens.

When the electron beam strikes the

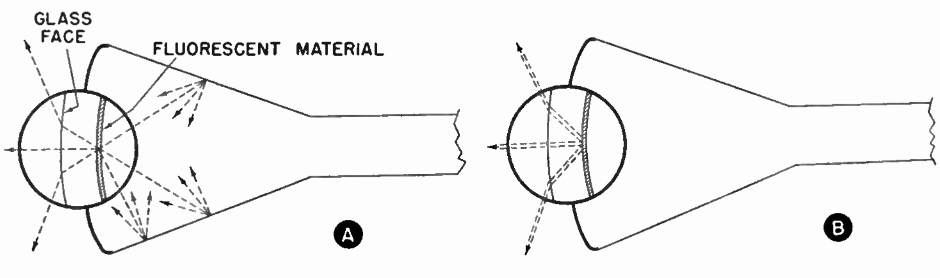


FIG. 18. In a conventional picture tube, light is emitted in all directions from an element of the fluorescent screen as shown at A; most of the light emitted by an element of the fluorescent screen is directed forward, if the screen has an aluminum backing, as shown at B.

fluorescent material on the tube screen, light is emitted in all directions, as shown in Fig. 18A. (The region in the circle is a greatly enlarged view of one element of the fluorescent screen.) Only a small percentage of the emitted light in a conventional picture tube is emitted toward the viewer. At least 50% of the light generated by the screen is emitted toward the back of the tube, and another 20% to 25% is lost by reflection from the glass on the inside of the tube face. If this reflected light is directed back to the screen and it falls on a picture area that is normally dark, the area will be illuminated, which results in a further reduction in contrast.

On the other hand, when the fluorescent screen is backed with a very thin layer of aluminum deposited on the fluorescent material, as in Fig. 18B, the light that would ordinarily go back toward the electron gun is reflected forward through the tube face. Often the aluminum-backed tubes are referred to as daylight tubes because, with the improved brightness and contrast, they can be viewed in full daylight.

ELIMINATING REFLECTIONS AND HALATION

In a conventional picture tube, the light at the point at which the beam strikes radiates in a number of directions as shown in Fig. 19A. Since there is no aluminum backing, light

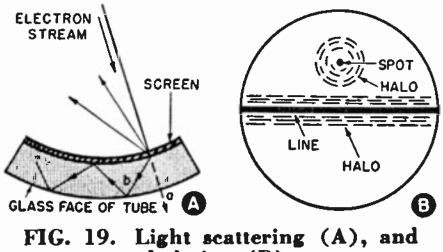


FIG. 19. Light scattering (A), and halation (B).

may be reflected back toward the gun structure or it may be internally reflected in the glass face of the tube as shown by the line b in Fig. 19A. This sidewise dispersion of the light results in a defect called *halation*. This defect prevents the necessary sharp division between bright and dark objects by causing shadowy lines to border the desired light lines. See Fig. 19B.

One method of overcoming halation and improving picture contrast is to use a dark binder with the phosphor crystals so that the light will not scatter. Halation can also be minimized by making the tube face of special filter glass that prevents the secondary light reflections. A piece of filter glass placed over the picture tube face is also helpful in preventing room reflections from disturbing the picture contrast. Ordinarily, any light falling on the tube face will lighten black areas in the picture and thereby reduce the over-all contrast range between the brightest bright and the darkest dark. However, with a filter-glass face plate, the room illumination can be higher without a resultant loss in picture contrast.

Tubes with filters to reduce halation as well as external glare are often called gray or black tubes. When they are not illuminated, the tube face appears darker than a picture tube that does not use a filter. Other types that employ both the aluminum-backing and the filter-glass face plate are at times referred to as black daylight tubes.

Another method that is occasionally used to reduce room glare involves mounting the picture tube so that it tilts downward slightly. Since there is little to cause reflections at the floor level, this gives an apparent improvement in contrast and reduction of glare when the picture is viewed with high room lighting.

FACE SHAPES

Although you may find a few picture tubes that have flat faces, the faces of most of the tubes in use are slightly curved. With an absolutely flat screen, it is more difficult to maintain sharp focus over the entire screen because the electron beam has to travel a greater distance between the gun and the outer edges of the screen than it does from the gun to the central portion of the screen. If the tube's face has a slight curvature, the outer sections of the screen are brought nearer to the gun so that it is less difficult to maintain a uniform focus. If the face curvature is too great, however, the picture is annoying to watch because the image appears curved and distorted.

There is also a safety consideration in designing a tube with a curved face. With a flat screen surface, there is a sharp bend between the face and the cone of the picture tube, and a slight jar or blow might be sufficient to cause the face to collapse. Thus, a limited curvature is preferable because it can be made stronger than one that has a sharp bend between the face plate and the cone.

IMPROVEMENTS IN THE ELECTRON GUN

One of the disadvantages of the usual type of gun is that the anode used in focusing the beam on the screen is often a part of both the first and the second lenses of the gun. When the focus voltage in this type of gun is adjusted properly, the crossover point occurs at the fluorescent screen. However, adjustment of the brightness control or brightness variations of the control-grid video signal can change the number of electrons

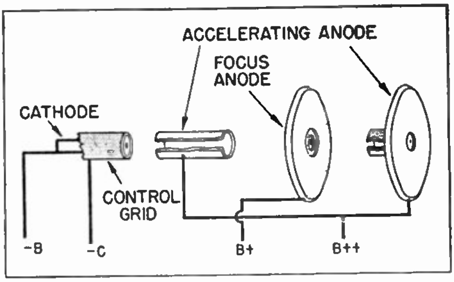
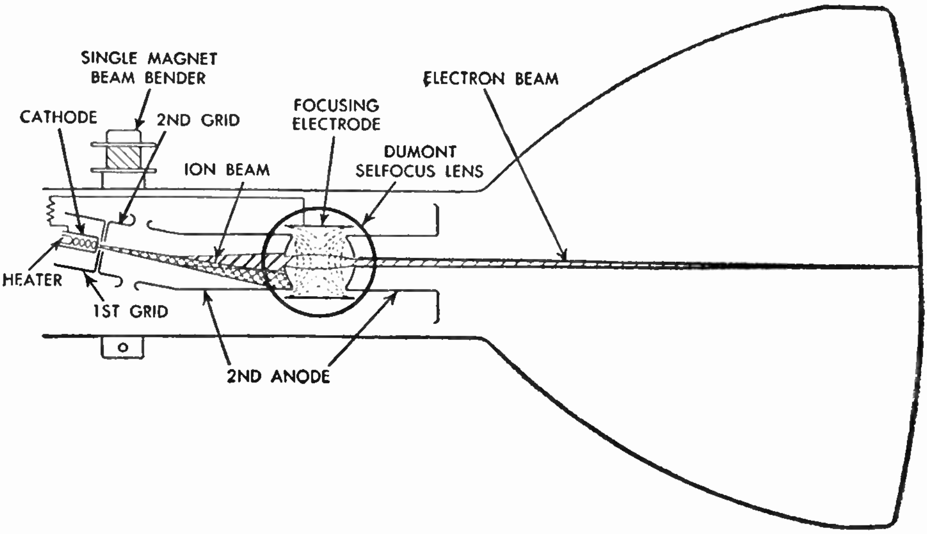


FIG. 20. Improved electron gun.

that strike the focus anode. This, in turn, alters the voltage ratio between the second anode and the focus electrode, and defocuses the beam.

To eliminate this disturbance, the second anode can be split and a focus anode in the form of a thin disc can be inserted between the anode sections as shown in Fig. 20. With this arrangement, the second anode is placed nearer the cathode, which results in more rapid acceleration of the electrons. Also, the focus anode serves as a buffer between the first and second lenses, minimizing the interaction between them. The accelerating anode is also made longer so it can serve as the collector for the diverging electrons of the beam—the number of which vary with control-grid changes. Since the focus electrode is thin, few electrons fall upon it. As a result, the ratio of the second anode voltage to the focus electrode voltage remains constant, and the focus does not change.

An example of a special gun for an electrostatic focus picture tube is shown in Fig. 21. This is a self-focus picture tube. With this arrangement, it is not necessary to use an external focus control because the gun itself has been designed to produce an in-focus picture when the ion trap has been set properly for maximum brightness. The self-focus tube remains in focus for wide variations in



Courtesy DuMont

FIG. 21. Self-focus or low-voltage electrostatic focus gun.

electrode potentials and for appreciable shifts in the filament and supply line voltages.

In the self-focus gun the second anode itself is split with the focusing electrode in position over the opening between the sections. The position of the focus electrode, its potential, and the width of the anode split are all designed to bring the beam to focus at the fluorescent screen. The ratio between the voltage of the two sections of the second anode and the voltage of the focus-electrode is always constant. As a result, variations in electrode potentials have much less influence on proper focus.

In one version of the self-focus gun, the focusing electrode is returned through an internal resistor to the cathode of the gun. Later versions of this type of picture tube bring the focus electrode out to one of the base pins so that a low value focus voltage can be applied to it.

FOCUSING PROBLEMS IN LARGE SCREEN TUBES

The length of a large screen picture tube is held to a practical dimension by deflecting the scanning beam over a wide angle. However, with this wide deflection angle, it is difficult to obtain uniform focus over the entire area of the screen. The spot, instead of being a small circle, is flattened to an egg-shaped spot at the outer edges of the raster as shown in Fig. 22A. This defect occurs in receivers using the older types of deflection yokes because they produce non-uniform magnetic deflection fields. Therefore, in passing through these curved sections of the field, the spot, instead of being round, as it is at the center of the screen, becomes elliptical. Naturally, the larger the screen area, the more objectionable the defect becomes.

This poor focus can be corrected by using "cosine" deflection yokes. In the cosine yokes, the windings of the deflection coils are designed so that

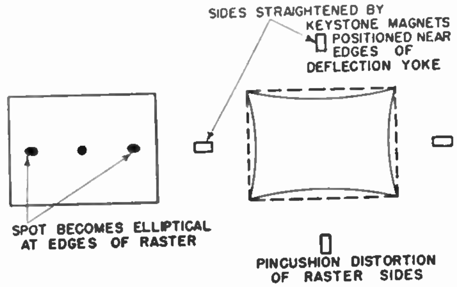


FIG. 22. Distortion problems of large-screen picture tube. A, at edges of raster, spot becomes elliptical; B, pincushion distortion of sides of raster can be straightened by keystone magnets.

there are more turns on the outside of the coil than at the center. This arrangement permits the development of uniform magnetic fields, and uniform focusing over the entire screen area. All modern TV receivers using large screen picture tubes have similar improved deflection yokes.

Still another type of raster distortion can occur in a large screen picture tube. To keep the over-all length of the large screen tube within practical limits, the neck is made short. This means that the beam must be deflected at a very wide angle (up to 110°) to reach the edges of the raster. It is apparent that the beam must travel a greater distance from the gun to the screen when it is scanning the edges of the raster than when it is directed toward the central portions of the screen. Since the distances are not equal, the actual lengths of the individual scanning lines do not remain uniform. For example, when the scanning beam is tracing a line at the very top (or bottom) of the fluorescent screen, it is at its greatest distance from the electron gun. Consequently, the length of the scanning line is very long for a given deflection angle. When the scanning beam is tracing lines at the center of the raster, the lines are nearest to the gun. At this position, the length of the scanning line is appreciably shorter because the scanned surface is nearer the electron gun.

This same non-uniformity exists both horizontally and vertically. As a result, the actual scanning raster is distorted on all sides (referred to as "pincushion" distortion) as shown in Fig. 22B. The longer travel paths at wide deflection angles cause a bowing-in of the scanning raster which is apparent on some modern receivers. This is seen often on a large screen picture when the receiver has a deflection system defect that presents difficulty in obtaining full picture width or full picture height.

The pincushion distortion is usually corrected in modern television receivers by positioning special pincushion magnets (sometimes called keystone magnets) near the fluorescent-screen side of the deflection yoke. It is also possible to minimize pincushion distortion with additional modification of the deflection yoke windings.

Picture Tube Circuits and Adjustments

In this section, we will discuss typical picture tube circuits used in modern television receivers and list the various signals and dc voltages that are applied to the tube electrodes. Then we will take up the proper placements and adjustment of the components on the tube neck.

DC VOLTAGE AND SIGNAL CIRCUITS

To obtain a suitably reproduced picture from a television receiver, a number of signals and dc voltages must be applied to the picture tube. This tube is the termination point for the video and blanking signals as well as the vertical and horizontal sweep waveforms. The voltage range includes the ac filament, the dc grid bias, and the very high dc anode voltages.

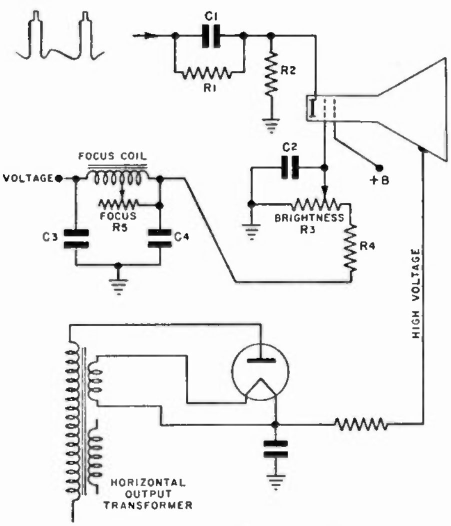


FIG. 23. The signals and dc voltages applied to a picture tube using electromagnetic deflection and magnetic focusing.

The various signals and voltages that must be applied to a picture tube using electromagnetic deflection and magnetic focusing are shown in Fig. 23. Video and blanking signals are applied through the compensating network consisting of capacitor C1 and resistor R1 to resistor R2 at the cathode of the picture tube. Since the signals are fed to the cathode, the blanking pulse and the black portions of the video signal must be positive in polarity. As you will learn later in the course, the signal must be fed to the picture tube in such a way that it will cause the number of electrons in the beam to increase when a bright portion of the scene is to be reproduced.

Although the coils are not shown in the illustration, sawtooth current waveforms are applied to the horizontal and vertical deflection coils to control the motion of the scanning beam.

The dc brightness voltage is applied to the grid of the picture tube through the brightness potentiometer R3 and filter capacitor C2. By adjusting the brightness control, you adjust the grid bias, and therefore, regulate the over-all or average screen illumination.

An external focus coil is provided with this type of picture tube. The focus control network consists of the focus coil, two filter capacitors C3 and C4, and the focus control R5. When the control is adjusted, it regulates the amount of dc flowing through the focus coil and in that way serves as a fine focus adjustment. Finally, a positive voltage of 350 volts is ap-

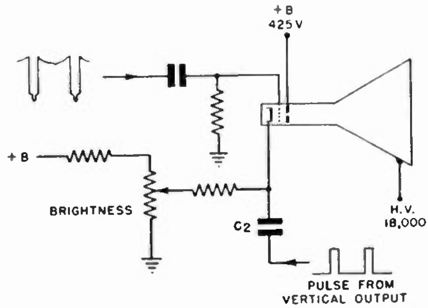


FIG. 24. Picture tube signal and voltage circuits for an electromagnetic picture tube using a permanent-magnet focusing arrangement.

plied to the accelerating anode of the picture tube, and a positive voltage of 14,000 volts supplies the required high-voltage potential for the picture tube second anode.

The same type of tube can also be used when focusing is accomplished by a permanent magnet, as shown in Fig. 24. In this arrangement, there is no focus coil or regulation of coil current. Instead, the permanent magnet is mechanically adjusted to regulate the strength or position of the focus field and to provide a fine adjustment of the focusing. In this circuit, the video and blanking signals are applied to the grid of the gun. Therefore, the polarity of the blanking pulse must be negative to shut off the scanning beam during retrace intervals. The brightness control is in the cathode circuit and regulates the positive voltage applied to the cathode to obtain the proper brightness bias between the grid and cathode of the picture tube.

Still another signal, called a *retrace blanking* signal, is applied through capacitor C2 to the cathode. It is in the form of a positive pulse developed in the output of the vertical amplifier. This positive pulse coincides with the vertical retrace period to cut off the scanning beam during vertical retrace intervals. Thus, the vertical retrace lines that weave from bottom to top of the scanning raster cannot be seen in the reproduced picture. Regardless of whether the video signal is applied to the grid or to the cathode of the picture tube, the vertical retrace lines are eliminated by the retrace blanking pulse. When there is a picture on the screen, the presence of the retrace blanking pulse permits more versatility in the adjustment of the contrast and the average brightness. Likewise, with changes in scene brightness, there is less likelihood of retrace lines becoming visible regardless of the type of scene being transmitted. In this picture tube circuit, a positive voltage of 425 volts is applied to the accelerating electrode, and the second anode voltage is more than 18,000 volts.

The anode voltage in most modern television receivers is developed in the horizontal output circuit. Although we will discuss horizontal output circuits in detail in another lesson, we will mention at this point that the high voltage is derived from a transient pulse of very high amplitude that is developed in the deflection output circuit. This positive pulse, which is present across the horizontal output transformer, is applied to the plate of a small high voltage rectifier tube as shown in Fig. 23. It is then filtered and applied as second anode voltage to the picture tube.

An example of an electrostatic focus picture tube circuit is shown in Fig. 25. Notice that with the exception of the grid, the various electrodes of the picture tube gun have fixed voltages applied to them. The dc voltage on the grid of the gun can be controlled with a potentiometer to obtain the proper average brightness. A retrace blanking pulse of negative polarity is also applied to the control

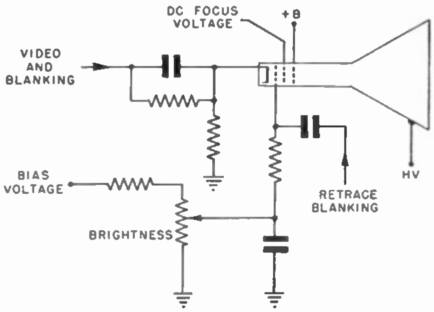


FIG. 25. Electrostatic focus tube.

grid, while the video and blanking signals are direct-coupled to the cathode.

When electrostatic focusing is used, no focus adjustment will be found on the neck of the tube. Instead, a low dc voltage is applied to the focusing electrode and adjusted with a potentiometer. Generally, this is in the form of a pre-set control to compensate for physical differences in gun construction. Since the setting of the control is not critical, it need be adjusted only when the receiver is first put into service, or after a picture tube replacement has been made.

The signal and voltage circuits for an electrostatic deflection and electrostatic focus picture tube are shown in Fig. 26. Again the composite video signal is applied to the control grid cathode circuit. Likewise, the brightness control circuit is associated with either the grid or the cathode of the picture tube to provide average brightness. The various electrodes of the picture tube generally obtain their supply potentials through a high-voltage bleeder network as shown. The

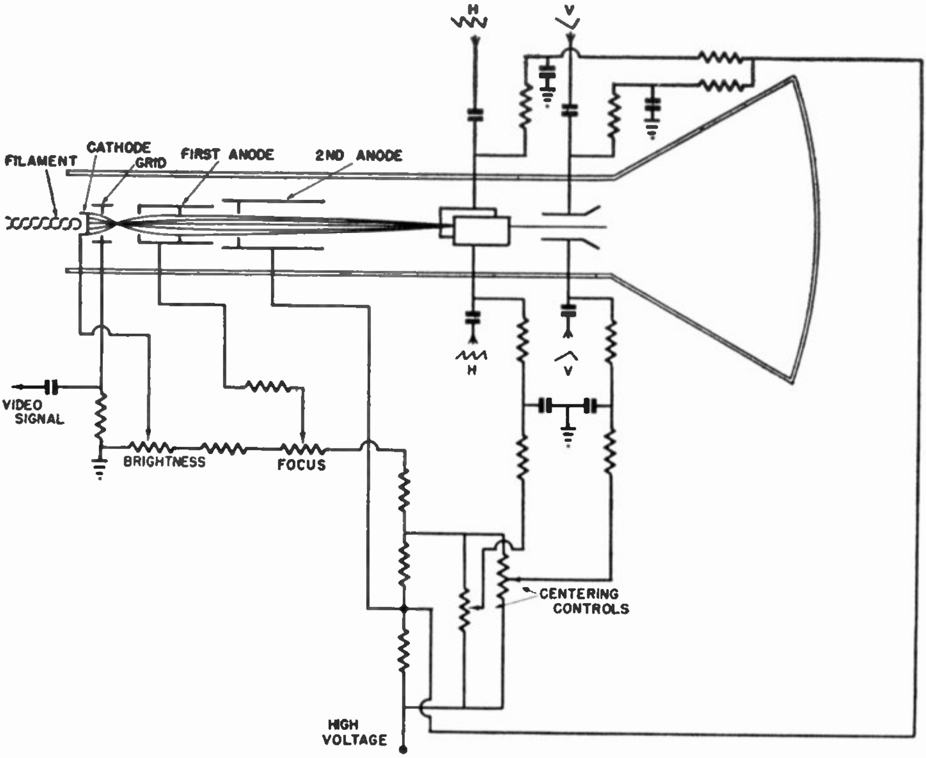


FIG. 26. Signal and voltage circuits for picture tube with electrostatic deflection.

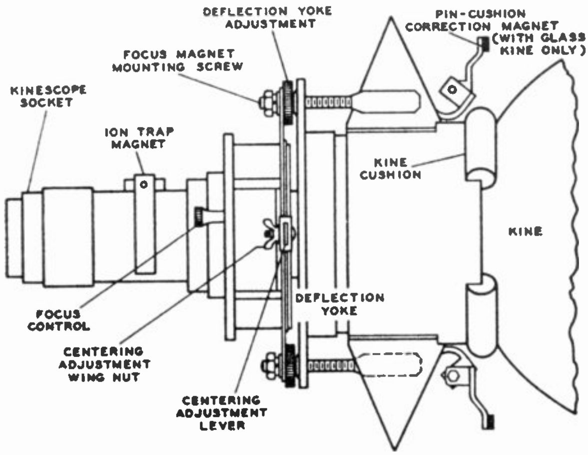
focus voltage is taken off through a potentiometer at the correct voltage division point along the bleeder network, while the second anode voltage is removed near the most positive high-voltage point. However, the voltage must be lowered slightly so that the centering controls can be inserted.

The movable taps on the centering controls are each attached to one plate of each pair of deflection plates so that the dc component of voltage between the pairs can be adjusted for proper centering both vertically and horizontally. Notice that sawtooth waves of equal amplitude but opposite polarity are applied to the two vertical deflection plates to obtain a balanced and linear vertical deflection. The same arrangement is used for the horizontal deflection plates.

PICTURE TUBE ADJUSTMENTS

To obtain the very best picture as well as to prevent possible damage to the picture tube, the components mounted on the neck of the picture tube must be properly placed and adjusted. The components on a tube with electromagnetic deflection and magnetic focus are arranged as shown in Fig. 27. The deflection yoke is placed as far up the neck of the tube as possible with the cushion resting against the cone of the tube. The pincushion magnets are near the fluorescent screen side of the deflection yoke.

The centering ring is just to the rear of the deflection yoke and is usually attached to it. Next in line toward the base of the tube is the focus coil or, as in Fig. 27, the focus magnet. It is a specific distance from the yoke and is adjustable to obtain the best focus. The last component on the neck of the tube is the ion-trap magnet.

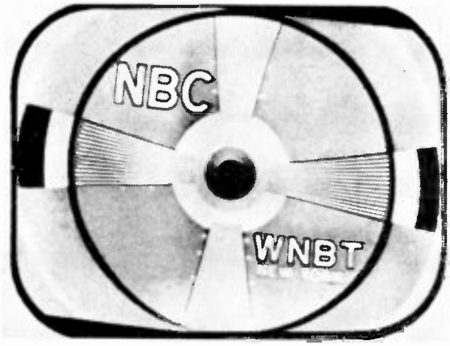


Courtesy RCA

FIG. 27. Proper placement of the components on the neck of an electromagnetic deflection and magnetic focus picture tube.

The ion-trap magnet adjustment is very important because it affects the brightness and contrast of the picture and it also prevents damage to the fluorescent screen and the apertures of the gun electrodes.

The deflection yoke must be positioned correctly to obtain a straight picture and one that does not tilt to the right or left as shown in Fig. 28. If the lines of the raster are not horizontal with the picture mask, you must rotate the deflection yoke until the picture is in the proper position. Generally, you will be able to shift



Courtesy RCA

FIG. 28. A tilted picture of this kind in a set using electromagnetic deflection means that the deflection yoke is rotated from its correct position.

Courtesy RCA

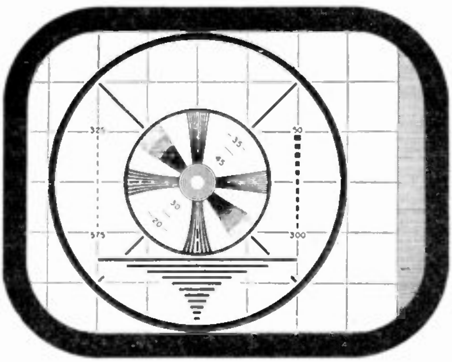
FIG. 29. Out of focus picture.

the entire yoke to the right or left after you loosen the holding wing nuts.

The focus magnet is generally located on the neck of the tube a specified distance from the deflection yoke as recommended by the manufacturer. When the focus control is adjusted properly, the reproduced picture will be distinct and clear instead of smeared as in Fig. 29.

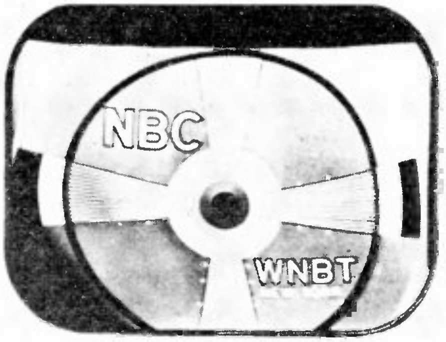
For the type of picture tube using a permanent magnet focus arrangement, a separate plate is also provided for correct centering. The centering plate is generally released with a wing nut and can be adjusted up, down, or sidewise to correct an off-center picture such as the one in Fig. 30.

When any corner of the raster is shadowed, as in Fig. 31, you must readjust the components on the neck of the tube (often the ion trap). The corner shadow indicates that the beam is not being guided through the aperture correctly. In fact, a portion of the beam probably is striking the aperture mask. If heavy ions are allowed to strike the edges of the aperture, they will eventually break down and distort the aperture holes. Therefore, you must reposition the ion trap



Courtesy Belmont Radio Corp.

FIG. 30. Picture off center horizontally.



Courtesy RCA

FIG. 31. The shadow at the bottom left of this picture is produced by an incorrect adjustment of the ion trap.

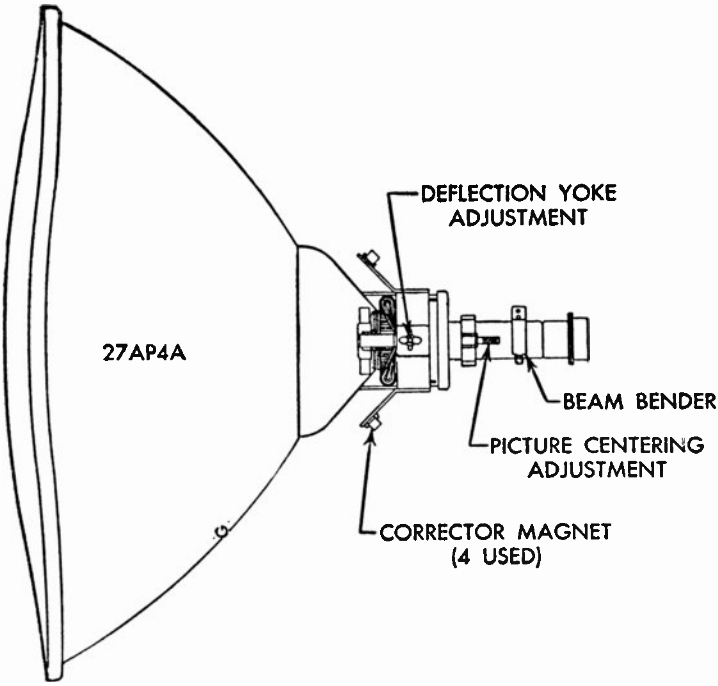
within the range of maximum brightness to eliminate the shadows, and then re-center and refocus the picture.

Pincushion magnets are used on most large screen picture tubes to obtain straight raster sides. These magnets are mounted on small hinged arms so that they can be moved forward or backward. Generally, you obtain maximum correction when you move the magnets toward the tube. This is shown in Fig. 32. To adjust the pincushion magnets, loosen the screws and move the magnets until the raster sides are straight. Then, tighten the screws, but be certain that you do not change the position of the magnets. Notice in the illustration in Fig. 32 that there are only the deflection yoke, the centering magnet, and the ion trap or beam bender on the neck of the tube; focusing is accomplished in the electron gun.

Now that you know the general functions of the components on the neck of the picture tube, let us go through a typical adjustment procedure. The following procedure is recommended by Sylvania for their picture tubes, as shown in Fig. 33.

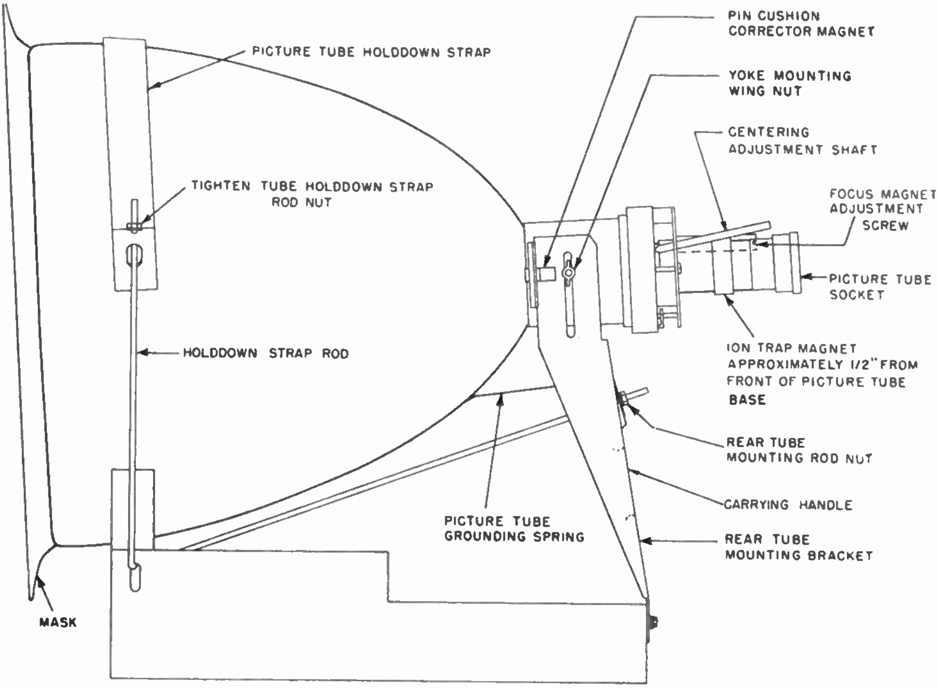
Before making any adjustments, check to be certain that the deflection yoke is positioned so that it presses against the flare of the picture tube. To do this, loosen the wing fasteners located at each side of the yoke, and push the yoke as far forward as it will go. If the picture is not square with the screen mask, rotate the yoke and then tighten the wing fasteners.

Next, be certain that the focus magnet is held firmly in position. Frequently, optimum focus must be a compromise because it is impossible



Courtesy Zenith

FIG. 32. Zenith picture-tube mount.



Courtesy Sylvania Electric Products, Inc.

FIG. 33. Sylvania picture-tube mount.

to obtain sharp line definition both horizontally and vertically. Therefore, when this adjustment is made, the received picture should be a test pattern or one containing vertical and horizontal lines.

The ion-trap magnet, focus-magnet, and centering-shutter adjustments interact on each other. Therefore, you may have to readjust them several times until they are correct. Before describing the adjustment procedure, let us note the function of each magnet.

The *ion-trap magnet* is used to obtain maximum brilliance of the raster or picture.

The *focus magnet* is used to obtain correct focus of the picture.

The *centering shutter* is an integral part of the focus-magnet assembly. Its function is to position the picture both horizontally and vertically.

With the receiver contrast adjusted to approximately three-fourths of maximum position, slide the ion-trap magnet on the picture-tube neck to approximately one-half inch forward of the tube base. Then, set the brightness control on the chassis to maximum. However, do not operate the receiver longer than necessary with the brightness at maximum.

Rotate and move the ion-trap magnet backward and forward on the picture-tube neck until the picture or raster is visible on the screen. Continue adjusting the trap until you obtain the greatest possible brilliance. Then, adjust the brightness to less than normal and readjust the ion-trap magnet for maximum brilliance.

Turn the adjustment screw on the focus magnet to obtain an in-focus picture. (This preliminary adjustment will not be necessary if the picture is already in focus.) If the picture is not centered on the screen, adjust the centering shutter; and with brightness at a low level, check to see that no corner-cutting exists.

Adjust the contrast and brightness controls to obtain a normal picture, and then adjust the ion-trap magnet to obtain the highest possible brilliance level. The focus should now be adjusted to obtain the best horizontal and vertical focus.

The correct position for the ion trap varies with the type of tube that is used in the receiver. In tubes having an asymmetrical type of electron gun, you may obtain the best ion-trap magnet adjustment with the magnet located on one side or the other of the diagonal slot in the picture-tube electrode assembly. In fact, it may be either between the slot and the tube base or over the slot. Never place the magnet between the slot and the focus magnet.

In other picture tubes, the best ion-trap adjustment may be obtained regardless of which way it is placed around the picture-tube neck. However, in some tubes you may find that you will obtain a better focus characteristic if you remove the ion trap from the tube neck and turn it over. In addition, picture tubes of the same type but made by different manufacturers may not require the same kind of ion trap magnet. For example, a single magnet ion trap may be required for one tube, while a tube of the same type made by a different manufacturer may require a double magnet. Newer tubes do not use double magnets, so when you are replacing an older tube using a double magnet, you may have to change to a single one. Always consult and follow the manufacturer's instructions.

Variations in the ion trap adjustments are not the only ones you will encounter in your television service work. In some receivers, you may be able to rotate the focus magnet. On these receivers, better focus may be obtained by rotating the focus magnet to a different angle and again adjusting the focus screw. However, after you make this adjustment, check the centering shutter to make sure that there is no corner-cutting when the picture is properly centered on the screen.

Recheck the ion-trap magnet, as previously mentioned, with brightness and contrast adjustments set for a normal picture, and carefully adjust the focus for the best possible compromise between horizontal and vertical focus. Since these adjustments are interdependent, recheck all three until the best picture is obtained.

Troubleshooting with the Picture Tube

The picture tube itself can serve as a very effective test instrument to isolate defects in a television receiver. Since so many signals and voltages terminate at the picture tube, the absence of one or more of these components will produce a characteristic picture defect. Thus, with a knowledge of what signals are required at the picture tube and how they influence the picture, you can isolate troubles to a defective section of the receiver almost immediately. In fact, as you increase your knowledge and understanding of how the television receiver operates, you will probably be able to isolate defects to a specific part merely by observing the picture on the screen.

As in radio receivers, tube failure is the most common receiver defect. Therefore, you can repair many sets quickly just by understanding a block plan of the receiver. For example, the block plan of a receiver shown in Fig. 34 demonstrates the procedure for localizing defects to just a few stages. Let us consider each major section and see how a failure in each of them will affect the receiver performance.

ANTENNAS

The antenna is a very important part of any receiver, but it is particularly important in fringe areas and in localities with reflection problems or high interference levels. The two major defects that can occur in an antenna system are an open or intermittent connection and a shift in antenna orientation.

A broken or shorted connection

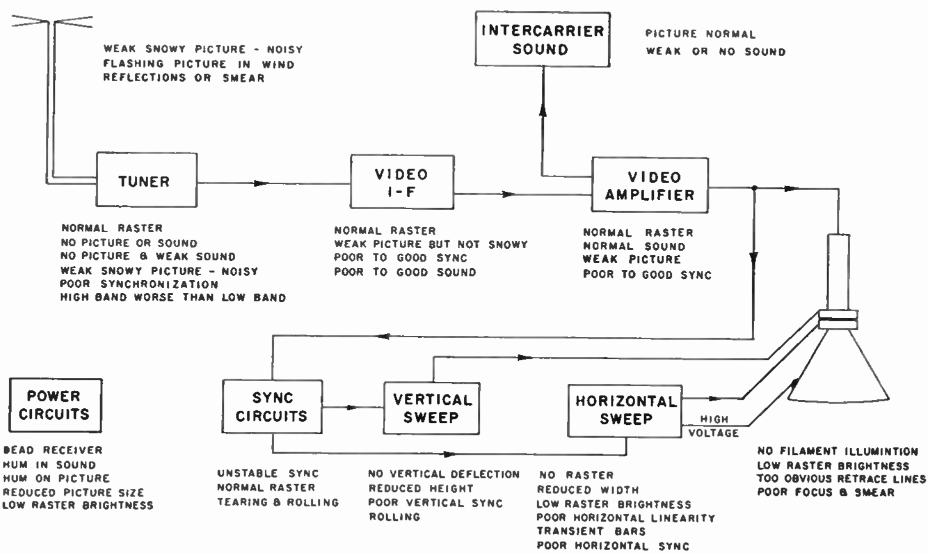


FIG. 34. Block diagram of receiver, showing effect of defects in each section on the picture and sound.

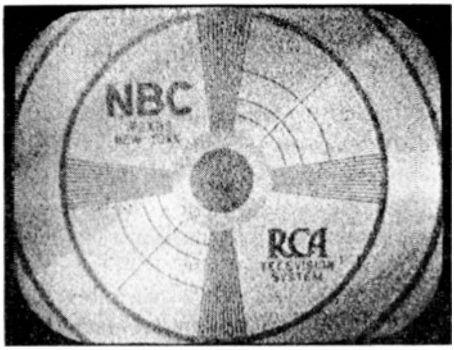


FIG. 35. Weak, snowy picture—defect in antenna or tuner.

somewhere in the antenna system can produce weak and erratic pictures, as shown in Fig. 35. Often certain channels are affected more than others; generally speaking, the weaker stations will be affected the most. A poor connection in the antenna and transmission line system can cause flashing and jumpy pictures. A windy day will often make an antenna defect intolerable because the wind will shake the antenna and cause the defective connection to "make and break" very rapidly.

Antenna defects, and improper orientation in particular, can bring about other picture disturbance. It can cause smeary pictures or reflections and ghosts.

TUNERS

Since the tuner is the first section of any television receiver, it must amplify both the picture and the sound signals that are picked up by the antenna. A serious tuner defect, therefore, will affect both the picture and the sound reproduction.

The two most common tuner defects are faulty tubes and mechanical selector troubles. Defects in the converter section also are common. For example, failure of the local oscillator tube in some receivers causes the loss of both picture and sound because there is no mixer action. A failing local oscillator tube will result in weak pictures and a weak sound output. This oscillator trouble often affects the high-band channels (7 to 13) more than the low-band channels (2 to 6). Because of the much higher frequency, many tuner disturbances will affect the high-band performance earlier or more drastically than the low-band performance.

An important point to remember is that in the earlier sections of the receiver only those failures that upset the dc operating voltages will in any way disturb the scanning raster. Thus, the raster size and brightness will usually remain normal when there is a tuner defect.

Contact troubles in the selector switch are quite common. Like other tuner troubles, worn or dirty switch contacts often will affect reception on the high-band channels while the low-band channels operate satisfactorily.

VIDEO I-F AMPLIFIERS

Many defects in the video i-f amplifiers of the television receiver affect the picture and sound in much the same way as a tuner defect. As with the tuner, faulty tubes in the i-f amplifier section are the most common complaints. Also, defects in this section will usually have no effect on the raster.

Most i-f amplifier defects result in a weakened picture and a weak to fair sound. This condition usually will help you to distinguish between defects in the i-f amplifier and in the tuner. Most tuner defects influence both the picture and sound—often in the form of a complete failure of picture and sound; furthermore, a tuner defect often affects the high-band channels more than the low-

Courtesy Philco

FIG. 36. Weak picture only—more characteristic of a video i-f defect.

band channels, where an i-f amplifier defect has an identical influence on the picture regardless of the channel. Likewise, with *many* i-f amplifier troubles, some trace of the picture still may be seen on the picture tube along with weak sound from the speaker.

A tuner defect generally causes a higher noise level (more snow in the picture and a noisier sound), while a defect in the i-f amplifier causes just a weakened picture and sound. Notice in Fig. 36 that high noise components are not present in the picture.

SOUND CHANNEL

A sound channel disturbance is quite obvious; the picture will be normal, but the sound may be weak or there may be no sound at all. When you encounter this condition in a television receiver, you can isolate the trouble to either the sound take-off point in the video i-f section, or to the actual sound channel itself.

Occasionally, a drift in the local oscillator frequency of the tuner can produce a good picture, but you may not be able to tune in the sound on certain channels. This type of defect is common, particularly in the old dual i-f channel receivers.

VIDEO AMPLIFIERS

Most failures in the video amplifier section of the receiver produce a weak picture and/or poor synchronization. However, the raster and the sounds are usually normal.

Most video amplifier defects cause a weak picture and the improper contrast and brightness ranges. There are certain types of video amplifier defects that clip off the sync pulses that rise above the video signal itself. When the synchronizing pulses are lost, the picture becomes unstable which causes it to roll or tear.

Notice that with just a fundamental knowledge of what goes on in the receiver and by actually observing the picture, you can isolate troubles rather quickly to a few stages. Many receivers may be repaired by substituting tubes in the suspected section. We must stress, however, that although this procedure applies to many types of defects, troubles may arise occasionally in the receiver that appear to be caused by a defect in one section when it actually is in another. This is due to interaction between the sections of the receiver (often a characteristic of a particular model of receiver). These troubles can be misleading because they create the same disturbance in the picture that would ordinarily be associated with a different section.

PICTURE TUBE

It is frequently difficult to decide whether or not a picture tube is bad because a number of signals and voltages from other sections of the receiver are used to operate it. Often you cannot obtain the final answer, even after making other tests, until you substitute a new picture tube.

The following are some of the telltale signs of a picture tube failure:

1. No filament illumination at the rear of picture tube.

2. Normal raster size, but inadequate picture brightness and poor focus.

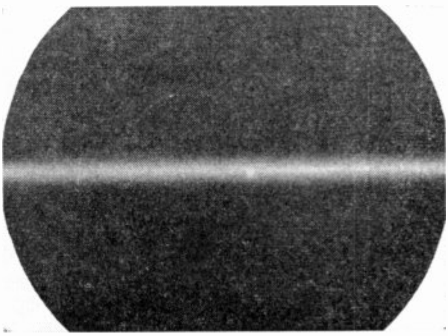
3. No changes in raster brightness with changes in the setting of the brightness control. Inability to adjust brightness and contrast to eliminate retrace lines.

4. A blue glow in the neck indicates gas in the tube.

VERTICAL SWEEP SYSTEM

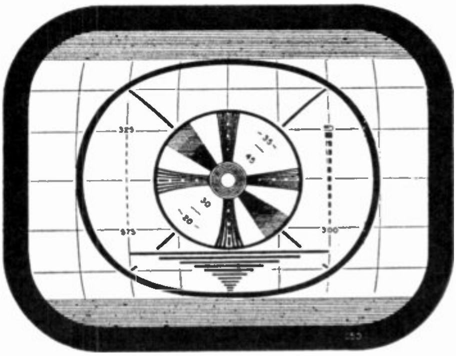
Most defects in the sync and sweep systems of the television receiver cause disturbances in the raster. They do not affect the sound or the video signal that is applied to the grid circuit of the picture tube. When the video signal fed to the picture tube is normal, you will notice that the fluorescent screen contains ample black and white information. This information, however, may be distorted or unstable, or the picture size may be reduced.

When there is a defect in the vertical sweep system, either a straight horizontal line will appear on the tube face, as in Fig. 37, the height of the raster will be reduced, as illustrated in Fig. 38, or the linearity will be poor. The picture will be stretched at the top or bottom, or the middle will be compressed.



Courtesy RCA

FIG. 37. Loss of vertical deflection.



Courtesy Belmont Radio Corp.

FIG. 38. Reduced picture height.

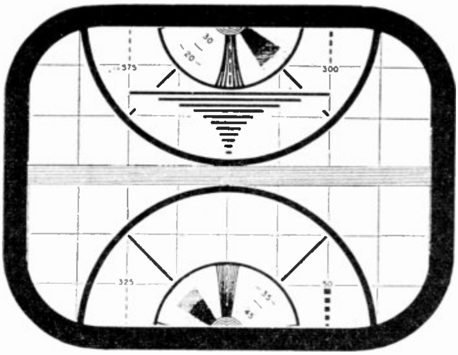
HORIZONTAL SWEEP SYSTEM

A complete failure of the horizontal sweep system not only results in a loss of picture width, but also in the complete loss of the picture raster. Since the high voltage for the picture tube is generated in the horizontal sweep system, the failure of this system results in the loss of the high voltage. Consequently, the picture tube is not illuminated.

Some horizontal sweep system defects can occur which prevent you from obtaining full picture width or proper raster brightness. Horizontal defects also can cause picture nonlinearity or spurious vertical bars in the raster.

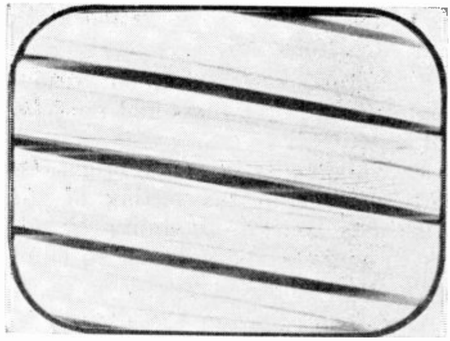
SYNC SYSTEM

When there is a synchronization defect in the receiver, the sound is normal, the raster size is normal, and a strong video signal component appears on the screen. If the sync defect appears in the earlier stages of the sync system, or is in the form of sync clipping in the video amplifier, both the horizontal and the vertical stabil-



Courtesy Belmont Radio Corp.

FIG. 39. Loss of vertical sync.



Courtesy RCA

FIG. 40. Loss of horizontal sync.

ity of the picture are affected. However, if the sync defect occurs after the horizontal and vertical sync components have been separated from each other, the synchronization of only one portion of the sweep system is affected. A loss of vertical sync causes the picture to roll, as in Fig. 39, while a loss of horizontal sync causes the picture to tear out horizontally as in Fig. 40.

POWER CIRCUITS

A serious power system failure usually results in a loss of voltage to a number of sections of the receiver and produces faulty operation in many stages. However, if a minor disturbance occurs in the power circuit, it most often influences the horizontal sweep system before any other section of the receiver. Generally, you are not able to obtain proper picture width and size, and occasionally, full picture height. There may be a border on either the left or right side of the picture, and, at times, the picture brightness may be reduced.

The two hardest working tubes in the receiver are the power rectifier and the horizontal output tube. They are the first tubes that should be substituted in the event of the loss of picture width or horizontal instability. They must be replaced occasionally in almost all receivers. The two tubes that require the next most frequent replacement are the horizontal oscillator and the local oscillator. Therefore, remember to check these four tubes in the receiver you service because peak performance can be obtained only if all of these tubes are operating efficiently.

The picture tube in many instances is your most effective test instrument in localizing receiver defects. When you understand exactly what goes into the formation of the picture and what each circuit contributes to the final result, you will be able to analyze the picture speedily and effectively, and decide what is the best procedure to follow in locating the defect.

Lesson Questions

Be sure to number your Answer Sheet 50B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next Lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of Lessons before new ones can reach you.

1. Why must the motion of the scanning beam be synchronized?

2. Why are the electrons in the scanning beam focused into a small crossover point?

3. What is the basic difference between electromagnetic deflection and electrostatic deflection?

4. What is the most common method of centering a scanning raster in a tube with electromagnetic deflection and focus?

5. Why is an aquadag coating used on the inside of the glass envelope of a picture tube?

6. Why are ion burns a problem in a tube with magnetic deflection and not in a tube with electrostatic deflection?

7. What are two advantages of aluminum backing on a tube?

8. Why are pincushion magnets used?

9. Why is the picture tube helpful in locating defective receiver sections?

10. Name three indications of picture-tube failure.

PAY ATTENTION TO LITTLE THINGS

It is the close observation of little things that is the secret of success in business, science, and every pursuit in life. Human knowledge is only an accumulation of small facts.

You may come across some facts and observations in your NRI course that may seem to be unimportant. But keep in mind that all will have their eventual uses and will fit into their proper places.

When Franklin made his discovery of the identity of lightning and electricity, people asked, "Of what use is it?" Franklin replied, "What is the use of a child? It may become a man!"

When Galvani discovered that a frog's legs twitched when put in contact with different metals, his observation did not seem important. But this observation was the "germ" of the telegraph.

Yes—it is well worth-while to pay attention to little things. When added up and used properly, great things may result.

J. E. Smith

ACCOUNTING AND RECORDS FOR RADIO-TV SERVICEMEN

REFERENCE TEXT 50RX-1

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

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For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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A Simple System of Records

EVERYONE wants to make money. That's one reason—maybe the main reason—why you took up radio-television servicing. However, to be a successful serviceman, you must not only be able to fix receivers, you must also know how to manage your business financially.

Put in simple terms, success in business means earning from it more than it costs you. To make money, you have to know how much to charge for your work. Overcharging and under-charging are equally bad. One drives away customers, and the other loses you money. You can't pull charges out of the air—to be fair to both you and your customers, charges must be based on your costs in time spent and material used. To get these costs, you need certain basic facts that can be obtained only by keeping records.

A busy serviceman doesn't have time to spend on an elaborate account system, so the simplest possible system is the best, especially when you first start out. Later, when your business has grown and you can afford to hire a clerk to answer your phone, keep your books, and relieve you of details, it may be to your advantage to have an accountant set up a more elaborate set of books.

In the beginning, when you can't afford extra help, you want a system of records that takes the least possible time. In this textbook, we have arranged such a system for you. It requires a minimum of work, yet it can give you all the important dollars-and-cents facts that you need to determine how much money you take in, how much you owe, what your expenses are, and what your profit is. The facts you need for tax returns and credit statements can also be extracted.

Incidentally, when you are in business, don't hesitate to get expert advice on bookkeeping, legal, or tax matters whenever you need it. It may cost you $10 or so to have an accountant fill out your tax forms properly, but he probably knows many perfectly legal ways of reducing your taxes. Even if he doesn't save you money directly, having these forms properly filled out can save you much time and bother. (The cost to you for this service depends on the completeness and accuracy of your records; so the better the shape they are in, the less it will cost you!) Don't try to save money by hiring an unqualified man; if you don't know a good one, get one recommended by your bank or another local successful businessman.

Now, what records do you need? The most essential record is of how much money came in, and how much went out. Before you can determine income, expenses, and profits, you must know your receipts and payments. Let's start with this, then go on to determine costs and profits. (We won't go into taxes in this text; special records are sometimes necessary for them. You should get help on them from your local authorities, your bank, or a tax consultant.)

A RECORD OF RECEIPTS

The first essential is to know how much money you take in. You won't, if you allow your personal and business funds to get mixed up. The best way to avoid this is to open a checking account *strictly* for business purposes. If you already have a personal bank account, do not use it for business. The first rule in our system is this:

All money that comes in to the business and all money that you receive for your service work must be deposited—without deductions of any kind—in your business account at the bank.

If your receipts are large, make a deposit every day. If not, make deposits twice a week. Establish this practice in the beginning and stick to it. Don't hold out any money for personal needs; we will show you how to withdraw earnings later.

Cash Receipts Record. Your bank book will show the amounts you have deposited, but not where they came from. Since some of your receipts aren't income, you need a record of the source of your receipts.

For this and almost all other records you need to keep, buy a standard record book from any stationery store. Get one that is "journal ruled," as illustrated in Forms 1 and 2 of this textbook.

A record book has enough pages to last you a long time, so you can keep several kinds of records in separate sections of one book. Turn to the center of the book and begin your Cash Receipts Register. Head your first page *Cash Receipts*. Then, as shown in Form 1, head the columns: *Date, Cash From, For, Amount,* and *Deposited.*

The second rule of good business practice is:

Cash Receipts

Date		Cash from	For	Amount		Deposited	
1952							
Jan.	2	John H. Student	Invested in business	100	00	100	00
	2	Sam Jones	Service job #1	7	93		
	2	Tom Smith	Service job #2	6	42	14	35

Form 1

Enter faithfully in your Cash Receipts Register all money received, including any that you invest in the business.

Form 1 is an example of how to begin. As shown here, your first entry should be whatever you originally invest in the business—the amount with which you start your business checking account. Then enter all other money as it is received. Suppose that on your first day of business you did two service jobs, one for $7.93 and another for $6.42. Enter these amounts as shown. Then, when you deposit the receipts for the day—$14.35, enter this amount in the Deposited column. At the end of the month, add the columns showing the amount received and the amount deposited. These totals should agree, and should equal the deposits shown in your bank book.

HOW TO MAKE PAYMENTS

Now that all the business money is safely in the bank, it is obvious that the next rule is:

Make all payments by check.

This is an extremely important rule. Checks serve as safeguards in many ways—they serve to show when bills have been paid, and they are much safer than cash. Of course, there are many little items that you need from day to day, and it is impractical to use checks for all of these. What should be done?

Petty Cash Fund. All businesses—large and small—pay for small items out of a petty cash fund. To start your petty cash fund, write out a check payable to yourself for $10, $15, or $20, depending on your requirements. Put this money in a safe, convenient place, a box or a drawer, or even a special wallet or money pocket. The important thing is to keep it strictly separate from all other funds.

Pay all small bills chargeable to your business from this fund. As you spend the money from this fund, place a receipt or a slip of paper in the money box, showing the exact amount of money spent, what it was spent for, and the date.

The total of these receipts and slips, plus the balance of cash left in the fund, should at all times equal the amount of the fund you began with. Thus, if your original petty cash fund is $15 and the balance of the cash on hand is $5.18, you should have receipts, slips, and tickets accounting for the expenditure of $9.82.

You may be out on a job and find it necessary to buy some small part out of your pocket. Be sure to collect from the petty cash fund when you return. A large part of your expenses will be paid from petty cash, and strict adherence to this rule is even more important to you than to a larger business.

When your petty cash fund gets low, take all the receipts or memos, and add them up. Write out a check payable to yourself for the total of these receipts, cash the check, and place the amount in your petty cash fund. The cash from the check, added to the amount remaining in the fund, should bring the amount of cash on hand to the original figure. Repeat this procedure as often as necessary. The receipts and memos should be clipped together or put in an envelope, marked plainly with their total and the date, and filed away as a "voucher," which we will explain later.

Payment Register. Large businesses keep a Payment Register, somewhat like the Cash Receipts Register, to record the purpose of every payment and the total for the month. We won't keep one because we can keep our totals on the check stubs (as will be shown later), and the purpose can be indicated, along with other information, by using a simple voucher system.

A VOUCHER SYSTEM

It is as important to keep a record of all payments made by the business as it is to record all receipts. It is equally necessary to know at all times how much you owe, which items are due, the bills that have been paid, and the date they were paid. A properly kept voucher system will give you this information with a minimum of work.

A voucher in its simplest form is any okayed or approved invoice or bill for goods purchased, or memorandum of services purchased. You do not need a special printed form. If you buy ten tubes from a radio supply company and they send you a bill, all you have to do is mark it "goods received and okay," date it, number it, and for your purpose it is a perfectly good voucher. When you take the slips from your petty cash box, put them in an envelope or fasten them together. Put a slip with them showing their total amount, and the date; number the slip, and it becomes a voucher. When you draw your earnings, write out a slip with your name on it, the amount, and the date; number it, and this memo becomes your voucher. In short, a voucher is just an explanation of the purpose of the payment.

The fourth rule of our system is:

Never make a payment of any kind unless you have a bill, or a complete memorandum showing the date, the amount, the purpose of the payment, and a voucher number. Vouchers should be numbered consecutively, starting with number 1.

A record of vouchers is kept in the same book as your Cash Receipts Record. Turn to the front of the book and head a page *Voucher Register.* As in Form 2, mark the columns: *Date, Pay to, For, Voucher No., Amount,* and *Date Paid.*

Let us suppose that your first transaction is to set up a petty cash fund. You make up a memorandum for "Petty Cash," write the amount, the date, and number it in the upper right-hand corner, "Vou. No. 1." You might next receive a bill for tubes. Check the bill carefully against the tubes you received, okay it, mark the date, and number it "Vou. No. 2" in the upper right-hand corner.

Enter all vouchers in the Voucher Register. Enter the amount due or to be paid in the Amount column and leave the Date Paid column blank until you actually write a check.

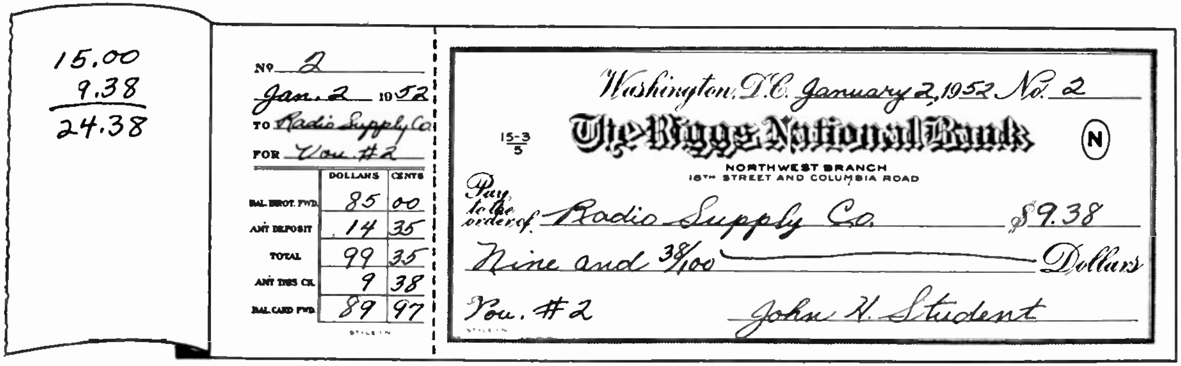
In addition to bills for parts and material, there will be other expenses

Voucher Register

Date 1952		Pay to	For	Vou. No.	Amount		Date Paid	
Jan.	2	John H. Student	Petty Cash	1	15	00	Jan 2	ck1
	2	Radio Supply Co.	Tubes	2	9	38	Jan 2	ck2
	6	Radio Supply Co.	Parts	3	3	90		

Form 2

BACK OF STUB #1



Form 3

of your business, such as light, heat, telephone, and rent. Bills for these expenses can be made vouchers in the same way. Number and date and enter them in your Voucher Register. If you maintain your servicing business in your home, only part of your monthly bills for light, heat, and rent will be chargeable to the business. Decide what proportion of the expenses are directly chargeable to your servicing business, and make voucher memos for the amounts.

After you have established credit with your local parts dealers, you will be billed on 30-day terms—that is, the bill must be paid within 30 days. Some wholesalers offer discounts for early payment—1% or 2% if paid within 10 days. When you get such a bill, if you think you will be able to pay it within 10 days, deduct the discount before entering it in your Voucher Register. Of course, if you neglect to pay this bill within the discount time, you'll have to make another entry in the Voucher Register for the amount of the discount you deducted so that your Voucher Register will show accurately what you pay.

In a case like this, use the same voucher number for the original bill and the discount memo. For example, suppose you get a bill for parts for $76.00, with a 2% discount for payment in 10 days. You believe you'll have enough cash to pay the bill within the discount time, so you deduct $1.52 (2% of $76.00) from the bill, making the amount you have to pay $74.48. This is the amount you enter in your Voucher Register. If you don't pay the bill within 10 days, you must make another entry in the Voucher Register for $1.52, so that you will have accounted for the whole bill in your records.

Voucher File. All vouchers must be carefully filed. Have one file for unpaid vouchers and one for paid vouchers. Elaborate facilities are not necessary—a cardboard box, a heavy envelope, or a file jacket may be satisfactory for each file. Place unpaid vouchers in your unpaid voucher file in *alphabetical* order, and paid vouchers in your paid voucher file in *numerical* order.

At the end of the month, your Voucher Register will probably show some items without payment notations beside them. These should be items that are not yet due. Check these unpaid items on your Voucher Register against your unpaid vouchers, and add them. You should have the exact total of the amount that you owe.

Writing Checks. All bills that are to be paid have been made vouchers with numbers on them, and are filed alphabetically in the unpaid voucher file. When the time comes to pay the voucher, remove it from the unpaid voucher file and use the following safe procedure in making up your check.

Before filling out the check, fill out the check stub. Show, in the usual spaces provided, the date of the check, the number of the check, the name of the person or firm to which the check is payable, and the number of the voucher that is being paid.

Now fill in the check completely, being careful of the check number, the date, and especially of the amount to be paid. In the lower left-hand corner of the check, put the number of the voucher being paid. If the payment is for more than one voucher, show all voucher numbers. This makes it easy in case of dispute to get out the paid vouchers covered by the check.

Now get out your Voucher Register and make sure that every voucher being paid is properly entered and that the amount of the check agrees with the total of the vouchers being paid, not only as shown on the vouchers, but also as entered in the register.

Then, note in the last money column of the Voucher Register, opposite the vouchers paid, the date of payment, and the check number. Mark the voucher "paid," showing the date of payment and the check number. Then file the voucher in the paid voucher file in proper numerical order.

Now complete the check stub. The balance and any deposit made since the previous check was written should be entered. Write the amount of the check, and subtract to get the current balance. Carry this balance over to the face of the next stub.

For example, suppose you want to pay Voucher No. 2 in the Voucher Register in Form 2. You would fill out a check as in Form 3. Your first check would have been to set up a Petty Cash fund of $15, leaving a balance of $85 from the original investment of $100. But the first day's receipts have been deposited—$14.35 (see Form 1), so the balance becomes $99.35. After deducting the amount of the second check, $9.38, a balance of $89.97 is left in the bank.

At the end of the month, you will want to know the total of the checks drawn for the month, to check against your Voucher Register. You can keep a running total of this by using the backs of your check stubs. On the back of the first stub write the amount of the first check and add to it the amount of the second check. Then write this total on the back of the second stub and add to it the amount of the third check, and so on. This gives you at any time the total amount paid out, so that at the end of the month you will have a record of checks drawn. Start afresh each month. Thus, as in Form 3, on the back of stub No. 1, write the total amount of the checks drawn so far, that is, $15 for check No. 1, and $9.38 for check No. 2, a total of $24.38. This procedure is carried out for each check.

RECONCILING YOUR BANK ACCOUNT

At the end of the month, when your paid checks are returned by the bank, place them in numerical order, check them against the stubs, and mark the stubs to show which checks have been paid. Some of your checks may not have cleared through the bank by the end of the month, so the bank-statement balance and your check-book balance won't agree. The checks that have not been returned by the bank are "outstanding." List and add the outstanding checks, (from their stubs), adding their total to your check-book balance shown on the face of the last stub at the end of the month; then you should have the balance as shown by the bank statement for that date.

Here is a simple way to test the accuracy of your record-keeping: add the total of the deposits as shown in your Cash Receipts Register for the month to the amount of cash in the bank as shown by your check book at the beginning of that month. Then subtract the total amount of the checks drawn during the month as shown by your check stubs. If your figures are correct, you will have the same balance as that shown on your check book.

This gives us our fifth rule, a very important one:

Check or balance your accounts once a month.

Make sure your work is accurate. If any mistakes have been made, find out where and correct them. Then your records will be dependable and will tell you the facts you need to know.

Job Costs and Billing

So far, our system has shown you how to account for all cash received and paid, how to handle payments, and how to use a Petty Cash fund. Now, avoiding accounting technicalities, we are going to show you a simple system of billing for your goods and services. This system includes a method of determining the cost and the profit on each service job, and at the same time, provides your customer with a bill and a complete statement of the work done.

JOB COSTS

We haven't the space here to go deeply into what to charge—Professional Rates are given elsewhere in your Course. Here, we want to show whether whatever charges you establish really give you a profit. In brief, here are the important facts:

The cost of parts and materials is just what you paid for them—you will soon become very familiar with these figures for most items, and you can look up your vouchers for those you forget. You will charge the customer the full list price for such parts. If there is no established list price, the easiest way to figure the selling price is to multiply your cost by 2. If the result is an odd amount, reduce it to the nearest multiple of 5 cents.

Figuring the charge for professional services, the so-called "labor" charge, is not this easy. Before you can say that any professional charge will earn a profit, you must know your overhead.

FIGURING OVERHEAD

Many pages could be devoted to the subject of overhead, but for practical purposes it is enough to understand that overhead is simply the total of all expenses incurred by your business during the month, not directly chargeable to particular jobs. These indirect expenses must be spread over all the jobs you do. Among the overhead items are:

(1) Rent, heat, light, water, gas, and telephone bills. (If you are working

from your home, you should charge the business a proportionate share of these household expenses; each month, prepare vouchers for such items, and draw a business check payable to yourself for them.)

(2) Depreciation on your automobile, test equipment, and shop equipment must be estimated and charged, so that you will have the money to replace these items as they wear out, become obsolete, or become so scratched and dented that they should be replaced. Tube testers must be replaced about every 3 years; other testers rarely last longer than 5 years. Assuming a 3-year life, 1/36th of the cost of your equipment must be added to the overhead every month. You can figure your car depreciation from automobile trade-in values; $300 a year isn't out of line for one getting a lot of use.

(3) Advertising.

(4) Taxes and permits—federal, state, and local.

(5) Insurances—fire, theft, liability, etc.

(6) Auto operation and repair.

(7) Miscellaneous things like solder, wire, stationery, replacement of small tools, radio and TV magazines, etc.

As you build up your business, you probably will have to adjust your overhead charge occasionally. After a while, your expenses will be predictable enough for you to estimate them for a year, then to divide by 12 to get the average monthly charge. This is desirable, because some items like heat come up only during certain months, but it's better to spread their expense over the year.

To find your overhead, make a list of your estimates of these indirect expenses. For example, you might have a list like the following, based on expenses for a year:

Rent	$ 300.00
Heat and light	120.00
Telephone	90.00
Depreciation on car	240.00
Depreciation on test equipment	60.00
Advertising	60.00
Taxes	180.00
Insurance	120.00
Car operation and repair	240.00
Miscellaneous	30.00
	$1,440.00

Dividing this figure by 12 gives you a monthly average of $120. Here are these same figures on a monthly basis:

Rent	$ 25.00
Heat and light	10.00
Telephone	7.50
Depreciation on car	20.00
Depreciation on test equipment	5.00
Advertising	5.00
Taxes	15.00
Insurance	10.00
Car operation and repair	20.00
Miscellaneous	2.50
	$120.00

Although your expenses, particularly at the beginning, may not be this high, be forewarned—they will probably get this high, or higher, as your business grows. You won't find much shop space in good business districts for as little as $25 per month, your car can depreciate faster than allowed here, and other costs like advertising, taxes, and insurance can be much higher. The test equipment figure is based on 1/36th of $180 worth of equipment; you will probably have to buy equipment worth much more than this as your business prospers, especially as you get into TV service work.

Distributing Overhead. The overhead must be distributed so that each service job pays a part of it. It is figured on the number of hours that you expect to devote to service work per month. Let's assume you plan to work 100 hours per month. Divide the monthly overhead, $120 in the example above, by the number of hours (100) and you get $1.20 as the overhead for each hour of labor.

Your professional charges must include this overhead, your earnings per hour of labor, and a reasonable profit. If you want to earn $1.50 per hour (or would have to pay a serviceman this much to do your work), then you must charge at least $2.70 ($1.50 + $1.20) per hour to break even. Most businesses set their charges at twice the labor cost; this would be $3.00 per hour, giving you a small profit.

As another example, let's suppose you are an expert, and figure your time is worth $2.00 an hour. Your "labor" charge will then be $4.00 per hour, which amply covers your overhead.

BILLING THE CUSTOMER

The customer must receive a statement of charges; you want to know not only the charges, but also your costs on each job. A combination bill and job ticket has been designed to serve both purposes.

Since the original copy of this bill (Form 4A) remains with the customer or is mailed to him, you should have a good job of printing done, using paper of good quality and a neat type set-up. A little care on your part, and a few extra pennies to impress your customers with the fact that you are careful and exact in your business methods, will help to convince them that your service methods and service work are also exact and careful.

The second or shop copy of the form (4B) is somewhat different from the original copy. It should be printed on card stock or paper that is stiff enough to stand on end in a file box, and preferably of a different color from the original copy. Be sure the printer arranges the lines on both copies to match, so that when carbon paper is used between the forms, the figures will appear in the proper places.

It is desirable to have these forms bound together, but if this costs too much, a paper clamp or clip board will hold both copies and the carbon paper between them in proper position for writing.

To get a clear impression on your file copy of the invoice, you will need a good pencil. We suggest a "copy" or "indelible" pencil, or a No. 3 lead pencil. A stiff-point fountain pen or ball-point pen is even better, but is not essential. Keep two or three well-sharpened pencils in your kit and at your shop so that you can always render a bill for every job.

Now examine Form 4A carefully. Your name, address, and telephone number should be attractively and plainly printed.

Notice particularly the little item, "Terms: Cash." If your customer is sound enough financially to have the job charged, cross off the word "cash"

Form 4A

JOHN H. STUDENT

AUTHORIZED RADIOTRICIAN AND TELETRICIAN
442 CAPITAL STREET
WASHINGTON, D. C.

Phone 3567

Job No. 1

Terms: Cash

Date Jan. 2, 1952

BILL FOR SERVICES, MATERIAL, AND PARTS

Name Sam Jones — Phone 2002

Address 3426 Main Street

Location of job 3426 Main Street — Time about 4 P.M.

Make and Model Chesapeake 21

Complaint No reception

Quantity	Material Used	Price	
1	Tube 50L6GT	1	65
1	20-20 Mfd. filter cond.	2	20
	Total	3	85
	Sales Tax		08
	TOTAL MATERIAL CHARGE ☞	3	93
	Check up and Test		
	Installation of Parts		
	Special Charges:		
	TOTAL FOR PROFESSIONAL CHARGES ☞	4	00
	TOTAL BILL ☞	7	93

DATE PAID Jan. 2, '52

Rec'd. By J.H.S.

THANK YOU

All repairs and materials listed above are guaranteed for 90 days, just as for a new receiver. Material covered by this guarantee will be replaced without charge if defective.

Work O.K.
Signed Sam Jones
Owner or Tenant

Form 4A

and write ten days or thirty days, or the date on which he agrees to pay. Some people have the false idea that, when no definite date of payment has been agreed upon, payment can be made at any convenient time, perhaps a year or two later. A few such customers can quickly stop your business from functioning, because of lack of funds. Never leave a bill, or mail a bill to a customer, without having the terms of payment clearly stated.

Now let us assume that you are receiving a call for service. Enter on the invoice the customer's name and address, the date, where the service call is to be made, and as much detail of the job as you can get, including the time when it can be done. Be sure to enter the job number (1 for your first job, etc.).

When you start working, lift up the original and the carbon paper and enter your starting time on the shop copy. As you use parts or material, enter them on the original copy, with the carbon in place, being sure to show the selling price. (Tubes have established list prices, so you use the price card furnished by your wholesaler. A condenser has no established list price, so doubling its cost is reasonable.) If you have to buy special parts while on the job, list them on the original, but lift up the original and the carbon paper and enter the cost price of these special parts on the shop copy. Incidentally, this may remind you to collect the cost of these parts from your petty cash fund when you get back to the shop.

Many states and cities have local sales taxes, usually 1% or 2% of the material used. If you live in such a locality, enter the tax in the space provided, then add to get the total bill for materials.

When you finish the job, enter the stopping time on the shop copy, figure the amount of time between starting and stopping time and enter it in the proper place. (Note: Unless you use a "check and test" fee to cover travel time, your working time must include the time spent going back and forth between the customer's home and your shop.)

Then on the original, with the carbon in place, enter the charge for professional charges. Notice that this is the total labor charge; and only this appears on the original or customer's copy. Now add the totals for material and professional charges, bringing the grand total down to the space *Total Bill.*

If the customer pays you, mark the bill paid, date it, sign it, and give the original to him. If the job is to be charged, get the customer to accept the bill by signing at the bottom after the words "Work O.K., Signed." Be sure the carbon is in place so that on your copy you have a complete okayed copy of the original bill.

As soon as you return to your shop, fill in the cost column on your shop copy. On the job illustrated, the cost price of the parts that sold for $3.85 was $2.02.

Also fill out the cost of labor. The job illustrated in Form 4B took 1 hour at $2.00 per hour. The overhead per

Form 4B

JOHN H. STUDENT

AUTHORIZED RADIOTRICIAN AND TELETRICIAN

442 CAPITAL STREET

WASHINGTON, D. C.

Phone 3567

Terms: Cash

Job No. 1

SHOP COPY

Date Jan. 2, 1952

RECORD OF SERVICES, MATERIALS, AND PARTS

Name Sam Jones

Phone 2002

Address 3426 Main Street

Location of job 3426 Main Street

Time About 4 P.M.

Make and Model Chesapeake 21

Complaint No reception

Quantity	Material Used	Cost Price		Selling Price	
1	Tube 50L6GT		92	1	65
1	20-20 Mfd. filter cond	1	10	2	20
	Total			3	85
	Sales Tax				08
	TOTAL MATERIAL ☞	2	02	3	93

LABOR: Serviceman on Job	Start	Stop	Hrs.	Rate	Cost Price		Selling Price	
John H. Student	4:00	5:00	1	2.00	2	00		
TOTAL LABOR COST AND CHARGED					2	00	4	00
Add Overhead @ 1.20 per hour					1	20	7	93

Total Cost of Job	5	22
Sales Tax		08
Add Estimated Profit	2	63
Total Billed	7	93

TOTAL BILLED ☜

DATE PAID Jan. 2, '52

J. H. S.

ENTERED ON CHARGE CARD

Work O.K. Signed Sam Jones

Owner or Tenant

Form 4B

hour from our example is $1.20, so this is written in. Add these costs to the cost of materials, giving you $5.22 as the total cost of the job.

The profit on this job is the difference between the total billed and the cost (plus tax, if any). Therefore you can fill in the estimated profit figure by simple addition. In our example it is $2.63, which is the total of the labor profit and the profit on materials.

Frequently you will make an outright sale of receiver parts, accessories, electric appliances, or a receiver. There will be no service cost, labor charges, or overhead charges on any such direct sales. Use your invoice form by making entries in the material spaces only, bringing the amount down to the *Total Bill* space. On your carbon copy, enter the cost to you of the goods, and figure your profit. This profit is known as gross profit, and should be high enough to cover all costs of selling and handling, and still leave you an actual, or net, profit.

If you sell a receiver, particularly a television set, you will have to install it, and perhaps erect an antenna. When there is an installation charge, use the form just as if you were making a service call. When there is no installation charge, you can show on your carbon copy your starting and stopping time, the cost of the time and the overhead; then add this total to the cost of the goods. Since this reduces the margin of profit on the receiver sale, you should keep an accurate record of installation costs for your own guidance.

The full value of this combination invoice or bill-and-job ticket will be brought out as you use it. From this form you can see what profit your charges are bringing in, so you can adjust your charges to your expenses. Referring to the cost sheets on past jobs, you have a dependable method for estimating a price on future work.

JOB CARD REGISTER

This is a simple record you can keep in an unused portion of the book containing the Voucher Register and the Cash Receipts Register. Write in the heading, *Job Card Register*, and head the individual columns: *Date, Customer's Name, Job No., Cost,* and *Selling Price*. (See Form 5.)

Job Card Register

Date		Customer's Name		Job No.	Cost		Selling Price	
1952 Jan	2	Sam Jones	(cash)	1	5	22	7	93
	2	Tom Smith	(cash)	2	4	20	6	42

Form 5

Name: Tom Smith — Date: Jan. 2, 1952

Address: 4350 Oak St. — Phone: Walnut 1776

Make: Kennedy — Year: 1950 — Model No.: 32

Circle Type of Set: AC-DC, Table, Console, Phono-Comb.

Tubes: 5Y3, 6V6, 6Q7, 6K7, 6SA7, 6K7

CHARGES FOR SERVICE AND SALES

Job No.	Date 1952		Complaint	Nature of Repair or Change	Amt. Charge		Date Paid 1952	Amt. Paid	
2	Jan	2	Weak	Align & new tubes	6	42	Jan 2	6	42
76	Oct	28	Install new record changer		58	00	Oct 28	33	00
							Nov 28	25	00
					64	42		64	42

PRINTED IN U.S.A.

Form 6

Enter each day's job tickets, writing down the date and the customer's name. Then show whether the work was paid by cash or charged. Fill in the job number, your cost, and the selling price in the proper columns.

It is particularly important to show whether the job is cash or charged, since there is no profit until you get the money. If the job is for cash, make the necessary entries in the Cash Receipts section of your record book. If the job is on a credit basis, you will need a *Set Record and Accounts Receivable Card* like Form 6. From your Job Card, make the necessary entries in the columns *Job No.*, *Date*, and *Amount Charged*, this latter being the amount charged the customer. When the customer makes a payment on account, the payment must be entered in the Cash Receipts Register, and the date of the payment and its amount entered on this card. If you wish your set record cards to be complete, cash jobs could be entered also as shown.

You should have a box or file in which to keep your Set Record and Accounts Receivable Cards on which there are unpaid balances; these cards should not be removed or put in the general file until the accounts have been paid in full.

The sum of the balances due, shown on the cards in the unpaid file, will be the amount owed to you by your customers at any time. When an account is paid in full, withdraw the card from the unpaid file, and file it with other record cards in the general file.

SUMMARY

As you can see, business records have a very practical use. They actually help you make money. By showing you how much a job costs, they provide the information on which you base your prices. The voucher system enables you at any time to find out just what you owe—accounts payable. The customers' sets cards can give you just what is owed to you—accounts receivable. Having this information at your disposal is not only a convenience, it's a necessity for tax returns and bank credit statements when you want to borrow.

Did you make an actual profit for the month? That depends on whether you did enough work to distribute all of your estimated overhead, and on whether your overhead estimate was reasonably close to your actual expenses. If both these conditions are true, and if your job cards show a reasonable profit on each job, then you probably earned a profit. However, it probably won't be the sum of your estimated profit figures. Therefore, the difference between the cost and selling price columns in your job card register is almost never your actual profit.

Remember that some items in your overhead may come due one month and not another—heat expenses come up in the winter; permits, licenses, taxes, and insurance fees may come together to give you an actual loss for some months. However, your system of averaging these expenses will gradually repay you during the following months, so it is better to figure your profits on longer time periods like six months or a year, rather than monthly.

You can't find your profit by determining the difference between the Cash Receipts and the payments of the month, either. Some of your Receipts may not be "income"—your investment in the business for example. Also, some of your payments won't be "expenses"—for example, when you buy parts to use in future jobs, buy test equipment, etc., you are exchanging assets. You are using cash to buy things that will be sellable or usable in your future business, rather than paying for things that are used up that month.

Because of technicalities like these, it's best to have a bookkeeper or accountant set up for you a "profit and loss" statement that shows your real profit.

How much have you earned? Of course, the business profit is yours. You can withdraw it, or you can leave it in as an investment to provide working cash needed to buy more equipment. In addition, you get the "labor cost" for every hour your job cards say you worked. If you hire someone, you would pay him this labor cost as his salary, but in a one-man or partnership business you do not technically pay yourself a salary. This money is lumped with the profit, and you draw money from this sum to meet your needs.

As you see, we have set up a simplified system, designed to save you time where possible. We have omitted forms and records that would be found in complete bookkeeping systems. We have extracted the basic records that you can keep easily, and we suggest that once or twice a year you have your records checked and completed by an accountant. There is no point in your trying to be a bookkeeper when you can get this detailed work done far faster by an expert. You are in a business where time is money; you can afford to pay for services that save you the time to do more service work.

Large Store Accounting

The simple system of record-keeping and accounting described for a small servicing and merchandising business should give you a good check on your costs and earnings while your business is small, consisting perhaps of a clerk, a serviceman, and yourself. As you diligently apply yourself to building up your business, the time will come when you will have a larger store, and employ several servicemen. If you branch out into the sale of radio and television receivers, refrigerators, electrical appliances and phonograph combinations, you will also hire salesmen and special servicemen.

A successful business can be established only by close study of business records. If you borrow money from the bank, you will have to render standard business reports. In order to prove that the taxes you pay are correct, you will need adequate accounting records. If you want to know whether certain lines are more profitable than others, only records, and not opinions, can give you the proper information.

The installation of a complete bookkeeping system to give the above facts is a job for a public accountant. Have one install a system for you. Keeping the books is a job for a bookkeeper. Be sure you hire one who is capable. The time to do this is when you *start* to grow and feel that you can afford a bookkeeper. If you get the information you want and use it intelligently, the bookkeeper's salary will be earned many times over.

Because installing and keeping an accounting system is a job for a specialist, it would be impossible to tell you all about it in a few pages. But every radioman who plans to become a radio merchant should know something about his bookkeeping system, what it contains, what it can do for him, and, in general, how it works. What are the essential features of an accounting system for a large store?

ESSENTIALS

The purpose of all accounting and bookkeeping is to arrive at two main objectives. These objectives are represented in two statements known as the "Balance Sheet" and the "Profit and Loss Statement"—the first representing the static position of the business, and the second the "action" of the business. In other words, the Balance

Sheet shows you exactly what the business is worth at a stated time, and the Profit and Loss Statement sets out the causes of changes in the worth of the business during a particular period. A Balance Sheet at the beginning of the year may show your worth to be $12,000, while a Balance Sheet at the end of the year shows your worth to be $24,000. You have an increase of $12,000, but from the balance sheets alone you do not know why. If you knew why, you would be better able to increase this earning to $15,000. The cause of increase is shown in the Profit and Loss Statement, and, for purposes of management, it is the most important of all statements.

The preparation of these statements can be most conveniently made if your books are kept on the double entry method. This means that theoretically there are two entries for every transaction. We say theoretically, because in no modern bookkeeping will you find two actual entries. For example, suppose you make three hundred sales in a month on credit; you would not make six hundred entries. You would make three hundred entries on one side of the ledger and perhaps only one on the other side. Now what do we mean by sides of a ledger?

THE LEDGER

You must know what a ledger is. In double-entry bookkeeping, the ledger is the book of final entry. All the facts of your business finally find their way into this book in condensed form. A page is headed with a title that tells you just what kind of information is shown on that particular page. Look at Form 7, an illustration of a sample ledger page (there are other rulings, but this one is the oldest and serves our purposes best), and you will get an idea of what a ledger is, and its purposes. Also, consult definitions at the end of this book for a better understanding of the ledger.

In order to develop the idea of the ledger, let us assume now that you have one enormous sheet on which you make all entries. This sheet is divided in half: the left half (or side) is called the *Debit* side (abbreviated Dr.), and the right side is called the *Credit* side (abbreviated Cr.). Every transaction that occurs in your business will affect an account listed in Forms 8 and 9. Since the two sides must be kept in balance, put every transaction in one of the classes shown on the debit or credit side of our illustration; then the balancing entry will be classified under one of the headings on the other side.

Now, referring to the lower section of Form 7 should enable you to understand the effect of every entry made to the debit and credit sides of this large sheet.

Suppose we sold a radio set that cost $20.00, for $30.00 cash. We would increase the asset (1)* cash, $30.00 by making a debit entry. We could decrease the asset (2) stock-in-trade, radios, by $20.00 and could show a profit (8) of $10.00 by making two credit entries on the credit side. However, in practice we do not make the two credit entries at this time because the two entries would not give the

*Refers to items on lower part of Form 7.

A Ledger Account

DR. | CR.

DATE	DETAIL	AMOUNT	DATE	DETAIL	AMOUNT

Balance Sheet Items

Assets:-
Subdivided:
Cash
Accounts Receivable
Notes Receivable
Radios
Parts
Automobile
Furniture and Fixtures, etc.

Liabilities:-
Subdivided:
Accounts Payable
Notes Payable
Finance Company, etc.

Net Worth or Capital
Subdivided:
Investment and Profits
(assets less liabilities)

Effect of entries on ledger accounts, the results of which affect the Balance Sheet and Profit and Loss Statement

TO DEBIT SIDE
(1) Increases Assets
(3) Decreases Liabilities
(5) Adds to costs or expenses
(7) Shows a loss
(9) Decreases Net Worth
(11) Measures Purchases

TO CREDIT SIDE
(2) Decreases Assets
(4) Increases Liabilities
(6) Decreases Costs or Expenses
(8) Shows profits
(10) Increases net worth
(12) Measures income
(14) Sets up reserves for contingencies
(16) Measures Sales Volume

Form 7

exact information desired for making up your profit and loss statement. Instead, we credit sales (16) with $30.00. Remember every sale should have three elements, the element of cost and the element of profit, on the credit side; and the asset element (cash, accounts receivable, or notes receivable) on the debit side. The same theory and practice applies when you pay your rent. You debit an expense account (5); and you credit an asset account (2). It is not so hard to understand, if you analyze each entry to determine its effect. As you recorded a debit or a credit on this large sheet, you would key this entry with the key number shown in Forms 8 or 9 that identifies the type and account.

JOURNAL

We will leave the ledger for the moment and introduce you to the journal. In modern accounting, the journal is of relatively little use. Because of labor-saving methods it is used only for extraordinary entries, for adjustments and corrections. We introduce it at this point because it ties in with the development of the ledger. Remember, we suggested that all entries might be made on one ledger sheet. Now let us move the debit column on the ledger sheet over beside the credit column, and you have the same ruling as shown in Forms 1 and 2. We have a journal instead of a ledger. The two transactions would appear as follows:

	Dr.	*Cr.*
Cash	30.00	
Sales		30.00
(Sale of one radio set, cost 20.00)		
Rental Expense	25.00	
Cash		25.00
(Rent on store paid for January)		

Now a journal kept in this manner would be of no benefit to us in determining our financial position quickly, so we make up an individual ledger sheet for every kind of asset, liability, or expense necessary to make up our Balance Sheet and Profit and Loss Statement.

In theory, we make every entry in the journal as shown, then we transfer (post) the individual items to the proper sheet in the ledger by making entries on the ledger sheet on the debit or credit sides exactly as they appear in the journal.

CLASSIFICATION OF ACCOUNTS

To get the best results from your accounting, you must determine exactly the information desired, and then you must accumulate the information in an orderly manner. To accomplish this end, you must make a survey of the business and determine what is necessary. The accounts in the ledger should be arranged as nearly as possible in Balance Sheet and Profit-and-Loss order to facilitate the taking off of these statements. To help you in this we give you a chart of accounts, Form 8, prepared by the Charles R. Hadley Company and printed with their permission. You should note that each item having a number represents a ledger sheet, and note particularly the arrangement of the accounts. This is an excellent and complete chart of ledger accounts.

Form 9 is a condensed form of a Chart of Ledger Accounts, which we

CHART OF GENERAL LEDGER ACCOUNTS

Pathfinder Bookkeeping System for Radio Dealers

ASSETS

CURRENT

Cash and Bank

1 Petty Cash
5 Bank
11 Cash Sales Clearing Account

Notes and Accounts Receivable

21 Contracts Receivable
22 Contracts Receivable Discounted
23 Notes Receivable
24 Accounts Receivable
39 Reserve for Bad Debts

Inventory

41 New Radios
42 Used Radios
43
44 Parts and Accessories
79 Reserve for Used Radio Revaluation

Other Current Assets

Accounts 80 to 89 may be used as needed to show investments in marketable securities and indebtedness of officers, stockholders, and employees.

FIXED ASSETS

101 Land
102 Buildings
103 Reserve for Depreciation on Bldgs.
104 Machinery, Fixtures and Equipment
105 Reserve for Depreciation on Machinery, Fixtures and Equipment
106 Automobiles
107 Reserve for Depreciation on Autos.
116 Leasehold Improvements
117 Reserve for Amortization of Leasehold Improvements

DEFERRED CHARGES

131 Prepaid Rent
132 Prepaid Insurance
133
134 Other Prepaid Expenses

OTHER ASSETS

151 Finance Company Reserve

LIABILITIES

CURRENT

Notes Payable

201 Notes Payable—Bank
202 Notes Payable—Others

Accounts Payable

211 Accounts Payable
217 Taxes Payable
218 Finance Charges
219 Finance Company Collections
220 Due to Finance Company on Repossessions

OTHER LIABILITIES

241 Mortgages
Accounts 242 to 249 may be used for bonds, debentures, or other fixed obligations

CAPITAL

251 Capital or Investment
(If a partnership, use a separate account for each partner, numbering accounts 251, 252, 253, etc. If a corporation, use a separate account for each class of stock.)

261 Drawing Account
(If a partnership, use a separate account for each partner, numbering accounts 261, 262, 263, etc. Not required if firm is incorporated.)

270 Surplus
(Use for corporation only. Not required for partnership or single proprietorship.)

271 Profit and Loss (Current)

REVENUES

SALES

341 New Radios
342 Used Radios
343
344 Parts and Accessories
345 Service Labor

COST OF SALES

441 New Radios
442 Used Radios
443
444 Parts and Accessories
445 Service Labor
479 Used Radio Inventory Adjustment

EXPENSES

Symbols:
- A Administrative and General Expense
- B Selling Expense
- D Automobile and Delivery Expense

501	Salaries	A	Officials or Proprietors
		A	Office and Clerical
		B	Salesmen
502	Indirect Labor	A	Janitors and Porters
		B	Non-Productive Shop
		D	Delivery Drivers
503	Commission & Bonuses to Salesmen	B	Salesmen
504	Employees Compensation Insurance	A	Office and Clerical
		B	Salesmen
		B	Shop
		D	Delivery Drivers
505	Rent	A	Rent
		A	Amortization of Leasehold
506	Taxes	A	Land and Buildings
		A	Machinery, Fixtures and Equipment
		B	Merchandise
		D	Taxes and Licenses on Automobiles
		A	Occupation Tax
		A	Corporation Tax
507	Supplies	A	Stationery and Office Supplies
		A	Janitors Supplies
		B	Shop Tools
		B	Shop Supplies
		B	Demonstrating Supplies
		D	Gas, Oil and Grease
		D	Other Automobile Supplies
		A	Miscellaneous Supplies
508	Advertising	B	
509	Gratis Material and Labor	B	
510	Heat, Light, Power and Water	A	
511	Communication	A	Telephone
		A	Telegrams
		A	Postage
512	Insurance	A	Buildings
		A	Machinery, Fixtures and Equipment
		B	Merchandise
		D	Automobiles
513	Freight, Express & Parcel Delivery	D	
514	Repairs	A	Buildings
		A	Machinery, Fixtures and Equipment
		D	Automobiles
515	Depreciation	A	Buildings
		A	Machinery, Fixtures and Equipment
		D	Automobiles
516	Bad Accounts	A	
517	Professional Services	A	Legal
		A	Auditing
518	Traveling and Entertainment	A	General
		B	Selling
528	Unclassified	A	Membership Dues and Subscriptions
		A	Donations
		A	Miscellaneous

MISCELLANEOUS GAINS AND LOSSES

OTHER INCOME

601 Interest Earned
602 Discounts Earned
603 Cash Over
604 Miscellaneous Income

DEDUCTIONS FROM INCOME

611 Interest Paid
612 Cash Short
613 Miscellaneous Losses

Form 8

COURTESY CHAS. R. HADLEY CO.

can recommend for a small or medium business.

CASH BOOK

In your ledger, you have an account with cash. You will find that you are making numerous entries to this account, and probably the work involved in doing this posting will become burdensome. There is a simple way to get around this. Use a special book for making cash entries; both incoming and outgoing cash. We still follow the rules that all cash be deposited and that you pay only by check. Use a journal-ruled book like that shown in Form 1. Open the book and head the left-hand page, "Cash Receipts," and the page directly opposite, "Payments." You now see what we have done—we lifted the cash page out of the ledger. All cash received is entered in detail on the left page, together with the deposits. (Of course, the amount received and the deposits should balance.) Also, all checks issued are entered in detail on the right page. Find the difference between the totals of the two sides each month. This difference, added to the balance at the beginning of the month if there is a debit balance, or subtracted if there is a credit balance, will give you the balance in the bank. You may post the totals of the pages at the end of the month to a cash account in the ledger, but this is not necessary. For detailed handling of this work, you should consult your accountant. This much is given you to show the development of many other books used in accounting and that, in many cases, these books are simply ledger accounts removed from the ledger.

You must understand that the detail as to the keeping of records showing who owes you money and how much, and to whom you owe money and how much, would be used in the double entry method, exactly as explained in the section considering a simple accounting system. Double entry is simply an elaboration of the method; you would still have the Cash Receipts Register, the Voucher Register and file, the Accounts Receivable Cards and the Job Card Register which would be the same as the Sales Record.

From what has been said up to this point, we may now summarize the essential features of a double entry bookkeeping system. With the cash book, the voucher register, the job card register, or their equivalents we have what are referred to in accounting as the books of original entry. This, of course, does not entirely eliminate the journal, which is used (as we said earlier) merely for the recording of extraordinary entries, such as correcting errors in your accounting, and closing the books at the end of an accounting period. From the totals of the columns in the books of original entry, postings are made to specific accounts in the general ledger at the end of the accounting period and these, in turn, serve to give information for the setting up of the Balance Sheet and the Profit and Loss Statement.

In the first section of this text we outlined a simple method of accounting for your guidance, believing that if you use this system you will have sufficient knowledge to guide you to success in

FORM 9

CHART OF LEDGER ACCOUNTS

Recommended for a Small or Medium Business

BALANCE SHEET ITEMS

ASSETS:

1. Current Assets.
    - 11 Cash in Bank
    - 12 Petty Cash
    - 13 Accounts Receivable
    - 14 Inventories
        - 141 New Radios
        - 142 Used Radios
        - 143 Tubes
        - 144 Parts & Accessories
        - 145 Misc. for Sale
    - 15 Tools and Shop Supplies

2. Fixed Assets.
    - 21 Furniture & Fixtures
        - 211 Allowance for Depreciation F & F
    - 22 Analyzers, Testers, etc.
        - 221 Allowance for Depreciation 22
    - 23 Automobiles
        - 231 Allowance for Depreciation Autos

LIABILITIES:

31. Notes Payable & Finance Co.
32. Vouchers Payable

CAPITAL:

41. Investment
42. Drawing Account
43. Profit and Loss

PROFIT AND LOSS ITEMS

5. Purchases for Sale
    - 51. New Radios
    - 52. Used Radios
    - 53. Tubes
    - 54. Parts and Accessories
    - 55. Misc. for Sale

8. Operating Expense. (Control)
    Distribution Columns for
    - 81. Salaries
    - 82. Service Labor
    - 83. Tool Expense
    - 84. Shop Supplies
    - 85. Rent
    - 86. Taxes
    - 87. Heat, Light, Telephone
    - 88. Depreciation
    - 89. Sales and Advertising
    - 90. Office Supplies
    - 91. Automobile Expense
    - 92. Miscellaneous Expense

6. Sales
    - 61. New Radios
    - 62. Used Radios
    - 63. Tubes
    - 64. Parts and Accessories
    - 65. Misc. Sales Items

7. Sales of Service
    - 71. Service Labor
    - 72. Overhead
    - 73. Estimated Profit

10. Miscellaneous Income & Losses
    - 101. Commissions Earned
    - 102. Commissions Paid
    - 103. Interest Received
    - 104. Interest Paid
    - 105. Discounts for Cash
    - 109. Bad Debts
    - 110. Misc. Income and Loss

Form 9

your undertaking. The section under Large Store Accounting is necessarily sketchy and is written only for the purpose of giving you an over-all knowledge of what to expect in an accounting system. We have given you only a very brief idea of the bare essentials and of the many books and records used for the purpose of giving more detailed information. In the final analysis they all tie in with some account in the General Ledger.

Definitions

Realizing the difficulties met by the beginner in business in understanding accounting terms, we have listed a few of them, each with a brief definition. Understanding each meaning will aid you in the operation of your business and in discussions with your banker and your accountant.

Account. As we use it, an account is a detailed statement found in the Ledger. Its heading shows the name of the asset, liability, income, or expense to which the items therein pertain. There is a column for charges and a column for credits, and a column for the difference or balance. There is space for the date, and such detail or explanation as you wish to enter. Accounts can be generally classified as: Asset Accounts, which record values owned; Liability Accounts, which record values owed; and Capital Accounts, which represent investment in the business, plus profits or minus losses. Income Accounts, for our purposes, show the amount and source of income, and the Expense Accounts show the detail of the costs of doing business, including the cost of goods sold.

Asset. An asset is something of value, owned. *Fixed assets* are those assets used for business purposes and have a determined value. They remain in the business, and are not bought and sold in the regular order of business. *Current assets*, are those that are coming in and going out. They are constantly increasing or decreasing through regular operation of the business.

Audit. To audit means to verify the accuracy of the books of account, also to check a bill for its accuracy as to prices, goods, and calculations,

Balance. A balance is the excess of the sum of the column on one side of an account over the sum of the column on the other side. If the debit or left-hand column has the larger total, the balance will be a debit balance; if the credit or right-hand column is the larger, it will be a credit balance.

Balance Sheet. A balance sheet is an orderly arrangement of assets, classified as to kinds, balanced against an orderly listing of liabilities plus capital. It shows the relation between different kinds of assets and between assets and liabilities. It shows proprietorship or net worth as represented by the difference in assets and liabilites.

Budget. A budget is a forecast of income, against which an estimated allotment of expenditure is made.

Capital. Your capital is your investment or equity in the business. It is the excess of assets over liabilities; or if there are no liabilities, the total of the assets invested. As a matter of good business and good bookkeeping, do not contribute funds to the business or take funds out of the business without charging or crediting the Capital Account.

Consignment. A consignment is a shipment of goods to a person, known as the consignee, to be held or sold for the benefit of the shipper, who is the consignor. Ownership and all rights in the goods remain in the consignor.

Depreciation. Depreciation is an estimated decline in the value of assets, due to the wear and tear of use and the ravages of time. It represents the difference between the cost and the scrap value of the asset, this value being divided by the time intervening between the date of purchase and the probable date of scrapping or other disposition. The time may be measured in months or years as suits the necessities of the accounting system. We may take our old car into the business at a value of $1200 on January 1. The following January its trade-in value may be $960. The depreciation will be $240.

Discount. Discount is a deduction from a listed figure or cost, and it may be a Cash Discount, which is an allowance of usually one or two per cent of the bill for prompt payment, or it may be a Trade Discount, which is a percentage reduction from a fixed or quoted price on a radio set or on standard parts.

Entry. An entry, for our purpose, is the recording of a fact in any of the books in our bookkeeping system.

Expense. An expense, briefly, is any expenditure of funds or other assets necessary to the carrying on of the business, excluding, of course, the substitution of assets for assets, as would occur in the purchase of goods for sale. Rent and labor are expenses. The exchange of cash or credit for receivers for later sale is not an expense, but an exchange of one kind of asset for another asset.

Expenses in a servicing business are *Direct Expenses*, that is, those that can be charged directly to a particular job; labor is one example. *Indirect Expenses* are those that must be estimated or allocated to many jobs. See definition of *Overhead*.

Income. Income is the value that comes into the business in exchange for goods and services. *Gross Operating Income* is total revenue, *Net Operating Income* is *Gross Operating Revenue* minus costs of operations. *Non-Operating Income* is that derived from sources other than operation such as interest on savings deposits.

Insolvency. Insolvency is inability to pay debts, frequently because of the inability to convert assets readily into cash. Bankruptcy is an excess of liabilities over assets, which makes it impossible for the person to meet his obligations under any circumstances.

Inventory. An inventory is an itemized list of goods or other assets, cost or selling price per item, and total value. You may inventory the accounts of your customers or you may inventory your liabilities, or furniture and fixtures.

Liability. A liability is a debt. It may be *current*, such as amounts that are due for rent, merchandise purchased; or it may be *accrued*, such as salaries to employees earned but not paid or due. There can be *fixed* liabilities, such as mortgages.

Obsolescence. Obsolescence is loss in value not due to wear and use, but to improvements or changes in design.

Overhead. Overhead is the cost of production or of doing business that cannot be definitely applied to a particular activity, and must be distributed to various jobs on a more or less arbitrary basis. For instance, in servicing, your tools suffer obsolescence and depreciation; you use solder; your car uses gas; the tires wear out, you must pay rent, you advertise. All these items amount to quite a sum of money in a month, but cannot be charged directly to any job. To take care of the situation, we arbitrarily add to the cost on each job an amount estimated to cover (totaling amounts added to all jobs) the total of these expenses for a given period. There are many ways of charging overhead, but the most satisfactory way for you in the service business is to charge it to each job as a fixed percentage of the actual labor cost.* The total overhead charged on jobs for a certain period may be checked against the actual expenditure for indirect items for the period and the percentage or rate adjusted up or down, to distribute the costs on future work more equitably.

Petty Cash. Petty Cash is a small sum set aside for the payment of small expense items where it is inexpedient to draw a check. In the books of account, the petty cash fund is a fixed amount as long as it is in existence. Checks are drawn at necessary times to replenish the fund. The slips or vouchers representing payments are classified and the check is charged to the various accounts affected.

Posting. Posting is the transfer of items from books of original entry to the Ledger.

Profit. Profit is the increase in net worth or capital from the beginning of a period to the end of a period. *Gross profit* is the excess of selling price over the cost of goods sold. *Net Profit* is the Gross Profit minus all costs of selling and all other costs of doing business.

Trial Balance. A trial balance is a list of balances of all ledger accounts. The balances listed in columns of debits and credits should total the same.

Turnover. Turnover is one of the vital factors in the operation of your business. It is the number of times that you can use a capital asset in a given period or the number of times that assets renew themselves in a given period. For instance, on the first of January you buy for sale a receiver for $100.00; you sell it for $167.00, and you do the same every month of the year. At the end of the year your cost of receivers sold would be $1200.00. Your investment is $100.00, your rate of turnover is 12, and your gross profit is $804.00. Had you bought and sold only two radios a year, your rate of turnover would have

* In the merchandising of radio and electric appliances, the selling price is set for you. In this case, it becomes the problem of the merchant to keep his overhead and direct expenses low enough to assure him of a reasonable profit, or give up the unprofitable line.

been 2, your investment still $100.00, and your gross profit $134.00. It is obvious that the higher the turnover figure the greater your gross profit.

If the selling price is not set by the producer of the product, and your turnover is high, you may figure a small profit on each sale and make just as much gross profit as you would if you had a small turnover figure and had added, to your cost of goods sold, a high profit.

Substitute the amount that you have invested for the hundred dollars above and divide this into your cost of sales for a year to get your capital turnover.

What is your turnover in accounts receivable, or how well are your customers paying? Are they taking too much time, or are you extending too much credit? Suppose your sales average $30.00 a day. When you balance your books, you find you have accumulated outstanding accounts of $1350.00. This shows your accounts receivable to be an average of 45 days' sales. In other words, you are granting 45-day terms of credit, while you think your selling terms are 30 days. You will have to speed up collections to pay your own bills in thirty days.

Voucher. A voucher is any bill, invoice, memorandum, or evidence of expenditure of funds or evidence of liability to pay out money. There should be present such proofs of correctness or evidence of payment as to make it of itself sufficient proof to be acceptable by anyone as a proper expenditure.

CUSTOMER COMPLAINTS

Every businessman expects a certain number of complaints in spite of his best efforts to please his customers. Some complaints are justified; it is human to make mistakes. Others are the result of misunderstandings, while a few are not justified at all.

You cannot avoid having some "call-backs," but your handling of these calls will have much to do with your customer good-will and your reputation.

Be just as pleasant and courteous in handling complaints as possible. The customer is doing you a favor by complaining to *you* rather than telling his friends that you cannot fix his set!

Even when the complaint is unjustified, it is frequently better to repair the set at no charge than to try to convince the customer that the new trouble is not related to your original repair.

Follow the practice of most businesses—charge these jobs to your overhead expense. Thus, by adding a small amount to the cost of each job, you can afford to handle these call-backs—you'll be keeping your customer good-will at no loss!

J. E. Smith

COLOR FUNDAMENTALS AND THE COLOR TUBE

51B

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL
NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 51

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in the same way.

☐ 7. Answer Lesson Questions.

☐ 8. Start Studying the Next Lesson.

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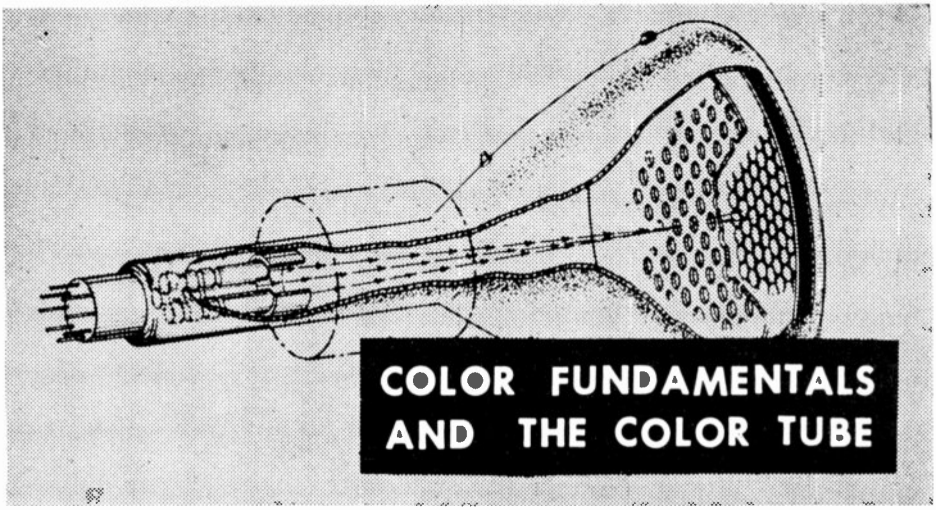


IN THE preceding lessons you studied the basic fundamentals of a monochrome television system. You also studied basic television circuits and black-and-white picture tubes. Now that you are about to start your study of color television, you should keep in mind what you have learned. Many of the circuits and principles used in monochrome television are also used in color television. The tri-color tubes used in color television, work on the same basic principles as the black-and-white picture tubes, except that different color phosphors are used to produce a color image instead of a black-and-white image.

As you already know, a television picture is transmitted line by line. In other words, the scene to be televised is broken up into a series of lines, which are scanned, and the brightness information along each line is transmitted as a series of electrical signals. The television receiver recombines these signals into a complete picture. In color television, the scene also must be scanned line by line, and, as you will see later, information in addition to the brightness information is required in order to produce color pictures.

It is important for you to realize that the video signal transmitted by black-and-white television stations contains only brightness information. In other words, the video signal contains the information needed to control the amplitude of the electron beam in the picture tube to produce a bright area, a dark area, or some shade of gray on the picture tube screen, depending upon the brightness of the area being scanned by the camera.

Black-and-white television receivers respond only to brightness information. Therefore, if a monochrome receiver is to produce a black-and-white signal from a color transmission, the color transmission must contain brightness information. We will see later that the brightness signal is one component of the color TV signal.

LIGHT

We are all able to describe light in general terms. We know that light is given off by the sun, and because of this light we are able to see. We also know that light is given off by a fire, and that it can be produced artificially by means of electric light bulbs. The light given off by the sun and by electric light bulbs is called white light—it does not have any perceptible color.

Actually, white light is made up of light of all colors. We can demonstrate this by passing the white light through a prism as shown in Fig. 1. When the white light passes through the prism, the violet light is bent more than the other colors; the blue light is bent more than all colors except violet; and the green light is bent more than all colors except blue and violet. The red light is bent the least. The result

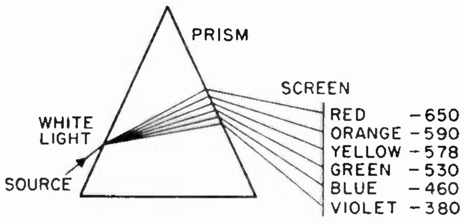


FIG. 1. When white light goes through a prism it is broken up into its componet colors.

is a color spectrum ranging from red and orange on one end through yellow, green, blue, and violet on the other end. You have seen an example of this in nature. Frequently after a storm a rainbow will appear in the sky. Here the white light is broken up into its various colors by rain drops acting as prisms. The violet and blue colors appear on the inside of the arc of the rainbow and red and orange on the outside.

As you might expect, since white light can be broken up into its many colors, the colors can also be combined to produce white light. As a matter of fact, it is not even necessary to have all the colors to produce white light. White light can be produced by combining red, green, and blue light. Red, green, and blue are called primary colors. It is possible to produce not only white light by combining these three colors, but all other colors in the spectrum as well.

You are probably already familiar with water color paint. Almost any school child can tell you that by using the proper combinations of red, blue, and yellow water color paints, it is possible to obtain any other color. In this case, the primary colors are red, blue, and yellow. With light, it is not the same; red and blue again are primary colors, but green replaces yellow.

The fact that it is possible to produce white light and also any color in the spectrum from three primary colors makes color TV possible. Color television would be extremely complicated if we had to transmit every color and shade in order to obtain good color television pictures.

So far, we have discussed only the primary colors and the fact that the primary colors can be used to produce white light and also other colors in the visible spectrum. In Fig. 2 we have shown the three primary colors, and also how the colors can be combined. Notice that red and green produce yellow, while blue and green produce cyan (a greenish blue). The combination of red, blue, and green produces white.

In addition to producing the various colors, we must also produce many shades of each color. In other words, we must distinguish between a very deep color, such as a deep dark blue, and a light color, such as a light blue.

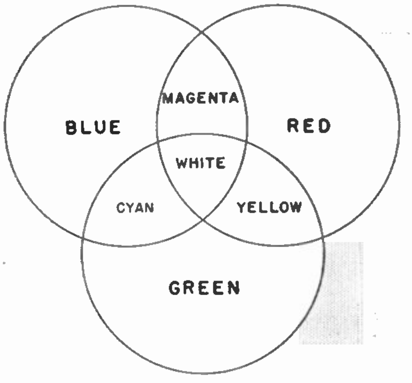


FIG. 2. Equal intensity levels of the primary colors red, blue, and green, form white. Red and blue form magenta, red and green form yellow, and blue and green form cyan.

The basic colors may be the same, but the sensation they produce in the eye is entirely different. Deep blue contains only blue, but the light blue contains blue light plus white light. The deep blue, containing only the one color, is referred to as a "saturated" color.

We have already discussed the fact that by means of three primary colors, full color pictures can be produced. We can use this fact in a relatively simple color television system by first breaking the scene to be televised into three primary colors at the transmitter, and then recombining them at the receiver. Let us see how we can do this.

FILTERS

Ordinary window glass is transparent. It will transmit practically all the colors in white light. Different types of plastic can also be made transparent so that they will pass all the colors in white light. However, it is also possible to make devices known as filters that will pass only certain colors. For example, it is possible to make a red filter that will transmit only red light and will completely block the passage of blue and green light. Similarly, a green filter will transmit green light, but block the passage of red and blue light; and a blue filter will transmit blue light, but block the passage of green and red light.

When we look at a scene, we see color in it, because the white light from the sun strikes the scene, and part of it is absorbed. For example, the white light strikes a red barn, the red light is reflected by the barn, and the other colors in the white light are absorbed. Similarly, when white light strikes the leaves on a tree, the green light is reflected by the leaves and the rest of the colors are absorbed.

If we examined a scene through a red filter, only the red light in the scene would reach our eye. Similarly, if we used a blue filter, only the blue light would reach our eye, and if we used a green filter only the green light would reach our eye.

A SIMPLE COLOR CAMERA

A simple color television camera can be made by using three separate lens systems and three camera tubes.

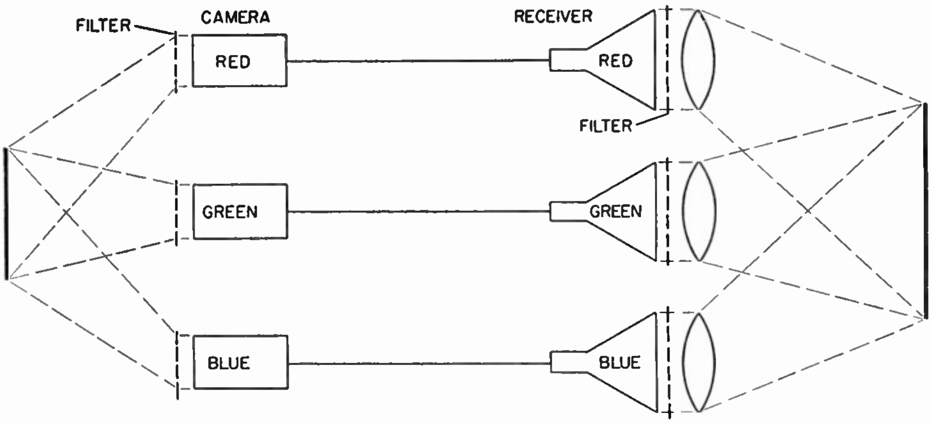


FIG. 3. A simple arrangement where three monochrome cameras used with suitable filters can be used with three black-and-white picture tubes with similar filters to produce a color picture.

The lenses are adjusted to focus the scene to be televised on each of the three camera tubes. Between one lens and one camera tube is a red filter, between another lens and another camera tube is a green filter, and between the third lens and the third camera tube is a blue filter, as shown in Fig. 3. With an arrangement of this type, three separate images can be obtained, one containing the red information, another containing the green information, and a third containing the blue information in the scene.

If the camera tubes are scanned in exactly the same way as a monochrome camera tube is scanned, three separate video signals can be produced. The video signal at the output of the red camera will be a brightness signal that contains the red information in the picture. Similarly, the video signal at the output of the green camera will contain the green picture information, and the signal at the output of the blue camera will contain the blue brightness information. By transmitting this brightness information to three separate picture tubes at the receiver, the three color images can be recombined to form the original full color picture.

A SIMPLE COLOR RECEIVER

If a color receiver actually used a system of this type, it would be almost three separate receivers. We will not go into the details of how such a set could be made because it is unimportant. However, we will discuss how the color picture can be reproduced.

In a color receiver of this type, three separate tubes are used in conjunction with an optical system, so that the images from the three tubes are projected into a single image on a screen. A red filter is inserted between one picture tube and its lens, a green filter between the second tube and its lens, and a blue filter between the third tube and its lens. As you can see from Fig. 3, the signal from the red camera is supplied to the tube with the red filter. The result will be a red image projected on the screen. The red image will contain only the red information in the original scene. In other words, if the scene being televised consisted of a red barn surrounded by green shrubs and trees, only the red barn would be reproduced by the red tube in the receiver. Similarly, the image of the green shrubs and trees would be picked up only by the green camera and reproduced only by the tube having this information applied to it. The image on the green tube would be projected through the lens and green filter producing a color image on the screen.

If a yellow object was being televised, the yellow would be broken into its primary colors of red and green so that signals would be produced by both the red and the green cameras. This would result in red and green images being produced on the screen, and these two colors would combine to produce the original yellow object.

We have not gone into the details of how the signals needed for a system of this type could be transmitted. However, since the signals are actually only brightness signals, three separate video carriers could be used so that the circuitry would be similar to the circuitry found in present-day monochrome television receivers. However, since three separate video carriers would be required, such a system would need a band width almost three times the 6-mc television channels allotted by the FCC. This would mean that we could have only about one-third as many TV stations operating on the present channels as we have today. In addition, since the television receiver would consist of three practically completely separate systems along with a complicated optical arrangement, television receiving equipment would be extremely expensive. Because of these disadvantages, this simple arrangement is not used. However, excellent color pictures can be reproduced using a system of this type.

A SEQUENTIAL COLOR SYSTEM

We pointed out in the preceding section, that two big difficulties of the simple color system discussed were that the band width required would be much wider than the 6-mc television channel, and the receiving equipment would be both costly and extremely difficult to adjust. The sequential color system overcomes some of these difficulties. In this system, a single camera is used in the transmitter and a single picture tube at the receiver.

In the field sequential system, the picture is broken into a series of color fields. In other words, first the red filter is placed in front of the camera and the scene is scanned. At the same instant a red filter is placed in front of the receiver so that a red picture is produced. After the camera has scanned the scene with the red filter in place, the red filter is removed, and then either the green or the blue filter is put in its place. Meanwhile, the same filter is put in place at the receiver so that a color picture corresponding to the color of the image

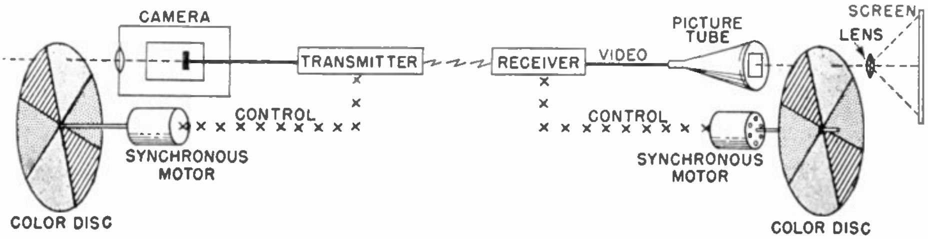


FIG. 4. The mechanical sequential system.

being scanned at the transmitter is obtained.

The filters can be arranged in a color disc, as shown in Fig. 4. The color disc in front of the camera is driven by a synchronous motor. The color disc at the receiver is also driven by a synchronous motor, which is controlled by sync pulses so that it will be maintained in step with the motor at the transmitter.

If the color fields are sent at a rapid enough rate, the three separate color fields will combine to give a whole color picture. Although the arrangement described here is a mechanical arrangement, it is also possible to work out an electronic arrangement so that the color disc is not necessary.

The field sequential system was actually approved by the Federal Communications Commission, and there were a few receivers made using the mechanical color disc. However, this system was not accepted either by the public or by the television station owners. In order to provide a sufficient number of fields per second to avoid color flicker, a new set of standards had to be used so that the monochrome television receivers could not produce a black-and-white picture when the color programs were being transmitted. As a result, stations were unwilling to broadcast color because there was no audience for the programs, and the public was unwilling to buy color receivers because there were no programs.

A Compatible Color System

The experience with the field sequential color system convinced both the television industry and the FCC that before there could be any success with color television, a compatible system would have to be adopted. Let us now investigate such a color television system. Although this system is somewhat complicated, we can break it down into sections that in themselves are not particularly difficult to understand.

COMPATIBILITY

You have probably heard the present color television system referred to as a "compatible" color system. By this we mean that the system is compatible with present black-and-white standards. In other words, a black-and-white television receiver can receive the color signal and produce a black-and-white picture from it. This is extremely important because it means that the black-and-white television receivers in the hands of the public will not be rendered obsolete by color television. As long as the owner is satisfied with black-and-white pictures, he can continue to use the receiver and obtain good quality black-and-white pictures, even though all the programs on the air may be transmitted in color.

The system is compatible the other way also. A color television receiver can receive the signal from a black-and-white program transmission and produce a black-and-white picture. This means the person who buys a color television receiver will be able to watch not only programs broadcast in color, but monochrome transmissions as well, and obtain a good quality black-and-white picture on the receiver. In general, a black-and-white picture produced on a color television receiver may have some slight coloring—the whites may be slightly blue or slightly red, but by carefully adjusting the set, the whites may be made close enough to pure white to be entirely satisfactory.

We have already pointed out that in black-and-white program transmission the only picture information transmitted is the brightness information. As the electron beam scans across a line on the television camera, an electrical signal representing the brightness along that line is produced. Therefore, if we are to have compatibility, in other words, if we are to be able to produce a black-and-white picture on a monochrome television receiver even when a color program is being transmitted, we must have a brightness signal. In color television the brightness signal is called the "Y" or "W" signal. Since most manufacturers refer to the signal as the Y signal, we will call the signal the Y signal in the rest of our discussion on color television. However, remember that in some other texts you may find the signal referred to as the W signal.

Now let us see how the Y signal is produced and why it can be used to produce a black-and-white picture on a monochrome television receiver.

THE Y SIGNAL

The Y signal is the brightness signal. It is also called the luminance signal. This signal is identical to the video signal produced by a monochrome camera. It contains only the brightness information, and it alone cannot be used to produce a color picture. However, when it is used with additional color signals, which we will discuss shortly, it can be used to produce color pictures.

The development of the Y signal is comparatively simple. First let us see what the brightness levels of the primary colors are in a monochrome TV system. If we were to place a white card in front of a monochrome camera, the light striking the white card would be reflected, and the image of the card would be focused on the camera tube. If the output of the camera tube were adjusted so that a video signal of 1 volt was produced by the light striking the white card, we could use this signal as a reference level.

If we substitute a red card, we will find that the signal voltage developed by the camera is .30 volt; in other words, red is 30% as bright as white. If we substitute a green card, we will find that the voltage in the output of the camera is .59 volt, because green is 59% as bright as white. If we substitute a blue card, the output voltage from the camera will be .11 volt, because blue is 11% as bright as white; and if we substitute a yellow card, the output voltage from the camera will be .89 volt, or 89% as bright as white. Notice that this is the sum of the brightness of red (30%) and green (59%) which combine to form yellow.

Now, keeping these brightness relationships in mind, let us see how we can produce a brightness signal (Y) from a color camera, that can be used to form a picture on a monochrome receiver.

The Y signal can be developed by a color camera by using an arrangement similar to that shown in Fig. 5. Here we have a separate camera to pick up each of the three primary colors. First these must be adjusted so that a red object will produce an output of 1 volt from the red camera, a green object an output of 1 volt from the green camera, and a blue object an output of 1 volt from the blue camera.

However, as we have learned, in a monochrome picture, the brightness level of red is 30% of white, green 59% of white, and blue 11% of white. Therefore, we must feed these signals to voltage divider networks.

The signal from the red camera is fed to a voltage divider network that is adjusted so that the output from the network is 30% of the input. This is indicated on the diagram as .30R. Similarly, the signal from the green

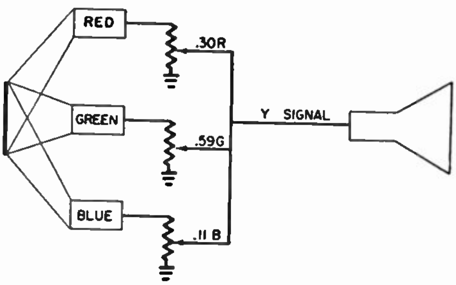


FIG. 5. A simple means of obtaining the Y signal.

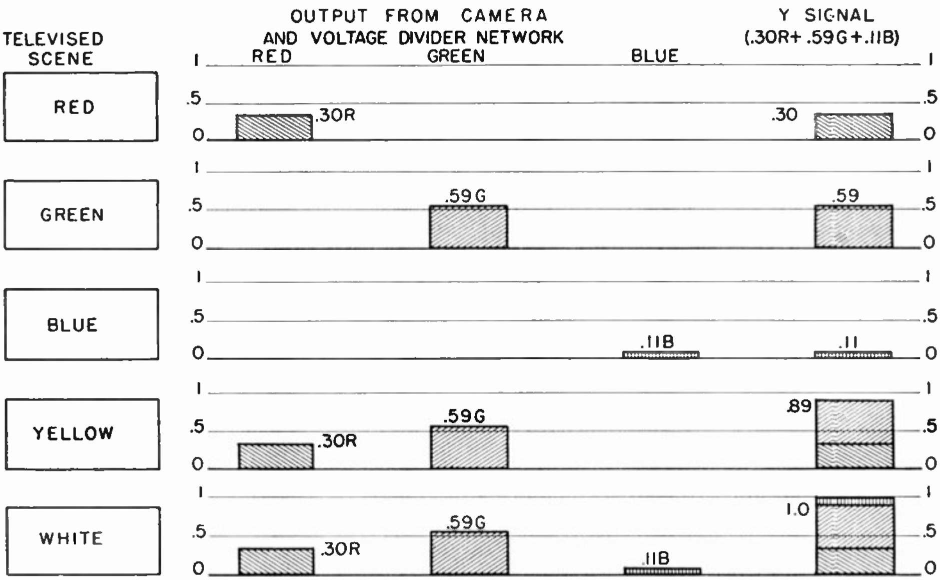


FIG. 6. The output from each color camera chain and the resulting Y signal for objects of each of the primary colors and white.

camera is fed to a voltage divider so that the output of the divider is 59% of the input, and the signal from the blue camera is fed to another divider so that the output from this network is 11% of the input. These signals are then combined, and the resulting signal is the Y signal. In Fig. 5 we have simply shown them coming together to a common lead, but, of course, in actual practice, a more elaborate arrangement would be required.

Now let us see what happens when colored cards are placed in front of the camera. We will see that the Y signal produced for each color will be exactly the same as the brightness signal that would be produced for that color by a monochrome camera.

In Fig. 6 we have shown by means of a chart what the output signal will be from each network for various colors and for white. Notice that if we place a red card in front of the color camera, the output from the red camera chain (the camera and its associated voltage divider network) will be .30 volt. There will be no signal from the green or blue cameras, and therefore the total Y signal will be .30 volt. This is exactly the same signal as we obtained from the monochrome camera.

If a green card is placed in front of the color camera there will be no signal produced by the red and blue cameras, but the output from the green camera and divider network will be .59 volt. The amplitude of the Y signal for green, therefore, will be .59, the same as the video signal amplitude from the monochrome camera. Similarly, a blue card will produce the same signal amplitude of .11 volt as the monochrome camera, and the

Y signal will be .11 volt.

So much for the primary colors. We know that insofar as the primary colors are concerned, the Y signal produced by the color cameras will have the same amplitude as the video signal produced by a monochrome camera. Now let us see what happens when we place the yellow card in front of the camera.

When a yellow card is placed in front of the camera, the yellow light will be broken up into the two components of red and green. The output from the red camera and divider network will be .30 volt as shown in Fig. 6. The output from the green camera and divider network will be .59 volt. These two signals are added to produce a Y signal of .89 volt—the same as the video signal produced when a yellow card is placed in front of the monochrome camera.

If a white card is placed in front of the camera, the signal produced by the red camera chain will be .30 volt, by the green camera chain .59 volt, and by the blue camera chain .11 volt. The resulting Y signal will have an amplitude of 1 volt, again the same amplitude as the video signal produced by the monochrome camera.

From the preceding, you can see that the Y signal is the equivalent of the video signal produced by a monochrome camera. This Y signal contains the brightness information in the picture. You know that a black-and-white receiver needs only the brightness information to produce a picture, and therefore, the Y signal transmitted by a station broadcasting a color program will be received by a monochrome receiver, which will produce a black-and-white picture from it.

A COLOR SIGNAL

So far we have shown how the brightness information in the color picture can be used to produce the Y signal. In Fig. 5 we have shown the signals fed to the simple voltage-divider networks. Actually, the circuit is much more complicated than this. Signals from the various cameras are fed to a complex voltage divider and adder circuit called a "matrix," where 30% of the red signal, 59% of the green signal, and 11% of the blue signal are combined to form the Y signal.

A block diagram of a color system, using the Y signal and three color signals, is shown in Fig. 7. In this circuit, the signals from the red, green, and blue cameras are fed to the matrix where the Y signal is produced. A signal from each of the cameras is also fed to an adder. An adder is simply a circuit that can be used to add two signals together. The Y signal is also fed to a phase inverter which inverts the phase 180 degrees so that there is a —Y signal at the output of the phase inverter; the —Y signal is fed into each of the adders. Now let us follow the signal from the red camera through the entire system and see what happens, when a red image is picked up.

At the output of the red camera, a signal of 1 volt is obtained. This signal is fed to the voltage divider in the matrix and also to the adder. At the output of the matrix is the Y signal, which is then inverted by the

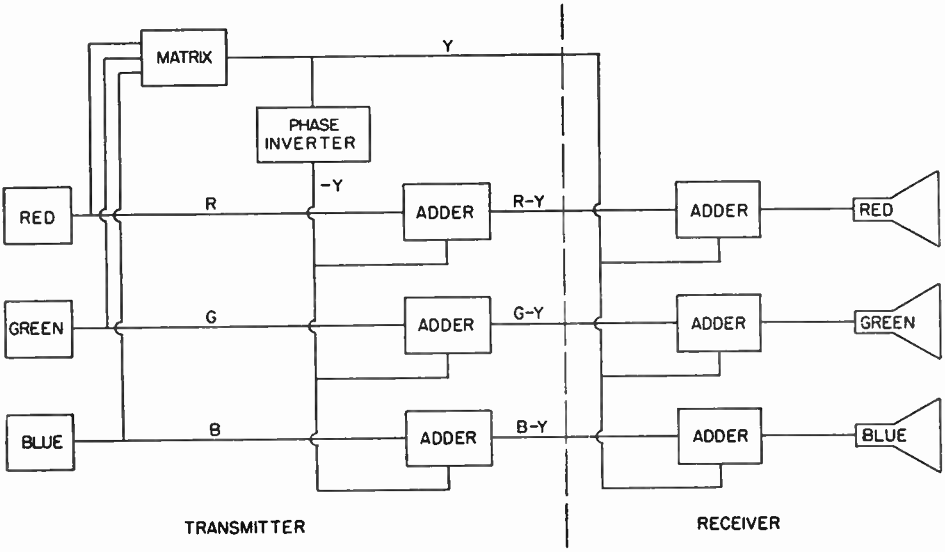


FIG. 7. A color system using a Y signal plus three color signals.

phase inverter. The —Y signal and the R signal are combined in the adder so that at the output of the adder a signal, known as R-Y, is available. This R-Y signal is fed to an adder in the receiver, and in this adder it is combined with the Y signal. The Y signal cancels the —Y signal so that at the output of the adder the total R or red signal is available. The red signal is then fed to a picture tube and produces a red image which contains the information originally picked up by the red camera.

The green and blue signals are fed to circuits similar to those used in the case of the red signal.

In the circuit shown in Fig. 7, we have simply shown the transmitter and receiver connected together by four wires. Before this system could be used for color television, we would have to devise some means of transmitting four separate signals. Fortunately, as you will soon see, it is not necessary to transmit all three color signals. A full color picture can be obtained by transmitting the Y signal and only two of the color signals.

AN IMPROVED COLOR SYSTEM

One of the disadvantages of the color system we have just discussed is that it is necessary to transmit a Y signal and also three color signals. The transmission of the signals would require a band width wider than the 6-mc TV channel presently in use by monochrome TV stations. To make it possible to transmit the entire color signal (and the accompanying sound) within the 6-mc channel, and because it is not necessary to transmit all three color signals, a system consisting of the Y signal and two color signals has been devised.

The simplified color system is shown in block diagram form in Fig. 8. Notice again that the three cameras feed to the matrix where the Y signal made up of .30R + .59G + .11B is produced. Again, the signal from the red camera is fed to one adder and the signal from the blue camera to another. The Y signal is fed to a phase inverter so that a —Y signal is available at the output of the phase inverter. This signal is combined with the R signal in one adder to produce the R-Y signal, and with the B signal in the other adder, to produce the B-Y signal. Notice that in the circuit shown in Fig. 8 there is no G-Y signal produced in the transmitter. Only the Y signal, the R-Y, and the B-Y signals are transmitted. Now let us look at the receiver and see how the color signals can be produced in the receiver from the Y signal and the two color signals.

Notice that a part of the receiver is similar to the arrangement shown in Fig. 7. For example, the R-Y signal is fed to an adder along with the Y signal. The Y signal cancels the —Y signal so that the signal in the output of this adder is the R signal. Similarly, the B-Y signal is fed to an adder along with the Y signal, and the signal in the output of this adder is the B signal.

Up to this point the receivers used in the color systems described in Figs. 7 and 8 have been identical. However, since the G-Y signal is not transmitted in the color system shown in Fig. 8, we must produce the G-Y signal in the receiver in order to add this signal to the Y signal to obtain the green signal to drive the green picture tube. The G-Y signal can be obtained by passing the R-Y signal through an amplifier having a gain of —.51 and the B-Y signal through an amplifier having a gain of —.19 and mixing the two signals together. Now let us look at exactly what happens in these two amplifiers so we can see how the G-Y signal is produced.

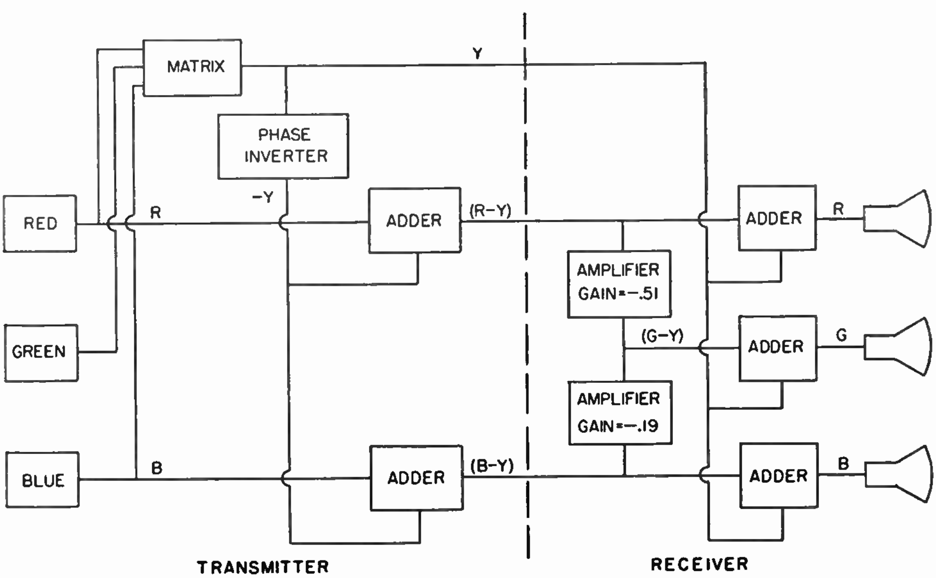


FIG. 8. A simplified color system using the Y signal and two color signals.

OBTAINING THE G-Y SIGNAL

The Y signal is made up of .30R + .59G + .11B. Therefore, the R-Y signal will be:

1R — (.30R + .59G + .11B)

This can be simplified by removing the brackets and writing the expression as 1R — .30R — .59G — .11B which can be further simplified by subtracting the .30R from the 1R to give us .70R — .59G — .11B. This is the R-Y signal.

If we have a signal whose amplitude is 1 volt and we feed the signal through an amplifier having a gain of 2, we know that the signal in the output of the amplifier will be 2 volts. We obtain the output signal simply by multiplying the signal by the gain of the amplifier. Similarly, if the gain of the amplifier was .5, we would multiply the 1-volt input signal by .5 and obtain an output signal voltage of .5 volt. Since we feed the R-Y signal through an amplifier having a gain of —.51, we simply multiply the R-Y signal by —.51 to obtain the amplitude of the output signal. In other words, —.51 (.70R — .59G — .11B) = —.357R + .301G + .056B. This is the amplitude of the R-Y signal after it has passed through the amplifier having a gain of —.51.

The B-Y signal may be written as: 1B — (.30R + .59G + .11B) = —.30R — .59G + .89B. This is the B-Y signal. This signal has to be passed through an amplifier having a gain of —.19. Again, as in the case of the R-Y signal being amplified by the amplifier having a gain of —.51, we can determine the amplitude of the B-Y signal after it has passed through the amplifier having a gain of —.19 simply by multiplying the B-Y signal by —.19. This gives us: —.19 (—.30R — .59G + .89B) = .057R + .112G — .169B.

Referring to Fig. 8, you will see that the signal from the output of the —.51 amplifier is added to the signal at the output of the —.19 amplifier. We can obtain the amplitude of this signal simply by adding the two together. The signal at the output of the —.51 amplifier is —.357R + .301G + .056B. The signal at the output of the —.19 amplifier is .057R + .112G — .169B. Adding these two signals:

—.357R + .301G + .056B
.057R + .112G — .169B

—.300R + .413G — .113B

This is the signal that will result when the outputs of the two amplifiers are combined, and it is equal to G-Y, because 1G — (.30R + .59G + .11B) = 1G — .30R — .59G — .11B = — .30R + .41G — .11B.

The G-Y signal is then fed to an adder where it is combined with the Y signal, with the result that the G signal will be available in the output of this adder.

SUMMARY

Since the color system using the Y signal and the two color signals is the most complex system we have discussed thus far, let us briefly review how it works. It is important that you understand the system, since it is the basis of the color television system in use today.

The outputs from the red, green, and blue cameras are fed to the matrix where the Y signal consisting of .30R

+ .59G + .11B is produced. The signal is a brightness signal—it contains only the brightness information. It does not contain any color information. The Y signal will produce a black-and-white picture on a standard monochrome television receiver.

The red signal is fed to an adder where it is combined with the —Y signal. The —Y signal is produced simply by passing the Y signal through a phase inverter. The signal at the output of this adder is known as the R-Y signal. Similarly, the blue signal is combined with the —Y signal in an adder to produce the B-Y signal.

In the block diagram of Fig. 8 we have shown the receiver and transmitter connected together by three wires. We will see later how the signals are actually transmitted.

In the receiver the R-Y signal is fed to an adder where it is combined with the Y signal. When we combine R — Y + Y, the Y's cancel and the R signal results in the output. Similarly, the B-Y signal is combined with the Y signal in an adder so that the B signal will be available at the output of this adder.

The R-Y signal is also fed to an amplifier having a gain of —.51 and the B-Y signal is fed to another amplifier having a gain of —.19. The gains of these amplifiers have been selected so that the combined signal resulting in the output of the two amplifiers will be the G-Y signal. The G-Y signal is then fed to the third adder where it is combined with the Y signal so that the G signal results in its output.

In this simplified color system we have transmitted a brightness signal and two color signals. The brightness signal will produce a black-and-white picture on a monochrome television receiver when a color program is being transmitted. The brightness signal plus the R-Y and B-Y signals will produce color pictures on a color receiver.

One obvious advantage of transmitting the brightness signals is that it will make it possible for monochrome receivers to produce black-and-white pictures during color program transmissions. Another advantage of breaking the signal up into a brightness signal plus separate color signals will become apparent after we discuss a few additional characteristics of color.

Transmitting the Color Signal

Up until this time we have shown the color transmitter connected to the color receiver by means of wires. We know, however, that the color signal must actually be transmitted by the TV transmitter like the signal from a monochrome television station. We will now discuss a few additional details about color and then see how the color program can be transmitted.

Two important characteristics of color are hue and saturation. It is important for you to understand what each means, and the effect of each on the color signal.

HUE

Hue refers to the dominant color. For example, when you look at the leaves on a tree, the dominant hue is green. In other words, the hue or color of the leaves is green. Similarly, the dominant hue of the light reflected by a red fire truck is red. The hue distinguishes the color. However, if you look around you, you will see that there are many different shades of each color. In other words, there are very deep colors and there are very light colors, known as pastels. A very deep red may have exactly the same hue as a light or pastel red. In each case the dominant color is red.

SATURATION

Saturation is the distinguishing characteristic between deep colors and light colors such as pastels. We say a color is *saturated* when it is a deep color. The only color present in a saturated color is the dominant hue. For example, if white light shines on a card that is painted a deep red, the only light that will be reflected by that card is red. The color has a red hue and is fully saturated.

On the other hand, if a pastel red (pink) having the same hue as the deep red is placed under the white light, some white light will be reflected by the card in addition to the red. The pastel red is not saturated.

It is important that you understand what is meant by hue and saturation. Hue refers to the dominant color, whereas saturation tells us whether it is a deep color or a pastel. A deep color containing only the one hue is a saturated color. A pastel color containing the dominant hue, plus some white light, is not saturated.

Pastel Colors. Now that we have discussed hue and saturation, let us consider the signal that will be produced by pastel colors. Suppose, as an example, that the color to be transmitted is a pale green.

In the preceding section we pointed out that a pale green is not a saturated green. In addition to the green, there will also be a certain amount of white light present. The white light can be divided into the primary colors of red, green, and blue; therefore, the white light in the scene will excite all three cameras. If we assume that the intensity of the white light is such that it produces signals of .5 volt at the output of the red, the blue, and the green cameras, and that the green light reaching the green camera produces an additional .5 volt, we will have a .5-volt signal from the blue camera, .5 volt from the red camera, and 1 volt from the green camera. These three signals are combined in the matrix using the same ratio of .30R + .59G + .11B. Since the red signal is only .5 volt, the total voltage contributed to the Y signal by this color will be .5 times .30 or .15 volt. Similarly, the signal contributed to the Y signal by the blue camera will be .055 volt. The green camera, however, produces the voltage of 1 volt, and therefore, the voltage contributed to the Y signal by this camera will be .59 volt.

Referring to Fig. 8, you can see that we will have a Y signal. We will also have R and B signals at the red and blue cameras, and therefore, we will have an R-Y and a B-Y signal when the signals are mixed with the —Y signal. Notice that in the case of pale color, we have signals from all three camera tubes, whereas when we are transmitting a fully saturated primary color we will have the signal from only the one camera.

In the receiver, the green picture tube will be excited to produce the green hue. In addition, the red and blue tubes will be excited. The output from the red and blue tubes will combine with part of the output of the green tube to produce the original white light. The rest of the output from the green tube will give the green hue that was originally picked up by the cameras. The result will be that the receiver will reproduce a pale, or non-saturated green.

The transmission of other pale colors is accomplished in the same way. The original hue is transmitted along with a certain amount of white light. Because the pastel colors are made up of one hue and a certain amount of white light, we are able to reproduce not only the saturated colors, but also the various shades and pastels.

TRANSMISSION WITHIN A 6-MC BAND

You already know that the television channels allotted by the FCC are 6 megacycles wide. In this channel, we must transmit not only the picture information, but also the accompanying sound. In the transmission of a color signal, we must find a method of transmitting not only the brightness information in the picture, but also the color signals. In addition, we must still leave room in the channel to transmit the sound signal.

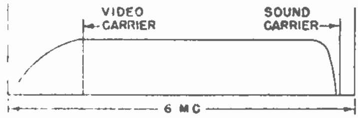


FIG. 9. A TV channel.

Present monochrome standards call for a spacing of 4.5 mc between the sound and picture carriers. If the color television system is to be compatible, this spacing must be maintained. Therefore, the color signals must be sent somewhere in the portion of the channel originally used for the transmission of the video signal.

The television channel is shown in Fig. 9. The video and sound carriers are within the 6-mc channel. The lower sideband of the video signal is partially suppressed, but the sideband extending above the video carrier in the direction of the sound carrier is transmitted fully out to 4 mc and then

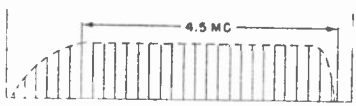


FIG. 10. How the sideband components are distributed.

cut off sharply beyond this point. However, this does not mean that this entire spectrum is occupied by signals. In fact, it was discovered that large areas of the spectrum were not occupied by signals at any time. In other words, the luminance (brightness signal) consists of a small group or "package" of frequencies centered on the line frequency, plus many harmonics of these frequencies. As shown in an exaggerated form in Fig. 10, therefore, we actually have sideband components spaced about 15 kc apart,

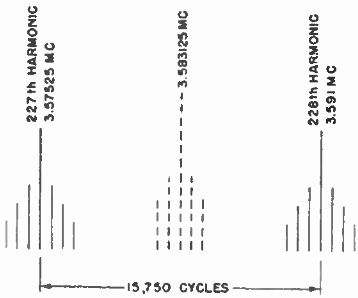


FIG. 11. Two sideband components with a new signal between them.

with empty spaces between them. If another carrier is chosen so that it falls halfway between two harmonics of the line frequency, as shown by the dotted lines in Fig. 11, and if it is modulated at the line rate, its sideband components will be between those of the original carrier, as shown in A of Fig. 12. Thus, it is possible to make two separate signals of this kind occupy the same spectrum space, providing the carriers are properly spaced and chosen.

We have already combined the luminance signals from all three color cameras to produce a Y signal that can be used to modulate the video carrier exactly as in monochrome television. If the chrominance (color information—hue and saturation) for all three colors can be sent on a subcarrier with the frequency chosen to fall between harmonics of the line-scanning rate, we could send the entire signal in the TV channel.

In color television a color subcarrier of 3.579545 mc is used. This in an odd multiple of the horizontal scanning frequency used for color television. The horizontal scanning frequency is 15,734.264 cps. Notice that this is slightly lower than the 15,750 cps used in monochrome television. However, the change is so small that black-and-white television receivers have no difficulty locking in on this frequency. Changing the horizontal scanning frequency means that the vertical scanning frequency must also be changed. In the monochrome television standards, the vertical scanning rate is 60 cps, but in color television it is 59.94 cps. Again, the change is so small that it causes no difficulty with monochrome television receivers.

The frequency of the color subcarrier is such an odd frequency that it is extremely difficult to remember. However, the frequency is almost 3.58 megacycles, and usually when service-

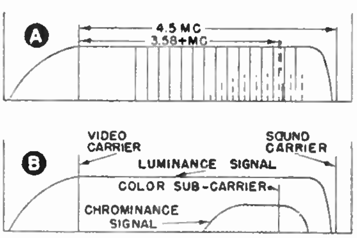


FIG. 12. How the chrominance signal is placed in the TV channel.

men and engineers refer to the color subcarrier frequency, they call it 3.58 mc.

Since this idea of using a color subcarrier is probably new to you, it might be worth while to review briefly how this system works.

The video information transmitted

by a monochrome station is grouped around harmonics of the horizontal line rate. By referring to Fig. 11, you will see lines representing the video information grouped around the 227 and 228 harmonics. Notice also that there is a space between these harmonics where there is no video information. In a color television system, the Y information is grouped around these harmonics, and the color information can be transmitted on a subcarrier falling between these harmonics. Harmonics of the color subcarrier will fall in the unoccupied spaces as shown in Fig. 12A. The information in the TV channel will be spaced more or less as shown in Fig. 12B.

THE DOUBLY-BALANCED MODULATOR

The transmission of the color information is accomplished by means of a doubly-balanced modulator. A schematic of this type of modulator is shown in Fig. 13. Notice that the color signal is fed into the grid of V1 and a 3.58-mc color subcarrier is fed to the No. 3 grids of tubes V2 and V3.

Let us first consider what would happen in this modulator if only the B-Y signal and not the 3.58-mc color subcarrier were applied to the modulator. When the color signal is positive, the phase splitter V1 will develop a negative signal in the plate circuit, and a positive signal in the cathode. The negative signal applied to the grid of V2 will cause the current in this tube to decrease, but the positive signal applied to the grid of V3 will cause the plate current in this tube to increase. Since the plates of the two tubes are connected together, the net result will be that the increase in V3 cancels the decrease in V2 so that there is no output signal. Similarly, if only the 3.58-mc signal were applied to the third grids of V2 and V3, when one grid is driven positive, the other grid will be driven negative so that there will be no signal produced in the output circuit.

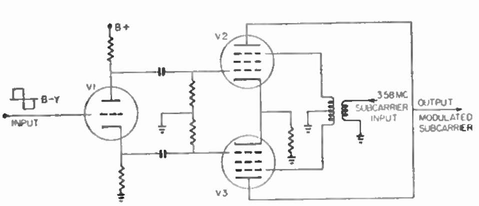


FIG. 13. Schematic of doubly-balanced modulator.

From the preceding discussion, you can see that neither the original color signal nor the original 3.58-mc signal will appear in the output of the doubly-balanced modulator. However, when the two signals are applied simultaneously to the modulator, an output signal will be produced. Let us see why this is so.

When the B-Y signal applied to the grid of V1 is positive, a negative signal will be developed at the plate circuit of V1 and a positive signal at the cathode. Therefore, a negative signal is applied to the control grid of V2, which will in effect increase the bias on this tube. At the same time, a positive voltage is applied to the control grid of V3, which will decrease the bias on it.

The increase in bias on V2 will reduce its gain, and the amplitude of the 3.58-mc signal appearing in the plate circuit of this tube will decrease.

Similarly, the reduction in bias on the grid of V3 increases its gain, and the amplitude of the 3.58-mc signal appearing in the plate circuit of this tube will increase. Therefore, since we will have a greater 3.58-mc signal appearing at the plate of V3 than at the plate of V2, the two signals will not completely cancel, and there will be a 3.58-mc output signal from the modulator.

The relative phase of the input 3.58-mc signal and the output 3.58-mc signal is important. Consider the 3.58-mc signal applied to the modulator. This color subcarrier is applied to the primary of the transformer. The signal applied to the No. 3 grid of V2 will be 180 degrees out of phase with the color subcarrier, and the signal applied to the No. 3 grid of V3 will be in phase with the color subcarrier. However, we know that the signal applied to the grid of the tube will be inverted and appear 180 degrees out of phase in the plate circuit. Therefore, if the signal at the No. 3 grid of V3 is in phase with the 3.58-mc color subcarrier, the signal appearing at the plate of this tube will be 180 degrees out of phase with the subcarrier signal. Therefore, for a positive B-Y signal, the output signal from the modulator will be 180 degrees out of phase with the color subcarrier. Fig. 14 is a vector diagram showing this phase relationship.

In discussing the output from the doubly-balanced modulator, we assumed that the B-Y signal was a positive voltage. This will be the case when a blue object is being televised, because the amplitude of the blue signal would be 1 volt and the amplitude of the Y signal would be only .11 volt; therefore, 1 volt minus .11 volt would give us a positive .89 volt. However, if we were transmitting a green object, the amplitude of the B (blue) signal would be zero, and the amplitude of the Y signal would be .59 volt.

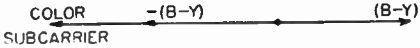


FIG. 14. Phase relationship between the B-Y output from the modulator and the color subcarrier.

(Remember from an earlier discussion that the B-Y signal is composed of — .30R — .59G + .89B.) Therefore, you would have a —.59 volt video signal fed to the phase-splitter. By the same line of reasoning that we followed previously, you can see that if a negative signal is fed to the phase-splitter, the output of V2 will be greater than the output of V3. Since the 3.58-mc signal fed to the No. 3 grid of V2 is 180 degrees out of phase with the color subcarrier signal, and since the tube itself will reverse the phase 180 degrees, the output from V2 will be in phase with the 3.58-mc color subcarrier. Therefore, when the B-Y signal is negative, the output signal will be in phase with the color subcarrier.

The transmission of the R-Y signal on the color subcarrier is accomplished in another balanced modulator in the same manner as the B-Y signal. However, before the 3.58-mc color subcarrier is fed to the balanced modulator, it is shifted in phase 90 degrees as shown in Fig. 15. Since the R-Y output from the modulator will be 180 degrees out of phase with the 3.58-mc signal actually fed to the

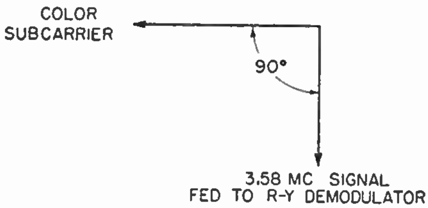


FIG. 15. The color subcarrier applied to the R-Y modulator is shifted 90°.

modulator, it will be 90 degrees out of phase with the color subcarrier as shown in Fig. 16. Similarly, if the R-Y signal should be negative, it will be 180 degrees out of phase with the output obtained when the R-Y signal is positive. The complete phase relationships between the color subcarrier and the R-Y and B-Y signals from the modulator are shown in Fig. 16.

Now let us see if we can establish some phase relationships between the primary colors and the color subcarrier. Let us consider what happens when the object being televised is a fully saturated red.

We know that the output of the red camera will be 1 volt. We also know that there will be no output from the green and blue cameras. The Y signal,

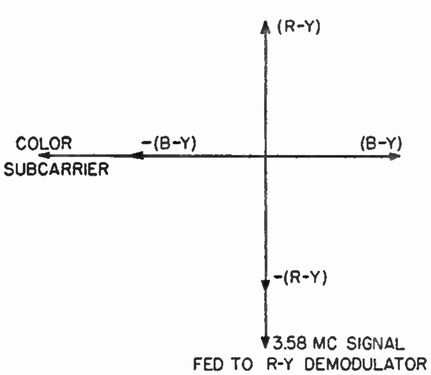


FIG. 16. Phase relationships between the B-Y and R-Y outputs from the modulator and the color subcarrier.

which is made up of .30R + .59G + .11B, will have an amplitude of .30 volt, obtained solely from the red camera, since the output from the blue and green cameras will be zero. The R-Y signal, therefore, will be 1 — .30 or .70 volt. The B-Y signal will be 0 — .30 or —.30 volt.

The R-Y signal is a positive signal and will be 90 degrees out of phase with the color subcarrier, as shown in Fig. 17. The B-Y signal is a negative signal, and it will be in phase with the color subcarrier. This is also shown in Fig. 17.

In Fig. 17 we have two vectors

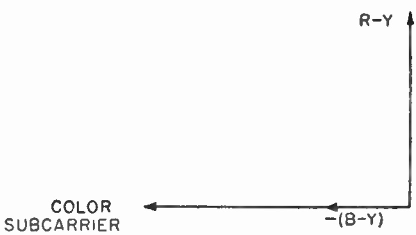


FIG. 17. R-Y and B-Y signals produced when transmitting a fully saturated red.

showing the relationship between the R-Y, B-Y, and color subcarrier. Any two vectors can be represented by a single vector by the vector construction shown in Fig. 18. This single vector shows the relationship between red and the color subcarrier, since the R-Y and B-Y vectors were produced in the transmission of a red signal. Notice that the vector representing red is obtained by plotting the amplitudes of R contained in the R-Y and B-Y signals.

By a similar construction the phase relationship between each of the primary colors and the subcarrier can be developed. In Fig. 19, we have shown

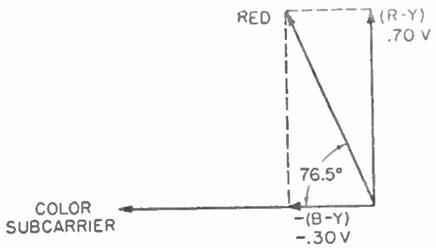


FIG. 18. Development of red from the R-Y and B-Y signals produced when transmitting red.

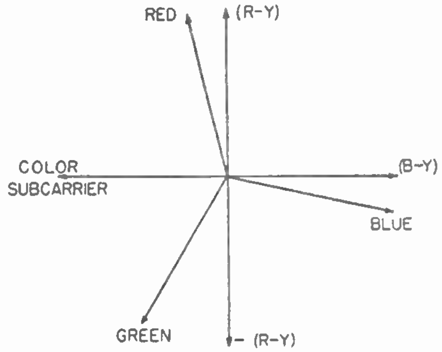


FIG. 19. Phase relationship between the color subcarrier and the R-Y, B-Y, and primary colors.

the phase relationship between the color subcarrier and the various color signals. You do not have to know how to develop this diagram nor is it necessary that you remember all the details of it, but the general idea behind it will help you understand the ideas that we are about to discuss.

The output from the two doubly-balanced modulators is combined with the Y signal in an adder, and the entire signal is used to modulate the video carrier. A block diagram of the transmitter is shown in Fig. 20. Notice that the output from the 3.58-mc oscillator is fed directly to one modulator along with the B-Y signal. However, the output from the oscillator is fed to a network that will produce a 90-degree phase shift before the signal is fed to the second modulator where it is combined with the R-Y signal.

In the reception of the color signal by a monochrome television receiver,

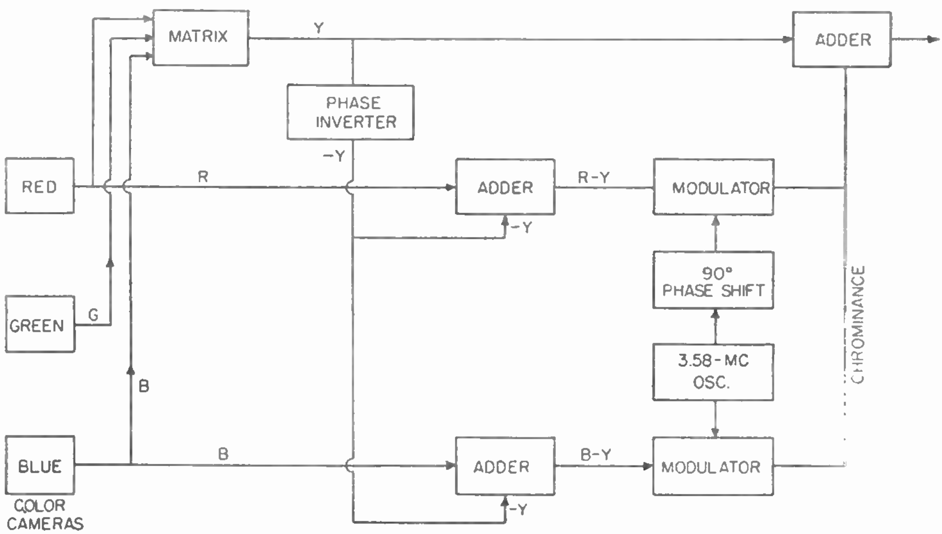


FIG. 20. Block diagram of an R-Y, B-Y transmitter.

the receiver accepts the Y signal and simply ignores the chrominance (color) information contained on the color subcarrier. The result is a black-and-white picture containing the brightness information picked up from the original scene.

In a color receiver, however, the additional circuits required to use the chrominance information are available; the Y signal is added to the chrominance information, and a full color picture is reproduced. Now let us investigate the special circuits needed in the receiver to detect the chrominance information.

THE SYNCHRONOUS DETECTORS

In the color television receiver the modulated color subcarrier is separated from the video signal and fed to two synchronous detectors to obtain the original R-Y and B-Y frequencies.

A simplified diagram of a synchronous detector is shown in Fig. 21. The 3.58-mc signal that is fed into the No. 3 grid, is generated in the receiver and synchronized so that it operates at exactly the same frequency and phase as the 3.58-mc subcarrier oscillator in the transmitter. Thus, the signal produced by the

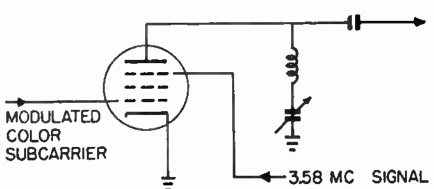


FIG. 21. Simplified diagram of a synchronous detector used to remove the color information from the chrominance subcarrier.

transmitter oscillator stage is used as a "reference" signal. When there is no signal applied to the No. 1 grid, the locally generated 3.58-mc signal will be produced in the plate circuit of the tube. This signal will be 180 degrees out of phase with the signal fed into the suppressor grid.

When the color subcarrier applied to the No. 1 grid is in phase with the 3.58-mc signal applied to the No. 3 grid, during the positive half of the cycle greater amplification of the 3.58-mc signal fed into the No. 3 grid will be obtained, because the No. 1 grid is also swung in a positive direction, increasing the gain of the tube. When the signal applied to the No. 1 grid swings negative at the same time that the 3.58-mc signal fed to the No. 3 grid swings negative, the gain of the tube will be reduced, and the amplitude of the pulse appearing in the plate circuit will be reduced. Because the tube inverts the phase of the signal, the negative pulses appearing in the plate circuit will be greater in amplitude than the positive pulses. This will have the effect of shifting the zero voltage line, or in other words, reducing the voltage between the plate of the tube and ground. When the signal applied to grid No. 1 is 180 degrees out of phase with the 3.58-mc signal fed to the No. 3 grid, exactly the opposite thing will take place, and the signal voltage between the plate of the tube and ground will increase.

Now let us consider again what happened when the B-Y signal was fed to the balanced modulator. Remember that when the B-Y signal was positive, the 3.58-mc modulated subcarrier at the output was 180 degrees out of phase with the 3.58-mc oscillator color subcarrier signal (the reference signal). Now, when the transmitted modulated color subcarrier fed to the control grid of the synchronous detector is 180 degrees out of phase with the 3.58-mc signal fed to the No. 3 grid of the detector, a positive voltage is developed in the plate circuit of this tube. The amplitude of this positive voltage will be proportional to the amplitude of the original B-Y signal.

A detector of this type will produce an output signal when the modulated color subcarrier fed to the No. 1 grid of the tube is either in phase with the 3.58-mc signal applied to the No. 3 grid or 180 degrees out of phase with it. There will be no signal produced when the phase difference between the two signals is 90 degrees. Therefore, by using two synchronous detectors, one in which the locally generated 3.58-mc signal fed to the No. 3 grid is in phase with the 3.58-mc reference signal in the transmitter, and the other operating with a signal fed to the No. 3 grid that is 90 degrees out of phase with the reference signal, the original B-Y and R-Y signals used to modulate the balanced modulator can be removed from the modulated color subcarrier signal.

SUMMARY

In the preceding pages, we have discussed the formation of the color signals and how the color signals could be transmitted by means of the chrominance subcarrier. We have given the impression that there are actually two separate signals transmitted on this subcarrier. Although this is true, the two signals combine so that in the transmission of a color, the effect will be like having a single signal of the required phase relationship to the reference color subcarrier. This was brought out in the discussion of Fig. 18 where the R-Y and —(B-Y) signals were combined to produce the red signal.

When red is transmitted, a chrominance subcarrier would be produced for the R-Y signal, and another for the —(B-Y) signal, but the two carrier voltages would add to give a single voltage having a phase displacement of 76.5 degrees from the reference subcarrier. In the receiver, the signal is separated into the original R-Y and —(B-Y) components by two separate synchronous detectors.

The NTSC Color System

So far we have discussed some of the characteristics of color. There are additional important color characteristics that have helped to make color television possible. Before we go any further let us now discuss some of the additional color characteristics that will be helpful in the study of the NTSC* color television system that is used in color telecasting today.

We have already discussed the fact that the most important details of a picture or scene can be obtained from the brightness information in the scene. In other words, if you examine a black-and-white snapshot you can gain a great deal of information from that snapshot. Actually, adding color to the snapshot adds very little to it in the way of information. Certainly it makes it more appealing to the eye, but the actual additional information conveyed is minor.

The eye cannot detect fine color detail. You can prove this to yourself simply by drawing three narrow colored lines close together. As you examine them closely you can see that the three lines are colored, but if you move the lines some distance away you will find that they blend into a single gray line. Even if we were to attempt to transmit the fine color detail in the picture, the eye could not detect it in the reproduced picture. We can take advantage of this fact to restrict the band needed to transmit the color information.

*The National Television System Committee, an organization formed by the television industry to set up standards for a compatible color television system.

Another important characteristic of color is that fine detail is more noticeable in some colors than in others. Colors in the orange and cyan regions will convey fine details better than other colors. This fact is important because orange approaches flesh in color. If we take advantage of this fact, by improving the color detail in this region, the facial details of people being televised in a color television system will be transmitted with considerable detail.

From the preceding discussion, you can see that there would be an advantage in having more detail in one color signal than in the other. Of course, we must also realize that the more details we try to transmit, the wider the band width that would be required. Therefore, if we try to transmit more color information in one of the color difference signals than in the other, we will need a wider band width for the one signal than for the other.

If we transmit the R-Y signal in the extended sideband, fine detail would appear either bluish red or bluish green, and if we transmit the B-Y signal in the extended sideband, fine detail would appear reddish green or yellowish green. However, we have pointed out that if we are to obtain the maximum advantage from the color details, the fine detail must be in the orange or cyan regions. To obtain either orange or cyan, we must transmit both the R-Y and the B-Y signals. Therefore, you can see that to obtain the best possible detail in our color pictures, color signals other than the R-Y and B-Y signals are required. We need one signal that will reproduce orange or cyan. Another color signal is used in conjunction with this signal to produce the remaining colors in the spectrum.

THE I AND Q SIGNALS

To obtain high definition in color television, color signals other than the R-Y and B-Y signals must be used. We can obtain the signals we need by taking the correct amounts of the R, G, and B signals. Two new signals, called the I and Q signals, are obtained in this way. The I signal, which contains the proper proportions of R, G, and B to reproduce orange and cyan, has a phase displacement of 57 degrees from the color subcarrier. The Q signal is displaced 90 degrees from the I signal. The I signal is transmitted by means of a vestigial sideband of the color subcarrier and can extend to a band width of 1.5 mc as shown in Fig. 22. The Q signal, which is displaced 90 degrees from the I signal, can then be sent in a .5-mc band width. A complete TV channel is shown in Fig. 22.

The phase relationship between the color subcarrier and the various color signals is shown in Fig. 23. Notice that the I signal is displaced 57 degrees from the color subcarrier and that the Q signal is displaced 90 degrees from the I signal.

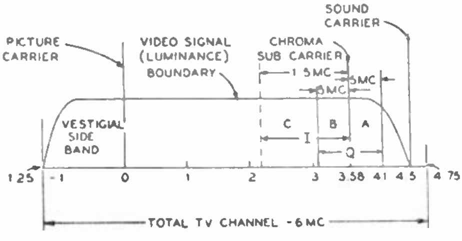


FIG. 22. The complete 6-mc TV channel containing brightness, color, and sound information.

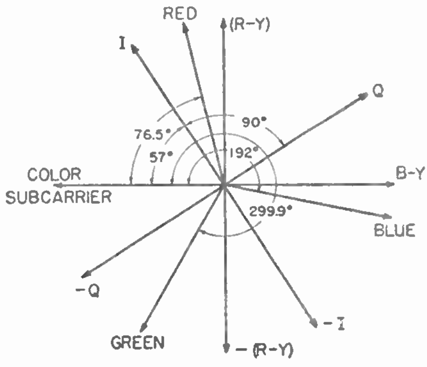


FIG. 23. Phase relationships between color subcarrier and color signals.

To produce the I and Q signals, a somewhat different arrangement is required in the transmitter. The matrix used to produce the Y signal is exactly the same as the matrix we have mentioned previously. The Y signal remains as .30R + .59G + .11B. To produce the I and Q signals, different matrixes are required. The I signal is .60R — .28G — .32B. However, instead of using the I signal, a —I signal is obtained by inverting the phase of the red signal 180 degrees. The —I signal is equal to —.60R + .28G + .32B.

The Q signal is made up of .21R + .31B — .52G. The —G signal is obtained simply by passing the G signal through an amplifier—this will invert the phase 180 degrees.

A simplified block diagram of a color television transmitter using the I and Q signals is shown in Fig. 24. Notice that the output of the three color cameras feed three matrixes, in

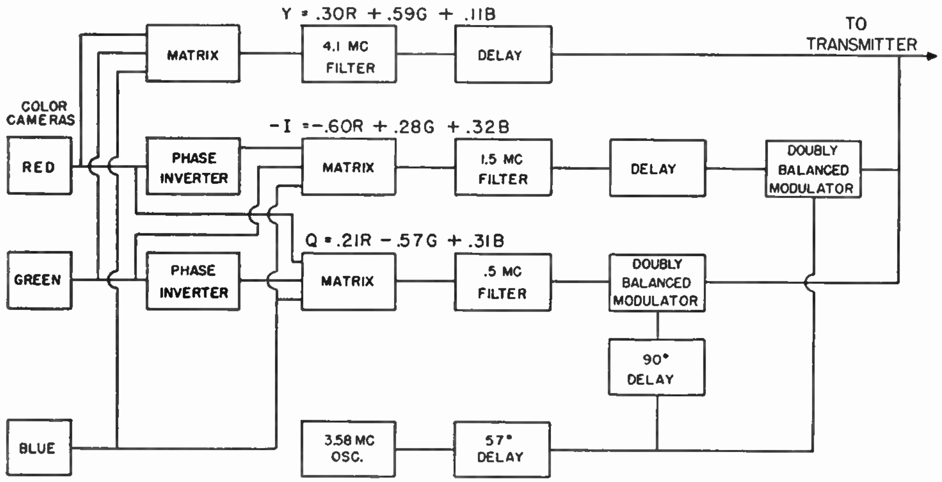


FIG. 24. Simplified block diagram of Y, I, and Q sections of a color TV transmitter.

one, the Y signal is developed, as in the case of the transmitters we have studied previously. The other two form the —I signal and the Q signal.

The —I signal is formed in this transmitter by inverting the phase of the red signal and then passing the —R signal with the green and blue signals to a suitable matrix where the proper proportions are taken to produce the —I signal. Similarly, the green signal is inverted in phase and then combined with the red and blue signals in the proper proportions to produce the Q signal.

In transmitting the brightness information and the color information in the picture, we are going to transmit practically all of the fine detail in the form of the brightness signal. The brightness signal will be practically identical to the signal transmitted by a monochrome television station. The band width of the Y amplifier in the transmitter will be 4.1 megacycles. A filter and a delay network are inserted in the Y system as shown. The delay network is needed because the speed with which the signal passes through the wideband Y amplifier will be greater than the speed with which the signal passes through the amplifiers with a somewhat narrower band width.

We have already discussed transmitting the chrominance information and the fact that the I signal will contain most of the usable fine color detail. The band width of the I signal, therefore, must be wider than the band width of the Q signal. Vestigial sideband transmission is used in the transmission of the I signal. A 1.5-mc filter is inserted in the I channel and the I signal is then fed through a delay network. Again, the delay network is necessary because the speed with which the signal passes through the I channel will be greater than the speed of the signal through the Q channel.

The band width of the Q channel is restricted to .5 megacycle by the filter installed in this channel. The band width of only .5 megacycle is all that is needed to produce high definition color pictures using the Y signal in conjunction with the I and Q signals.

The —I signal is fed to a doubly-balanced modulator. However, instead of feeding the subcarrier directly to the modulator, a 57-degree phase delay is introduced between the subcarrier and the balanced modulator. This will establish the correct relationship between the I signal and the reference subcarrier.

An additional 90-degree delay is introduced in the 3.58-mc color subcarrier before it is fed to the doubly-balanced modulator to which the Q signal is applied. At the output of the doubly-balanced modulators, we will have two signals. The I signal will be displaced in phase by 57 degrees from the color subcarrier. The —I signal will be displaced by an additional 180 degrees or a total of 237 degrees (see Fig. 23). The Q signal will be displaced by 147 degrees from the reference subcarrier and the —Q signal will be displaced by 327 degrees from the color subcarrier. Remember that the polarity of the I and Q signals will depend on what color is being transmitted.

We could go through a more detailed discussion of the formation of the I and Q signals. They can be drawn in vector form using the figures we have given for the amounts of red, green, and blue signals taken to form each of the signals. However, there is nothing to be gained by a detailed analysis of these signals. The important points in this discussion are that the I signal contains information in the orange and cyan regions and for this reason it contains most of the fine detail that will be conveyed by the color signals. The band width of the amplifier handling the I signal therefore, must be wider than the band width of the amplifier handling the Q signal, which contains little or no fine detail.

Just as it was possible to produce the I and Q signals from the red, green, and blue signals, you will see later that it is possible to produce the R-Y, B-Y, and G-Y signals from the I and Q signals and then to combine these signals with the Y signals to produce the original red, green, and blue signals.

THE I AND Q RECEIVER

In the preceding color system that we discussed using the R-Y and B-Y color signals, you will remember that we first fed the R-Y and B-Y signals through amplifiers and combined the two signals to obtain a G-Y signal. Finally, we added the Y signal to the R-Y, B-Y, and G-Y signals to give us the red, blue, and green signals. Now let us see how the red, green, and blue signals can be obtained from the I, Q, and Y signals.

In a receiver designed for the I and Q color signals, the 3.58-mc color subcarrier in the output of the video detector is fed to two separate amplifiers. As shown in Fig. 25, one amplifier has a band width of .5 mc and the other has a band width of 1.5 mc. The outputs of these amplifiers are fed into separate synchronous detectors.

The 3.58-mc local oscillator generates a signal that is in phase with the 3.58-mc signal generated at the transmitter. This signal is then fed through a 57-degree phase shift or delay network and then fed to the synchronous detector into which the output from the 1.5-mc amplifier is fed. This detector will detect the I signal. The output from the 57-degree delay network is also fed to another 90-degree phase shift or delay network, and the output from this network is fed to the second synchronous detector. This detector will detect the Q signal.

The operation of the synchronous detectors used in this circuit is exactly the same as the operation of the synchronous detector shown in Fig. 21. Since the I signal is shifted in phase by 57 degrees or 237 degrees from the 3.58-mc signal, the I detector will detect the I signal. It will not respond to the Q signal because the Q signal is 90 degrees out of phase with the I signal. Similarly, the Q detector will detect only the Q signal because the 3.58-mc signal fed to this synchronous detector will either be in phase or 180 degrees out of phase with the Q signal.

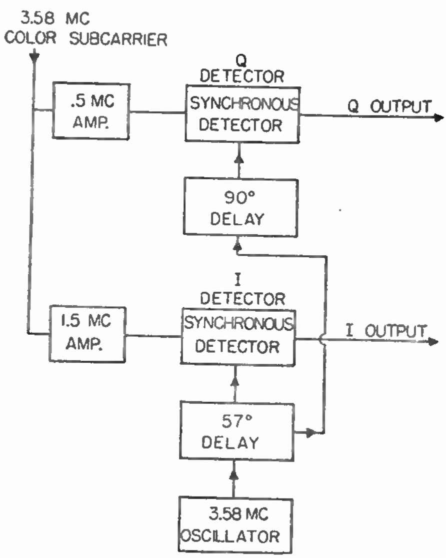


FIG. 25. Block diagram of I and Q detector circuits.

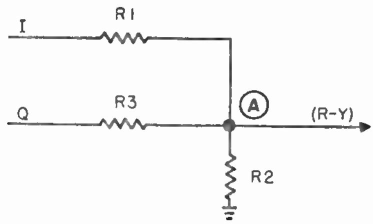


FIG. 26. A matrix used to obtain the R-Y signal from the I and Q signals. Similar matrixes can be used to obtain the B-Y and G-Y signals.

Of course, the I and Q signals at the output of the synchronous detectors will be comparatively weak, and therefore, they are usually fed to amplifiers. The two signals may then be combined in the proper proportions to produce the color difference signals.

An example of a typical matrix that may be used to combine the I and Q signals to produce the R-Y signal is shown in Fig. 26. Now let us see how this matrix operates. The resistance values of R1 and R2 are chosen so that between point A and ground, .945 of the I signal is present. The value of R3 has been chosen so that between point A and ground, .621 of the Q signal is present. Therefore, between point A and ground we have .945I + .621Q. Now in place of the I and Q, let us write in the original values of the I and Q signals. This will give us

$$.945\ (.60R - .32B - .28G) +$$
$$.621\ (.21R + .31B - .52G)$$

Therefore, from the I signal we get .567R — .302B — .264G, and from the Q signal we get .130R + .192B — .323G. By adding these two signals, we will have:

.567R — .302B — .264G
.130R + .192B — .323G

.697R — .110B — .587G

This is equal to the R-Y signal. R-Y can be written as 1R—.30R—.11B—.59G, which is .70R — .11B — .59G.

You will see that .697R is for all practical purposes the same as .70R and similarly .587G is for all practical purposes the same as .59G. Therefore, by taking the proper proportions of the I and Q signals, we have obtained the R-Y signal. Similarly the G-Y and B-Y signals can be obtained. To obtain the G-Y signal, we take —.271I — .647Q, and to obtain the B-Y signal we take —1.11I + 1.70Q.

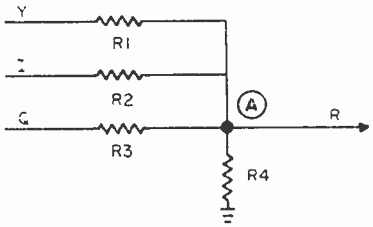


FIG. 27. Matrix used to obtain the R signal from the Y, I, and Q signals.

Once we have the R-Y, G-Y, and B-Y signals, all we need do is add the Y signal to obtain the original red, green, and blue signals.

A somewhat different arrangement of the matrix shown in Fig. 26 is shown in Fig. 27. In Fig. 27 an additional network is added. In this circuit, the Y signal is fed through R1. R1 and R4 act as a voltage divider on this signal. The amplitude of the Y signal at the input, and the values of R1 and R4 are adjusted so that the signal between point A and ground is equal to Y. The values of R2 and R4 are selected so that between point A and ground we have .945I, and similarly dividers R3 and R4 are selected so that between point A and ground we have .621Q.

With a network of this type, you can see that the I and Q signals will be combined exactly as they were in the matrix shown in Fig. 26. If these two signals alone were applied between point A and ground, we would have the R-Y signal. However, since we are also adding the Y signal, we will have the R-Y and the Y signal between point A and ground. The —Y and the +Y signals will cancel, so that between point A and ground we will have the R or red signal voltage. Similar networks that select the proper ratios of I and Q signals can be used to produce the G and B signals directly from the Y, I, and Q signals.

SUMMARY

Now let us briefly review the advantages of transmitting the I and Q signals in preference to the R-Y and B-Y signals. As we pointed out, there is very little to be gained by transmitting a great deal of color detail. Detail falling in the green, blue, or red regions cannot be detected by the eye. The eye can detect only a certain amount of color detail, and it detects this detail best in the orange and cyan regions. To produce orange and cyan from the R-Y and B-Y signals we need both color signals. However, by combining the proper proportions of red, blue, and green in the matrix at the transmitter, we can in effect produce the I signal that contains the orange and cyan information in the picture. In other words, we can produce orange and cyan on the picture tube from the I signal alone. This means that if we use a wide band width for the I signal, we can obtain all of the color detail we need for high-quality pictures. At the same time, the Q signal can be transmitted in a much narrower band width. The I and Q signals can then be combined to produce all other colors needed for full-color, high-definition pictures.

COLOR SYNCHRONIZATION

As we have discussed the R-Y, B-Y receiver, and also the I and Q type of receiver, we mentioned that the 3.58-mc oscillator in the receiver must be in synchronization with the oscillator in the transmitter. This synchronization is maintained by means of a 3.58-mc color burst which is transmitted on the back porch of the horizontal sync pulse as shown in Fig. 28. The burst consists of about 8 cycles of the 3.58-mc color subcarrier and is sufficient to maintain the oscillator in the receiver in synchronization with the oscillator at the transmitter. We will discuss circuits used to keep the oscillator in synchronization in more detail later.

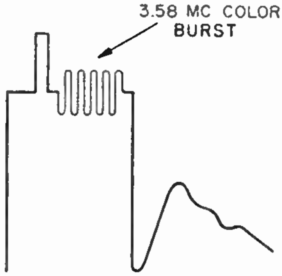
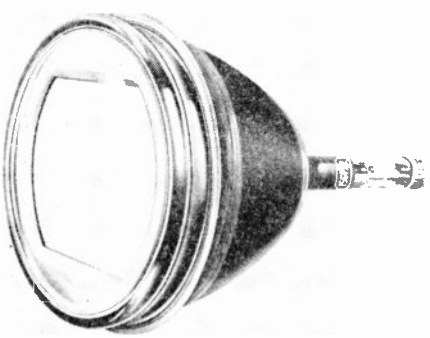


FIG. 28. The color burst on the back porch of the horizontal sync signal.

Tri-Color Picture Tube

Thus far in our discussion of the color television system, we have shown that color pictures can be reproduced by using three separate picture tubes. Remember that each of the tubes reproduces the brightness information contained in the scene for each primary color. Individual color filters positioned in front of the tubes convert the brightness information into each of the primary colors. Then, the three color images are projected, one over the other, on a screen to produce a full color picture.



Courtesy RCA

Three-gun tri-color picture tube.

Essentially the same method is used in the color picture tubes in the present color television receivers. Instead of three separate picture tubes and color filters, a single picture tube containing three electron guns is used to reproduce the three primary color images on a fluorescent screen.

The three-gun color tube, however, is not the only method that can be used to obtain color pictures in a color receiver. It is possible also to reproduce full color pictures with a tube containing a single electron gun. This method will be discussed later in this section. Now let us study the three-gun type and find out how it operates.

RCA SHADOW-MASK TUBE

At present, the most commonly used color picture tube is what is called the

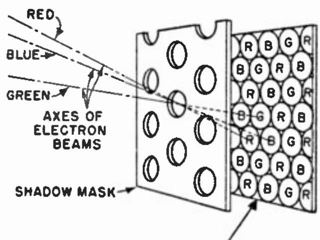
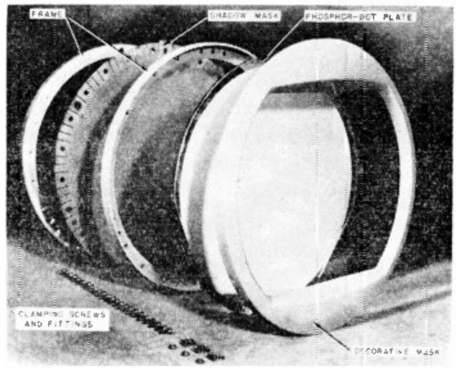


FIG. 29. Basic plan of a tri-color tube.

shadow-mask type. Basically, it consists of a three-gun source of electrons, a color-dot screen, and a shadow-mask through which the electron beams must pass in order to strike the proper color dots.

One gun and its scanning beam is provided for each of the three primary color signals. The beam from each gun is directed through the aperture mask to its corresponding phosphor dot as shown in Fig. 29. There are hundreds of thousands of individual color dots (a complete set for each primary color) positioned in tight triangles

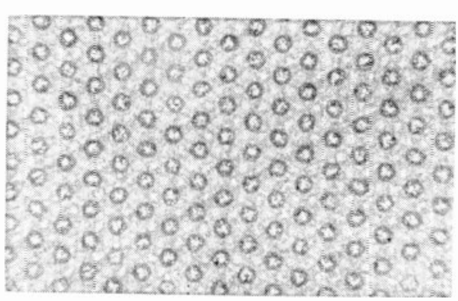


Courtesy RCA

Viewing-screen assembly of tri-color tube.

over the entire fluorescent screen. The beam from each gun must be controlled so that its electrons fall only on dots of the primary color it represents. To do this, the beams are guided through each mask aperture at just the proper angles. In fact, the mask itself functions as a buffer to prevent the beam from the red gun, for example, from striking any of the blue or green dots.

The color dots that make up the fluorescent screen in the tri-color picture tube, as shown in Figs. 29 and 30, are so tiny that they cannot be seen individually. Thus, when the three beams excite the phosphor dots, the three primary color images appear superimposed and are able to repro-



Courtesy RCA

FIG. 30. Magnified segment of color-dot pattern on screen.

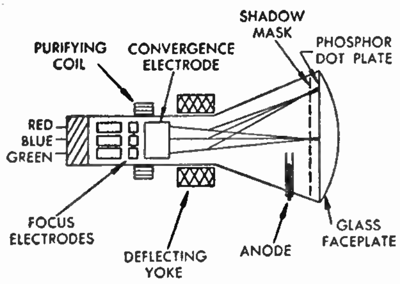


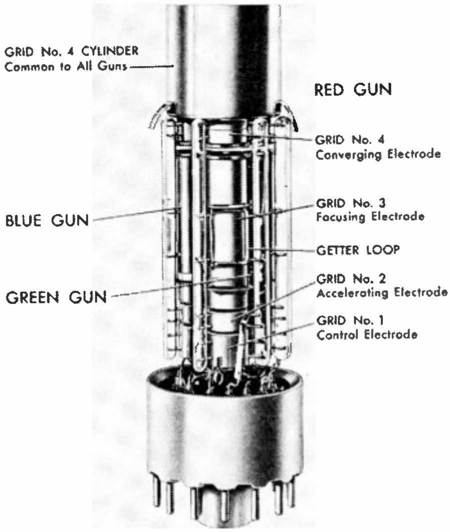
FIG. 31. Tri-color picture tube components.

duce the color picture. The holes in the mask must necessarily be extremely small; consequently the mask must be positioned so that each aperture is aligned exactly right with respect to each dot trio (one red, one green, and one blue dot).

The major components of the tri-color tube are shown in Fig. 31. Starting from the base of the tube, we first find the three electron guns which are mounted parallel to the center axis of the tube and 120 degrees apart. Next, there are the convergence components consisting of the convergence electrode and the purifying coil. The convergence elements differ from any electrodes studied in the monochrome picture tube because they control three electron beams instead of a single beam. In the tri-color tube, not only must each scanning beam be focused and controlled individually, but also all three scanning beams must converge or come together at the apertures so that they penetrate the mask and strike the proper phosphor dots. When the beams are positioned correctly, the three primary color images produced on the screen will appear superimposed, one over the other, to form a full-color picture. This convergence must occur uniformly over the entire color screen.

The deflection yoke, which is mounted against the bell of the tube, forms the scanning raster in much the same way as a yoke on a monochrome picture tube. In the tri-color tube, however, it must control three electron beams instead of one. The viewing screen assembly consists of the shadow-mask and the phosphor dot plate. Mounting frames and fittings are required to hold the mask and the plate in proper relationship to each other and to the face of the tube.

Electron Gun. The electron gun of an RCA color picture tube, shown in Fig. 32, is a multiple electrode device. **Each of the three guns contains an indirectly heated cathode, a control grid, an accelerating electrode (grid No. 2), and a focusing grid (grid No. 3) that functions in conjunction with the convergence electrode (grid No. 4). The red gun elements, which are shown down the center, are labeled. The ele-**



Courtesy RCA

FIG. 32. Electron gun of tri-color tube.

ments are the same in the other two guns. Notice that grid No. 4 is a two-section arrangement which consists of a small diameter convergence electrode at the exit of each individual gun, plus a large diameter cylinder or cup that is common to all three guns.

The focusing of each scanning beam is regulated by the potential difference between grid No. 3 and the individual focusing electrode sections of grid No. 4. A beam aperture associated with grid No. 3 confines the beam to the dense central section to produce as fine a beam diameter as possible. A conductive coating on the inner surface of the picture-tube neck and the cone functions as the high-voltage anode. The difference in potential between the neck coating and the common grid No. 4 serves as still another electronic lens to bring the beams together at the convergence point which is at the plane of the aperture mask. Thus, there are really two focusing actions—focusing of each scanning beam at the fluorescent screen and the focusing of the three beams together to form a convergence point (or cross-over) at the apertures.

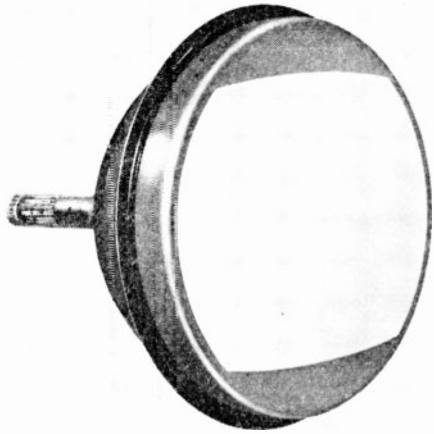
To obtain precise focusing and convergence with this tube, three magnets are mounted externally on the tube neck, and positioned so that a magnet is directly over each gun. An external purity coil is also used to form a magnetic field that regulates simultaneous positioning of the three beams. As a result, the axis of each beam can be made to coincide with the center of its respective color dots. The deflection yoke, too, must be designed carefully and positioned properly to avoid any distortion at the raster edges.

Even with all these precautions, it is often a difficult task to bring each beam to focus, and to bring all three beams to a convergence point at each aperture over the entire surface of the mask and screen. As in a monochrome picture tube, the distance that the electron beams must travel from the guns to the outer extremities of the raster is longer than the distance between the guns and the central raster area. To correct for this variation, special parabolic waveforms are applied to the focus and convergence electrodes of the color picture tube. These horizontal and vertical waveforms correct the focusing of each scanning beam as well as the convergence of all three beams as they scan from left to right and down the color tube screen.

The correction waveforms are referred to as "dynamic" convergence voltages. The dc voltage applied to the convergence electrode is adjustable and is spoken of as the "static" convergence voltage. Static convergence also is provided by the three magnets on the neck of the tube.

CBS COLORTRON

The 19-inch CBS Colortron tri-color tube also employs a three-electron gun assembly, shown in Fig. 33, with the guns arranged 120 degrees apart in a triangular pattern. However, instead of being parallel to the central axis of the tube, each gun is tilted (approximately 1 degree) toward the axis. The slight mechanical tilting of the guns as well as the curved shadow-mask that is used in this tube improves convergence of the beams at



Courtesy CBS

CBS 19-inch Colortron color tube.

the screen. You can see that each gun consists of a cathode, a control-grid, an accelerating grid, a focus electrode, and a final anode.

Instead of an internal convergence electrode, three convergence coils are placed around the neck of the tube, as shown in Fig. 34, between the deflection yoke and the purity device. Because the guns are tilted, only a single beam corrector magnet is needed, instead of the three required by a tri-color tube using an internal convergence electrode.

Starting at the base, the components that are mounted on the color tube neck are the beam corrector magnet, which is associated with the blue gun, the purity device and its adjustment tabs, the convergence coil assembly, and the deflection yoke; and a field neutralizing coil is mounted around the face of the tube. Although the color tube is shielded internally by an aluminized surface and is also protected by an external shield, the field neutralizing coil, that surrounds the face-plate, generates a uniform magnetic field that can be regulated and used to cancel the influence of any external stray field. Thus, external fields cannot pull the three beams off center and cause them to strike the wrong dots. Incorrect coloring of this type is called color impurity or color contamination.

The deflection yoke, as in a conventional picture tube, is located at the point where the neck joins the cone. The position of the yoke can be shifted somewhat to obtain the best color purity at the edges of the raster. In a color receiver, the centering is usually accomplished by regulating the dc flow in the deflection coils. Of

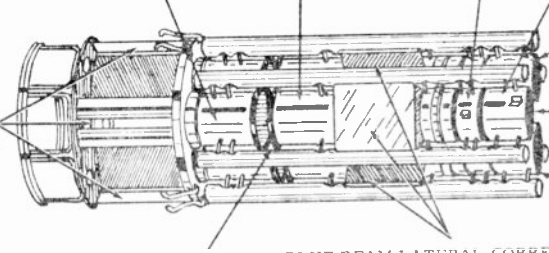
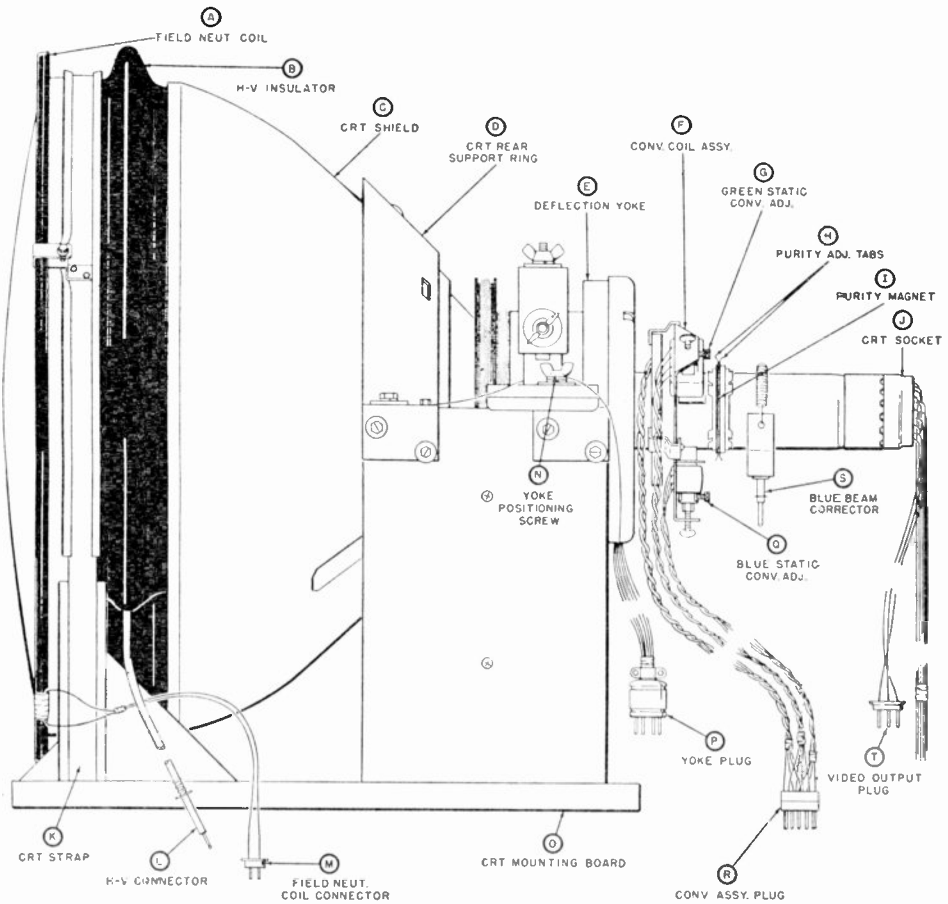


FIG. 33. Electron gun of CBS Colortron tube.



Courtesy Motorola

FIG. 34. Picture tube assembly for CBS Colortron.

course, the deflection yoke must be designed carefully to form the most uniform magnetic field possible. Good field uniformity, especially at the raster edges, assists greatly in obtaining true convergence and true colors over the entire screen area.

Three pairs of pole pieces, 120 degrees apart, are attached directly to the guns. Three external convergence coils, one for each gun, are mounted over the pole pieces. By regulating the current waveforms in the convergence coils, the dynamic convergence of each of the electron guns can be controlled separately. Convergence magnets are also associated with the convergence coil assembly to obtain the proper static convergence.

The three scanning beams must be positioned in a triangular pattern after they leave the plane of the aperture mask. Therefore, in addition to the fixed magnet adjustment, a separate blue adjustment is used to place the blue beam at a centered location between the red and green beams.

These four adjustments permit the

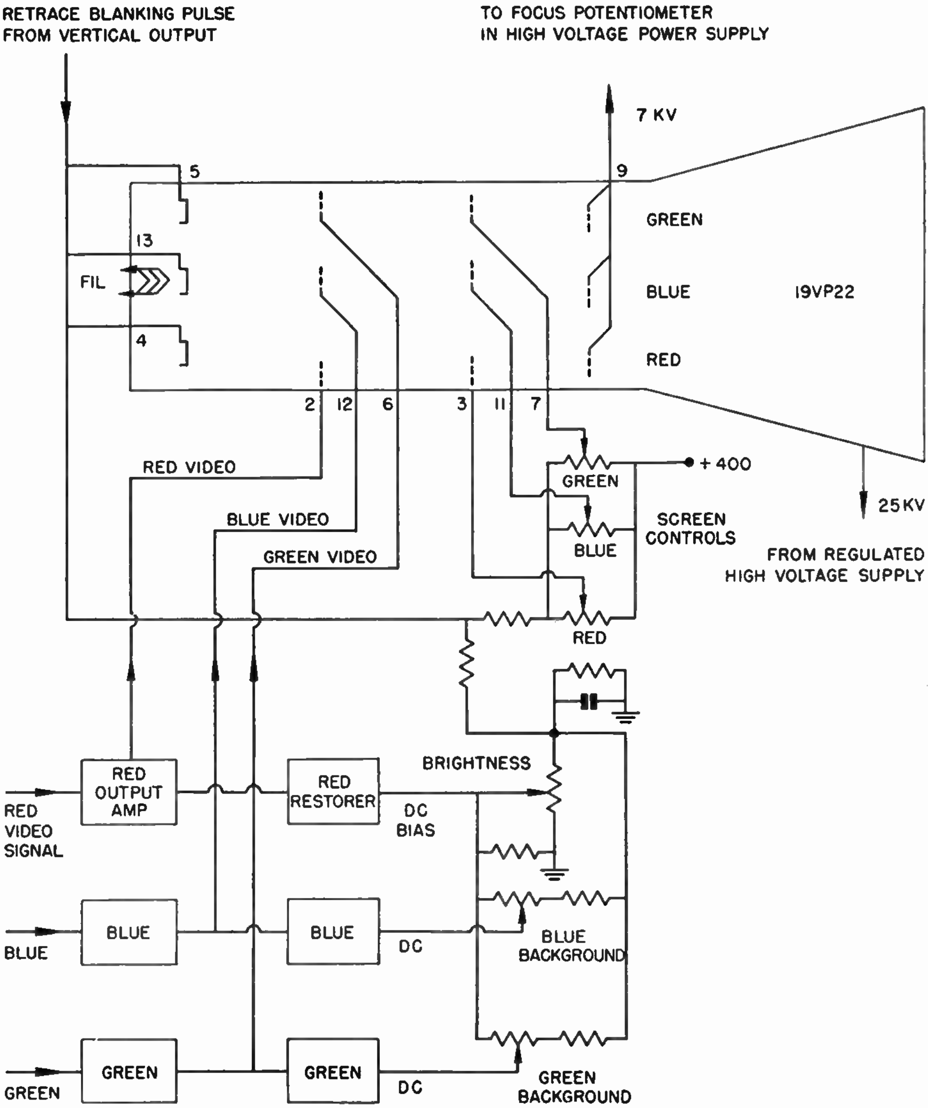


FIG. 35. Typical color picture tube circuit.

proper convergence of the three scanning beams at the aperture. After passing the convergence point, the beams separate and each strikes the proper color dot on the screen. The convergence waveforms in the convergence coils maintain this relationship between the three scanning beams over the entire surface of the color screen.

The purity magnet, which is over the focusing electrode, controls the position of the three scanning beams simultaneously. With the purity coil, it is possible to align the scanning beams with the centers of the phosphor dots so that pure hues and color saturation can be obtained.

EXTERNAL CONVERGENCE COIL CIRCUITS

Now let us discuss the voltage and signals that are applied to each electrode in a picture tube using *external* convergence coils. A typical circuit is shown in Fig. 35. Notice that a separate grid-cathode circuit is associated with each gun. The cathodes are connected together and returned to dc voltage circuits so that the over-all picture brightness can be regulated. The cathodes also are connected to the vertical output stage of the receiver to obtain a retrace blanking pulse for each gun.

The brightness control circuit associated with the common cathodes serves as the red reference brightness adjustment, while two individual brightness or background controls are used to adjust the grid bias on the green and blue guns. Since these controls regulate the absolute brightness and the relative brightness settings of the individual guns, it is possible to correct for gun and phosphor variations so that each set of phosphor dots can be illuminated properly with respect to the other two. When the dots emit equal illumination, a true white is produced on the screen.

The next group of electrodes are the accelerating grids—one for each gun. Again, the voltage applied to each electrode is adjustable to compensate for variations in the phosphor dots. The adjustments of the screen controls, together with the background controls, establish a true half-tone scale for proper rendition of a monochrome picture. At the same time, they establish proper relative beam intensities among the three guns so that color hues can be produced faithfully.

Although they are not shown in the illustration, the convergence coils receive their excitation from three separate convergence output stages—one for each primary color. The three separate adjustments associated with each convergence coil regulate the amplitude, phase, and shape of the convergence waveform. The procedures for adjusting the many controls of the color receiver and its picture tube will be presented at length in a later lesson.

The final two electrodes of the color picture tube are the focus electrode and the final anode. These two electrodes receive their voltages from the horizontal output stage. The high-voltage pulse developed in the horizontal output circuit is first rectified to form a high dc voltage. Then, it is supplied to a voltage regulator circuit to develop a regulated 25,000 volts for

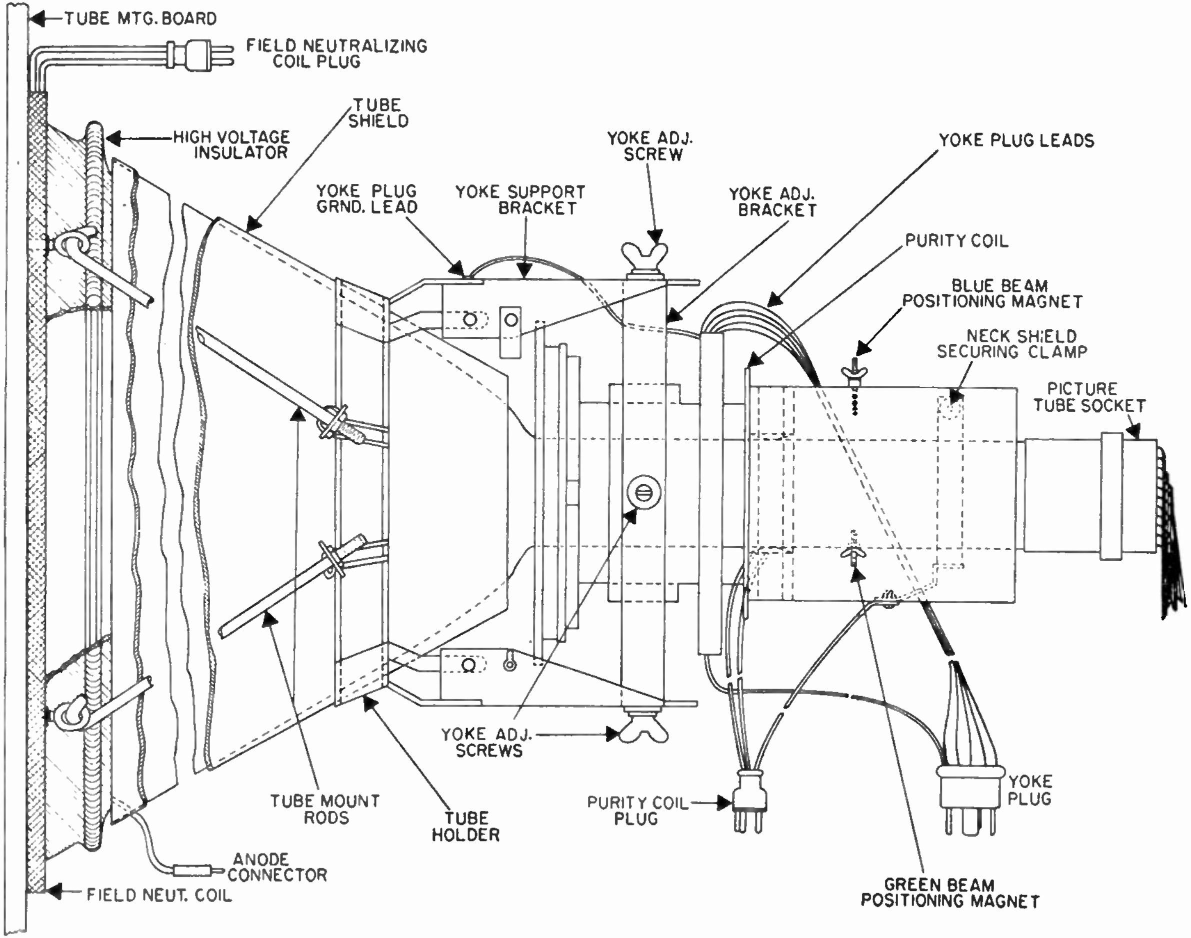


FIG. 36A. Mounting assembly for tri-color tube using internal convergence electrode.

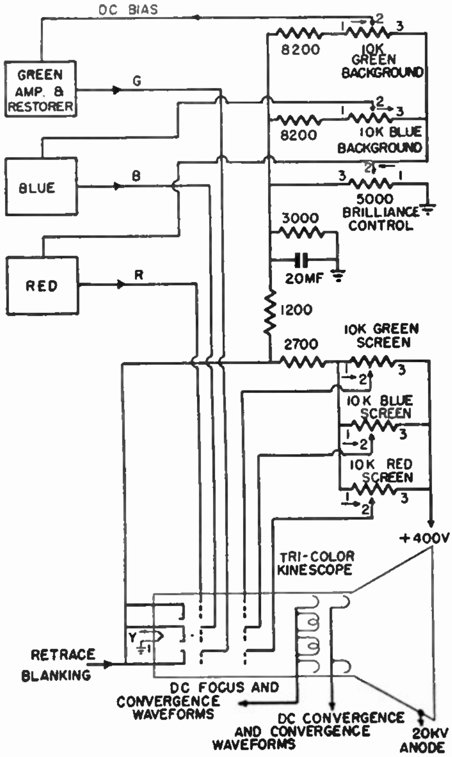


FIG. 36B. Picture tube circuit for tube shown in Fig. 36A.

the anode and approximately 7000 volts for the focus electrode.

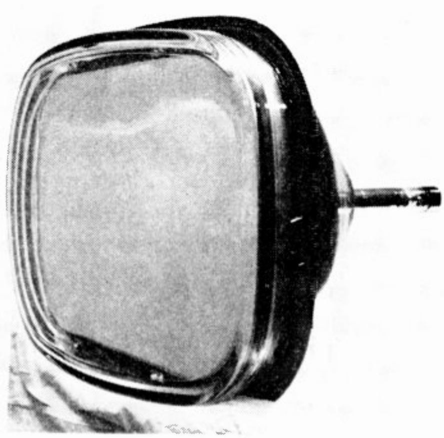
INTERNAL CONVERGENCE ELECTRODE CIRCUITS

The picture tube circuit and mounting assembly for a tri-color picture tube employing an *internal* convergence electrode are shown in Fig. 36. Notice that the circuit arrangement is almost the same as the circuit in Fig. 35. In this circuit, the signals are applied to the control grids of the guns. A brightness control associated with the red gun again regulates the bias applied to all the guns, while separate controls permit individual adjustment of the green and blue gun biases. Also the accelerating electrode voltages are obtained as in the previous circuit.

Unlike the previous circuit, however, convergence voltages are applied to tube electrodes instead of coils. Adjustable dc voltages as well as convergence waveforms are applied not only to the convergence electrode but also to the focus electrode.

SINGLE-GUN COLOR TUBES

We have discussed the three-gun color tubes at some length because they are more widely used at present than any of the other types that have been developed. However, single-gun tubes have also been developed. Although they are not being used commercially at this time, this type, because of its relative simplicity, may be the solution to many of the problems encountered in the present color television receivers. The idea of a single-gun tube is very attractive because there is only one beam to control and adjust instead of three, as



Courtesy Chromatic TV Labs

Single-gun 21-inch Chromatron tube.

in the three-gun type. Therefore, when using these tubes, the problems of convergence and balance are practically eliminated.

One color picture tube that uses a single electron gun is the Chromatron. Instead of using color dots as in the tubes described previously, the fluorescent screen is made up of parallel strips of colored phosphor. By studying the illustration in Fig. 37, you will see

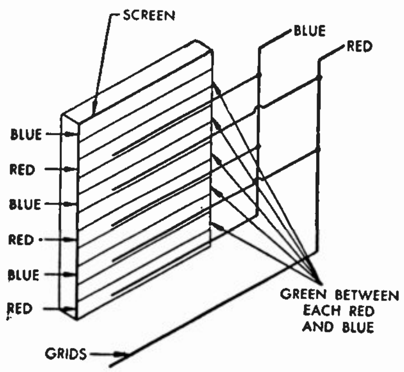


FIG. 37. Detail of single-gun Chromatron grid and screen structure.

that the phosphor strips are arranged so that there are green strips separating the red and blue ones.

The Chromatron differs from the conventional three-gun type also in that grids composed of closely-spaced parallel wires are used instead of a mask. These wires are located in front of the phosphor plate on the electron gun side of the screen, and are placed so that there is a wire in front of each red and each blue strip. There are none in front of the green strips. All the wires in front of the red phosphor strips are tied together and brought out to a single terminal, and all the wires in front of the blue phosphor strips are tied together and brought to a single terminal. A third terminal connects to the aluminized layer on the back of the phosphor screen.

There are hundreds of individual phosphor strips from top to bottom of the screen. In fact, there are more phosphor strips than there are active lines on the screen of the standard monochrome picture tube. When in operation, the line structure is so fine that at ordinary viewing distances the lines are invisible.

To show you how the Chromatron reproduces a color picture, let us refer to Fig. 38. The fine stream of electrons from the electron gun, Fig. 38A, is directed toward the phosphor strips. A voltage is applied between the grid wires and the aluminized backing on the phosphor screen to focus the beam on the phosphor strips. This is called a "post-deflection" voltage. Sometimes the Chromatron is called the PDF (Post-Deflection Focusing) Tube. The difference in potential between the red and blue grids causes the beam to converge on the proper color strips. However, the strip that the beam strikes must correspond to the primary color signal being supplied to the grid circuit of the electron gun. In other words, when there is a red signal being applied to the control grid of the gun, the beam must strike the red phosphor strip.

Fig. 38B shows that when there is a zero potential between the red and blue grids, the electrons travel down the tube and strike the green strips. However, when a positive potential is present on the grid wires in front of the red strips, and a negative potential on the wires in front of the blue strips, the electron beam is pulled toward the red as shown in the figure. Conversely, a positive potential on the blue grid with a negative potential on the red grid causes the beam to be deflected to the blue phosphor strip. Therefore, by applying the correct voltages to the red and blue grid wires, it is possible to direct a beam to the proper color strips, and obtain a color picture on the screen.

The signals applied to the grid circuit of the electron gun used to vary the strength of the electron beam are somewhat different from those described for the three-gun tube. Because the Chromatron has only one electron gun, the NTSC simultaneous color signal must be converted to a fast-switching sequential signal. When the beam is directed toward the red strip, for example, the electron gun must be excited by a red primary color signal. The same relationship must exist when the beam is directed toward the green or the blue phosphor strips. Thus, the signal arriving at the control grid of the picture tube must be continually shifting from one primary color to another. This color switching action can be done with proper receiver circuits. In fact, the circuits required to make the change-over from the NTSC simultaneous signal to a sequential signal are no more complex than those associated with a shadow-mask type of picture tube.

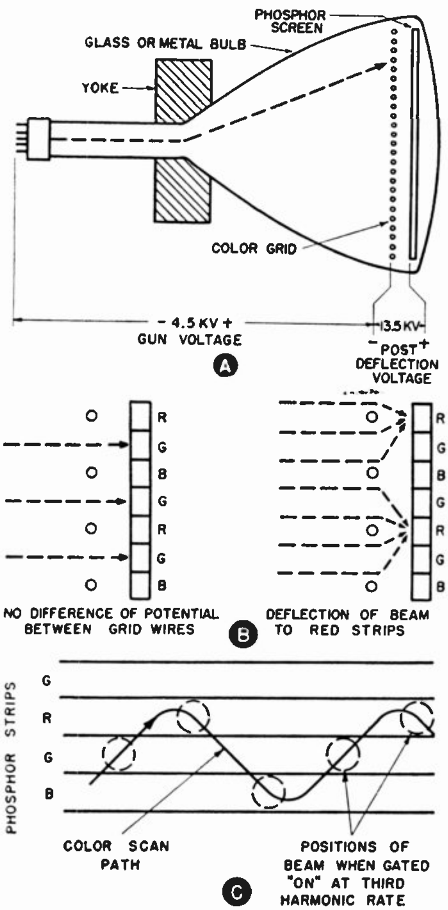
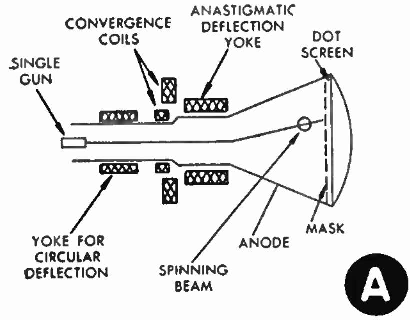


FIG. 38. Operation and gating of Chromatron.

The scanning beam in the Chromatron picture tube moves across and down the picture tube screen in the conventional manner to trace the scanning raster. As the beam moves horizontally across the screen, it must be deflected vertically to excite all three color strips as shown in Fig. 38C. This deflection can be accomplished by applying a sinusoidal variation between the red and blue grids.

In a practical system employing the NTSC standard signal, it is possible to apply a sine wave having the same frequency as the chrominance subcarrier to the color grids of the Chromatron. Thus, as the scanning beam moves across the screen, it will be deflected vertically at the subcarrier sine-wave rate. As a result, this



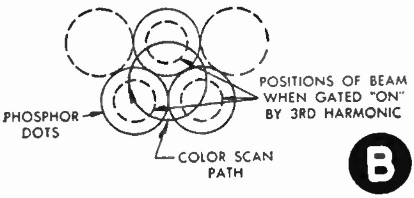


FIG. 39. Single-beam excitation of phosphor-dot screen.

vertical deflection of the beam can be synchronized by the color burst signal that is transmitted on the back porch of the horizontal blanking pulse. The color burst signal also can be used to synchronize the signal applied to the control grid of the electron gun. Therefore, the samples of the three primary colors that are taken during the period of one cycle of the subcarrier signal are applied simultaneously to the control grid and the color grids. As the samples are taken, the scanning beam moves to the corresponding color strips to reproduce the color picture on the screen.

A single electron gun can also be used with a picture tube that contains a mask and a phosphor-dot screen. In this arrangement, a single scanning beam is rotated in a tight circle as indicated in Fig. 39A. As the rotating beam moves in front of an aperture, it is keyed on and off at three relative positions. These positions correspond to what might be considered the original positions of the three separate scanning beams used in the three-gun type. At one instant of time, the beam is in a position that corresponds to the position of the beam from the red gun; an instant later, it has rotated to the position of the corresponding blue or green beam, as illustrated in Fig. 39B. All three primary color dots can be excited by properly controlling a single rotating beam.

When the beam is in position to excite the red dot, only the red primary color signal must be present at the control grid of the gun. Similarly, as it shifts to the blue or green position, the primary color signal must also be switched at the control grid. Also, for correct excitation of the phosphor dots, the NTSC simultaneous signal must be translated into a fast-switching sequential signal. The frequency of rotation of the beam can be at the subcarrier frequency with the result that the center of each individual phosphor dot is illuminated once during each cycle of the subcarrier frequency. As the beam is rotated, the beam strength, and thus the brightness of each color dot, varies according to the sequential signal applied to the grid of the electron gun.

The single-gun color tubes have some advantages over the three-gun types. Probably the most important advantage from the standpoint of the serviceman is that the adjustments are greatly simplified. There are no convergence problems because the tube uses a single electron beam. Also the reproduced pictures, on the

Chromatron especially, are brighter. Since a mask is not used in front of the phosphor screen, a larger proportion of the electrons in the beam strike the phosphor material. Although it may not be either of the types discussed in this lesson, the single-gun tube eventually may be the solution to the color tube problem.

We stressed in the lesson on monochrome picture tubes how the picture tube itself can be used to localize receiver troubles. The same thing is true and is even more important in a color television receiver. There are many more circuits associated with the color receiver, and the two additional color characteristics of hue and saturation must be considered. With a knowledge of how the receiver operates, you will be able to localize troubles quickly by evaluating the nature of the disturbance as it appears on the picture tube screen.

Color Definitions

The following definitions are of many of the words that are frequently mentioned in color television discussions. If you are to obtain true benefits from these discussions you must know and understand what the words mean. As an example, any service instructions involving the hue and saturation of a color picture become meaningless unless you know what the characteristics of hue and saturation represent.

Brightness—The visual sensation of the amount of light received. This information is contained in the Y signal and in the monochrome TV signal.

Chrominance—Hue and saturation of a color. The chrominance channel or chrominance signal is used to convey the hue and saturation information contained in the picture.

Color—The characteristics of color are brightness (luminance), hue (dominant wavelength), and saturation (purity).

Color Burst—A few sine waves of the color subcarrier frequency added to the back porch of the horizontal blanking for color synchronization.

Color-Difference Signal—The signal which conveys the hue and saturation information. The luminance information is not present or has been subtracted from each primary color as indicated by the expressions (G-Y), (R-Y), and (B-Y).

Color Subcarrier—The carrier whose sidebands contain the hue and saturation information of the color picture.

Compatibility—The characteristic of a television system which permits a monochrome receiver to pick up a color broadcast, and a color receiver to pick up a monochrome broadcast.

Dilution—The amount of white light mixed with a saturated hue to form a desaturated hue of specific purity.

Dominant Wavelength—The average wavelength of a band of frequencies representing a specific hue.

Hue—Hue is the dominant wavelength of a color which we are able to see as red, yellow, purple, etc.

Interleaving—The principle of interlacing the luminance and chrominance signals in the transmitted sideband spectrum to minimize interference.

Luminance—The brightness or intensity of light from a surface. The luminance signal or channel is used to convey the brightness components of a color picture.

I-Signal—A modification of the R-Y and B-Y signals, which contains the hues of orange and cyan. Because the eye is more sensitive to color detail in these portions of the spectrum, the signal has a band width of 1.5 mc.

Matrix—A circuit for separating a group of incoming signals into another group of signals which contain specific percentage levels of each of the incoming signals.

Monochrome—Black-and-white or neutral color scale. The monochrome signal and channel conveys the brightness or luminance detail of the color picture.

Primary Color—One of the basic colors of a three-color system. By the addition of the proper proportions of two or three of the primary colors. white light or any of the secondary colors can be reproduced.

Purity—The absence of any incorrect color (called color contamination) in the reproduced picture, which results when one or more of the electron beams strikes the incorrect phosphor dots. This may be the result of stray magnetic fields or improper placement of the three beams as they emerge as a group through the holes in the shadow mask.

Q-Signal—The chrominance component which contains the hues of green and magenta. In these portions of the spectrum, the eye is able to distinguish hues in large areas but not in fine or moderate detail. Therefore, the band width is .5 mc.

Saturation—The freedom from white dilution of a color of a given hue. A highly saturated or vivid color is almost free of white dilution, while a pale color has a high percentage of white dilution.

Secondary Color—A color produced by proper mixture of primary colors.

Sequential Color System—A three-color system in which primary colors are presented to the viewer in sequence—first red, then blue, then green, etc.

Simultaneous Color System—A color system in which the three primary color images are displayed on the screen simultaneously.

Spectrum, Visible — Range of colors that produce visual sensation.

Y-Signal—The signal that conveys the luminance or brightness detail of a color picture. Sometimes called the "W" signal.

Lesson Questions

Be sure to number your Answer Sheet 51B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of lessons before new ones can reach you.

1. What type of information is contained in the video signal transmitted by a monochrome TV station?
2. Name the three primary colors used in color TV.
3. What is the brightness or luminance signal used in color TV called?
4. What are the values of the signals used to make up the Y signal?
5. What is the difference between a saturated red and a pastel red such as pink?
6. What is the approximate subcarrier frequency used in color TV?
7. Are the horizontal and vertical scanning rates used in color TV the same as those used in monochrome TV?
8. Name the two color signals used in the NTSC color system.
9. Why is a wider bandwidth used for one color signal than the other in the NTSC color system?
10. How are the electron guns in the CBS colortron modified to improve convergence?

EACH DAY COUNTS

Each day of our life offers its own reward for work well done, its own chance for happiness. These rewards may seem small, and these chances may seem petty in comparison with the big things we see ahead. As a result, many of us pass by these daily rewards and daily opportunities, never recognizing that the final goal, the shining prize in the distance, is just a sum of all these little rewards we must win as we go along.

J. M. Smith

TV TUNERS

52B

RADIO-TELEVISION SERVICING

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 52

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. Introduction .... Pages 1-5

Here you are introduced to tuners. The functions of tuners and problems of interference are discussed.

☐ 2. The RF Stage .... Pages 6-12

In this section triode and pentode rf stages are discussed. You learn about cascode amplifiers, gain controls, and coupling to the mixer.

☐ 3. The Converter Section .... Pages 13-15

Here you study mixers and oscillators.

☐ 4. Complete Tuners .... Pages 15-29

Several types of tuners are described—turret tuners, step tuners, and continuous tuners.

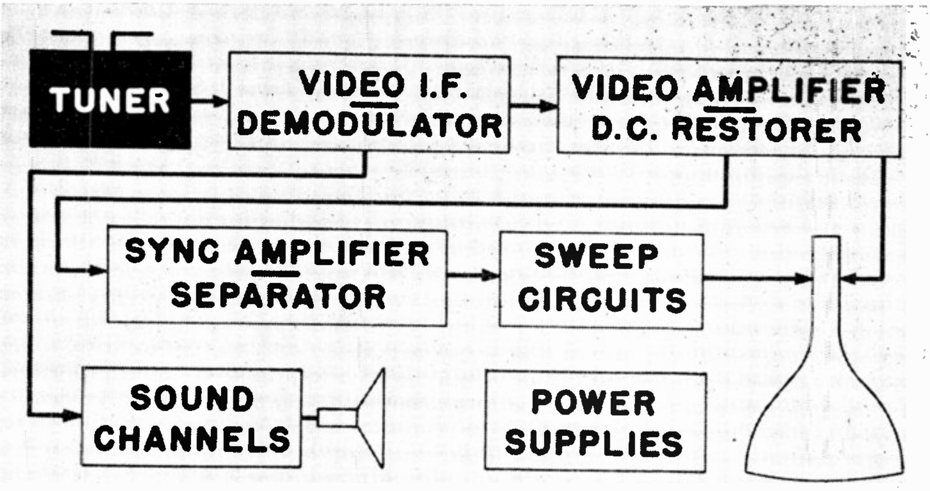
☐ 5. Servicing Tuners .... Pages 29-36

This section tells about servicing the different types of tuners and about tuner alignment.

☐ 6. Answer Lesson Questions.

☐ 7. Start Studying the Next Lesson.

FM3M460 **1960 Edition** Printed in U.S.A.



PRECEDING lessons of this television series have introduced you to the idea of producing a picture by means of a television system—you have been introduced to the basic circuits and have made a study of the television picture tube. This lesson begins a detailed study of the circuits of a TV receiver with the section called the "input tuner" or simply the "tuner."

Basically, this section corresponds to the preselector-converter section of the sound receiver. However, instead of being an integral part of the receiver, the tuner is usually made on a separate sub-chassis, which is aligned, and then the completed unit is mounted on the main chassis. As a matter of fact, few television manufacturers actually build their own tuners—most of them buy the tuner already assembled from one of the companies specializing in tuner manufacture.

You may wonder why the tuner is built on a separate chassis and treated by the receiver manufacturer as though it were a *separate* part of the TV receiver. Let us consider what the tuner must do and look at some of the problems that must be overcome, and you will see why the tuner is indeed a "special" part of the television receiver.

Functions. The tuner, like the preselector-converter in a sound receiver, must initially select the desired signals, and, by the heterodyne process, produce from it the desired i-f signals. You already know that the television channel is 6 mc wide. An ideal tuner would amplify all signals in the television channel equally, and reject all signals falling outside the channel. Of course, it is impossible to design a tuner that will do this; therefore, tuner design is somewhat of a compromise between band pass and gain characteristics.

The preselector must pass the full 6-mc band occupied by each television channel. A 6-mc band width can easily be obtained at the frequencies used by the TV stations, simply by using low-Q resonant circuits. However, low-Q circuits that pass the 6-mc band width, usually pass not only the 6-mc TV channel, but also frequencies on both sides of the channel. As a result, various types of interference are frequently encountered.

The response curve of a tuner is usually shaped so that it fits properly with the i-f response curve. For example, if the i-f response is a band-pass type, having two peaks on either side of a resonance point, the response curve of the tuner should have a single peak in the valley of the i-f response; the overall response of the two will then be relatively flat.

A tuner does not usually have much gain. The gain depends on the impedance of the resonant circuits used in the tuner. The impedance depends upon the Q, which, as we have said, is kept low to give the required 6-mc band width.

TV tuners are required to work at VHF and UHF frequencies. Therefore, the tuner must be designed so that it is compact with leads kept as short as possible. Because they have many parts crowded into a small space, tuners are often difficult to service.

Various methods have been worked out to change from one channel to another—we will discuss the systems in more detail later in this lesson.

TV Channels. The present television channels are listed in Fig. 1.

CH.	FREQ. (MC)
	VHF
2	54-60
3	60-66
4	66-72
5	76-82
6	82-88
7	174-180
8	180-186
9	186-192
10	192-198
11	198-204
12	204-210
13	210-216
	UHF
14	470-476
15	476-482
16	482-488
17	488-494
18	494-500
19	500-506
20	506-512
21	512-518
22	518-524
23	524-530
24	530-536
25	536-542
26	542-548
27	548-554
28	554-560
29	560-566
30	566-572
31	572-578
32	578-584
33	584-590
34	590-596
35	596-602
36	602-608
37	608-614
38	614-620
39	620-626
40	626-632
41	632-638
42	638-644
43	644-650
44	650-656
45	656-662
46	662-668
47	668-674
48	674-680
49	680-686
50	686-692
51	692-698
52	698-704
53	704-710
54	710-716
55	716-722
56	722-728
57	728-734
58	734-740
59	740-746
60	746-752
61	752-758
62	758-764
63	764-770
64	770-776
65	776-782
66	782-788
67	788-794
68	794-800
69	800-806
70	806-812
71	812-818
72	818-824
73	824-830
74	830-836
75	836-842
76	842-848
77	848-854
78	854-860
79	860-866
80	866-872
81	872-878
82	878-884
83	884-890

FIG. 1. Table of channel numbers and corresponding frequencies.

Channels 2 through 6 inclusive are the low-band VHF channels. Channels 7 through 13 inclusive are the high-band VHF channels. Channels 14 through 83 inclusive are the UHF channels. Each of these channels is 6 mc wide and contains one complete video signal and the accompanying sound signal.

The VHF channels were assigned first, and originally there were thirteen of them. Channel No. 1 was 40 to 50 mc; this is now assigned to other services, but, since many receivers had already been manufactured with the channel selectors marked for channel 1, channel 1 was simply dropped and the numbers on the other channels were not changed.

Some TV receivers are manufactured with *all-channel* tuners that can tune all 82 channels. However, there are comparatively few of these receivers and most sets are designed primarily to cover all of the VHF channels and at the most, three or four of the UHF channels. As a matter of fact, millions of receivers that were manufactured before the UHF channel assignments were made must have UHF converters to pick up the UHF channels.

INTERFERENCE PROBLEMS

Interference is far more annoying in the picture of a television receiver than in the sound of a radio, because the eye is far more critical than the ear. Consequently, television receivers are designed to eliminate interference as much as possible. Let's see what can be expected of the input tuner in this respect.

Man-Made Interference. Interference resulting from the operation of electrical apparatus can best be eliminated at the source. About all that can be expected of a tuner in eliminating such noise is that it should be able to reject noise whose frequency is more than 15 to 20 mc on either side of the channel frequency.

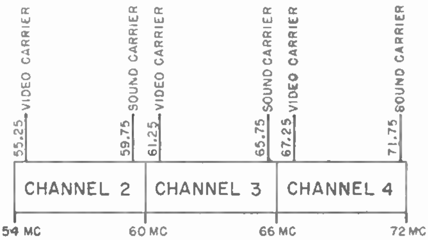


FIG. 2. The sound and video carrier frequencies of channels 2, 3, and 4.

FM Interference. Both the low-band VHF channels and the high-band VHF channels are subject to interference from stations in the FM broadcast band (88 to 108 mc). The low-band VHF channels, particularly channels 5 and 6, are so close to the FM broadcast band that a strong nearby FM station operating near the low end of the band may be able to get right through the tuner and cause considerable interference. FM image interference may also be encountered on channel 2 in many of the older television receivers that used a 21-mc i-f.

The second harmonics of the FM broadcast band range from 176 to 216 mc and can cause interference in the high VHF band. Interference of this type, however, is usually confined to locations close to the FM transmitter.

Adjacent-Channel Interference. We have already mentioned that most tuners pass not only the entire 6-mc channel to which they are tuned, but also a good portion of the channels immediately below and immediately above it. The sound and video carrier frequencies for channels 2, 3, and 4 are shown in Fig. 2. If the set is tuned to channel 3, the band width may be such that the channel 2 sound signal, which is at the high end of the channel, and the channel 4 picture signal, which is at the low end of the channel, may get through the tuner. This is called adjacent-channel interference. Traps are inserted in the video i-f amplifier to prevent adjacent-channel sound and/or adjacent-channel picture interference. You will seldom encounter this type of interference in large metropolitan areas having their own TV stations, but you will often find it in rural areas between two large cities.

Image Interference. Image interference was originally encountered in some of the older TV receivers that used tuners with extremely poor selectivity. However, this type of interference has been practically eliminated in modern tuner design, particularly since the trend is to use i-f's in the order of 45 mc.

I-F Interference. If a TV receiver is near a strong station using a carrier frequency in the i-f region, it is quite possible for the signal to get through the tuner and cause interference. Interference of this type can be eliminated by installing a high-pass filter in the antenna input lead. We will describe traps in more detail later.

Summary. Interference was a serious problem in early television receivers that first appeared on the market about 1947. However, a great deal of progress has been made in tuner design. Shielding has been improved considerably, selectivity has been improved, and new circuits have been developed. All these improvements have helped eliminate interference and improve tuner performance.

Practically all of the early post-war television receivers used a picture i-f frequency in the neighborhood of 25.75 mc, and a sound i-f of 21.25 mc. In later designs, the i-f frequencies have been changed to 45.75 mc for the video, and 41.25 mc for the sound. This change alone has helped eliminate interference.

Improvements in tuner design have greatly simplified the serviceman's job. However, since there are still many receivers in use having the early tuner designs, you should be familiar with the problems encountered in these tuners. In spite of the improvements made in tuners, they still require servicing—tubes burn out, parts break down, etc.

We will now begin to study in detail some of the tuner circuits. The better you understand how these circuits operate, the easier it will be to service them quickly and professionally.

VHF AND UHF TUNERS

As we have already mentioned, because the positioning of the parts and the shielding is so critical, the tuner is manufactured as a complete unit on its own sub-chassis; then, when it is

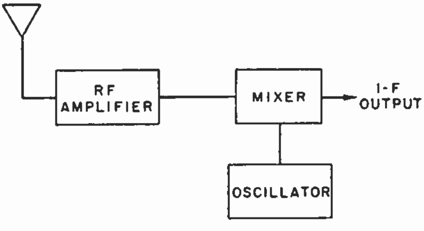


FIG. 3. Block diagram of a VHF tuner.

completed and aligned, this sub-chassis is mounted on the main television receiver chassis. This greatly simplifies the problems of layout and shielding. Now let us take a brief look at the block diagram of a VHF tuner, and after we have studied it, we will look

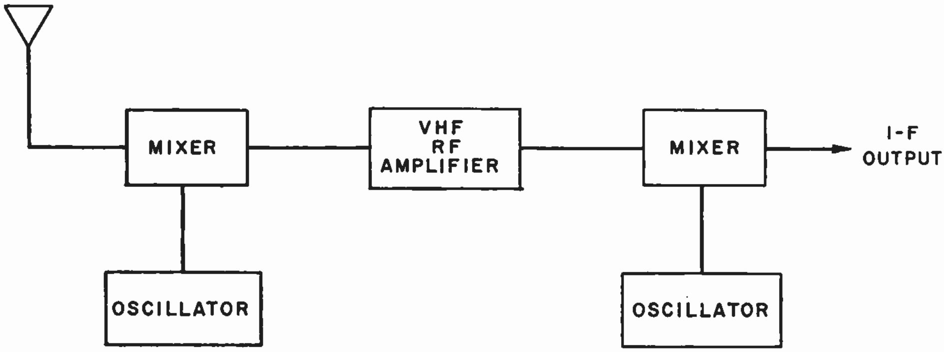


FIG. 4. Block diagram of a UHF tuner.

at a UHF tuner.

VHF Tuners. A block diagram of a VHF tuner is shown in Fig. 3. Notice that the tuner consists of an rf stage, a mixer, and an oscillator.

The rf stage may use either a pentode or a triode tube. Early tuners frequently used triode tubes in a push-pull circuit. Later, improved tuners appeared, using pentode rf stages, and now still later, tuner designs use a dual triode tube in a *cascode* circuit. We will study all these circuits in this lesson.

Separate tubes may be used in the mixer and oscillator stages, but the trend in modern tuner design is to use a single dual triode tube, one of the triodes being used as the mixer, and the other as the oscillator. Most of the older TV receivers, however, used separate mixer and oscillator tubes.

UHF Tuners. It is not too difficult to design rf amplifiers that will work on the highest VHF channels, but problems are so great on the UHF channels that rf amplifiers are not usually used.

The block diagram of a typical UHF tuner is shown in Fig. 4. Notice that in effect we have simply added a converter consisting of a mixer and an oscillator in front of a typical VHF tuner. This procedure is being used by most manufacturers. The UHF mixer is usually a crystal mixer, and the oscillator a specially designed UHF tube. The rf amplifier of the VHF tuner then acts like a first i-f stage and the VHF mixer becomes a second mixer.

The UHF mixer input circuit is extremely broad and usually is capable of covering a number of TV channels without adjustment. The desired UHF station is tuned in by varying the oscillator frequency. In spite of the fact that the UHF mixer tuning is extremely broad, there is not generally too much interference encountered with an arrangement of this type because of the selectivity of succeeding stages.

Now that you know what stages are likely to be found in a tuner, let's study some practical rf, mixer, and oscillator stages.

The RF Stage

In order to have as much selectivity as possible, and at the same time to maintain an adequate band width the rf stage of a TV receiver must be designed so that its impedance matches that of the transmission line. Most input circuits are similar to those shown in Fig. 5.

Fig. 5A shows a balanced input with two antenna terminals. The input is balanced because each terminal has the same impedance to ground. The input impedance between the two terminals is 300 ohms. Receivers with this type of input should be connected to the antenna with 300-ohm transmission line (commonly called twin lead).

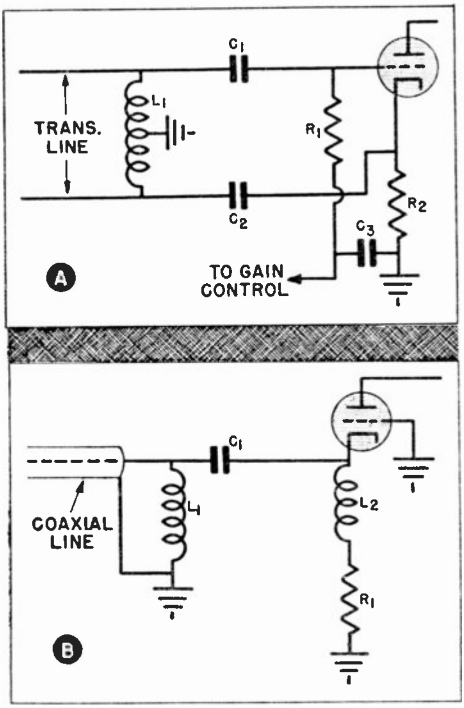


FIG. 5. Tuner input circuits. The circuit at A is a balanced input and that at B is unbalanced.

The circuit shown in Fig. 5B is an unbalanced input with one side of the input circuit directly grounded. A receiver using this type of input is connected to the antenna by means of a coaxial line. Receivers having this type of input usually have an input impedance of 75 ohms.

Gain in the rf stage improves the signal-to-noise ratio and every bit of gain ahead of the converter is important when weak signals are being received. Since considerable noise is generated in the converter stage, any rf gain that increases the signal strength before the signal reaches the converter will help the signal override the normal converter noise. However, even at best, the amount of gain obtainable in the rf stage is relatively small. The television set, like a broadcast receiver, must depend on the i-f amplifier for most of its gain.

TRIODE RF STAGES

You already know that one of the undesirable characteristics of a vacuum tube is that it generates a certain amount of noise. Triodes are far less noisy than pentodes, and they were used in the rf stages of many of the early TV tuners. However, the triode tube, because of the grid-to-plate feedback, either requires neutralization or must be used in a grounded-grid circuit.

Neutralization. Two neutralized triode amplifiers are shown in Fig. 6. In Fig. 6A there is a neutralization system for a single tube, in which the capacitor CN feeds back part of the energy from the plate tank circuit to the grid circuit. The energy fed through

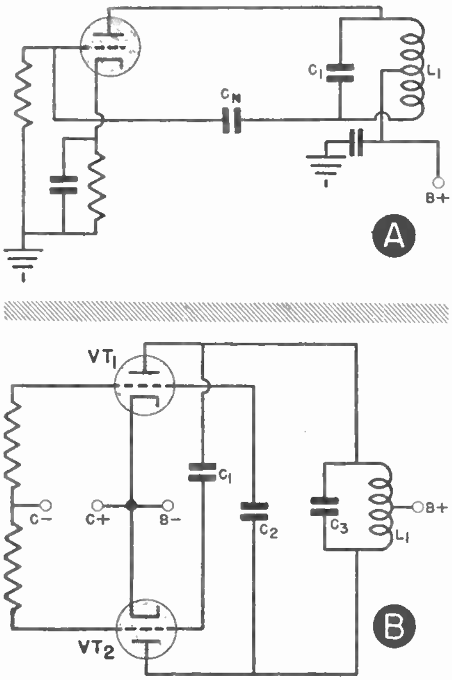


FIG. 6. Two kinds of neutralized triode amplifiers.

this circuit is 180° out of phase with the energy fed through the plate-to-grid capacitance of the tube, and therefore the two signals cancel.

The circuit for a push-pull triode amplifier is shown in Fig. 6B. Push-pull circuits of this type were used in many of the older tuners for several reasons. The input capacities in a circuit of this type are in series across the input, an arrangement that effectively cuts the total capacitance in half. This arrangement also gives a balanced input and permits neutralization without the loss due to loading, that occurs in the tapped coil circuit in Fig. 6A.

In the circuit shown in Fig. 6B, the capacitors C1 and C2 are the neutralizing capacitors. C1 is connected to feed the signal from the plate of VT1 to the grid of VT2, and C2 is connected to feed a signal from the plate of VT2 to the grid of VT1. The capacitors provide signals 180° out of phase with the signal fed back through the plate-to-grid capacities of the tubes.

Neutralization will work over the very wide number of channels only if the different tuning coils are carefully designed to provide the proper feedback ratio. To avoid such problems, some tuner manufacturers have used a grounded-grid amplifier instead of circuits requiring neutralization.

Grounded-grid Circuit. In the rf stages with which you are most familiar, the cathode is grounded, and the signal source is placed between grid and ground as shown in Fig. 7A. In the grounded-grid circuit shown in Fig. 7B, the signal is placed between the cathode and ground, and the grid is connected directly to ground. Insofar as the grid action is concerned, either

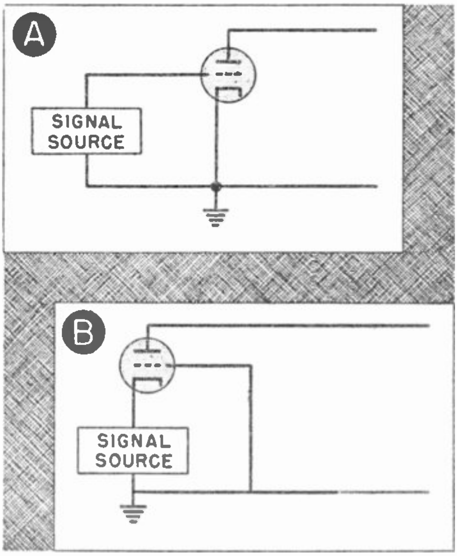


FIG. 7. This illustration shows the basic difference between the common grounded-cathode amplifier (A) and the grounded-grid amplifier (B).

position of the signal source will produce the same result, because it is the voltage between the cathode and the grid that matters. However, with the grid at ground potential, it effectively acts as a shield between the signal source and the plate. As a result, the grid-plate capacity no longer provides a feedback path, so neutralization is generally unnecessary. However, the grounded-grid circuit gives less gain than a conventional neutralized triode stage does, because the signal source is in the plate circuit and hence effectively feeds into a low resistance. The signal source is therefore heavily loaded, and if it is a tuned circuit, its Q and gain will be low.

PENTODE RF STAGES

A typical pentode rf stage is shown in Fig. 8. As we have already pointed out, a pentode is noisier than a triode; however, a carefully designed pentode rf stage can have the advantage of increased gain, and still have a reasonable noise level. Another advantage of a pentode rf amplifier is that it does not require neutralization.

The pentode rf amplifier shown in Fig. 8 is not very different from an rf stage that might be found in a broadcast receiver. However, tubes used in an rf stage of this type are usually designed for operation in the VHF region. Low plate and screen voltages are used to keep tube noise at a reasonable level.

An rf stage of this type is kept as compact as possible. The stage is carefully shielded. Notice the decoupling resistor, R3, used in the plate circuit lead and also the bypass capacitors C4 and C3 in the plate and screen circuits.

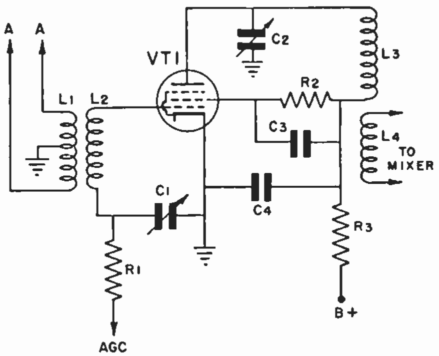


FIG. 8. A pentode rf stage.

THE CASCODE AMPLIFIER

A basic cascode amplifier is shown in Fig. 9. Since this may be the first time you have seen a circuit of this type, an explanation of how it operates should be helpful to you.

The input signal across coil L1 is applied to tube VT1, which is connected in a standard grounded-cathode circuit. The output signal from this tube is developed across coil L2, which feeds into VT2 through condensers C3 and C2. VT2 is a grounded-grid amplifier.

You might expect that VT1 would oscillate, since the circuit is a conventional grounded-cathode amplifier.

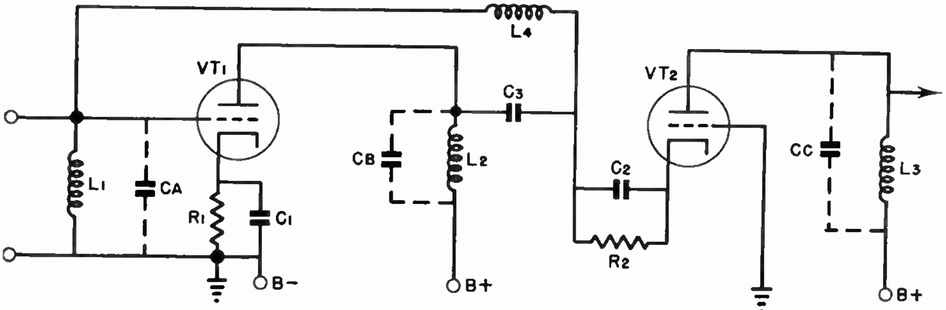


FIG. 9. A basic cascode amplifier, with ac coupling.

However, before a tube will oscillate, there must be sufficient load-impedance in the plate circuit to develop a reasonably strong feedback signal. The tube VT2 is in effect in the plate circuit of VT1 and presents a very low impedance to VT1. The result is that the impedance in the plate circuit of VT1 is so low there is not sufficient energy developed to produce oscillation.

The coil L4 feeds energy in the proper phase to alter the apparent input resistance of VT1 so that the noise input will be reduced. The low noise level is the chief advantage of the cascode circuit.

In the circuit shown in Fig. 9, ac coupling is used between VT1 and VT2, the dc circuits of the two stages are isolated from each other. A practical cascode amplifier very often uses dc coupling as shown in Fig. 10. The operation of this circuit is similar to the operation of the circuit in Fig. 9. Again, VT1 is a conventional grounded-cathode amplifier and VT2 is a grounded-grid amplifier. VT1 does not oscillate, because of the low impedance in the plate circuit. The grid of VT2, although not connected directly to ground, is grounded through C4. C4 acts as a short circuit at signal frequencies; therefore, insofar as the signal is concerned, the grid of VT2 is effectively grounded and acts as a shield between the cathode and the plate of the tube.

The cascode amplifier is becoming increasingly popular. The gain when new dual triode tubes designed specially for this type of circuit are used, is approximately the same as the gain of a single pentode stage. However, the

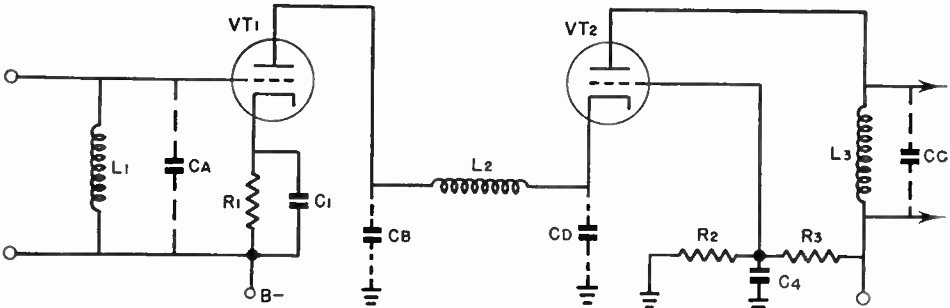


FIG. 10. A dc-coupled cascode amplifier.

noise level in an amplifier of this type is extremely low, and therefore an excellent signal-to-noise ratio can be obtained.

The cascode amplifier is sometimes used as an rf amplifier in a UHF tuner

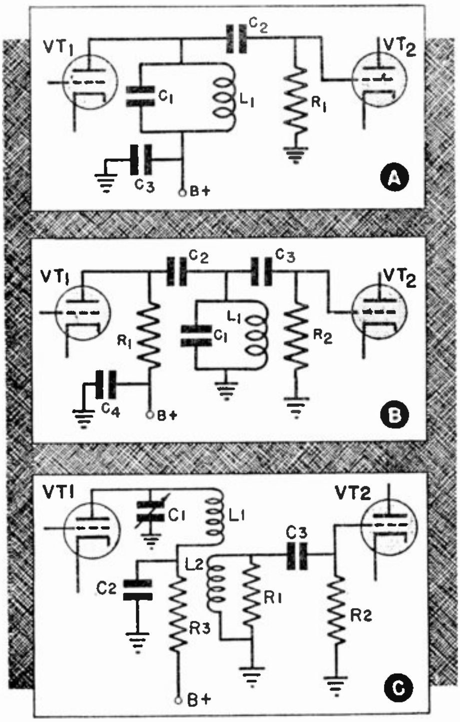


FIG. 11. Three forms of resonant coupling used between the rf and mixer stages.

or converter. However, because of the difficulty of designing UHF circuits, the amplifiers are usually designed for use in the VHF region, and if the tuner is required to cover the UHF channels, a separate mixer and oscillator are used ahead of the VHF tuner to convert the UHF signal to one of the VHF channels first. The VHF preselector then is used as an i-f amplifier.

When a tuner is switched from one channel to another, the resonant frequency of the tuned circuits used in the preselector must be changed. This can be accomplished by changing the inductance and/or the capacitance in the resonant circuit. The practice in modern tuner design is to change the inductance. We will go into more detail on this subject when we study complete tuners. At that time we will see how the problem of changing the resonant frequency of the tuned circuits is overcome.

GAIN CONTROL

The gain of the rf stage is usually controlled by applying agc (automatic gain control) voltage to the grid of the rf tube. This will normally provide satisfactory control of the gain of the rf stage except in very strong signal locations where the receiver is close to a strong TV station. In cases of this type, resistance voltage dividers, called attenuators, are inserted in the transmission line to decrease the signal from the powerful station to a level that can be handled by the receiver.

Some of the older TV receivers did not use agc. In these receivers the gain of the rf stage was controlled by a contrast control that varied the bias on the rf and i-f stages. However, this arrangement will be found only in the older TV receivers: practically all modern sets have agc voltage applied to the rf stage.

COUPLING TO MIXER

Several methods of coupling the rf stage to the mixer are shown in Fig. 11. The tubes shown are triodes, but the same arrangements could be used with pentodes equally well.

Fig. 11A shows the basic tuned-plate coupling. The tuning is needed to provide selectivity. However, the resistor

R1 loads the tuned circuit to broaden its response. The resonant circuit is therefore used to provide selectivity, and a low value of grid resistance is used in the following stage to broaden the response of the resonant circuit so it will not be too selective. Although we want selectivity, we must also keep in mind that the TV channel is 6 mc wide and the coupling network must be capable of handling the entire channel.

Another coupling arrangement is shown in Fig. 11B. In this circuit, the grid resistor may be made large so that the detector can be operated as a grid-leak detector. The resonant circuit is loaded by R1, which will be a comparatively low resistance, to obtain the required band width.

A third coupling arrangement is shown in Fig. 11C. In this circuit, inductive coupling is used between the coil in the plate circuit of the rf stage and the coil in the grid circuit of the mixer. The coils are over-coupled to produce a double-peak response. The required 6-mc band width can easily be obtained in this way at the frequencies encountered in the tuner.

We have already mentioned that the response of the tuner need not be flat over the entire 6-mc channel. Sometimes the response is deliberately peaked somewhat in order to make up for deficiencies in the i-f amplifier.

In Fig. 12A the desired over-all rf-if response curve is shown. In Fig. 12B we have shown the response curves of the i-f amplifier and the tuner. Notice that the i-f response has two peaks with a valley between them. The over-all response can be flattened by designing the tuner with a somewhat peaked response at the frequency where the video i-f response dips. The net result is a flat over-all response like that shown in Fig. 12A.

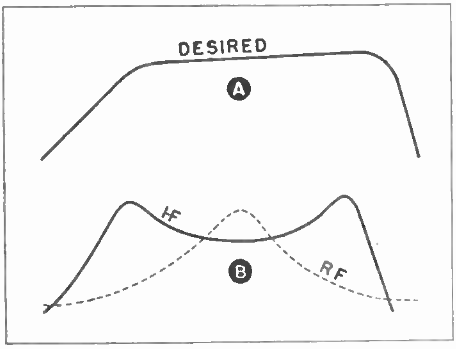


FIG. 12. The desired over-all response (A) of the rf and video i-f sections can be secured by matching the response of the two sections (B).

Very often you'll see a coil, having no capacitor in parallel with it, in the plate circuit of an rf stage. Fig. 13A shows a circuit of this type. This is a parallel resonant circuit. Let us examine it.

Capacitor C1 is a trimmer capacitor, and since it is connected in series with L1, and the two are connected between the plate of the tube and ground, you

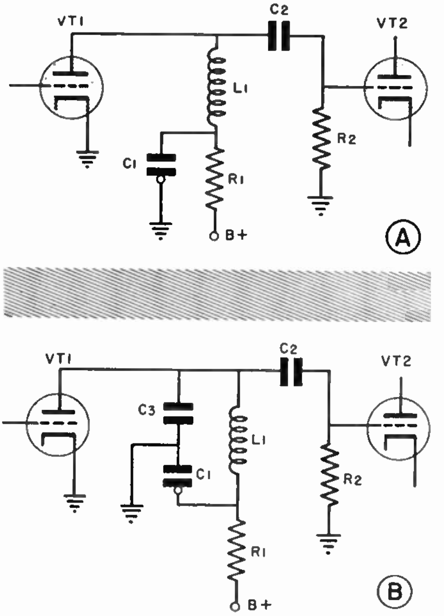


FIG. 13. A typical coupling arrangement used between the rf and mixer stages.

might think that L1 and C1 form a series resonant circuit. You know that a series resonant circuit offers a very low impedance at resonance and therefore would not provide an effective load for VT1. However, at the high frequencies handled in the tuner, the plate-to-cathode capacity of VT1 and the capacity to ground of the wiring in the plate circuit, actually form a comparatively large capacitor. If the circuit of Fig. 13A is redrawn as shown in Fig. 13B, you will see that the shunt capacity represented by C3 is actually in series with C1, and the combination of the two condensers will in effect be in parallel with L1. The circuit made up of L1 and the two capacities is therefore a parallel resonant circuit and offers a high impedance at the resonant frequency.

You might think the shunt capacities in the circuit are extremely small, but at the high frequencies used for television, their effect is so large that a low value of inductance must be used in the circuit on the high VHF channels. As a result, the circuit gain is low. This is one reason why C1 is connected as it is; when capacitors are connected in series, the total capacity will be less than the capacity of the smaller of the two. Therefore with C1 in series with C3, the effective capacity across L1 is reduced, and therefore a larger inductance can be used.

The Converter Section

The converter section of a television receiver, like that of a radio, consists of a mixer-detector and an oscillator. In a radio, a single i-f signal is produced by beating the incoming signal with a signal from a local oscillator. In a television receiver, two i-f signals are produced, the sound i-f and the video i-f.

Although pentagrid converters are commonly used in radio receivers to perform the functions of both the mixer-detector and of the local oscillator, television receivers generally use two separate tubes, although they may be in one envelope. The pentagrid converter is not suitable for use in TV tuners.

MIXER-DETECTOR

You already know that considerable noise is generated in a mixer tube. The noise level is high because the strong signal from the local oscillator swings the mixer plate current close to cut-off. When the plate current is low, random noises generated by the tube will be maximum. When used as amplifiers, pentodes are noisier than triodes. This is also true when they are used as mixers—a triode mixer will generate far less noise than a pentode mixer.

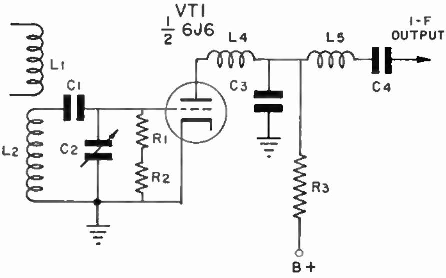


FIG. 14. A triode mixer circuit.

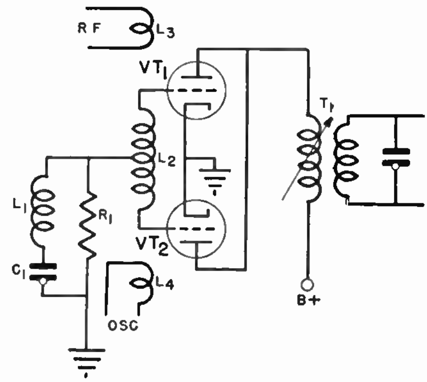


FIG. 15. A push-pull input, parallel output converter stage.

In early tuners, triodes were always used because of their lower noise factor. With the development of the cascode amplifier for use in the rf stage, and the resulting improvement in the signal-to-noise ratio available at the input to the mixer, many late model tuners use a pentode mixer to take advantage of the higher gain available with a pentode tube. In metropolitan areas where the signal is reasonably strong, there will be no objectionable mixer noise noticeable in the picture. However, in areas where the signal is weak, the noise generated by the mixer may be noticeable.

Triode Mixers. A simple triode mixer circuit is shown in Fig. 14. Grid-leak bias is used; the bias voltage is developed across resistors R1 and R2. Coil L1 is in the plate circuit of the rf amplifier, and it is inductively coupled to coil L2. The two coils are overcoupled to give the desired 6-mc band width. The oscillator is also inductively coupled to L2.

Another triode mixer is shown in Fig. 15. Here, coil L2 is tuned by the

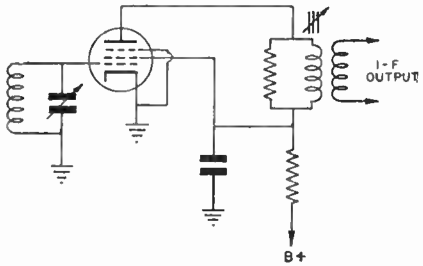


FIG. 16. Simplified schematic of a pentode tuner.

input capacity of the two tubes VT1 and VT2 that act together as the detector. Coil L3 feeds the incoming rf signal into L2, and L4 feeds in the signal from the oscillator.

The converter bias is obtained from the drop across R1; C1 and stray circuit capacity act as the grid capacitor. Transformer T1 is the first i-f transformer, both windings of which are tuned. The primary of T1 is a parallel resonant circuit that uses the output capacity of the two tubes as its shunt capacity.

The signals from L3 and L4 are applied to the two grids simultaneously. When the two signals are mixed, the beat products (i-f signals) at the two plates will be in phase. Therefore, the tube plates are connected in parallel to the primary of T1. As far as the original components (the rf input signals and the oscillator signal) are concerned, however, the two grids are being fed in push-pull; therefore, the tube plate current components resulting from each input component will be out of phase, and, because the plates are connected in parallel, these plate-current components will cancel. The output of the stage will contain neither of the original input signals—only their difference frequency, which is the desired i-f, and a few undesired harmonics. This push-pull input, parallel output connection also tends to cancel any incoming interfering signals at the i-f frequency, because they are fed in push-pull just as the desired incoming signal is.

This type of circuit was used in many of the early TV receivers, but the push-pull input, parallel output type of mixer-detector has been replaced by the single-tube circuits.

Pentode Mixers. A simplified schematic of a pentode mixer is shown in Fig. 16. Notice that the circuit is similar to the circuit you might expect to find in a broadcast-band radio receiver. The oscillator and the rf signals are inductively coupled into the grid of the mixer stage.

When a pentode mixer is used, low plate and screen voltages are used to keep tube noises at a minimum. Special tubes containing a pentode and a triode in one envelope have been developed for use in TV tuners.

OSCILLATORS

The oscillators used in TV tuners are generally triodes. As we mentioned previously, a separate tube is usually used as the oscillator, although it may be in the envelope with the mixer.

A typical oscillator circuit is shown

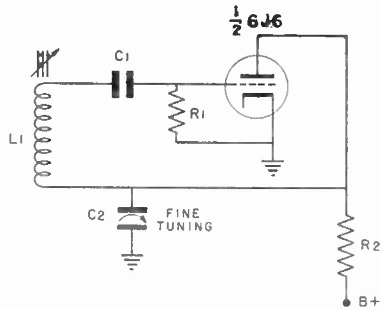


FIG. 17. Schematic of a simple triode oscillator.

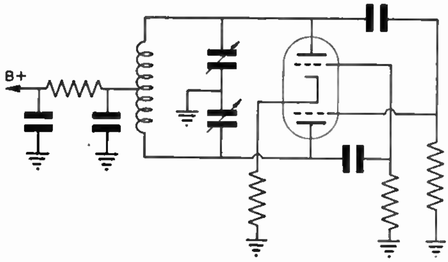


FIG. 18. Simplified schematic of a push-pull oscillator.

in Fig. 17. The oscillator tube is one half of a dual triode tube—the other half is the mixer. Generally, when a dual tube of this type is used, the coupling between the two sections of the tube is sufficient to inject the oscillator signal into the mixer. In some cases, additional coupling is provided.

An adjustable slug inside the oscillator coil L1 is used to adjust the oscillator to the correct frequency. Once the oscillator has been properly adjusted, any minor changes in oscillator frequency can be taken care of by adjusting the fine-tuning control.

The fine tuning requires only a very small change in capacity to produce any change in frequency that might be necessary. Most manufacturers use a capacitor consisting of two fixed plates and a movable dielectric. The dielectric is attached to a shaft mounted on the channel-selector switch and, by rotating the fine-tuning control, the position of the dielectric between the two plates of the tuning capacitor can be changed. Changing the dielectric changes the capacity of the capacitor, which in turn changes the oscillator frequency.

Some of the early television receivers used a dual triode tube in a push-pull oscillator circuit. A simplified schematic of this type is shown in Fig. 18. The circuit is shown for reference purposes only; we will not go into an explanation of it, since the circuit is no longer used in modern tuner design.

Complete Tuners

Up to this point we have studied separately the rf amplifier, the mixer, and the oscillator circuits used in TV tuners. Now, we will see how these circuits are put together in complete tuners and also how the task of switching from one channel to another is handled. There are a number of different types of tuners using different tuning systems. We will cover the more popular systems in detail.

You already know that the frequency of a resonant circuit can be changed by changing the inductance and/or the capacitance in the resonant circuit. Therefore we can change the frequency of a resonant circuit by keeping the capacity in the circuit constant and changing the inductance. We could, on the other hand, keep the inductance constant and change the capacity. We could also change both the capacitance and the inductance in the circuit. All three arrangements have been used in commercially manufactured tuners. However, in the majority of tuners, the capacitance in each circuit is held essentially constant, and the frequency of the resonant circuits changed by changing the inductances.

TURRET TUNERS

More television receivers have been manufactured using turret tuners than

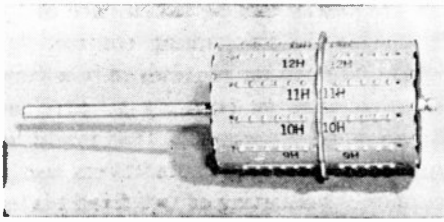


FIG. 19. The drum from a typical turret type of tuner.

any other type. The tuner is called a turret tuner because the coils required for the various TV channels are mounted on a turret or drum as shown in Fig. 19. The individual coils used in a tuner of this type are mounted on strips. Usually the rf and oscillator coils are mounted on one strip, as in the strips shown beside the tuner in Fig. 20, and the antenna coil is mounted on another strip. Separate strips are used for each of the television channels to be received.

The drum is mounted inside the tuner, as shown in Fig. 20, so that the contacts from one set of coils will connect the coils to the external circuits through the fixed contacts inside the tuner (Fig. 21). To change from one channel to another, the drum is rotated until the coils for the desired channel are in contact with the stationary

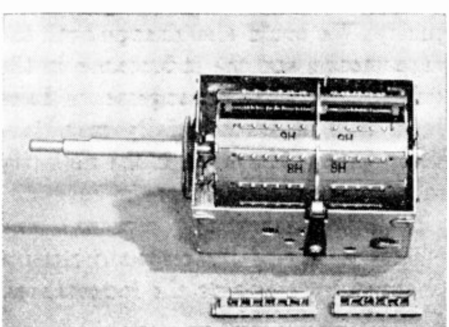


FIG. 20. Photo of turret tuner showing drum mounted in place and one set of strips removed.

contacts.

The complete schematic of this tuner is shown in Fig. 22. Coils L101 and L102 are mounted on the strips located to the rear of the drum. Oscillator coil L105, and coils L103 and L104 are mounted on the front of the drum. A slug inside the oscillator coil is accessible through a small hole in the front of the tuner case. It may be necessary to

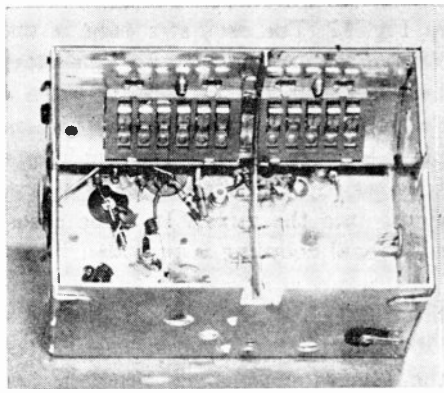


FIG. 21. A photo of the inside of a turret tuner chassis showing the stationary contacts.

"touch up" this adjustment when the tuner is first put into service, and from time to time as the tubes and parts age. Let us take a closer look at this tuner to study some of the circuits it uses.

The transmission line from the antenna is connected to terminals A. The primary of the input transformer, L101, is center tapped, providing a balanced input. L102 is inductively coupled to L101, and applies the signal induced in it to the grid of a pentode rf amplifier. The plate coil, L103, and the mixer-grid coil, L104, are overcoupled to provide the desired 6-mc band width. The oscillator signal is fed into the mixer by the coupling between coils L104 and L105.

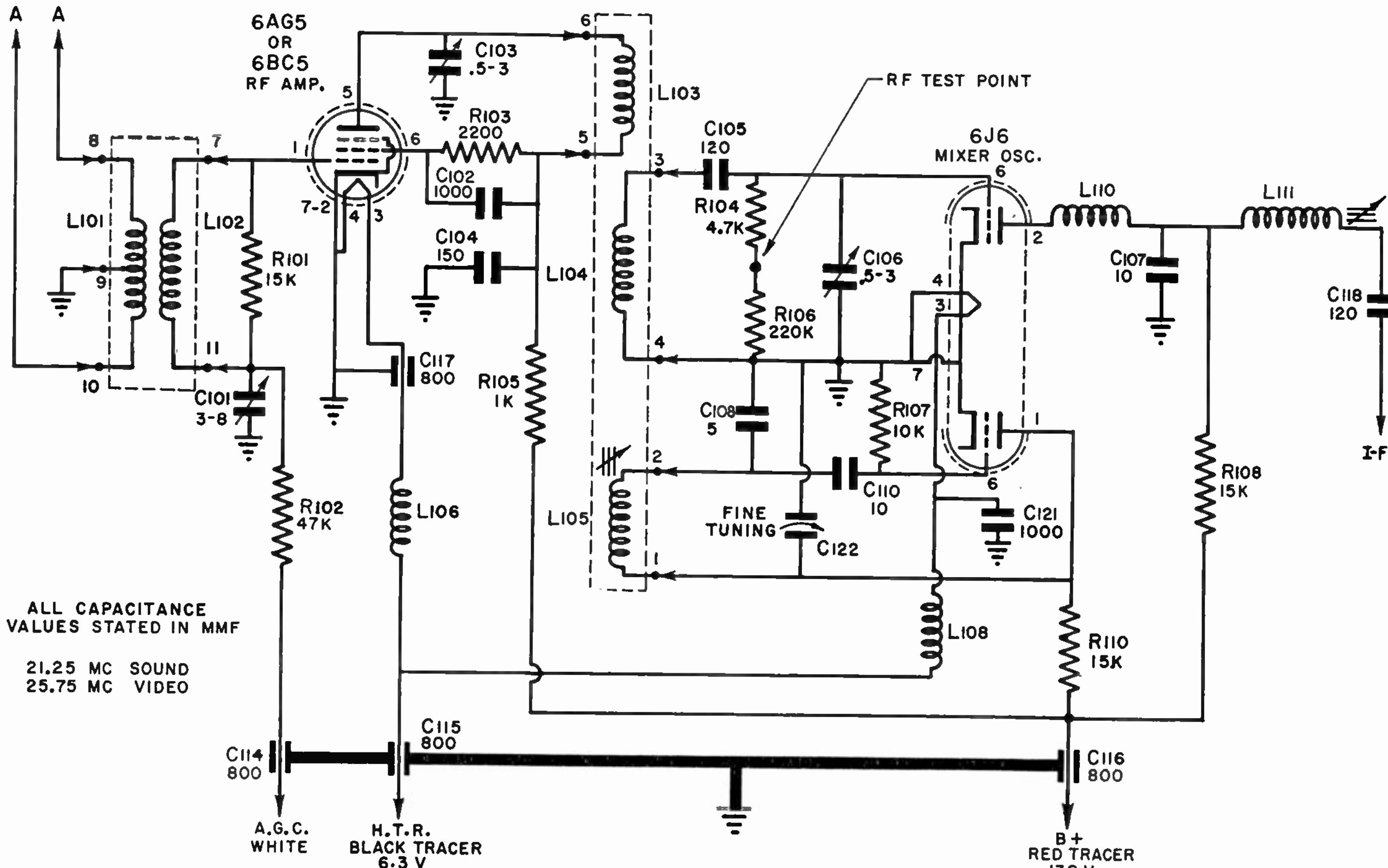


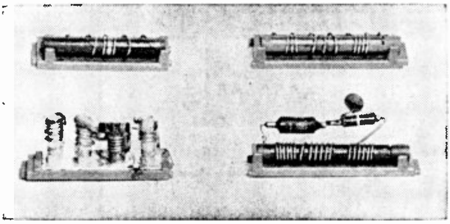
FIG. 22. Schematic of a VHF turret tuner.

This circuit is used to cover all twelve VHF channels. The tuner is switched from one channel to another, simply by rotating the drum, which in turn inserts a new set of coils in the circuit.

The tuner can be used on the UHF channels by inserting UHF strips. The strips for an unused VHF channel are removed and the UHF strips inserted in their place.

The schematic of the tuner with the UHF strips in place is shown in Fig. 23. Notice how the circuit is changed by the insertion of the UHF strips. The incoming signal is selected by the resonant circuits consisting of L202-C202 and L203-C203. The signal is then fed directly to a crystal mixer where it is mixed with a locally generated signal. This signal is obtained by feeding a signal from the local oscillator to a crystal harmonic generator. The incoming UHF signal is mixed with a harmonic of the oscillator and converted to a signal in the VHF region. The VHF signal is then fed to the original rf amplifier by T201. The signal is amplified by this stage, which is now acting as an i-f amplifier, and fed to the 6J6 mixer. In the 6J6 the signal is mixed with the fundamental of the oscillator to produce the required sound and video i-f signals.

There are several important things to notice about the way in which the tuner is used on the UHF channels. There is no rf stage ahead of the UHF mixer. A crystal mixer is used to convert the UHF signal. This is standard practice—crystal mixers outperform vacuum tube mixers at UHF. Double conversion is used to reduce the signal to the sound and video i-f signals, and the 6BC5 tube, that was used as the rf tube at VHF, now serves as an i-f tube. By using this tube as an i-f amplifier, excellent image rejection can be obtained, because the first i-f stage operates at VHF. In addition, it is possible to take advantage of the extra gain that can be obtained from this stage.



Courtesy P. R. Mallory Co.
UHF (below) and VHF strips from a turret-type tuner.

Although the results from this type of UHF tuner arrangement may not be as satisfactory as those obtained from a tuner designed primarily for UHF reception, generally speaking, the performance is entirely satisfactory.

STEP-TYPE TUNERS

In this section we will discuss a tuner using rotary switches as shown in Fig. 24. In this type of tuner, the inductances are mounted right on the rotary switch. Tuning to a lower channel simply adds inductance to the circuit. When you start off at channel 13, you

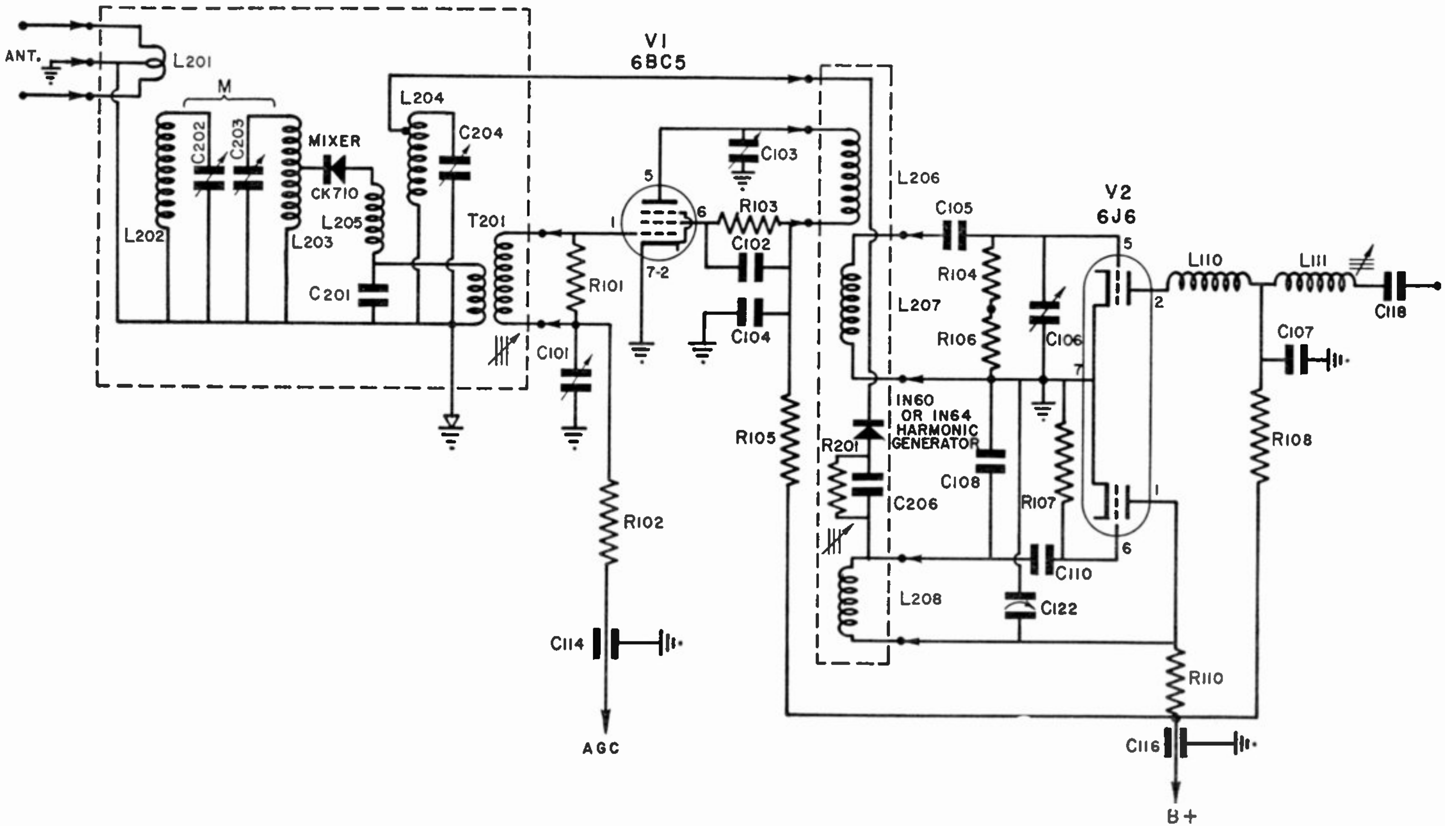
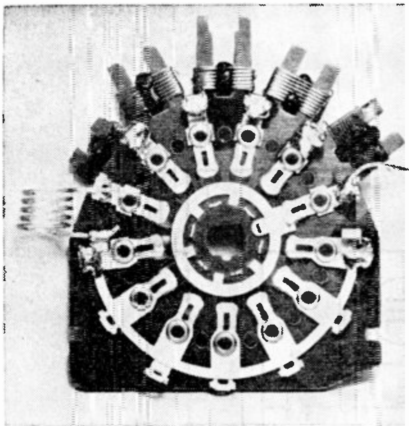


FIG. 23. Tuner with UHF strips installed.



Courtesy Radio Maintenance Magazine

FIG. 24. One of the switch decks used in the rf section of an RCA tuner. The inductance for the high band is provided by the semi-circular loop of metal at the bottom of the deck.

have a relatively low inductance in the circuit. If you switch the tuner to channel 12, you leave the original inductance in the circuit and add an additional inductance. Each time you switch the tuner to a lower channel, inductance is added, until you have tuned to channel 2, when all the inductance will be in the circuit.

With this type of tuner, a defect in any coil upsets the performance of all channels below it. For example, a defect in the coil connected between the channel 5 and channel 6 contacts on the switch may upset the performance of a number of channels. Channels 6 through 13 inclusive would work satisfactorily, but channels 2, 3, and 4 might be affected by the defect.

A schematic design of the tuner from which the switch deck shown in Fig. 24 was taken, is shown in Fig. 25. This is a tuner used in one of the older TV receivers. Notice that push-pull rf and oscillator circuits are used. The mixer circuit is the push-pull-input-parallel-output circuit that we discussed previously.

The channel selector switch is shown in the channel 1 position. (This early model TV receiver covered all 13 VHF channels.) All the inductance in each stage is in the circuit. To switch to a higher channel, the channel switch moves to the right. When you switch to channel 2, coils L1 and L2 are removed from the rf circuit, L27 and L28 from the mixer circuit, and L53 and L54 from the oscillator circuit.

In a tuner of this type, inductances that are added when you switch from one high-band VHF channel such as channel 9 to a lower channel such as channel 8, are actually just short pieces of wires soldered between the switch terminals. However, when you switch from channel 7 to channel 6, coils L11 and L12 in the rf unit provide a rather large change in inductance because you are switching from the 174-180 mc channel to the 82-88 mc channel. Coils L37 and L38 perform a similar function in the mixer circuit, and L63 and L64 in the oscillator circuit.

The resonant circuits are all parallel resonant circuits. But except in the oscillator circuit, where fine tuning is used, there are no capacitors across the tuned circuits. The tube capacities form the necessary parallel capacity.

Although this type of tuner was used in many of the early television receivers, the use of the push-pull tubes has been discontinued and you will not find this type of tuner in any modern receiver. Rotary switches, however, are still used, and you will probably service many of the older TV sets using tuners similar or identical to the one we have just discussed.

The schematic diagram of a modern

tuner using rotary switches is shown in Fig. 26. Inductance is added to the circuit as you tune from the higher channels to the lower ones in the same manner as in the preceding tuner.

In the input of the tuner there are a number of traps. Two i-f traps are used to eliminate interference that may be caused by nearby transmitters operating in the i-f pass-band. An FM trap is also incorporated and can be tuned to eliminate FM interference that might be caused by a nearby FM station.

The rf amplifier is the dc type of cascode rf circuit, which we discussed previously. The rf tube is specially designed for use in this type of circuit.

A specially designed tube is also used in the mixer-oscillator stage. The pentode section is the mixer, the triode section is the oscillator. The oscillator signal is injected into the mixer grid through capacitor C22. C27 is the oscillator fine tuning.

A schematic of this tuner may appear rather formidable and you might think that it would be an extremely difficult job to trace out all the circuits in the tuner. As a matter of fact, it would be difficult to try to trace out *all* of the circuits, but as a serviceman, you will have no occasion to try to do this. The important things for you to recog-

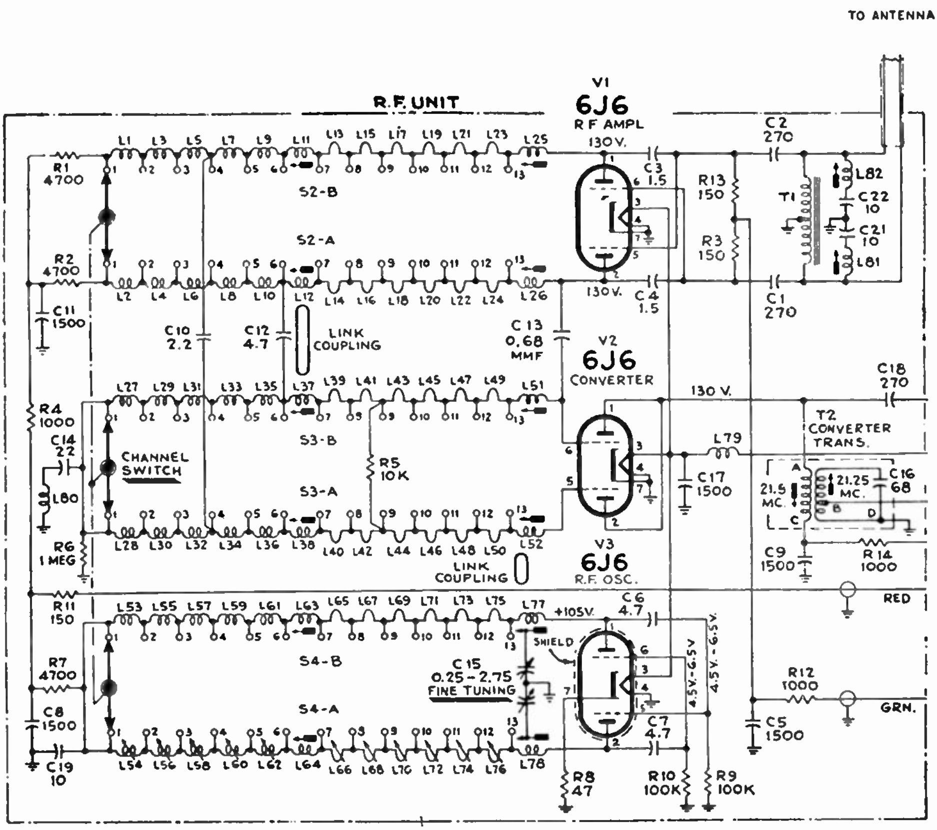


FIG. 25. The schematic diagram of the tuner in which the switch deck shown in Fig. 24 is used.

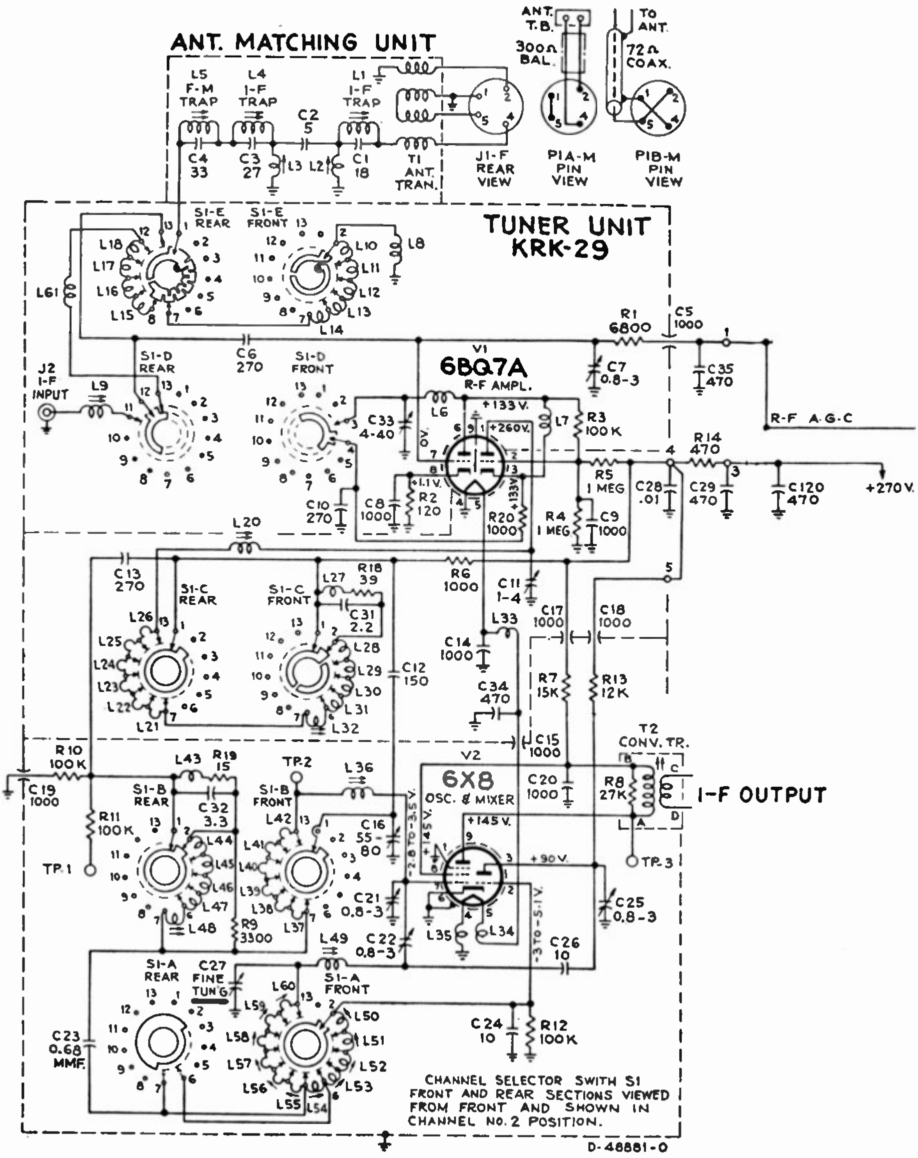


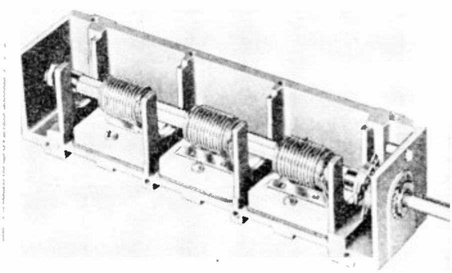
FIG. 26. A modern tuner using rotary switches.

nize are the types of circuits used and how the tuning is accomplished, so that when you have to service a tuner of this type, you will know what type of defect may be expected to cause the trouble you have encountered.

Insofar as the actual circuits themselves are concerned, as we mentioned previously, the rf amplifier is essentially a conventional dc-coupled cascode amplifier. The mixer and oscillator circuits are standard. Tuning is accomplished by varying the amount of inductance in the circuit. The switches marked S1-E tune the input to the rf amplifier, switches S1-C are used to tune the output circuit of the rf amplifier, switches S1-B tune the input of the mixer and switch S1-A tunes the oscillator circuit. That is about all you have to know about the tuner to start to service it. When you have isolated the trouble to one circuit, you can then trace out that *one* circuit if necessary.

stage and the input of the mixer are both tuned. The rf, mixer, and oscillator coils are mounted on a single shaft, and tuning is accomplished by small contacts that ride on the coils, shorting out part of each coil. As the tuner is tuned towards the higher channels, more and more of the coils are shorted out.

This type of tuner was originally quite popular because it could tune the



Courtesy P. R. Mallory and Co., Inc.
FIG. 27. This is the Mallory Inductuner (Trademark registered U. S. Patent Office) that is used in several brands of TV sets.

CONTINUOUS TUNERS

In a step tuner, switching from channel to channel is in steps; in a continuous tuner, the frequency of the resonant circuit is made continuously variable. This can be accomplished by varying either the inductance or the capacitance in the circuit. Both systems have been used in TV tuners. The more popular of the two systems is to vary the inductance. A photo of a variable inductance used in many TV tuners is shown in Fig. 27. The schematic diagram of the tuner in which this variable inductance is used is shown in Fig. 28.

In this tuner, a grounded-grid rf amplifier is used. The input circuit is untuned, but the output of the rf

entire VHF TV spectrum and it also covered the FM broadcast band.

This continuous tuner provides a very simple tuner arrangement. The greatest difficulty with it is that a number of spurious responses are obtainable at various points over the tuning range. In addition, it is somewhat more difficult to find the TV channels than it is with the step tuner that can simply be switched to the desired channel. However, once the receiver owner learns how to use this type of tuner, it is quite satisfactory.

A large number of receivers have been manufactured using the Inductuner. However, the tuner is not used to any extent in modern receivers; step tuners, particularly the turret tuner are far more popular.

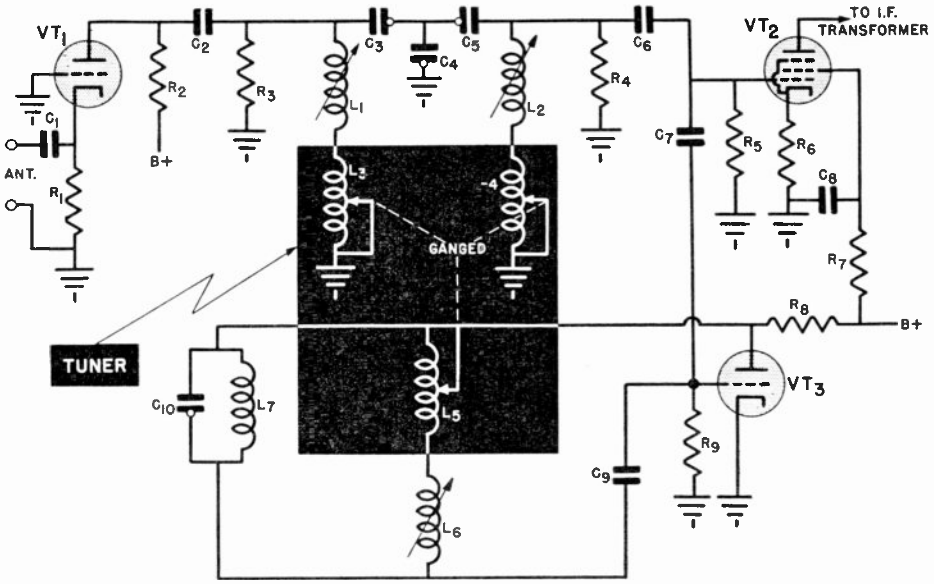


FIG. 28. The schematic of an input tuner in which the Mallory Inductuner is used.

A variable capacity continuous tuner was used in a few TV receivers. A two-position switch is used in this type of tuner so that in one position the low-band VHF channels can be tuned, and in other position, the high-band VHF channels are covered.

However, this type of continuous tuner was not nearly as popular as the variable inductance type, and you will seldom find it.

COMBINATION UHF-VHF TUNERS

The schematic diagram of a tuner that can be set up for any 16 TV channels is shown in Fig. 29. Usually the tuner is set up to cover the 12 VHF channels and four of the UHF channels. The tuner is a turret type, and the strips for any unused channel can be removed and strips for another channel inserted.

A cross-over network is used in the antenna input circuit. The lead-in from a VHF antenna can be connected to one set of terminals and the lead-in from a UHF antenna to the other set. The signals are fed through a network to the stationary contacts marked 1 and 2 on the diagram.

When the tuner is used on any of the VHF channels, a 6BQ7A cascode rf amplifier is used. The output from this amplifier is fed to a crystal mixer where the rf signal is beat with the signal from the local oscillator. The output of the mixer is fed to an i-f amplifier. Let us examine the tuner in more detail. Let us see what happens when the tuner is turned to channel 2.

In the channel 2 position, the coil strip on the top of the diagram, marked A, will be connected to the stationary contacts. In this position the signal from the antenna is fed to the primary of T6, and the secondary of T6 applies the signal to the rf amplifier input. The signal is amplified by the 6BQ7A used in a dc-coupled cascode amplifier, and

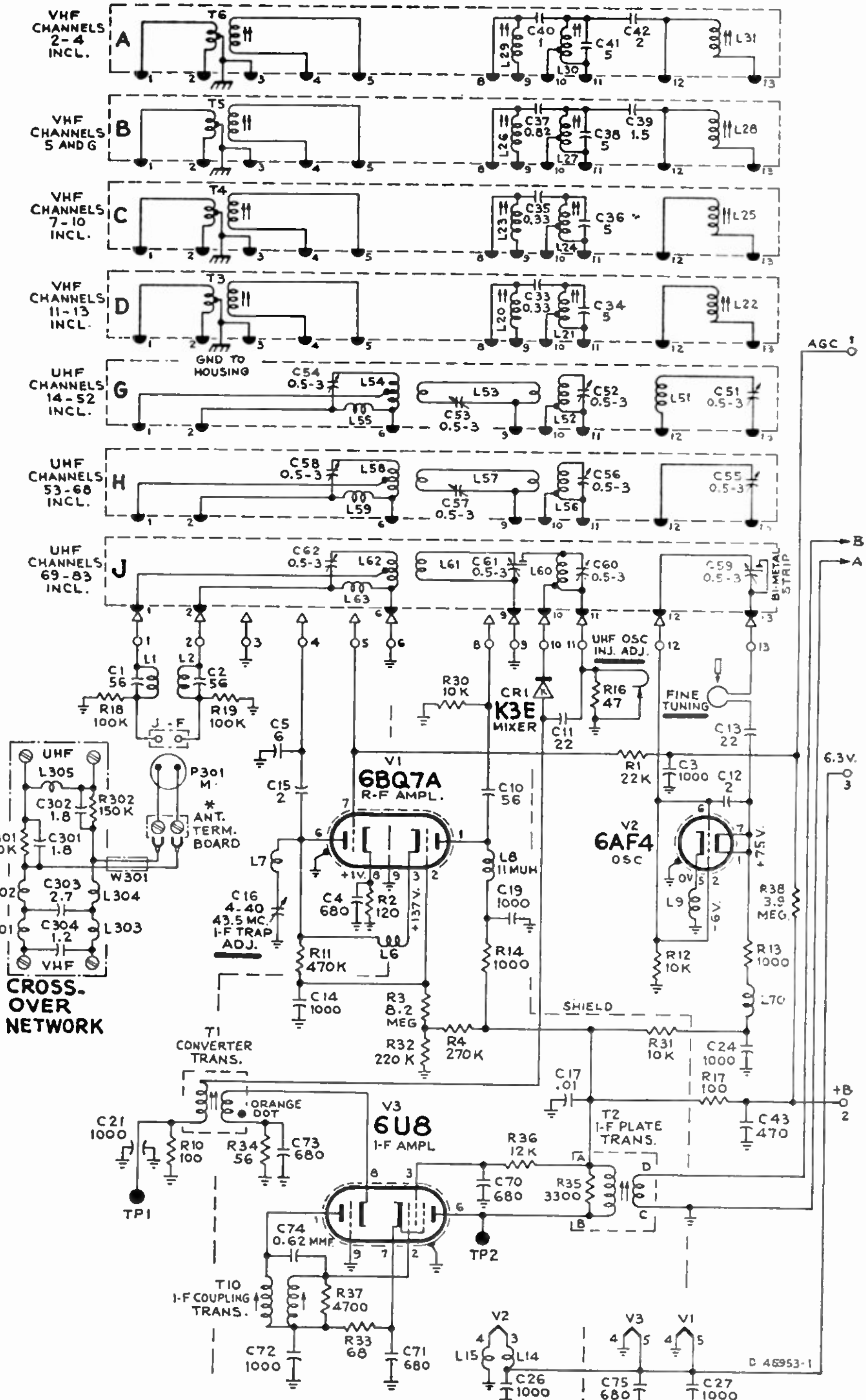


FIG. 29. A VHF-UHF tuner used in an RCA color TV receiver.

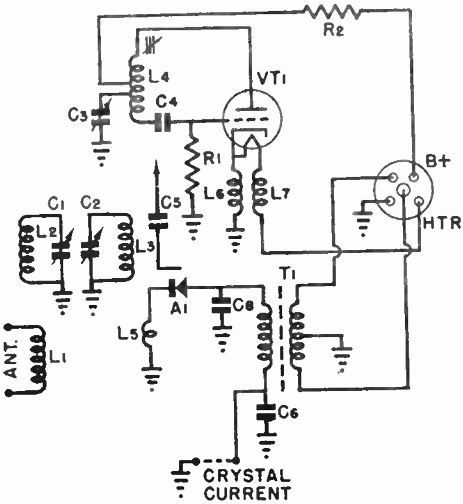


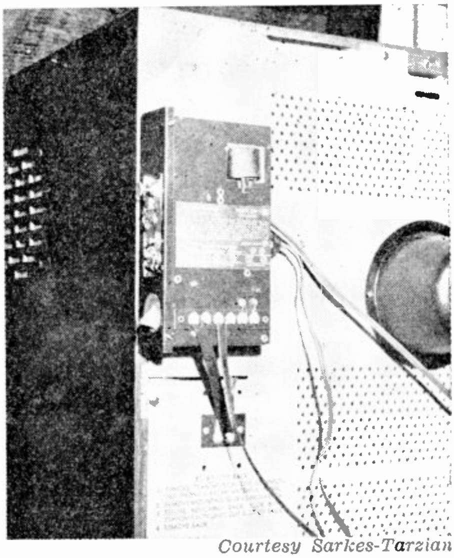
FIG. 30. A single-channel UHF converter.

the output from this stage is fed to the stationary contact marked 8. Coil L29 provides a tuned load in the output of the rf amplifier, and the signal is coupled to coil L30 which is connected to the mixer input. Coil L31 is the oscillator coil; on this channel, the signal is coupled through C42 to the mixer coil. The incoming signal and the signal from the local oscillator are fed into the crystal mixer.

The output signal from the mixer is fed to the converter transformer T1. The secondary of the converter transformer is connected to the cathode of the triode section of the 6U8 i-f amplifier. This tube is used in a grounded-grid circuit. The output signal from the triode section, is coupled through i-f coupling transformer T10 to the grid of the pentode section of the i-f amplifier, and the output from this stage is fed to the following video i-f stages.

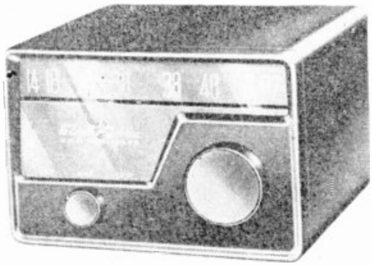
When the tuner is used on the UHF channels, the rf amplifier is not used. Let's examine the tuner circuit when the UHF strips marked G are in place. The signal from the antenna again is fed through the stationary contacts of terminals 1 and 2 to L54. L54 is inductively coupled to L52 through the link L53. The coil L52 connects to the mixer. The oscillator signal is mixed with the incoming signal, and the output fed directly to the triode section of the 6U8 i-f amplifier.

Notice the difference in the circuit of the tuner when it is used on UHF channels compared to the circuit on VHF channels. When it is tuned to a VHF channel, the rf stage is used before the mixer. However, when it is tuned to a UHF channel, the signal is fed directly to the crystal mixer—there is no rf amplifier. As we have pointed out previously, this is more or less standard practice, because it is extremely difficult to design an rf amplifier that will function efficiently at the high frequencies of the UHF channels. On the other hand, if the signal can be converted to a lower frequency immediately, then it can be handled with



Courtesy Sarkes-Tarzian

How a single-channel converter may be mounted on the rear of a VHF set.



Courtesy P. R. Mallory Co.
The UHF converter shown schematically in Fig. 31.

comparative ease.

Note that this tuner does *not* utilize the VHF rf amplifier as an i-f amplifier on UHF channels. The mixer output is at the receiver i-f frequency, and the VHF rf amplifier is completely out of the circuit when a UHF channel is being received.

UHF CONVERTERS

In theory, the process of UHF signal conversion is the same as that in the mixer stage of an ordinary superheterodyne receiver. However, UHF circuits differ considerably in physical appearance from the equivalent circuits for lower frequencies.

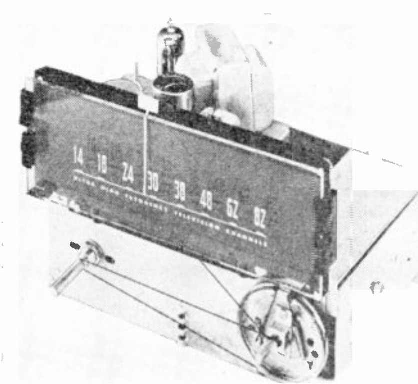
UHF tuned circuits require very low inductance and capacity. Therefore, the coils are apt not to be coils of the type that you are used to seeing at all. In a UHF circuit, an inductance "coil" is often a single loop of wire. Capacitance is usually supplied by the capacity between circuit elements rather than by a separate capacitor connected into the circuit. To ensure reliable values of capacity and inductance in UHF converter circuits and to keep the noise at a minimum, the old familiar mixer tube is replaced with a crystal mixer.

There are a number of different types of UHF converters on the market, and it is likely that they will be made for some time, because, as we have mentioned previously, many TV receivers are made to cover the VHF channels only, and when these sets are used in the UHF area, they must be used with a converter.

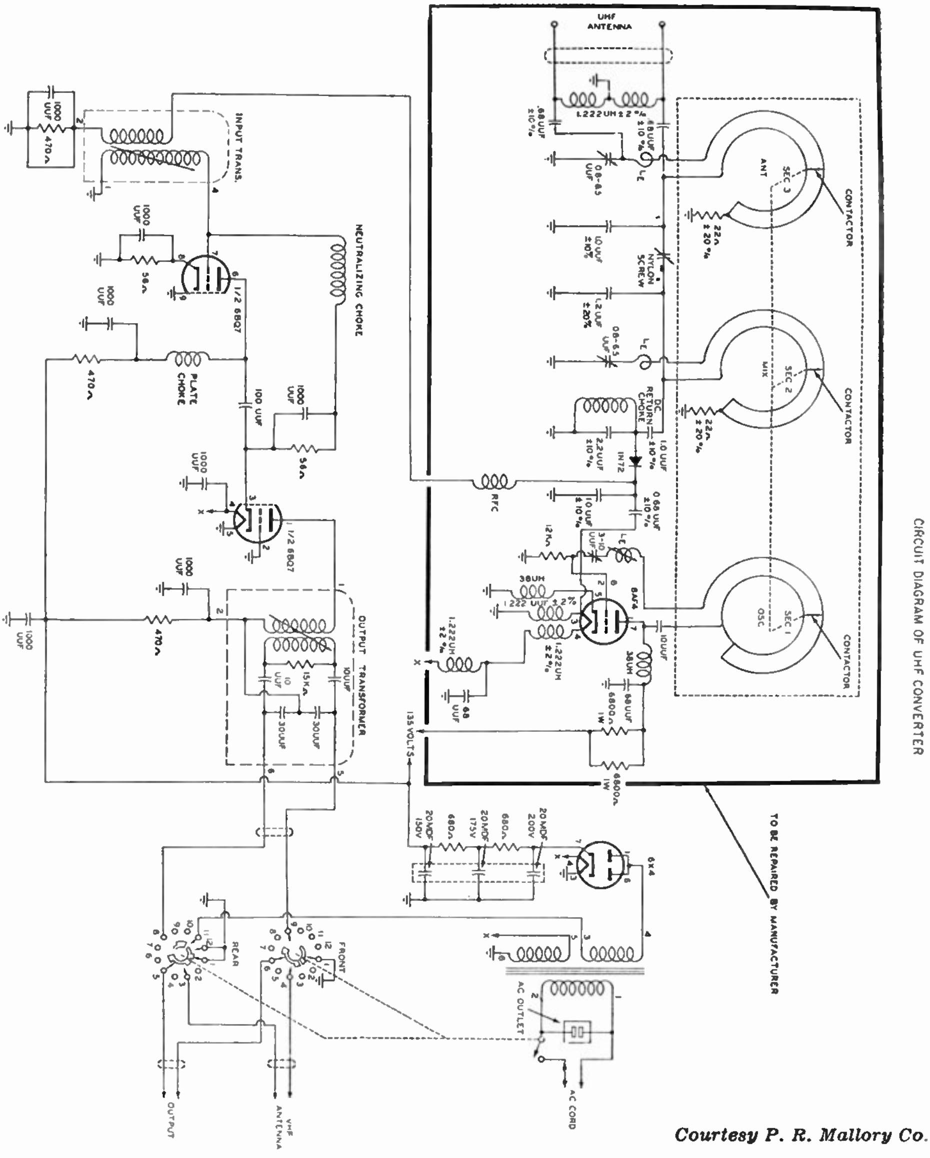
Practically all converters use the same basic principles we have talked about previously. The incoming signal is immediately mixed with a signal from a local oscillator to convert it to a lower frequency that can be handled more conveniently.

A simple single-channel UHF converter is shown in Fig. 30. Notice that the signal is fed to a crystal mixer and mixed with the local oscillator signal. The signal is converted to the frequency of one of the unused VHF channels so that the UHF channel can be received by tuning the set to the unused VHF channel. This particular converter is quite small and can be conveniently mounted on the rear of a TV receiver.

A more elaborate continuous tuning type of UHF converter is shown in Fig.



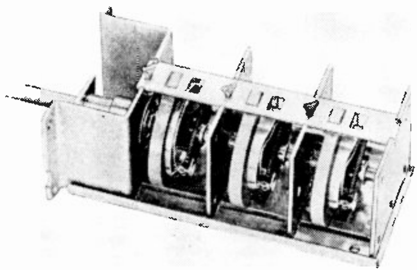
Courtesy P. R. Mallory Co.
Chassis of UHF converter shown in Fig. 31 removed from cabinet.



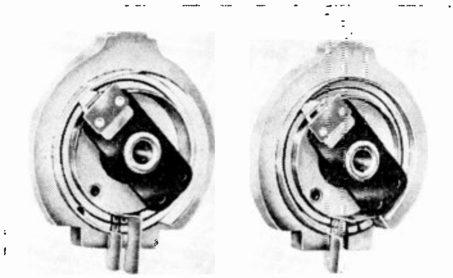
Courtesy P. R. Mallory Co.

FIG. 31. Schematic of a continuous tuning UHF converter.

31. This converter covers the entire UHF TV band. The signal is fed to a crystal mixer where it is mixed with the signal from the local oscillator. The output signal is fed to an i-f amplifier, which is an ac-coupled cascode amplifier. It operates in the VHF region, and the output from the converter is fed to a switching arrangement. The VHF antenna is connected to the converter. When the converter is turned off, the VHF antenna is connected to the output terminals on the converter. These terminals in turn are



Courtesy P. R. Mallory Co.
Coil assembly from Mallory UHF converter.



Courtesy P. R. Mallory Co.
Individual coils from Mallory UHF converter.

connected to the antenna input terminals on the VHF receiver. When the converter is turned on, the VHF antenna is automatically disconnected and the output of the converter connected to the output terminal.

Needless to say, we cannot discuss all the UHF converters on the market, but the circuits in any converters you are likely to encounter will be similar to those we have discussed.

Servicing Tuners

Fortunately, the most frequent source of trouble in tuners is defective tubes. Tubes may often test good in a tube tester or work satisfactorily in another circuit, but fail to work properly in a tuner. Whenever a defect has been isolated to the tuner, if there is the slightest possibility that the trouble may be due to a defective tube, new tubes should be tried.

In replacing the oscillator tube in a tuner it may be necessary to align the oscillator circuit. You will very seldom find two tubes that have exactly the same interelectrode capacities. Therefore, when you change oscillator tubes, since the capacities are very critical at the VHF and UHF frequencies, some re-adjustment of the oscillator circuit may be necessary. If the oscillator is easily aligned, as in tuners having a separate adjustment for each channel, this is not too much of a problem. However, if the tuner is of the type where the adjustment of one channel affects the other channel, as in the tuners shown in Figs. 25 and 26, it is usually worth while to try several oscillator tubes in the circuit, in the hope of finding one having approximately the same interelectrode capacities as the original tube, so that alignment will be unnecessary.

When the defect is something other than a tube defect, you may find it somewhat difficult to repair the tuner. The difficulty usually stems from the fact that tuners are so compactly made that it is difficult, in fact almost impossible in some cases, to get at the defective part to make the necessary replacement. However, some tuners are easier to repair than others, and in the following section we will go into some of the commonly encountered defects and how to repair them.

TURRET TUNERS

The turret tuner is the easiest type of tuner to repair, because when necessary, the entire drum can be removed so you can get at any of the parts in the tuner in order to replace them. In addition, if a defect affects only one channel, the chances are that replacing the strips used on that channel will clear up the trouble.

One of the most common troubles in this type of tuner is noise due to failure of the contacts to make a good connection. This often happens simply because the contacts have become dirty. Contact cleaning strips are available, and they can be installed in this type of tuner by removing an unused set of strips and inserting the cleaning strips in their place. They have a very fine abrasive in place of the metal contacts on a regular strip, which tends to clean the stationary contacts as it passes over them. Contact cleaning strips will reduce the amount of trouble you are likely to encounter from dirty contacts.

If the contacts are already dirty when you are called in to service the tuner, the best procedure to follow is first to clean them to remove the dirt that has already accumulated on the contacts, and then insert a set of contact cleaning strips. You can clean the contacts on the individual strips by wiping them off with a rag with a suitable solvent applied to it. You can buy non-inflammable solvents from your local wholesaler. However, this usually will not eliminate the difficulty. The stationary contacts inside the tuner must also be cleaned. To clean these contacts, the drum must be removed from the tuner.

In some receivers, the drum can be removed from the tuner without even removing the tuner from the chassis. However, it is generally more convenient to work on the tuner if it is removed from the chassis, and since there are only a few leads connecting to the chassis, it is not too difficult to disconnect them so the entire tuner assembly can be removed.

To dismantle the tuner, first locate the screw on the plate of the fine-tuning condenser. Remove this screw, and the top plate will come off. You will now find it possible to slide the fine tuning shaft off the selector shaft. A brass spring is now visible on the selector shaft; it should be removed. If there is a washer under the spring, it too should be removed.

Next, you'll see a spring, with a roller mounted on the end of it, on the side of the tuner. The roller fits into notches in the metal ring separating the two sets of strips. The spring-loaded roller snaps into a notch to hold the tuner in position. Locate the screw holding the spring in place, and remove the screw, the roller, and the spring.

The drum is held in place now only by two wire springs, one at each end of the shaft. With a large pair of pliers, grasp one spring near the end and move it so that it clears the notch in the tuner case. It will come away so that you can remove the spring. Do the same to the spring on the other end of the tuner and the drum will come out. Once you have removed the drum, you can get at the stationary contacts to clean them, or you can get at the parts inside the tuner to make any necessary repairs. Incidentally, if you remove the drum to clean the contacts, be very careful not to move wires or parts inside the tuner, as the position of these parts is very critical.

Except for replacing the channel strips and cleaning the contacts, you will seldom have to repair this type of tuner. Kits of parts that you are likely to need in repairing a tuner of this type are available from most wholesalers.

If you dismantle a tuner to repair it, clean the contacts and then renew the lubricant at the points of contact between the drum shaft and the tuner chassis. A small amount of a conductive lubricant (one containing graphite such as Grapholine) should be used on both ends of the shaft and on the detent ring.

STEP TUNERS

Step tuners using rotary switches such as the tuners shown in Fig. 25 and 26 are not as easily repaired as the turret tuners. There is no drum that can be removed from this type of tuner to enable you to get to the defective parts. Often it is extremely difficult to reach a defective part to make the necessary replacement.

One of the most common troubles in this type of tuner, other than tube defects, is in the failure of the rotary switch to make a good contact on one or more channels. This is usually because the contacts are either dirty or sprung.

If the contacts are dirty, cleaning them with a suitable solvent will often clear up the difficulty. To get the solvent on the contacts, many servicemen put the solvent in a small oil can that has a long nozzle. The nozzle can then be placed right on the contacts causing the trouble, the solvent readily applied to the contacts, and then the channel selector switch rotor worked back and forth. This will usually clear up trouble caused by dirty contacts.

When the contacts are sprung, the difficulty can be overcome by bending the sprung contacts slightly. To do this, rotate the channel selector switch to a channel other than the inoperative one, and then bend the contacts very slightly with a screwdriver or some similar object. You can bend the contacts slightly so that the rotating blade (wiper) of the switch will make a better contact. However, you must avoid pushing the contact too far, otherwise it will bind on the wiper. If you should find, in attempting to make a repair of this type, that you bent the contact too much, do not try to force the switch into position. Instead, try bending the contact back slightly. If you try to force the switch, you simply break either the stationary or the rotating contacts.

A common trouble, encountered in older tuners of this type, is that instead of snapping from one position to another, the tuner shaft rotates freely. When this happens, the set owner often fails to position the tuner shaft properly, so that all the contacts are making good connection.

Normally the switching mechanism in this type of tuner is locked in position by a ring, a spring, and a steel ball. The ring has a series of holes, arranged in a circle, in it. The spring is attached to the tuner shaft, and the ball bearing is positioned between the spring and the ring. The ring is called a detent ring and the shaft the detent shaft. Eventually, the metal in the spring may lose its temper and become soft, and when this happens it no longer snaps the ball bearing in place. The ball may drop out and then the tuner shaft can simply be rotated freely.

This difficulty can be overcome by replacing the detent shaft. Replacement shafts are available from most large wholesalers.

To replace the shaft, you must first remove the fine tuning shaft. To remove the fine tuning shaft, the springs

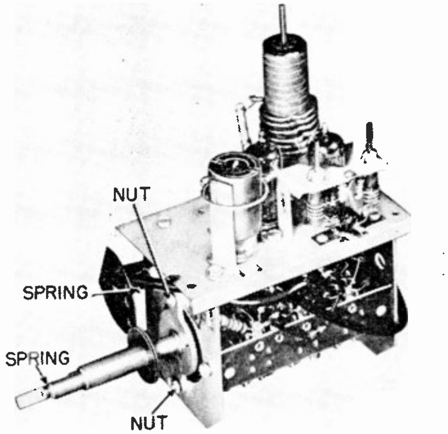


FIG. 32. Photo of a tuner showing the springs and nuts that must be removed to install a new detent.

shown in Fig. 32 must be removed. These springs can be removed by working them out with a screwdriver. Once the springs have been removed, the fine tuning shaft can be slipped off the main tuning shaft.

After you have removed the fine-tuning shaft, the two nuts marked C and D can be removed and then the detent ring and the entire tuning shaft can be slipped out of the tuner. The spring marked E can then be removed and the shaft slid out of the detent ring assembly and a replacement shaft complete with spring installed.

When the new shaft is installed in the tuner, you must avoid forcing it through any sections of the switch. Rotating the shaft slightly back and forth should enable you to work it through the various sections of the switch without the necessity of forcing it. When assembling the shaft and the detent ring, be sure to put the ball bearing in place before you slide the shaft back inside the tuner. CAUTION: Do not move switch wafers while shaft is out.

When it is necessary to make electrical repairs in this type of tuner, you'll find that a soldering iron with a long thin point is invaluable. There is no extra space in this type of tuner; there certainly is not enough room to enable you to work with a large blunt soldering iron.

CONTINUOUS TUNERS

The continuous tuner shown in Figs. 27 and 28 is not much easier to work on than the step tuner that we have just discussed. However, it is usually possible to make any necessary repairs. A common trouble in this tuner is noise as you tune from one channel to another. Sometimes this noise occurs intermittently when a TV station is tuned in. This usually indicates that one of the sliding contacts is not making good contact on one of the coils. This may simply be caused by dirt.

The variable inductances are shown in Fig. 27. This unit is usually completely shielded when mounted on the tuner. However, the shielding can be removed from the top of the unit so that the coils will be out in the open as shown in Fig. 27. Once you have removed the shielding the coils can be cleaned by applying a cleaning solvent. After you have cleaned the contacts, you should apply a small amount of conductive lubricant. If you find that the sliding contacts are dirty, use an oil can to drop some solvent on the contacts and then rotate the tuner shaft back and forth to work the solvent onto the contacts.

A common mechanical defect encountered in this tuner is that the shaft on which the coils are mounted may break at the front where it is coupled to the tuning mechanism. Frequently a broken shaft can be repaired so that you can continue to use the tuner.

To repair the shaft, the first step is to move the sliding contacts so that they will be at one end of the coil, placing all the inductance in the circuit. Next, tune the dial to the low-frequency end of the band. Then, carefully set the sliding contacts so that the fingers on the contact ride properly on the coils and at the same time ride in the center of the metal slides fixed to the insulation on the bottom of the tuner frame. Carefully rotate the shaft enough to line up the broken ends to a perfect fit, and then glue the broken shaft. The glue sold under the trade name of *Liquid Solder* will usually make a fine strong joint if the directions for using it are carefully followed.

As soon as the glue has been applied, make sure that the two pieces of the shaft are in perfect alignment. If the two pieces of the shaft are not lined up perfectly, the coils will ride up and down as they are rotated, with the result that the sliding spring will either make poor contact or slip off the coil completely. Allow twenty-four to forty-eight hours for the glue to harden before attempting to use the tuner.

If you are unable to repair the tuner in this way, a new variable inductance unit may be obtained and installed in the tuner, or else a complete new tuner can be obtained.

OTHER TUNER DEFECTS

Since there are many different types of tuners, there are many defects that you might encounter. However, most of the defects in tuners are due to either tube failure or mechanical defects. By carefully studying the tuner as you rotate from one channel to another, you can generally see the various contacts that are made on each channel. If a defect is mechanical, and is due to the failure of one of the contacts to make a good connection, using an insulated alignment tool, carefully touch the contacts and apply a small amount of pressure to them one at a time to find the one making poor contact. Once you have located the contact causing the trouble, you can usually eliminate the difficulty either by cleaning it or by bending it slightly as described previously.

A few tuners have been made using afc (automatic frequency control) on the oscillator. Very often this type of tuner does not have any fine tuning control; therefore as the tubes and parts in the oscillator circuit age, the oscillator frequency may shift so far that the afc is unable to pull the oscillator back to the correct frequency. This difficulty can be overcome by readjusting the oscillator to bring it back to the correct frequency. Very often it is worth while to try a new oscillator tube in the circuit. Usually when the oscillator tube starts to drift, it will continue to give trouble.

A few tuners use circuits where the oscillator tube is extremely critical. Sometimes it is necessary to try several oscillator tubes before you will find one that operates satisfactorily. If you suspect that the oscillator is not operating, try feeding an i-f signal into the mixer to see if a signal can get through the receiver. You can use a modulated rf signal; set the frequency to the middle of the i-f pass-band. If the signal gets through the receiver, a series of wide horizontal bars will appear on the picture tube. If the i-f signal does get through, change the signal generator frequency to one of the TV channels (preferably one of the channels causing the trouble), tune the channel selector switch to that channel to see if the horizontal bars still appear on the picture tube. If they do not, you can be sure that the oscillator is not operating, but before tearing into the oscillator circuit looking for a defective part, it is usually worth while to try at least two or three tubes, in case the first one you try fails to clear up the trouble.

TUNER ALIGNMENT

Fortunately, with the exception of the oscillator circuit, tuners seldom require alignment. Tuned circuits in the rf and mixer stages are usually so broad that they will not drift far enough to cause any trouble. However, if it is necessary to replace a part in one of these tuned circuits, you may find that you'll have to realign the circuit, but normal aging of the components and tubes will seldom cause any trouble.

The oscillator circuit, however, will drift far enough in frequency so that some adjustment will be required. This is particularly true of the older tuners, which lack the stability found in the oscillator circuits of newer tuners.

In a turret-type tuner, where new coils are switched into the circuit for each channel, a slug is usually inserted in the oscillator coil. The slug can be reached with a long alignment tool inserted from the front of the reeciver. It is not usually necessary to remove the set from the cabinet. When adjusting the oscillator slug, set the fine tuning control in its mid-position, turn the channel selector switch to the desired channel and adjust the oscillator slug until you receive the correct TV channel.

If you turn the slug in too far, the slug will slide on into the coil. When this happens, you must remove the strip from the tuner and then get the slug out of the coil. In most turret tuners the slug is threaded and the thread simply works through a spring on the

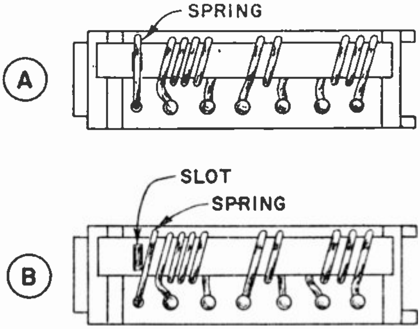


FIG. 33. How to get the oscillator coil slug back in place when it is run in too far.

side of the coil. If the slug drops inside the coil, lifting the spring as shown in Fig. 33 will clear the way so the slug can be shaken out of the coil. Once you have removed the slug, you can put the spring back in position, and then screw the slug back into place.

Incidentally, when adjusting a turret-type tuner, you have to be careful that you get the correct channel. Usually there is sufficient range in the oscillator adjustment so that you can adjust the oscillator to get a channel above or below the desired one. For example when adjusting the coil for channel 7, if you turn the slug too far, you may find that the station operating on channel 9 comes in on the channel 7 position.

In the tuners shown in Figs. 25 and 26, you know that they are changed from channel to channel by adding inductance in the circuit. A certain amount of inductance is placed in the circuit on channel 13. When you tune to channel 12, you add inductance to the circuit. Therefore, if the adjustment for channel 13 is off, and you correct this adjustment, you can expect it to have some effect on the channels below channel 13 because the inductance for channel 13 is a part of the tuned circuit for every other channel. Therefore, when it is necessary to make any adjustments on the oscillator circuit in this type of tuner, you should tune the tuner to the highest channel and make any necessary adjustments, and then go to the next channel and so on until all channels have been adjusted. Of course, you will probably have a number of channels on which no stations are received. Needless to say it is not necessary to adjust these channels unless the adjustment is so far off that it is affecting lower channels.

For example, if you have a station operating on channel 10 and also one operating on channel 8, you may find that when you try to adjust the oscillator for channel 8, you are unable to bring in the station. If you received a station on channel 10 properly, set the oscillator adjustment for channel 8 approximately in the mid-position and then try adjusting the channel 9 oscillator adjustment. Note approximately how many turns you rotated it so you can return it to its original position if this fails to clear up the trouble. However, often you'll find that adjusting channel 9 causes the picture to begin to appear on channel 8, and then the final adjustment can be made on the channel 8 adjustment. Since the coil added for channel 9 is still in the circuit when you switch to channel 8, if its inductance is too far off, it may affect channel 8 and the other lower channels.

Whenever it is necessary to align a tuner, it is imperative that you obtain the manufacturer's alignment instructions. There is no standard procedure for aligning tuners. It varies from tuner to tuner. You must know exactly what shape of response curve you are to obtain from the tuner, if you are going to do a complete alignment job. Remember, that as we already pointed out, in many cases the tuner response is deliberately peaked to make up for deficiencies in the i-f response. Therefore, unless you know how the response curve is supposed to be shaped, and also the order in which the various tuner adjustments are to be made, you should not attempt to align the tuner. You can seldom improve the tuner's performance by attempting to align it when you do not know how it should be aligned, but you can very easily upset the performance of the entire receiver.

UHF TUNERS

Servicing UHF tuners and UHF converters is similar to servicing VHF equipment. In a UHF tuner, in addition to the possibility of defective tubes, there is also the possibility of a defective crystal. When soldering a replacement crystal in place, avoid heating the replacement crystal any more than is absolutely necessary. Crystals are delicate and easily damaged by excessive heat.

The oscillator tubes used in UHF tuners are far more critical than those used in VHF equipment. Sometimes a tube will fail to oscillate for no apparent reason in one converter, although it might work fine in another. In another occasion the distributed capacity may be so far off in one tube that you cannot even locate the desired channel when the tube is in the circuit. Several replacements should be tried until satisfactory results are obtained.

It should not be necessary to make any alignment adjustments in the mixer circuit of a UHF converter. The input circuit of these converters is extremely broad and will pass the 6-mc TV channel and in most cases 20 to 30 mc on each side of the channel. Any adjustments on the oscillator must be made carefully and slowly. Usually the oscillator can be tuned over a very wide frequency range and if the oscillator adjustment is made rapidly, you may pass right through the frequency of the TV station.

SUMMARY

Summarizing, we can say that tuners are often somewhat difficult to repair because of their compactness and the difficulty of getting at the defective components. Turret tuners are usually the simplest types to repair. Tubes are critical; a tube may fail to work in a tuner for no apparent reason; you should try replacement tubes, rather than rely on a tube tester. Alignment is seldom needed in any circuit other than the oscillator circuit.

Many tuner troubles are due to open resistors or shorted capacitors. These defects can be located in the same way as you would locate similar defects in an ordinary broadcast receiver. An ohmmeter and/or a voltmeter can be used to locate these defects.

Lesson Questions

Be sure to number your Answer Sheet 52B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of lessons before new ones can reach you.

1. What stages are usually found in a VHF tuner?
2. Is interference from the channel immediately above the channel to which the set is tuned likely to be adjacent-channel sound or adjacent-channel picture interference?
3. What type of mixer is usually used in a UHF tuner or converter?
4. What is the chief advantage of a triode mixer over a pentode?
5. What is the most common mechanical trouble encountered in turret-type tuners?
6. What is the most common electrical trouble encountered in tuners?
7. Would you expect to find a fine-tuning control on a continuous tuner?
8. In the circuit shown in Fig. 29, what resistance reading would you expect to obtain on an ohmmeter when measuring between pins 2 and 6 of the 6BQ7A?
9. If a tube tester indicates that a tube is good, does this necessarily mean it will work satisfactorily in the oscillator stage of a TV receiver?
10. When adjusting the oscillator coil slug in a turret-type tuner, where would you set the fine tuning: *fully clockwise; fully counterclockwise;* or *in the mid position?*

ALL MEN WANT TO SUCCEED

Here's a quotation I ran across the other day that made me think of several fellows I know:

"All men want to succeed. A few men want success so badly that they are willing to work for it."

Isn't it true that almost every fellow you know *wants* success, *wants* more money, *wants* security?

But how many of these men are willing to buckle down and study—work—think—to get the good things they want?

It is very true that only *comparatively few men* are really willing to work for success.

You are one of those few men. You have proved this fact by enrolling for the NRI course—by working to complete many of your Lessons. *You* are taking the first and most important step toward success.

J. E. Smith

VIDEO I-F AMPLIFIERS AND VIDEO DEMODULATORS

53B

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE NO. 53

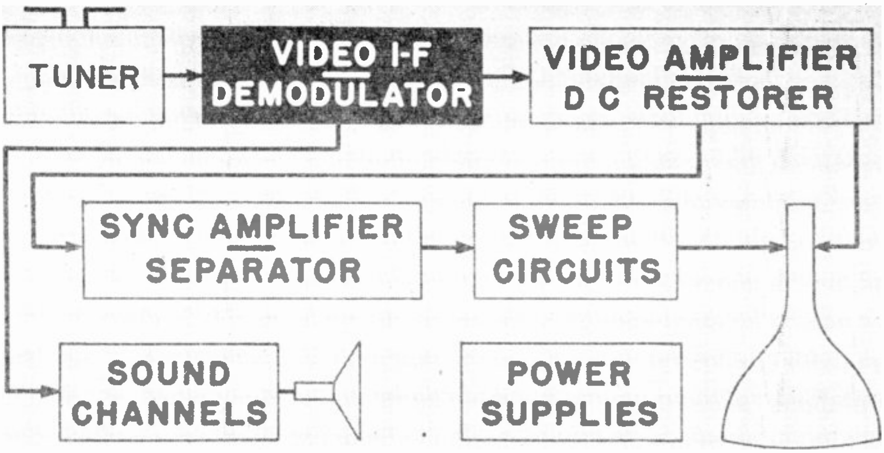
For each study step, read the assigned pages first at your usual speed. Re-read slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

(An Affliate of the National Radio Institute)

FM3M260

1960 EDITION

Printed in U.S.A.



IN A previous lesson you learned that the tuner in the television receiver selects the desired signal and, by a heterodyning process, converts it to an intermediate frequency signal. The section following the tuner, *the video i-f amplifier,* must amplify the weak output signal from the tuner to a satisfactory level for application to the video demodulator. The i-f amplifier system passes two signals—the picture signal and the FM sound signal. Its ability to amplify these signals and pass them with fidelity is extremely important. To get a better understanding of what is required, let us briefly describe the four major requirements of the video i-f system.

Band Width. The video i-f system must have adequate band width to pass the wide band of frequencies necessary to carry the picture detail.

Sensitivity. The video i-f system must provide not only adequate amplification for the strong incoming signal, but also must be able to handle a wide range of signal amplitudes. It must not overload on strong signals, and it must have the sensitivity required to amplify a very weak signal so that it can be reproduced as an adequate picture.

Reception of Vestigial Sideband Transmission. The video i-f system must have a properly shaped response pattern. As you have studied in previous lessons, one sideband of the transmitted video signal is suppressed so as to conserve the frequency spectrum and obtain the best possible resolution (picture detail) in the assigned six-megacycle channel. The video i-f system, then, must compensate properly for this suppression.

Selectivity and Rejection of Interference. Because TV tuners do not have the selectivity needed to reject interfering signals close to the frequency of the TV channel, the video i-f amplifier must provide the selectivity required to eliminate these undesired signals. Special resonant circuits called traps are used to sharpen the response drop-off at the ends of the desired spectrum. (The ends thus formed are called "skirts.")

Let us now consider each of these characteristics in detail, and find out how each affects the design of the video i-f amplifier and the overall response curve obtained from its output. This knowledge of how each factor influences the video i-f response is helpful because often it is possible to determine the most likely source of trouble by noting the type of disturbance in the reproduced picture.

BAND WIDTH

You can best understand the need for the wide band i-f system by studying the frequency spectrum transmitted by a typical television station. Fig. 1 shows the frequency spectrum for channel 2. Notice that a channel 2 station is assigned the frequencies between 54 and 60 megacycles; the picture carrier is at 55.25 mc and the sound carrier is 59.75 mc.

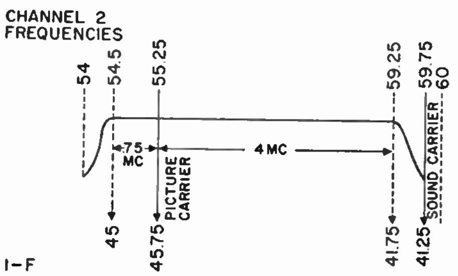


FIG. 1. Transfer of signal to i-f range by tuner. The local oscillator is operating at 101 mc.

The low-frequency sideband portion of the amplitude-modulated picture carrier is partially suppressed. The linear amplification on this side extends down to 54.5 mc. As this point the response must drop off in 0.5 mc to zero level at the channel boundary of 54 mc.

The high-frequency sideband (above the carrier frequency), on the other hand, extends out *linearly* to 59.25 mc. This four-megacycle high-frequency sideband is needed to convey the fine detail of the picture. Therefore, any frequency in this sideband must be faithfully amplified and passed on to the video demodulator at the output of the video i-f system.

In the next .5-mc range, between 59.25 mc and the sound carrier frequency, the response pattern again falls off to zero. This prevents the video signal from interfering with the frequency-modulated 59.75-mc sound carrier and its sidebands. In the intercarrier i-f system used in modern receivers, the sound carrier frequencies must be passed through the i-f amplifier at a reduced amplitude to prevent them from causing interference in the video range. Finally, an additional .25-mc range exists between the sound carrier and the band-end frequency of 60 mc.

When the station selector of your television receiver is set to channel 2, the input of the receiver accepts the entire range of frequencies from 54 mc to 60 mc, which includes the carriers and all the sideband components. In the tuner, these signals are heterodyned with a local oscillator signal. A typical frequency for this local oscillator, when the receiver is tuned to channel 2, is 101 mc. The video i-f, then, is made resonant to the *difference* frequencies present at the output of the mixer.

You may calculate the signal frequencies passing into the i-f amplifier from the tuner output by subtracting the various frequencies indicated in Fig. 1 from 101 mc. Thus, for channel 2, the picture i-f carrier frequency in the i-f strip will be 45.75 mc (101 minus 55.25) and the sound i-f carrier 41.25 mc (101 minus 59.75). Note that when the carrier frequencies are subtracted from the local oscillator frequency, the sound i-f carrier is lower than the picture i-f carrier.

If the transmitted signal contains a 59.25-mc sideband, this signal will appear at a frequency of 41.75 mc in the

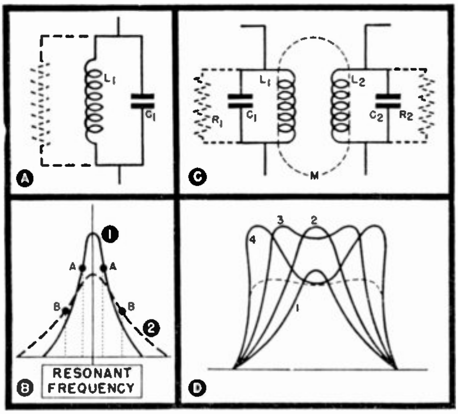


FIG. 2. How the addition of load resistors affects the band width of A, a single-tuned resonant circuit; and C, a double-tuned over-coupled transformer.

video i-f amplifier. The video i-f amplifier must pass this signal. Since the video i-f carrier is 45.75 mc, the video i-f amplifier must have a band width of 4 mc to do this, so that a picture can be reproduced with the same detail as that produced by the television camera.

How Wide Band Width is Obtained. In your lesson on tuners, we discussed the basic methods of obtaining a wide band width. Let us review a few significant facts.

A conventional single-tuned parallel resonant circuit, shown in Fig. 2A, has the peaked response indicated by the solid line in Fig. 2B. The height of this peak depends on the Q of the circuit; if the Q is high, the peak will be high. When load resistors are connected across the resonant circuit, the peak is reduced, and at the same time, the bandpass of the circuit is increased as indicated by the dashed curve.

It is customary to consider that the bandpass includes all the frequencies whose amplitudes are 70% or more of the peak. Thus, the bandpass of curve one, from A to A, is considerably narrower than the bandpass of curve 2, from B to B. As the loading of the resonant circuit is increased by connecting smaller and smaller value resistors across it, the band width becomes greater because the peak is lowered even more.

An important factor to note, however, is that with this reduced peak and broader band width, the gain of the stage associated with the resonant circuit becomes lower. Consequently, to obtain sufficient gain from a video i-f system, you must use many more i-f stages than are usually used in a radio receiver.

Another method of obtaining a broad band width is to use an over-coupled, double-tuned resonant transformer, illustrated in Fig. 2C. In this method, the degree of coupling as well as the individual loading of the two resonant circuits determines the band width and stage gain.

For example, curve 1, in Fig. 2D, represents rather loose coupling, where the linkage between the two resonant circuits is not close. Increasing the coupling by moving the windings nearer to each other or by providing an easier coupling path increases the output to a maximum, as illustrated by curve 2.

The coupling at this point is called critical coupling. If the coupling is increased beyond this point, it is called over-coupling, and the over-all response becomes double-humped as indicated by curve 3. The band width is substantially greater than that shown in curve 2. A further increase in the coupling produces curve 4, which shows a wide separation between the humps and a deep valley center between them. By shunting the primary and secondary windings of the resonant transformer with resistors, the double humps can be re-

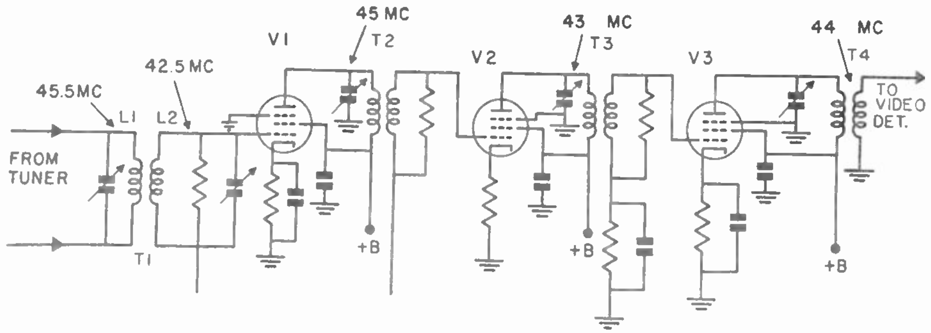


FIG. 3. General plan of a wide band amplifier.

duced to the same level as the valley producing the dashed curve. As you can see, this method produces a very wide band width, but it also lowers the amplitude considerably. As with the method described previously, you have to use additional i-f amplifier stages to obtain the necessary gain.

A wide-band system could be designed using either the single-tuned type of resonant circuit or the over-coupled type of resonant circuit. However, each resonant circuit would have to be loaded properly and tuned to the same frequency to give the required overall gain and the proper band width.

In actual practice, however, although the same basic principle of loading the resonant circuit is used, the individual resonant circuits are tuned to *different* frequencies. This technique, called *stagger tuning*, permits an individual resonant circuit to have a fairly high Q because its band width does not need to be as great as the over-all band width required of the entire amplifier system. (However, the responses are still not peaked.) In addition, the use of stagger tuning improves the stability of the amplifier system because there is less likelihood of feedback and consequent oscillations at any one frequency in the i-f range.

It is possible to use a stagger-tuned arrangement with either the single-tuned coil or the double-tuned transformer. The double-tuned transformer can be over-coupled or not, depending upon the amplifier design requirements. In fact, in a number of receivers, one over-coupled transformer and three or four single-tuned resonant circuits are used. A rather common arrangement is illustrated in Fig. 3.

By properly choosing the frequencies for the various resonant circuits, we can obtain a symmetrical, broad-band response for this amplifier, as shown in Fig. 4. As an example, let us suppose that the center frequency of the pass band is to be 44 mc. Therefore, the input resonant circuits are set for the band edges of 42.5 mc and 45.5 mc as illustrated by the response curves for L1 and L2 in Fig. 4. Two

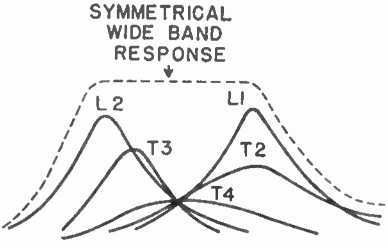


FIG. 4. Proper choice of frequencies for the various resonant circuits shown in Fig. 3 will give the symmetrical overall curve shown by the dashed lines.

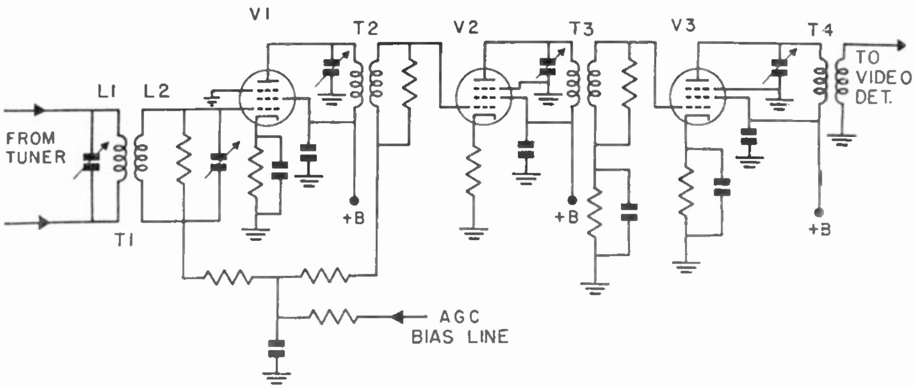


FIG. 5. Addition of agc bias to a wide-band amplifier.

of the intermediate single-tuned transformers are adjusted to 43 mc and 45 mc, and the final one is set at center frequency, or 44 mc. The over-all response curve for the amplifier system, which is the total gain of the individual curves, is shown as the broad symmetrical curve in Fig. 4.

Because of other requirements and problems in a typical television receiver, such a symmetrical response for the video i-f system cannot be used. In fact, the over-all response curve must be non-symmetrical. Therefore, let us discuss these other requirements and notice the changes that must be made in the basic amplifier to obtain a desired over-all non-symmetrical response.

SENSITIVITY

The sensitivity requirements of the i-f amplifier are very strict. Not only must the television receiver accept a wide range of frequencies, but also it must be sensitive enough to amplify weak signals as well as strong ones adequately. For example, many locations have local VHF stations and are at the same time in the fringe area of other VHF stations. Thus, the i-f system must be able to offer maximum amplification and sensitivity to a weak signal, but not overload or distort when on a strong local signal.

Earlier receivers often had a contrast control in the video i-f system so the owner could adjust the gain of the i-f strip according to the strength of the incoming signal. This method was undesirable because the owner had to readjust the control for each station, and the contrast control adjustments changed the shape of the video i-f response curve.

In the modern television receiver, the gain of the video amplifier system is automatically regulated by a circuit called the "automatic gain control" or "agc" system. The agc system develops a dc bias for the i-f stages according to the received signal strength. Consequently, when a strong signal is received, the agc system places a high bias on certain of the video i-f amplifier tubes. The high bias reduces the amplifier gain and prevents overloading of the i-f stages.

When a weak signal is being received, the bias decreases to permit maximum amplification and highest sensitivity to the incoming signal. The addition of an agc system to the basic wide band amplifier of Fig. 3 is shown in Fig. 5.

A defect in the agc system usually shows up as an i-f amplifier defect.

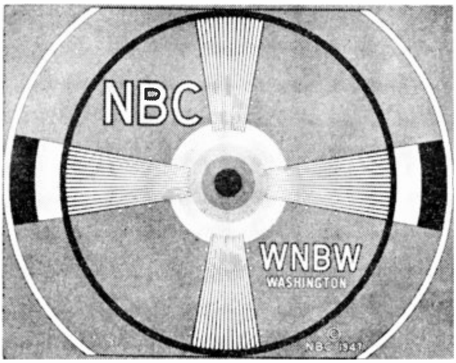


FIG. 6. Normal halftone picture (left) compared to overcontrasty picture with i-f system overload.

For example, if any type of defect in the agc causes a permanently high bias to be applied to the video i-f amplifier stages, the sensitivity of the receiver will be poor, preventing the reception of weak signals. Likewise, a defect in the agc system can cause a low bias on the i-f tubes when a strong signal is received. This will result in overloading of the i-f amplifier, causing clipping of the i-f signal and loss of control of the horizontal and vertical deflection circuits. This same type of defect could also cause an overcontrasty picture—the picture loses its tonal range and the video is concentrated in the form of blacks and whites with very few gray tones in between. The effect of this condition on the picture is shown in Fig. 6.

RECEPTION OF VESTIGIAL SIDEBAND TRANSMISSION

As mentioned previously, to obtain the best picture detail in the 6-mc allocated channel, one sideband must be partially suppressed. This method of transmission is called vestigial sideband transmission. Let us see exactly what it means and what can be gained by using this type of transmission.

You already know that when an rf carrier is modulated, the modulating signal produces sidebands. For example, if a 1000-kc signal is modulated by a 1 kc audio signal, sideband frequencies of 999 kc and 1001 kc are produced. (Note that the sidebands extend the same distance on each side of the carrier signal.) Similarly, when a carrier is modulated by a video signal, two sidebands are produced. If the frequency of the video signal is 4 mc, and the carrier frequency is 60 mc, the lower sideband would be 56 mc, and the upper sideband 64 mc. In other words, the band of frequencies occupied by the carrier and sidebands would extend from 56 to 64 mc, or over a band width of 8 mc! To amplify this band width adequately, the design of the i-f amplifier system would have to be very critical.

Of course, we could eliminate one of the 4-mc sidebands by means of filters. However, we would lose half of our power, and reduce the reception range. Also, this reduced power would produce some amplitude distortion. Therefore, in actual practice, *vestigial sideband transmission* is used. This is a *compromise* arrangement giving a band width between the band width required for the transmission of only one sideband and that required for the transmission of both sidebands.

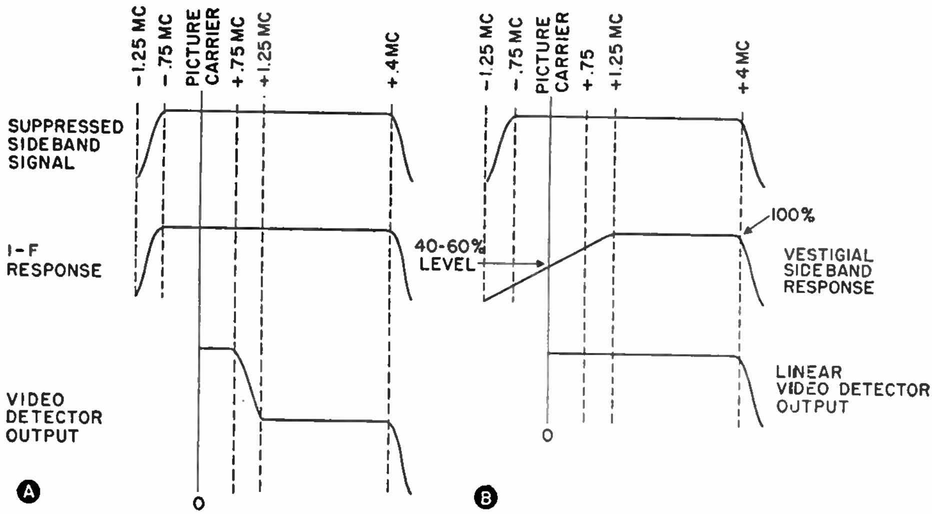


FIG. 7. Response curves showing need for a symmetrical video i-f response with partial sideband suppression.

In television, the practice is to transmit the entire upper sideband and a small portion of the lower sideband. The rest of the lower sideband is attenuated by means of filters at the transmitter. As a result, if the video signal that modulates the transmitter is a low-frequency video signal, both the upper and lower sidebands are transmitted. On the other hand, if the signal is a high-frequency video signal, only the upper sideband is transmitted. Let us now refer to the response curves in Fig. 7 to see how vestigial sideband transmission affects the design of the video i-f amplifier system.

As shown in Fig. 7A, video modulation frequencies up to .75 mc above and below the carrier signal are transmitted at full amplitude; those between .75 mc and 1.25 mc are transmitted at full amplitude on the high-frequency sideband, but attenuated on the low-frequency sideband, and those over 1.25 mc are transmitted only on the high-frequency sideband.

The video detector develops an output signal whose amplitude at a given frequency is the sum of the amplitudes for that frequency in both sidebands. If a wide band i-f amplifier had a symmetrical response, the video detector would produce a stronger signal component for sideband frequencies up to .75 mc (total amplitude of the upper and lower sidebands is highest), a lesser output for sidebands between .75 mc and 1.25 mc (lower sideband is partially suppressed), and a minimum output for frequencies between 1.25 mc and 4 mc as shown in Fig. 7A. Thus, the low frequency components of video information would be stronger at the output of the video detector than the high-frequency components, although both components might have originated at the camera tube with equal amplitude. Poor response at high frequencies and emphasis of low frequencies would destroy the picture detail.

To equalize the over-all response of a television system in which partial sideband suppression is used it is necessary to have a non-symmetrical video i-f response curve as shown in Fig. 7B. The actual video i-f carrier occurs at approximately 50% of maximum amplitude. In fact, the video i-f curve has a linear tapered response from approximately 1.25 mc on the high-frequency side of the carrier frequency. Thus, the video sideband components below 1.25 are given less amplification as they pass through the video i-f amplifier, but the modulation components above 1.25 mc are amplified fully. As a result, the output at the video detector is equalized. The over-all response of the system becomes linear from low frequencies up to near the 4-mc limit.

It should be apparent how important the alignment of the video i-f system is. The video i-f carrier must be somewhere between the 40% and 60% limits on the video i-f response curve. If the picture carrier is too high on the response curve, the lows are emphasized more than the highs, and the picture detail suffers, as shown in Fig. 8. If the picture carrier is too far down on the response curve, the actual carrier level is reduced, and sync stability and sensitivity in the reception of a weak fringe area signal are poor.

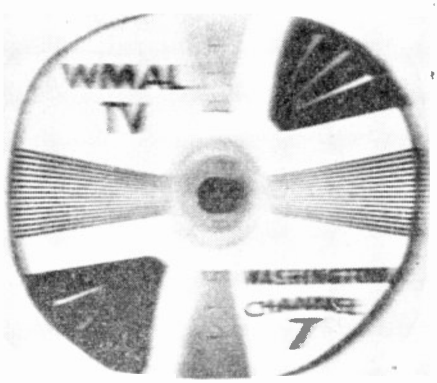


FIG. 8. Loss of picture resolution.

In the adjustment of a receiver for fringe area reception, the picture carrier is sometimes located above the 70% point on the response curve. This modification improves sensitivity and synchronizing stability in the reception of weak signals. The loss in picture detail is not noticed because of the high noise level (snow) that already exists in the weak-signal picture.

How the Non-Symmetrical Response Pattern is Obtained. To obtain the desired vestigial sideband response curve, the frequencies of the various resonant circuits in the i-f amplifier must be chosen to "tilt" the response curve away from a symmetrical pattern. Instead of the symmetrical assignment of frequencies for the various resonant circuits as suggested in Fig. 3, the asymmetrical (non-symmetrical) assignments in Fig. 9 are used.

Thus, the apparently odd choice of resonant frequencies shown in Fig. 9 permits the formation of a response curve of the proper shape for a partial sideband suppression system.

Each resonant circuit in the video i-f amplifier has a more decided influence on one portion of the curve than another. Consequently, in alignment touch-up work, you need not go through the entire alignment procedure to make minor improvements in the over-all performance of the video i-f amplifier. By gaining a knowledge of what resonant circuits influence what parts of a response curve, you can do much to obtain the very best performance from a given i-f strip. You will learn these in the alignment discussion of this lesson. We have already discussed the action of the local oscillator of the tuner in heterodyning with the incoming signal to produce the i-f range indicated on the diagram in Fig. 1. Let us now add the response of the video i-f amplifier as shown in Fig. 10. These frequency ranges are

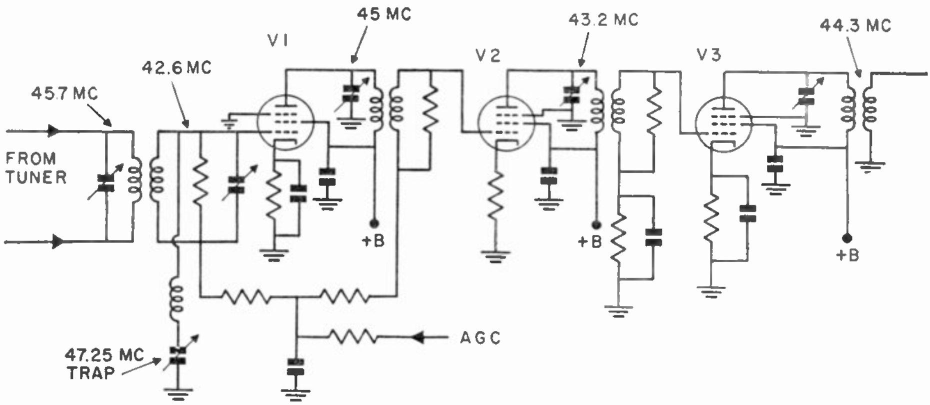


FIG. 9. Shifting of resonant frequencies and proper control of gain to obtain desired asymmetrical video i-f response.

typical for the modern television receiver. Notice that the position of the picture i-f carrier frequency of 45.75 mc is at the 50% point on the response curve. We have also shown various key frequencies at the end of the linear portions of the sidebands as well as the location of the sound i-f carrier.

Now, referring to Fig. 10, let us demonstrate briefly what we have learned about the partial sideband suppression system. Let us assume we are to transmit a .75-mc component and a 2-mc component of video information, originating with equal amplitude at the output of the camera. If we were modulating a channel 2 station, the 2-mc component would produce a sideband at 57.25 mc, or 2 mc above carrier frequency. There would be no low-frequency sideband because it would be removed by the transmitter. The .75-mc signal component would produce a high-frequency sideband at 56 mc, and a low frequency sideband at 54.5 mc. At the receiver, these two sidebands would heterodyne with the local oscillator frequency of 101 mc to produce an i-f sideband at 43.75 mc for the 2-mc video component, and two i-f sidebands, at 45 mc and 46.5 mc, for the .75-mc component.

As shown in Fig. 10, the 45-mc sideband is given 90% of full amplification and the 46.5-mc component only 10% of full amplification. At the output of the video detector, the amplitudte of these two sidebands will be added, so that it will equal the ampli-

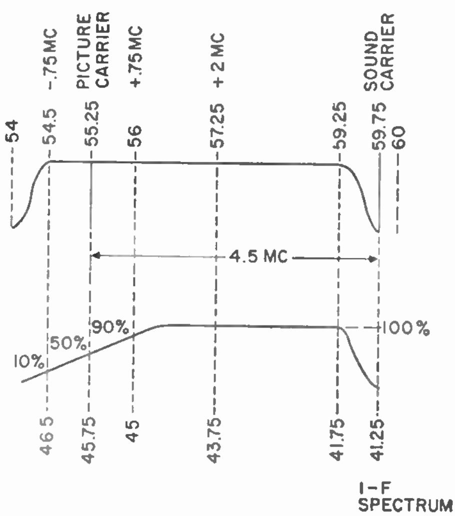


FIG. 10. Frequencies for typical asymmetrical i-f response. The receiver is tuned to channel 2; the local oscillator is operating at 101 mc.

tude of the 43.75-mc sideband which is given full amplification, matching the original relative amplitudes at the output of the camera.

SELECTIVITY AND REJECTION OF INTERFERENCE

We have discussed the need for a wide-band amplifier, how we get the various frequencies that make up the response curve, and how the curve is properly shaped to take care of the partial sideband suppression. The next factors to be considered are the proper positioning of the sound information, and finally, the location of response rejection frequencies to prevent adjacent channel signals from causing interference with the desired signal.

Positioning the Sound Information. The system of sound and picture separation used in the modern television receiver is referred to as "intercarrier" because the sound i-f is the *difference* frequency between the sound and picture carriers in the video i-f system. Note that the frequency difference between the picture and sound carriers in the original transmission shown in Fig. 10 is 4.5 mc. This difference between the 41.25-mc sound i-f carrier and the 45.75-mc picture i-f carrier is also 4.5 mc.

The 41.25-mc sound i-f signal and the 45.75-mc video i-f signal beat together in the video detector to produce a 4.5-mc signal that is amplitude-modulated with the video information and frequency-modulated with the sound information. For example, when the original sound carrier frequency of 59.75 mc is deviating the full 25 kilocycles, the sound i-f carrier of 41.25 mc will also deviate the full 25 kc. In like manner the 4.5-mc signal produced in the detector will contain the same deviation. As a result, the 4.5-mc signal can be amplified and applied to an FM detector to reproduce the original audio information.

An advantage of the intercarrier system is that the sound i-f carrier will always be constant at 4.5 mc, regardless of drift in the frequency of the local oscillator. Consequently, the frequency stability of the local oscillator is no longer as much of a problem as in the earlier television receivers using a separate sound system.

A specific problem in the intercarrier system is a defect referred to as "intercarrier buzz," an annoying hum in the sound output. The amount of hum depends on the strength of the video signal being received, the type of picture information, and the setting of the fine tuning and contrast controls of the television receiver.

Intercarrier buzz is caused by video modulation components in the sound output. This may be due to improper adjustment or drift in the i-f alignment, or to improper amplitude relationships between the sound and picture carriers on the video i-f response curve. To minimize intercarrier buzz, the amplitude of the sound i-f carrier passing through the video i-f strip should be very much lower than that of the picture carrier (preferably less than 10% of the picture carrier amplitude).

Sometimes intercarrier buzz occurs only when the station is transmitting a commercial. This buzz is not due to a receiver defect but is due to the high modulation level used at the transmitter.

The most important consideration for the serviceman in obtaining minimum intercarrier hum in a receiver, is the proper alignment of both the sound i-f and the video i-f amplifiers. The video i-f amplifier must be aligned properly to position the sound carrier correctly with respect to the video carrier. Proper alignment in the sound i-f section and, in particular, proper balancing and adjustment of the discriminator or ratio detector will keep intercarrier buzz at a minimum.

It is particularly important that an accurately calibrated signal source be used to adjust the sound i-f amplifier. Since the signal frequency of 4.5 mc is established by the transmitter, the i-f transformers must be aligned exactly at this frequency. If there is no accurately calibrated signal generator available, the signal from a TV station can be used.

Adjacent Channel Interference Rejection. Still another requirement of the video i-f system is to reject interference from adjacent channels.

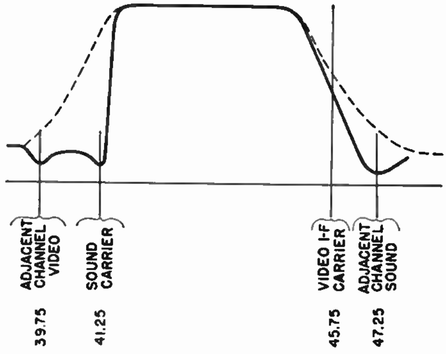


FIG. 11. Influence of traps on sharpening asymmetrical video i-f response, indicating adjacent channel sources of interference. The solid line shows the curve with the traps inserted.

You already know that TV tuners are broad-band devices and that they do not have enough selectivity to reject interfering signals close to the channel to which the receiver is tuned. In some localities, it may be possible to receive signals from several adjacent channels. For example, if the receiver is tuned to channel 3, and the signals from stations on channels 2 and 4 can also be picked up, the channel 2 sound signal and the channel 4 video signal may get through the tuner and into the video i-f amplifier.

When the receiver is set on channel 3, the local oscillator frequency is 107 mc. The picture carrier frequency is 61.25, and the sound carrier is 65.75. The i-f output frequencies of the tuner for channel 3 are indicated in Fig. 11.

If there is a channel 2 station in operation, the 59.75-mc sound carrier may pass through the tuner into the i-f amplifier. In passing through the tuner, it too will mix with 107 mc to produce an i-f frequency of 47.25 mc. If this 47.25-mc signal is not suppressed, it can beat with the 45.75-mc picture carrier frequency to produce an interfering 1.5-mc difference frequency at the video detector output. The 1.5-mc signal is frequency-modulated, and will produce the herringbone pattern shown in Fig. 12.

This type of interference is called *adjacent channel sound* interference. It can be minimized only by making certain that the video i-f amplifier has a *minimum sensitivity* to the 47.25-mc signal. Consequently, it is necessary to incorporate various trap circuits in the video i-f amplifier to reject and/or absorb the frequency and prevent its passing through the video i-f amplifier. The result of

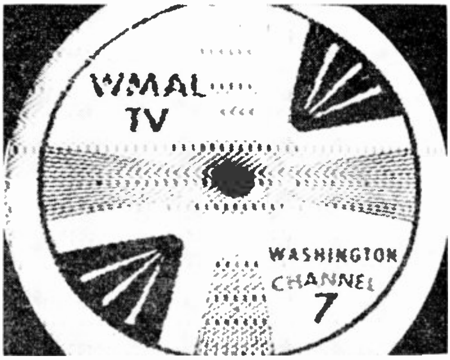


FIG. 12. Adjacent-channel sound interference.

FIG. 13. Adjacent-channel picture interference.

using such a trap circuit is to alter the shape of the video i-f response so it has a minimum point located at the trap frequency, as can be seen in Fig. 11.

A strong picture carrier component from a channel 4 station can also enter the tuner and pass into the i-f strip (with the tuner set on channel 3) to produce a superimposed picture component on the desired signal. This is illustrated in Fig. 13. The channel 4 picture carrier of 67.25 mc, when mixed with the local oscillator frequency of 107 mc, produces an i-f interference of 39.75 mc. Many receivers incorporate 39.75-mc traps in the video i-f system to make certain there is minimum sensitivity in the video i-f at this frequency. The effect of the traps on the response curve is shown by the solid line in Fig. 11.

The use of a number of traps prevents interference from adjacent channel stations. However, proper adjustment of the trap circuits is not the only factor that can minimize adjacent channel interference. The tuner response will also affect adjacent channel interference. Interference can also be kept at a minimum by the selection and careful orientation of a highly directive antenna.

A trap circuit can be either a series resonant circuit in shunt with the signal path (Fig. 14A) or a parallel resonant circuit in series with the signal path (Fig. 14B).

When a series resonant trap is used, it is often connected from the grid of the tube to ground. The trap acts as a short circuit at its resonant frequency so that very little voltage at the interfering frequency appears between the grid of the tube and ground.

When it is a parallel resonant circuit, it has a high impedance and acts as a *voltage divider* because its impedance at the undesired frequency is much higher than the grid-to-ground impedance of the succeeding stage. Therefore, a greater percentage of the interfering signal voltage is dropped across the trap leaving only a weak interfering signal between the grid of the following stage and ground.

A third type is the absorption trap illustrated in Fig. 14C. When it is used, it is tuned to the undesired frequency and positioned near one of the regular resonant circuits of the video i-f amplifier. The trap absorbs energy at the undesired frequency and dissipates it in the form of a high circulating current within the trap resonant circuit. The presence of the parallel trap coupled near to the regular resonant circuit *reflects,* therefore, a severe *load* at that frequency, and lowers the Q of the regular tank circuit to the undesired signal. Consequently, the amplitude of the undesired signal is much less than the desired video signals passing through the amplifier.

A cathode trap is often used to provide degeneration at the undesired frequency. The trap in Fig. 14D consists of a parallel resonant circuit that has a high impedance at the undesired

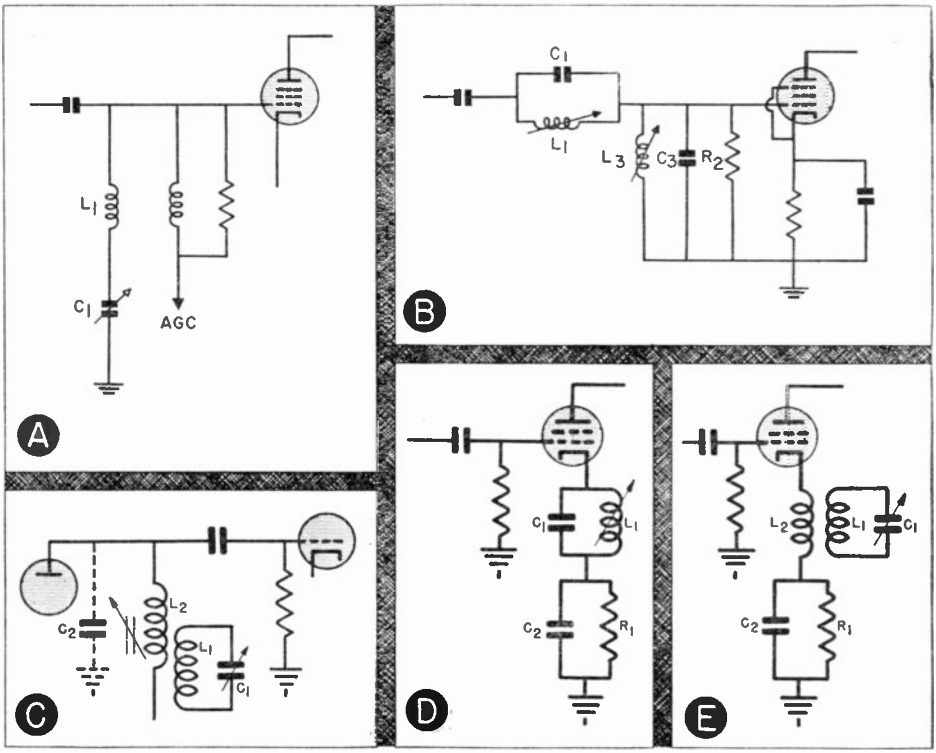


FIG. 14. Interference trap circuits. A, a shunt-inserted trap; B, a series-inserted trap; C, an absorption trap; D and E, degenerative traps.

frequency. The voltage developed across the trap is in phase with the grid voltage and therefore reduces the net grid-to-cathode voltage. As a result, the stage has little or no gain at the undesired frequency, and again, the desired video spectrum is made to dominate the interference frequency.

A better control of the response shape can often be obtained with an *inductively coupled* trap in the cathode circuit, see Fig. 14E. With this high Q trap, the cathode circuit can be made to have maximum degeneration at the undesired frequency without causing any attenuation of the nearby desired frequencies that carry the video detail.

Typical I-F Amplifiers

Three basic types of video i-f amplifiers are used in television receivers. There are two intercarrier types, the wide-band, high-detail i-f amplifier and the economy-type, narrow-band i-f amplifier. In the older receivers, an i-f system, referred to as a dual-channel i-f, was commonly used. Let us discuss in detail a typical example of each basic type.

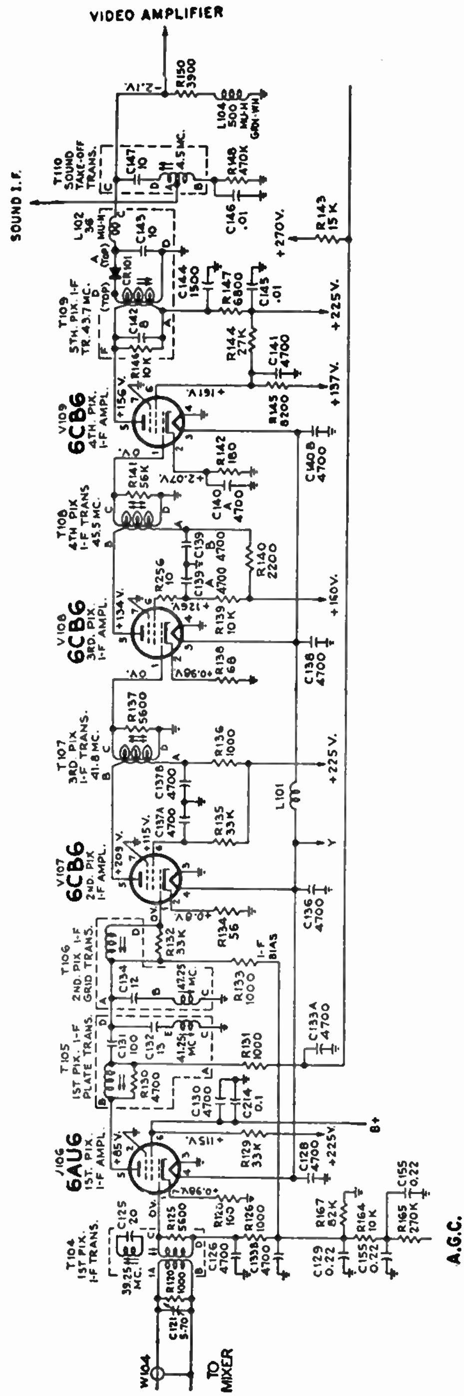


FIG. 15. Stagger-tuned wide-band i-f system.

WIDE-BAND INTERCARRIER I-F AMPLIFIER

The wide-band intercarrier i-f system generally uses four amplifier stages to obtain the necessary sensitivity for the wide band of frequencies to be passed. In the wide-band system, a number of individual traps must be used to obtain the necessary selectivity and proper positioning of picture and sound carriers on the response curve. A typical circuit is shown in Fig. 15.

The first i-f stage is spaced a short distance from the output of the tuner and therefore impedance coupling is used between the tuner and the i-f stage input. This minimizes signal attenuation and reduces the tendency of the first i-f stage to oscillate because of feedback into the input of this stage. The circuit has two separate transformers; the first one is located in the tuner. Its secondary is connected to the primary of the input transformer T104, which is located close to the first i-f tube. The response curve produced by the two transformers is the typical double-hump, overcoupled response curve. The small capacitor C121 acts as a fine adjustment for proper positioning of the sound carrier frequency on the response curve. An absorption trap is associated with the second transformer T104 and is tuned to 39.25 mc, the adjacent channel picture frequency. Loading resistors R120 and R125 reduce the Q of the primary and secondary windings of T104 to give the desired band width.

AGC bias is supplied to the grids of the first and second i-f stages through the decoupling filters consisting of resistors R126 and R133 and capacitors C126 and C133B. Remember, it is the automatic bias applied to these stages that permits the i-f amplifier to present peak sensitivity to a weak signal and still not overload on a strong signal.

An over-coupled transformer serves as the coupling link between the first and second i-f stages. Note that the primary and secondary are mounted in separate shields, and therefore, there is no inductive coupling between the two sections. However, it is possible to obtain over-coupling between two resonant circuits by using a common mutual element as shown in Fig. 16A. This mutual element can be a capacitor, an inductor, or a combination of both, such as the traps used in the circuit of Fig. 15.

The series trap adjustment in T105 permits proper setting of the 41.25-mc sound so it can be positioned at a point on the response curve that is less than 2% of the amplitude of the picture carrier. To minimize adjacent-channel sound interference, a series resonant trap is included as part of T106. This trap is tuned to 47.25 mc, the adjacent channel sound i-f.

Note that the cathode resistors of the first three stages in Fig. 15 are not by-passed. Although this causes a slight reduction in gain, it improves the stability of the amplifier system by making it less subject to oscillation. It also minimizes changes in input capacity of the individual stages with changes in bias. Therefore, the response curve shape does not change appreciably with variations in applied signal strength and agc.

The input capacity of each individual stage, of course, is a part of the resonant circuit. If the capacity changes, it shifts the frequency of the resonant circuits of which it is a part, and could upset over-all response. Notice also how thoroughly each plate and screen voltage supply point is de-

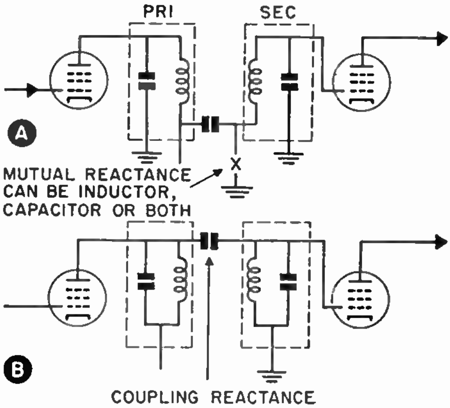


FIG. 16. Overcoupled transformers—the circuit used between V1 and V2 of Fig. 15 is a modification of the circuit shown in A, but sometimes the arrangement shown in B is used.

coupled to prevent instability and feedback through the common power circuits.

The following three stages of the i-f amplifier contain single-tuned transformers. Although each one has two separate windings, they function as one because of the very tight coupling obtained by interlacing the primary winding with the secondary winding. This coupling method is called "bi-filar" winding. It eliminates the need for a coupling capacitor, which with the grid resistor would produce a long time-constant grid circuit. If the grid circuit had a long time constant strong noise impulses would increase the bias on the stage and reduce the gain of the i-f system. Because there is no coupling capacitor, each grid circuit has a very fast time constant so that the action of each stage is instantaneous. Therefore, the stage gain does not change during bursts of high-amplitude noise.

The bi-filar tuned circuits are stagger-tuned and loaded by resistors to obtain proper band width. The final bi-filar transformer is loaded by a resistor across the primary. The crystal

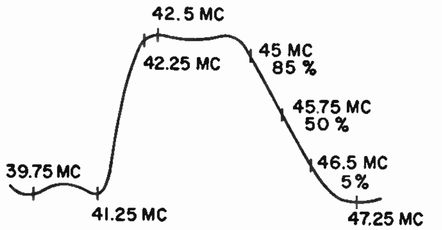


FIG. 17. Overall i-f response for the i-f system shown in Fig. 15

video detector is the load across its secondary. Later in this lesson we will discuss the video detector in detail.

The desired over-all response of this video i-f system is shown in Fig. 17. This response curve and the influence the individual circuits have on the response curve will be discussed in detail in the alignment section.

NARROW-BAND INTERCARRIER I-F AMPLIFIER

The narrow-band, economy-type i-f system used for an intercarrier receiver generally consists of just three i-f stages, as shown in Fig. 18. It has a linear response that may extend out to as much as 2.75 mc (26.2 mc to 23.5 mc), with 3 to 3.25 mc between the 50% down points on the response curve (Fig. 19). This type of i-f amplifier can be made to have almost the same sensitivity as a four-tube wide-band system, but at a sacrifice in frequency response and picture detail.

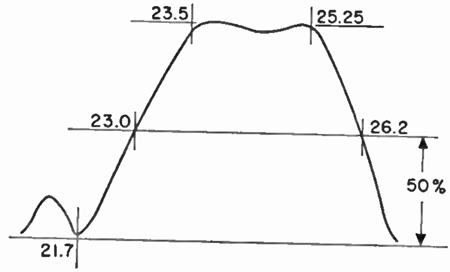


FIG. 19. Response curve for the narrow-band intercarrier i-f system shown in Fig. 18.

The advantages of the narrow-band i-f system, however, are simplicity of design and ease of alignment. Because of the narrow band width, it is not as subject to adjacent-channel interference, so adjacent channel traps are not always used.

In the circuit shown, there are three transformers: The first two are single-tuned with tightly coupled windings. A third single-tuned circuit couples the output of the last i-f stage to the cathode of the video detector. Associated with this final transformer is an absorption trap tuned to the sound carrier frequency. It is adjusted to bring the sound carrier to the proper amplitude on the response curve.

AGC bias is applied to the first two stages, and plate and screen supply voltage lines are filtered with in-

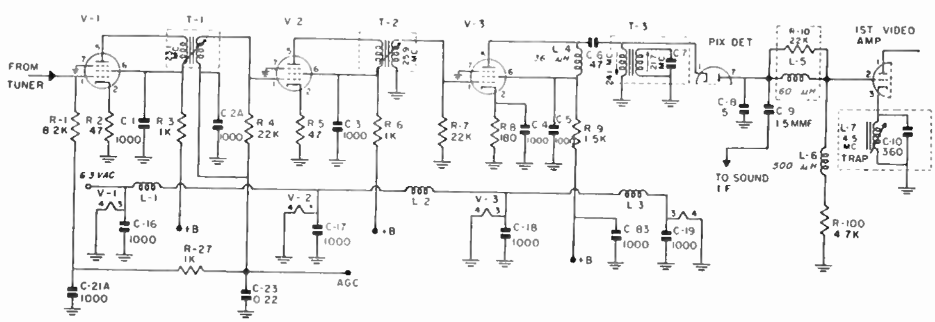


FIG. 18. Narrow-band i-f system.

dividual decoupling circuits. The cathode resistors of the first two stages are un-bypassed to improve the i-f stability. Also, each filament is filtered with an inductor-capacitor combination.

DUAL CHANNEL I-F SYSTEM

In the older television receivers, a system of dual channel amplification of picture and sound information is used. This system is shown in block form in Fig. 20. In the dual channel system, the sound i-f may be separated from the picture i-f at the output of the mixer, at the input of the first i-f stage, or at the output of the first or second i-f amplifier. Generally, the sound signal is removed with an absorption take-off resonant circuit and applied to the first *sound* i-f amplifier. Instead of being tuned to the intercarrier difference frequency of 4.5 mc, as in the systems discussed previously, the sound i-f amplifier is tuned to the actual sound carrier intermediate frequency. Notice that the sound i-f is 21.25 mc and the picture i-f is 25.75 mc. Frequencies of this order were used in most early model TV sets using this type of sound system.

The video i-f system has a band width that accommodates both the picture carrier and its sidebands. It also includes various sound i-f traps, which attenuate any sound i-f component that might be passing through the video i-f amplifier after the sound take-off point. Consequently, there will be no sound interference in the picture signal at the output of the video i-f amplifier.

One advantage of the dual channel system is that it is possible to obtain a very flat wide band response with good high-frequency detail up to near the 4-mc limit. A disadvantage of the

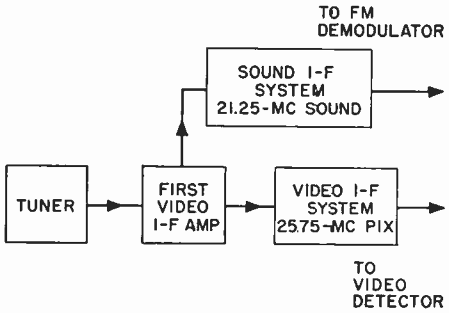


FIG. 20. Block diagram of a dual i-f system.

dual channel system is the added cost and the closer tolerance on local oscillator frequency drift. In the intercarrier system, the sound i-f frequency is always constant because it is the frequency difference between the transmitted picture and sound carriers. In the dual channel receiver, the sound i-f is the difference between the arriving sound carrier frequency and the *local oscillator frequency*. Consequently, the sound i-f produced in the mixer is dependent on the local oscillator frequency stability. The dual channel i-f system, however, is not subject to intercarrier buzz because picture modulation components are not present in the sound information.

A typical dual-channel picture i-f system with four stagger-tuned i-f stages is shown in Fig. 21. The input circuit is again a dual transformer arrangement which permits low impedance and low-loss coupling between the tuner and the i-f input. Notice that a trap is associated with each transformer. These traps assist in minimizing possible sources of interference and, at the same time, permit proper shaping of the response curve to obtain the wide-band video response shown in Fig. 22. Notice that the video i-f response is flat to almost 22.1 mc. Therefore, when properly aligned, it certainly can handle video detail up to 4 mc.

The trap associated with the input

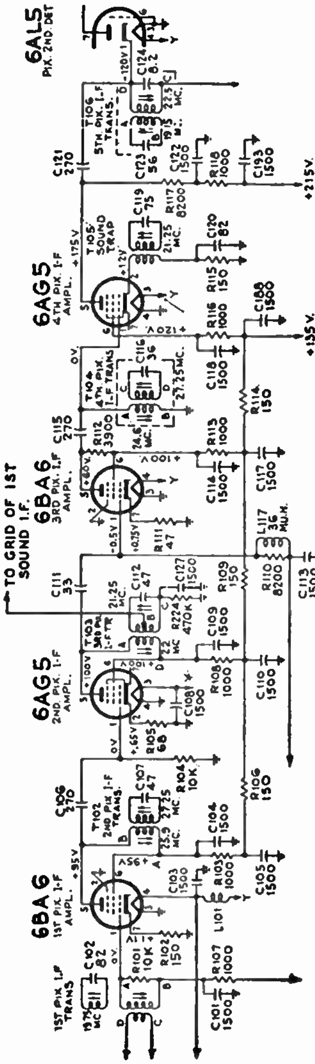


FIG. 21. A dual-channel video i-f system.

transformer tunes to 19.75 mc, the adjacent channel picture frequency. The trap between the first and second i-f stages tunes to 27.25 mc, the adjacent channel sound frequency. The sound take-off point in this circuit is located in the plate circuit of the second i-f stage. It is an absorption type trap. The trap functions both as the source of the sound i-f signal for application to the sound i-f channel and as a sound trap to prevent the sound signal

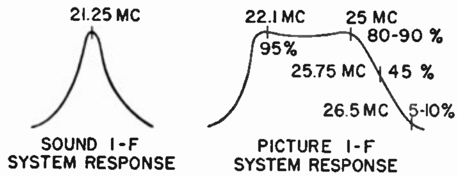


FIG. 22. Response curves for the dual-channel video i-f system shown in Fig. 21.

from passing into the rest of the video i-f section. An adjacent channel sound trap is located at the output of the third i-f stage, and an additional adjacent-channel picture trap is located at the input to the video detector. To further attenuate any sound-carrier component that may have entered the picture i-f section, a cathode trap is located in the cathode circuit of the fourth picture i-f stage. In other respects, this system is similar to the i-f systems discussed previously—agc bias is applied to the first and third i-f amplifier stages, the first three stages do not have cathode by-pass capacitors, and the plate and screen supply voltage circuits are carefully decoupled.

Video Detectors

The final requirement of the video i-f system is to detect or demodulate the video i-f carrier to obtain the desired picture information. Since the video carrier signal is *amplitude-modulated,* we can use a conventional diode type detector. However, the diode must be connected to obtain the proper output polarity, and the diode load resistor must be low enough in value to prevent the loss of the high-frequency components of the video information. In addition, the video detector circuit must be designed to obtain proper filtering of the intermediate frequencies and their harmonics and to keep radiation at a minimum. We will investigate each of these requirements in detail later in this lesson.

The modulation information applied to the video detector is in the form of an envelope with positive and negative excursions about the zero axis, as shown in Fig. 23. The greatest peak-to-peak amplitude variation occurs during the sync pulse interval. During the transmission of the blanking pedestal, the amplitude declines to 75% of the sync pulse value. The amplitude of the blanking interval is the same as the maximum amplitude of the video signal, which occurs when black is being transmitted.

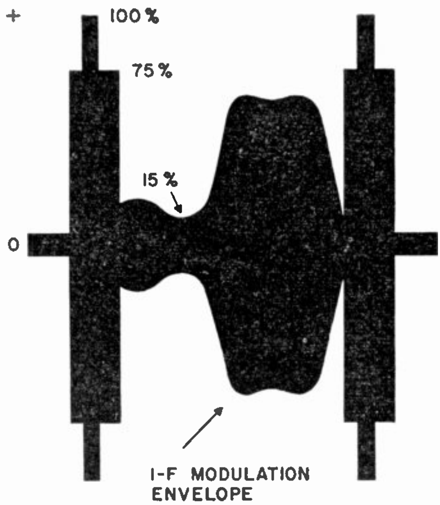


FIG. 23. The modulation information applied to the video detector is in the form of an envelope, as shown here.

As the screen brightness increases, the peak-to-peak variation of the i-f signal falls and reaches a minimum value of about 15% of the peak sync pulse amplitude. This minimum value corresponds to the most intense white portion of the picture. The method of transmission in which the greatest signal amplitude is for black and the least amplitude is for white, is referred to as *negative transmission.*

Let us now observe how this modulation envelope and the relative peak-to-peak variations influence the output of a typical diode detector.

When the modulation in the form of an envelope, as shown in Fig. 23, is applied to the plate of the video detector shown in Fig. 24A, the detector will conduct only on the positive portion of the envelope. During the negative half of each cycle, the plate will be negative with respect to the cathode and the diode will not conduct.

The output of the video detector will therefore be a series of pulses produced by the positive half of the video i-f carrier. The amplitude of the pulses will vary with the modulation. For example, during any of the sync pulses, the voltage applied to the diode plate is maximum, and therefore, the diode draws maximum current. When this current flows through the diode load resistor, it develops a positive output voltage with the sync pulse itself being the most positive part of the output signal. For white information, the peak diode current is substantially less. Therefore, the positive voltage developed across the diode load resistor is substantially smaller, as you can see in the waveform drawing.

It is also possible to connect a diode so that it conducts on the negative half of the modulation envelope instead of on the positive half. In other words, the diode conducts when a negative signal is applied to its cathode, but does not conduct when a positive signal is applied. This circuit is shown in Fig. 24B.

As far as producing the video signal is concerned, it does not matter whether the negative or the positive portion of the envelope is used. Both halves contain the same modulation information, but the polarity of the output signal changes. With the diode conducting on the negative portion of the modulation envelope, the output also swings negative. Consequently, during the sync pulse interval, the highest negative voltage is developed across the diode load resistor. You can see that the output voltage will be negative with respect to ground by studying the direction of current flow in Fig. 24B. During the blanking pedestals, this negative voltage pulse drops to 75% of the sync level. When transmitting an intense white, it drops to 15% of the sync pulse level.

In the circuits in Fig. 24, notice that the two output signals from both diode detectors are identical, except they are of opposite polarity. By properly connecting the diode detector, it is possible to obtain either a negative or a positive composite video signal at the output to meet the requirements of the entire system following the video detector.

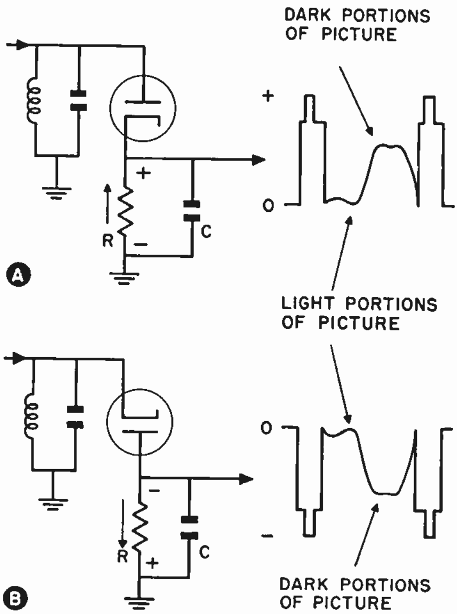


FIG. 24. The output of the diode detector shown at A is a composite signal with positive polarity and negative picture phase. The diode detector at B is connected so the composite signal output has negative polarity and positive picture phase.

The uni-directional characteristic of the diode (current can flow in just one direction) permits the detector to demodulate the video information of the i-f signal. However, to reproduce this information faithfully, it is necessary to filter out the i-f signal that carries the modulation. This is accomplished by a filter consisting of the diode load resistor and its shunt capacity. The time constant of this filter is much longer than the period required for the individual i-f cycles. Therefore, the capacitor discharges very little during successive cycles of the i-f signal. However, the time constant must be short enough to follow any high-frequency video signals present in the detector output.

Although we will discuss the subject of time constant in detail in the video amplifier lesson, let us consider briefly its significance in relation to the circuits in Fig. 24. When a capacitor charges through a series resistor, it requires a certain amount of time for that capacitor to charge. After a capacitor has been charged, it requires a specific amount of time to discharge as well. Since the series resistor limits the flow of current, we can control both the charging time and the discharging time of a capacitor by varying the value of the resistor.

In the circuits in Fig. 24A, the *charging time* of capacitor C is governed primarily by the resistances of the tube and the components in the plate circuit. This circuit, then, acts as the series resistor. When the signal amplitude decreases enough to permit the capacitor to discharge, the discharge path must be through resistor R, which is now the series resistor. Let us see how the time constant affects the signal in the output circuit of the video detector.

Initially, a number of cycles of the i-f frequency are required to charge the capacitor across the output of the diode detector. Once it is charged, however, the capacitor will not lose that charge quickly because the time required to discharge through the diode load resistor is longer than the time between successive i-f cycles. Thus, the charge on the capacitor will not vary with the cycle-to-cycle variations of the intermediate frequency signal, and the actual i-f cycles will not be present in the output signal. The video information, on the other hand, occurs at a much lower frequency, and the charge and discharge rate of the capacitor is able to follow the video frequency modulation information. Therefore a video signal will be developed across the output of the diode detector.

As an example, let us consider what occurs during the sync pulse interval, as shown in Fig. 25. The sync pulse itself is approximately 5 microseconds long. During this time, several hundred individual i-f cycles occur in the modulation envelope (for purposes of illustration, we have shown only

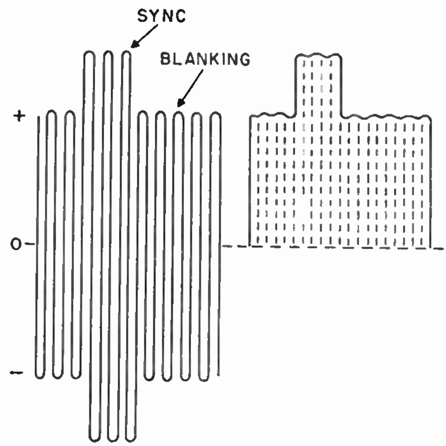


FIG. 25. Demodulation action during blanking-sync interval. A, the individual cycles that make up the interval. (We have shown only a few cycles although actually there are over 500.) B, after rectification and filtering. The dashed lines indicate the previous position of the i-f cycles, now filtered.

three). When this envelope is applied to the plate of the detector, as in the circuit of Fig. 24A, the detector draws current only during the positive half of each i-f cycle. This current flow charges the capacitor C in the output circuit of the detector. Because of the long time required to charge and discharge the output capacitor, the voltage remains essentially constant at a value that corresponds to the peak amplitude of the i-f cycles during the sync pulse period. Notice in Fig. 25 that the output is in the form of a pulse and that it does not follow the individual i-f cycle variations, indicated by the dashed lines.

SIGNAL POLARITY AND PICTURE PHASE

The terms signal polarity and picture phase may be somewhat confusing. When speaking of the polarity of the *composite video signal,* it is customary to assign to it the polarity of its *sync pulse.* For example, the output of the diode shown in Fig. 24A, with the sync pulses of the composite signal swinging positive, is referred to in these three ways: *sync positive composite signal, positive-going composite signal,* or *positive-going sync signal.* Notice that each expression assigns a polarity to the over-all signal that corresponds to the polarity of the sync pulse.

The term *picture phase,* on the other hand, refers to the *polarity* of the *picture information* (the scene and picture tube brightness). When we say the video signal has a *negative* picture phase, we mean that the negative part of the video signal represents the *bright* portions of the scene, while the positive part of the same video signal represents the *dark* portions of the transmitted scene. Conversely, when we say the video signal has a *positive* picture phase, we mean that the positive part of the signal represents the bright portions of the scene, while the negative part of the signal represents the dark portions of the scene.

The signal at the output of the detector shown in Fig. 24A is a *positive*-going composite signal and has a *negative* picture phase; the output shown in Fig. 24B is a *negative*-going composite signal and has a *positive* picture phase.

Signal polarity and picture phase are important because the composite signal must be applied to the picture tube with the proper polarity. The bright portions of the scene must cause the beam current in the picture tube to increase, while the dark portions must cause it to decrease. When we apply the composite video signal to the *grid* of the picture tube, it must have a *negative-going polarity* because the blanking pulse must drive the beam current to cut-off. The less negative portions of the video signal cause the screen to light up until we have maximum brightness at 15% of the sync pulse interval. This negative-going composite signal is one that has a positive picture phase, because the most positive portion (or least negative portions of the signal) represent maximum brightness or maximum beam current and full illumination of the picture tube screen.

If we apply the signal to the cathode of the picture tube, it must have a positive-going polarity, because we cut off the beam by the application of a positive blanking pulse. (The pulse drives the cathode positive with respect to the grid—therefore the grid is negative with respect to the cathode.) Thus, the picture phase is said to be *negative* because driving the cathode negative causes an increase in picture brightness.

Now, suppose the video amplifier system following the detector contains a single amplifier stage. If the signal is to be applied to the grid of the picture tube, the output of the video detector must be of positive polarity (negative picture phase). Since each amplifier stage reverses the phase of the input signal 180°, this composite signal appears as a negative polarity signal (positive picture phase) on the grid of the picture tube. If the cathode of the picture tube is to be driven by the composite video signal, the output of the video detector would have to be of *negative* polarity, so that after reversal by the single video amplifier stage, a positive polarity signal would be present at the cathode of the picture tube.

When a two-stage video amplifier is used, the polarity of the output of the video detector must be the same as the signal needed to drive the picture tube, so that after two reversals, the picture phase at the output of the video amplifier will be the same as the picture phase at the video detector output.

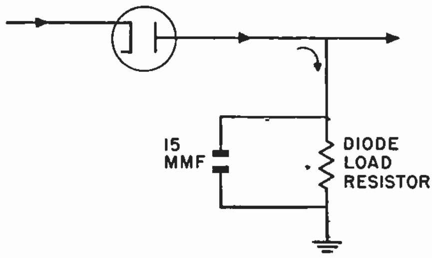


FIG. 26. A typical diode video detector output circuit.

FREQUENCY RESPONSE OF VIDEO DETECTOR OUTPUT CIRCUITS

The video detector, because of the small value of the load resistor, is not nearly as efficient as the same type of detector in an AM radio. The diode load resistor in an average radio receiver may be a megohm or more. But in a video detector, it is limited to a few thousand ohms to help prevent the loss of the high-frequency components of the video modulation. Loss of the high-frequency components is also caused by the capacity, even though it is small, that shunts the diode load resistor. As you have learned, the reactance of any capacitor decreases with frequency. Therefore, the higher the frequency, the lower the reactance, and the more shunting effect the capacitor has on the diode load resistor.

Although we will take up frequency response in more detail in the following lesson on video amplifiers, let us consider some of the basic facts now so that we can better understand the operation of the video detector output circuit.

Let us assume that the value of the diode load resistor in Fig. 26 is 30,000 ohms. If there is a small capacity of only 15 mmf shunting this resistor, the effective load impedance of the diode circuit at low frequencies will be 30,000 ohms—the value of the load resistor. The reactance of the capacitor will be so high that it will have very little effect on the total impedance of the circuit. However, as the frequency of the signal increases, the reactance of the capacitor decreases, until at a frequency of approximately 350 kilocycles, the reactance of the capacitor has fallen to a value of 30,000 ohms.

We might at first conclude that with two 30,000-ohm components in parallel, the resultant impedance would be 15,000 ohms, and the signal would be effectively half what it would be with 30,000 ohms. However, since we are placing a *resistance* and a *reactance* in parallel, when the two are equal, the impedance, instead of dropping 50%, drops 30%, so the response of the video detector output circuit is 30% less at 350 kilocycles than it is at the lower frequencies where the effective impedance is nearer to 30,000 ohms. Since the video information contains useful variations up to approximately 4 mc, the attenuation of these higher frequencies in the output circuit is much greater because the reactance of the small capacitor is much lower.

If we reduce the value of the diode load resistor from 30,000 to 3000 ohms, the capacitor will have little influence on the response at 350 kc, because its reactance will be ten times as high as the resistance of the diode load resistor. In fact, not until the frequency reaches 3.5 mc will the reactance of the capacitor equal the resistance of the resistor. Consequently, with the new low value of video detector load resistor, the output response does not drop 30% until a frequency of 3.5 mc is reached. This more nearly meets the requirements for the demodulation of the high-frequency component of video information.

Note, however, that to obtain this more linear wide-band frequency response, we have been forced to lower the value of the diode load resistor, which in turn lowers the efficiency and output of the video detector. Therefore, to obtain a wide-band response from any amplifier circuit, we must sacrifice gain to obtain linear output over a wide range of frequencies. This factor again demonstrates the need for a multi-stage i-f amplifier in order to build up the i-f signal to a suitable level for producing a usable output from the video detector.

The high-frequency response at the output of a video detector can also be improved by placing small inductors, called peaking coils, either in series or in shunt with the detector output circuit. The peaking coils have an inductive reactance that either cancels or isolates the influence of the capacitive reactance on the output load circuit. Peaking will be discussed at length in the lesson on video amplification. At this point, let us just state that the function of the peaking coil is to improve the high-frequency response in the video amplifier system by compensating for the tendency to high-frequency losses because of the shunt capacities in the circuit.

CRYSTAL VIDEO DETECTORS

A crystal diode may also be used as a video detector in a television receiver. Like the vacuum tube detectors described previously, the crystal, which is actually a small block, or wafer, of germanium, conducts current well in one direction, but it will pass only a very limited current in the opposite direction. The germanium crystal, therefore, is said to have a low forward resistance but a high reverse, or back resistance.

The typical germanium crystal diode, shown in Fig. 27A, consists of the following basic components: (1) A small germanium wafer, (2) a contact whisker, (3) insulating structure, and (4) external contact leads. In the example, the entire area of one side of the crystal wafer, corresponding to the cathode in a vacuum tube diode,

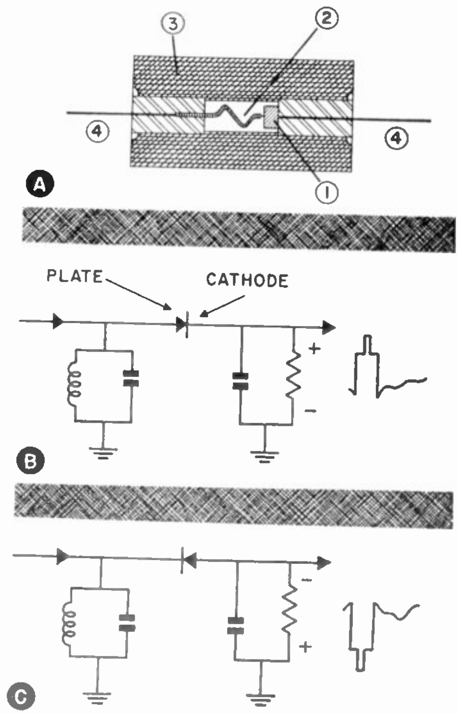


FIG. 27. Crystal diode as a video detector.

is in contact with a small sheet of metal. A lead connects to the metal base and serves as one of the external contact leads. A cat whisker (fastened to the second external lead) establishes a point-contact on the second side of the wafer, and corresponds to the vacuum tube diode plate.

When a modulation envelope, as shown in Fig. 23, is applied to a crystal diode, the diode functions just like a vacuum tube diode detector. A high current flows when the modulation applied to its plate is positive, but no current (or a very small amount) flows when the modulation applied to the plate is negative.

The crystal detector has a number of advantages insofar as television application is concerned. Since it is small, it lends itself to compact mounting and shielding. The crystal and its output circuit can be enclosed in the same can with the last output tuned circuit of the video i-f system. It requires no filament power. Therefore, possible

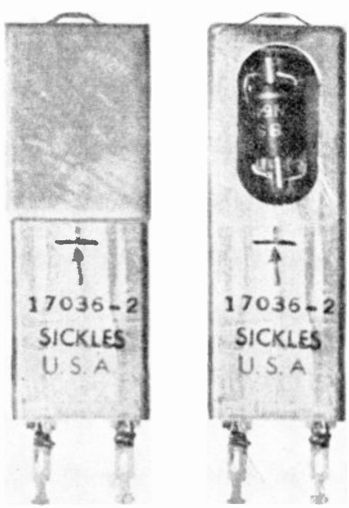


FIG. 28. Video detector assembly.

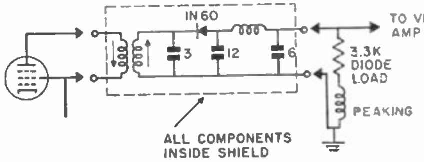


FIG. 29. Typical video detector using crystal diode.

radiation of spurious frequencies through the heater circuit can be minimized. In addition, the crystal diode has little effect on the high-frequency response because its capacity is much less than that of vacuum tube diodes.

When replacing a crystal diode in a television receiver, remember that the plate of the detector is always represented by the *triangle*, as in Fig. 27B. Thus, to obtain a *positive* polarity video signal at the output of the crystal detector circuit, the *triangle* must be connected to the top of the last i-f coil as shown in Fig. 27B. For a negative-going composite signal at the output, connect the *flat bar* (cathode) to the top of the i-f coil as in Fig. 27C.

A crystal detector can be checked with an ohmmeter. When the detector is normal, the forward resistance will be just a few hundred ohms while the reverse resistance will be more than 10,000 ohms. However, this test is not always conclusive. When a crystal fails to pass the test, it should be replaced. Even when a crystal does pass the test, if all indications point to a defective crystal, try a new one in the circuit.

TYPICAL VIDEO DETECTOR CIRCUITS

A typical crystal detector and filter assembly for a 45-mc i-f strip is illustrated in Fig. 28 and shown schematically in Fig. 29. The entire unit, consisting of the final picture i-f transformer, the crystal detector and holder, and the output filter section, is enclosed within a shield can. Notice in Fig. 28 that the crystal can be quickly and easily replaced by removing the small shield, which is a part of the assembly.

Any type of demodulator generates harmonics. In this arrangement the entire detector assembly is completely shielded. Therefore, harmonics of the i-f cannot radiate and interfere with the performance of the receiver. The complete shielding and the thorough filtering by the low-pass filter output circuit also attenuates any other frequency above the i-f range that might be generated and reach the video detector output circuit. If the harmonics of the i-f were not attenuated, they would cause interference on the high-band channels or at the high-frequency end of the low-band channels.

A similar crystal video detector is used in the video i-f amplifier of Fig. 15. In this circuit, the crystal detector is connected so that a negative polarity composite signal is developed across the diode load resistor and applied to the grid of the video amplifier. This video amplifier stage, in turn, supplies a positive polarity composite signal from its plate circuit to the cathode of the picture tube. In this assembly, too, the i-f transformer, the crystal detector, and the output filter are enclosed in the shield.

Notice in Fig. 15 that at the output of the video detector, a series resonant circuit is tuned to 4.5 mc and used as the take-off point for the sound i-f system. You learned that the net voltage drop across a series resonant circuit is at a minimum at the resonant frequency. However, the series current is high, which develops an appreciable voltage across each one of the elements individually. Consequently, it is possible to tap off a strong 4.5-mc component from across the inductor of this resonant circuit and use it as excitation for the grid of the first sound i-f amplifier. The series resonant circuit also functions as a 4.5-mc trap to prevent 4.5-mc interference or *tweets* on the reproduced picture. This interference produces dark diagonal lines across the picture. Whether or not the series resonant circuit is shielded depends on the design requirements of the receiver.

Proper tuning of this take-off point is very important. The adjustment should be performed either with a receiver signal or an accurate 4.5-mc crystal-controlled signal source. Improper tuning of the trap can cause either an interference beat on the picture or a high level of intercarrier buzz.

Going back to Fig. 18, we see an example of a vacuum tube type video detector. Again the diode detector is connected so that a negative-going composite signal is developed across the diode load resistor. Both series and shunt peaking are employed to avoid attenuation of the high video frequencies. The sound is removed through a small 1.5-mmf capacitor and applied to a parallel resonant circuit at the grid of the first sound i-f amplifier. This resonant circuit is tuned to 4.5 mc. Likewise, a cathode degenerative trap is connected in the cathode circuit of the first video amplifier to minimize the feed-through of the 4.5-mc component into the video amplifier.

In some of the earlier intercarrier receivers, the sound take-off is in the plate circuit of the video amplifier. It is in the form of a parallel resonant circuit. The 4.5-mc component at this point is quite strong because of the added gain contributed by the first video amplifier, making it difficult to remove all of the 4.5-mc interference from the picture, so this method is not used in newer receivers.

I-F Amplifier Response Curves and Alignment

We have discussed at length the techniques used to obtain a desired response curve in a video i-f system. We learned that the response curve indicates much about the performance of a video i-f system. Therefore, from the curve, you will not only be able to align the i-f system for peak performance but you will also be able to recognize defects in this system by observing the response curve.

The easiest and most accurate method of obtaining a visual response curve at the output of an i-f amplifier system is, of course, with a sweep generator and an oscilloscope. To understand how the curve is obtained on the oscilloscope screen, let us first consider a very basic method of plotting the response curve.

OBTAINING A RESPONSE CURVE

When a signal (having a frequency within the range of the i-f amplifier) is applied to the input of the amplifier system, it causes a direct current to flow in the video detector circuit, which in turn produces a voltage drop across the diode load resistor. The voltage developed across the diode load resistor will depend on the gain of the video i-f amplifier at the frequency to which the signal generator is set, and on the amplitude of the input signal.

If the signal generator (the frequency source) is tunable throughout the frequency range of the video i-f amplifier system, and we vary the frequency of the generator in half-megacycle steps and carefully measure the voltage across the load resistor with a voltmeter, we can obtain a series of voltage readings across the video de-

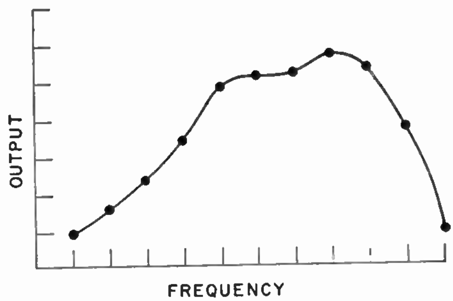


FIG. 30. Response curve plot.

tector load resistor in half-megacycle steps throughout the pass band. If the signal amplitude at the output of the signal generator is kept constant for each frequency that is applied to the video i-f input, the dc voltage readings across the video detector load resistor represent the relative gain in the video i-f signal for each of the frequencies applied to the input. Therefore, after accurately reading the meter, and plotting the readings on a graph, we can draw a line connecting the dots and obtain a response curve for the video i-f system. A typical response curve obtained in this manner is shown in Fig. 30.

This method of plotting a response curve is extremely tedious. Furthermore, unless the amplitude of the frequency at the input is exactly the same for each checked frequency, and the signal generator is accurately calibrated so that the check points are exactly as indicated, the resulting curve will not be correct. Another disadvantage of this method is that it permits precise measurements only at the actual checked frequencies.

A speedier and more accurate method of obtaining a response curve is with the use of a sweep generator and an oscilloscope. The sweep oscillator (in the sweep generator) is set to

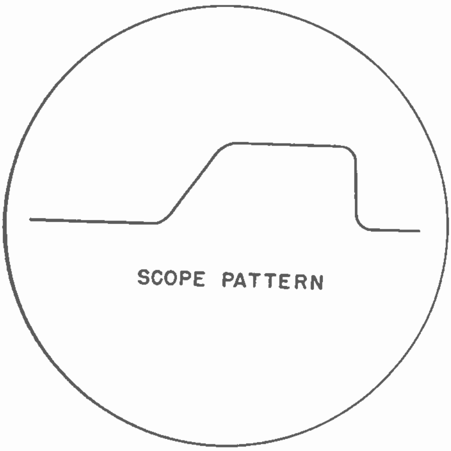


FIG. 31. A typical response curve obtained with an oscilloscope and a sweep signal generator.

vary the output frequency of the sweep generator over the video i-f pass band at a specific rate.

For example, the sweep oscillator can be adjusted so that its output changes in the frequency range between 40 mc and 50 mc. All frequencies within that range are applied to the video input. Usually, the rate at which the frequencies are scanned is 120 times per second. With an oscilloscope connected to the output of the diode detector and properly adjusted, this signal, having the shape shown in Fig. 31, will be reproduced on the screen. Since each of the frequencies within the range from 40 to 50 mc is being applied to the i-f amplifier, the resultant response curve on the oscilloscope screen represents the gain of the system for each frequency applied to the input.

You can readily see, therefore, that any variation in the performance of the video i-f amplifier will be indicated in the response curve. By comparing it to the curves given in the manufacturer's diagrams for the receiver, you will be able to determine the alignment, frequency response, and gain of the system, as well as to detect the presence of noise and interference signals.

ALIGNMENT

A very detailed explanation of the television alignment procedures will be given in a future lesson. Therefore, in this lesson, we will describe only briefly the equipment used, the methods of inter-connecting the alignment equipment, and the alignment procedures for the video i-f system.

There are two basic methods that you may use to interconnect the alignment equipment to obtain the response curve. The first method, shown in Fig. 32A, uses a marker generator, a sweep generator, and an oscilloscope. The sweep output of the generator is connected to the amplifier to be aligned or tested, and the output from the video detector is applied to the vertical input terminal of the oscilloscope. To synchronize the motion of the oscilloscope scanning beam with the rate of the frequency change at the output of the sweep generator, the horizontal deflection voltage is generated in the sweep generator and applied to the horizontal amplifier of the oscilloscope. The internal oscilloscope sweep generator, therefore, must be turned off when this method is used.

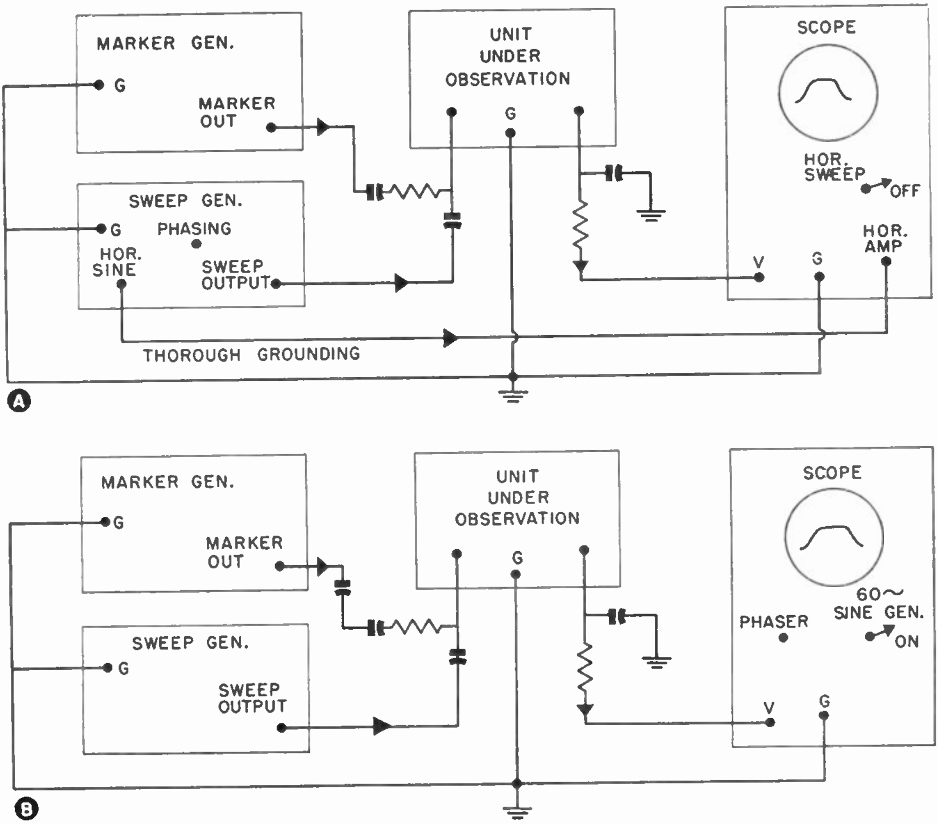


FIG. 32. How to interconnect equipment to obtain a response curve.

The second method of interconnection is shown in Fig. 32B. The internal sine-wave generator in the oscilloscope is used together with its associated phasing adjustment. Therefore, it is not necessary to run a line between the sweep generator and the oscilloscope. Since the frequency changes in the average commercial sweep generator follow a sine wave, it is possible to obtain proper synchronized motion between the oscilloscope beam and the frequency change at the output of the generator.

When using the equipment shown in Fig. 32, certain precautions must be taken to obtain a good response pattern. For example, it is extremely important that you have a good ground system between the various units. If the system is inadequate, the response pattern can be distorted. The signal level applied to the amplifier being tested or aligned must be no higher than necessary so that the signal does not overload any of the video i-f stages. Methods of setting bias and signal levels vary. You should always follow the manufacturer's recommendations. If the stages are overloaded, the response pattern will be distorted.

Study the response curves in Fig. 33. The curve at A illustrates a normal response pattern. The curve at B may seem to indicate a very good flat response. However, this curve was obtained by increasing the signal generator output until some of the video

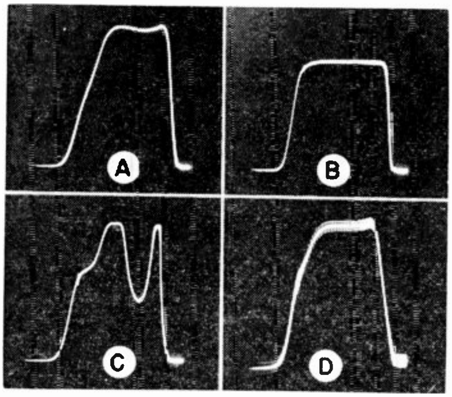


FIG. 33. Normal video i-f curve, A; i-f amplifier overloaded by too strong sweep signal, B; change in shape of response curve by poor grounding, C; noisy pattern—no capacitor across scope input, D.

i-f stages were overloaded, causing the signal to be clipped as it goes through the amplifier system. The response curve, therefore, is not a true indication of the video i-f response. This can be corrected by increasing the attenuation at the output of the sweep generator until the i-f stages are no longer overloaded.

The shape of the response curve in Fig. 33C indicates that the equipment is poorly grounded. Hum fields, either 60-cycle or 120-cycle, are causing the sharp dip in the curve. The pattern in Fig. 33D indicates that a higher than normal amount of noise is getting through the system. This can be eliminated by shunting the input of the oscilloscope with a capacitor of 1000 to 5000 mmf.

How to Mark the Response Curve. When accurate alignment is required, especially in color television receivers, you should use a marker system. In Fig. 32, a marker generator is used in both set-ups. The purpose of the marker is to place small pips on the response curve to identify frequencies on the curve.

Usually, the signal that causes the pip is produced by a crystal oscillator or an accurately calibrated variable-frequency oscillator. It is very weak so that it does not distort the shape of the response curve; it is used merely to indicate and locate various points on the curve. When inserting the marker signal into the circuit, you must choose the point of attachment and the method of insertion that prevents any mis-shaping of the response curve. The amplitude of the marker should always be controlled so that the pip can just be seen on the curve.

The proper amplitude and point of connection of the marker generator will produce the shape of the pip shown in Fig. 34A. Note that it is clear and that it can just be seen. The illustration in Fig. 34B indicates that the marker has been applied at a location where it distorts the shape of the response curve.

As stated previously, the amplitude of the marker signal should be kept extremely low. Otherwise, the pip will appear on the curve as shown in Fig. 34C. If the shunt capacitor is not present at the input of the oscilloscope, the marker pip spreads out and

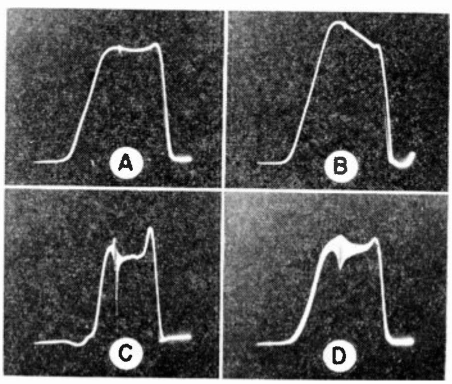


FIG. 34. Appearance of marker on response curve. A, good marker presentation; B, marker inserted improperly; C, marker amplitude too high; D, no scope capacitor causes marker to spread.

hides the true shape of the response curve. This is shown in Fig. 34D.

From the illustrations in Figs. 33 and 34, you can see that accurate adjustment of the signal generator and marker and the proper interconnection of the pieces of equipment are extremely important.

ALIGNMENT PROCEDURES

In a later lesson we will make a detailed study of typical alignment procedures. However, the following general alignment information should help you to understand video i-f amplifiers and also give you a general idea of how they are aligned.

The first, and perhaps the most important step in aligning a television receiver is to obtain a copy of the manufacturer's service information. Practically all manufacturers provide detailed alignment instructions. If you follow the instructions step by step, you should have no difficulty in aligning the receiver. The alignment information is generally prepared by the manufacturer to give the serviceman information on the simplest and most direct way of aligning the receiver. There is no doubt that the exact order with which the steps are carried out can be varied somewhat, but this often leads to difficulties.

In most cases the manufacturer will recommend applying a fixed bias to the agc controlled tubes. The exact value of bias and information on when it should be applied will be given in the alignment instructions.

In general, the alignment procedure recommended by most manufacturers for the video i-f section of a television receiver is in this order:

Alignment of traps, adjustment of individual tuned circuits of the video i-f section, and finally a touch-up of the video i-f alignment using a sweep generator and oscilloscope.

To adjust the traps, you will need an accurately calibrated signal generator or a marker generator and a voltmeter. The voltmeter is connected across the video detector load resistor and the unmodulated output of the signal generator fed into the i-f amplifier. The signal generator is set to the frequency to which the trap is to be adjusted, and then the trap is adjusted for *minimum* voltage across the detector load resistor.

When adjusting the trap, the output from the signal generator should be set to give a reasonable indication on the voltmeter. If the trap is adjusted and the reading on the voltmeter decreases, it may be necessary to increase the output from the signal generator. When the trap is set so that there is minimum voltage across the detector load resistor, the trap offers maximum resistance to the frequency to which the signal generator is tuned.

After the traps have been adjusted, the individual tuned circuits in the video i-f amplifier should be adjusted. Again, to adjust the tuned circuits you will need an accurately calibrated signal generator or a marker generator and a voltmeter. The voltmeter is connected across the video detector load resistor as before, and the output from the signal generator is fed into the video i-f amplifier.

The manufacturer will usually indicate the frequencies to which the various tuned circuits should be adjusted. The normal procedure is to start with the last tuned circuit—in other words, the tuned circuit between the video detector and the last video i-f stage. The signal generator is set to the frequency to which the circuit is to be tuned, and then the resonant circuit is adjusted for maximum voltage across the detector load resistor.

When adjusting the tuned circuit, the output from the signal generator should be adjusted to get a reasonable indication on the voltmeter. As the circuit is brought to resonance, the output on the meter will increase. As the meter reading increases, the output from the signal generator should be decreased, until the final adjustment is made using as small a signal from the signal generator as possible. If the output from the signal generator is too high it may be impossible to peak the circuit correctly.

Sweep alignment. After the traps and the i-f coils have been adjusted, the response should then be checked using a sweep signal generator and an oscilloscope. In some receivers it may be necessary to align one or more of the tuned circuits with the sweep generator. However, in most cases some preliminary adjustment can be made with a marker generator or a signal generator and then only a *touch-up* adjustment will be required with a sweep signal generator. The adjustment should be made to make the response curve resemble as closely as possible the response curve shown by the manufacturer.

One important point to keep in mind when touching up the i-f alignment is that if the response curve is distorted, the chances are that the distortion can be corrected by the adjustment of one of the coils peaked at or near the frequency at which the distortion occurs. For example, notice that with the

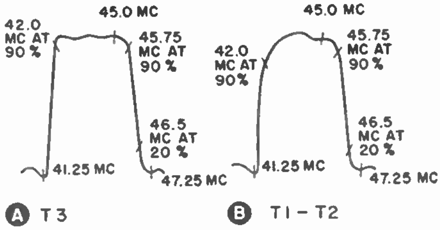


FIG. 35. Alignment response curves.

exception of the falling off near 42 mc the response curve in Fig. 35B is similar to the curve in Fig. 35A. If the manufacturer's response curve is like Fig. 35A and you obtain a curve similar to Fig. 35B, more than likely the variation in the curve is due to the fact that one of the resonant circuits that should be peaked near 42 mc is not properly adjusted. Adjusting this circuit will probably clear up the trouble. On the other hand, adjustment of the circuits normally tuned around 45 mc will only distort the curve at this frequency and will do nothing toward improving the response curve at 42 mc. Therefore the frequency at which the curve varies from the curve shown by the manufacturer usually indicates which resonant circuit should be adjusted to clear up the difficulty. Of course, there may be some interaction between circuits and it might be necessary to adjust more than one of the circuits to obtain best results, but at least by studying the curve you should be able to determine where to start in order to improve the response curve.

Troubleshooting in the Video I-F System

Troubleshooting in the video i-f system can best be accomplished using two basic techniques: signal tracing and observing the response curve on an oscilloscope. The technique to use depends on the type of disturbance that appears on the picture tube screen.

As in most electronic servicing, the first step is to check the tubes. In the video i-f system, checking the tubes by substitution is the most common method, because many tube checkers do not locate all the possible tube variations that could influence the performance of the video i-f system. If all the tubes are good, and there is every indication that there is a dead or weak i-f stage, you can go on to conventional signal-tracing techniques.

In signal tracing you can use the regular marker generator or any type of signal generator that covers the i-f frequency range of the receiver. There are three output indicator possibilities: An oscilloscope, the picture tube itself, or a dc vacuum tube voltmeter. If an oscilloscope or the picture tube is used as an output indicator, the signal from the signal generator must be modulated. The signal generator can be connected first to the grid of the last i-f stage, and then moved back through the individual stages of the i-f system until the dead or weak stage has been located. If an oscilloscope or a vacuum tube voltmeter is used, it must be connected across the detector load resistor.

The response curve tells practically everything about the operation of the video i-f system. Therefore, the more obscure troubles in the system can best be located by observing the response pattern on an oscilloscope. This involves setting up the sweep generator, marker generator, and oscilloscope. Any changes in the operation of the system are made apparent immediately on the response curve.

One of the difficulties in locating a defect in the i-f system is that the disturbance that appears on the picture tube screen may be caused by a defect in the tuner or video amplifier system as well as in the i-f system. Thus, when servicing the receiver, you must first isolate the defect to one section of the three.

For example, if a receiver has a normal raster and a weak picture or no picture, accompanied by weak sound or no sound, we can isolate the defect to either the tuner or the i-f system. However, this is as far as we can go without performing some test to isolate the defect further. By trying to pass a signal from a signal generator through the video i-f stage, we can soon isolate the trouble to either the i-f or the tuner.

A weak picture or no picture accompanied by a good sound output can often be isolated to trouble in the video amplifier instead of in the video i-f system. This is true, in general, for the intercarrier type of receiver. For a dual channel i-f system where the sound i-f is separate from the video i-f, a defect in the video i-f system may not affect the sound.

If the receiver operates normally when a weak signal is received, but becomes unstable and at times produces a reverse picture for a strong signal, you can trace the defect to the agc system. Overloading the i-f system in this manner produces the pic-

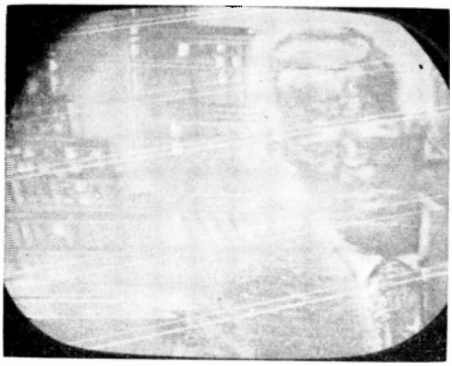


FIG. 36. Picture i-f overload, poor sync stability, and picture reversal.

ture shown in Fig. 36. As you learned, the action of the modern agc system must permit the video i-f amplifier to present maximum sensitivity to a weak signal, but when a strong signal is received, the gain of the amplifier must be reduced sharply to prevent overload. If the agc system is not functioning properly, the reduction in video i-f gain does not occur. Thus, the sync pulses are clipped or the picture appears to have too much contrast because the last or the last two video i-f stages are overloaded.

Poor picture quality can be caused by a defect anywhere from the antenna through the video amplifier. However, such a disturbance within the video i-f system can usually be isolated by observing the response curve. For example, smear and loss of resolution in the picture can be caused by a drop-off in the response at the high-frequency end of the curve, or by improper placement of the video i-f carrier. If the carrier is too far above the 40% to 60% level, the low end of the video spectrum will be emphasized. This results in poor high-frequency detail.

Often a picture will have trailing whites or echoes that may be caused by too fast a drop-off of the response at the high-frequency end or resonance at some intermediate frequency in the i-f range. Any defect of this kind will be apparent on the response curve. Therefore, you will know whether you should service the video i-f section or some other part of the receiver.

REDUCTION OF INTERCARRIER BUZZ

Complaints of intercarrier buzz at the audio output are common for intercarrier receivers. Since it is caused by interaction between the sound carrier and video modulation components, this type of disturbance can arise in a number of sections of the receiver. Perhaps the most common reason for a high buzz level is improper alignment of the FM demodulator. In the modern receiver, however, a special balance control often is associated with the demodulator to permit tuning for minimum buzz level. As far as the video i-f system is concerned, the buzz level can rise if the sound take-off trap is not tuned precisely to the 4.5-mc intercarrier frequency. Likewise, any resonant traps between the video detector output and the input to the video amplifier system must be set carefully on 4.5 mc.

As mentioned in the discussion of the response curve, there are specific resonant circuits in the video i-f system that control the position of the sound carrier. To obtain minimum intercarrier buzz, these circuits must be aligned precisely. In addition, improper operation of the agc system and consequent overloading of the i-f system can also raise the intercarrier buzz level.

Video I-F System of a Color Television Receiver

Although the i-f system of a color television receiver is essentially the same as that of a monochrome receiver, except for the addition of one or two stages, it must be able to amplify the additional chrominance, or color, information that is contained in the identical band of frequencies transmitted for monochrome reception. (The width of the channel used to transmit a color picture is no wider than the channel used to transmit black and white pictures.) As a result, the i-f system must have a broader band width; economy-type i-f systems, however, have been used in some color receivers. The alignment of the i-f system, in particular, is much more critical than in the black and white receiver.

To transmit a color program, there must be three separate carrier signals: the regular picture and sound carriers and the *chrominance* subcarrier, which is modulated by the color information. The placement of these signals within the 6-mc channel is shown in Fig. 37. We refer to the monochrome information that amplitude-modulates the picture carrier as the *luminance* component of the color signal. It carries the brightness variation of the color scene and establishes the picture detail. The chrominance subcarrier does not convey brightness detail, but it does carry information in regard to the *hue* and *saturation* of the color signal. Hue refers to the degree of redness, yellowness, etc., in the picture, while saturation refers to the purity of the color and determines whether it is a deep or a pastel shade.

A detailed discussion of the color signal is given elsewhere in your course. Remember only a narrow band of frequencies is required to convey the chrominance information (about a 1.5-mc band on the low-frequency side of the chrominance sub-carrier and about a 600-kc band on the high-frequency side of the chrominance subcarrier), as shown in Fig. 37.

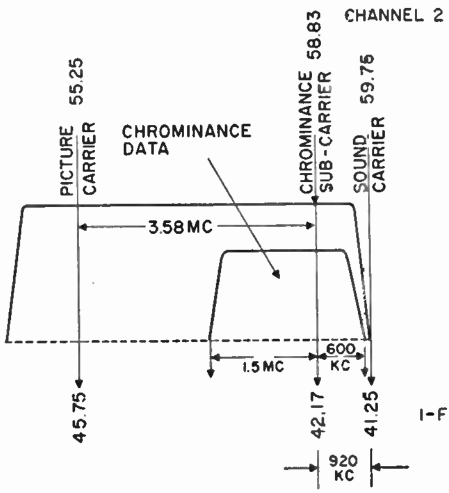


FIG. 37. Distribution of signal information for color transmission.

To minimize interference between the picture carrier and the chrominance subcarrier, the subcarrier is located at the high-frequency end of the video spectrum, and at a frequency of 3.58 mc above the picture carrier. The frequency of the chrominance subcarrier has also been chosen so that the information it conveys has the least opportunity to interfere with the luminance detail that is also transmitted over the same frequency spectrum.

REQUIREMENTS OF THE VIDEO I-F SYSTEM

The additional information contained in the same 6-mc channel, along with its position at the high-frequency end of that channel, imposes a strict band width characteristic on the i-f system. For example, when a channel 2 station is transmitting a color picture, the sound and picture carriers are located at 59.75 mc and 55.25 mc respectively. In addition, a chrominance subcarrier is present on a frequency 3.58 mc above the picture carrier (58.83 mc). In the i-f system there are the picture and sound carriers at 45.75 mc and 41.25 mc, plus an additional subcarrier at 42.17 mc. Therefore, the video i-f response, shown in Fig. 38, must be linear up to 42.17 mc, and approximately 500 to 600 kilocycles beyond. In other words, the video i-f must have a flat response between 45 mc and 41.65 mc.

Furthermore, to minimize sound interference or intercarrier problems, the response must drop from 41.65 mc to a very minimum at the sound carrier frequency of 41.25 mc (in just 400 kc). You can see, therefore, that the video i-f system must be accurately aligned. To accomplish this, an accurate marker system is a necessity.

TYPICAL COLOR VIDEO I-F SYSTEM

A typical video i-f system for a color receiver will have four or five i-f stages to obtain the proper sensitivity. In addition, the band width of each individual stage will be somewhat greater than in a monochrome receiver, and the alignment procedures more exacting.

The one major circuit difference between the video i-f system of a color receiver and that of a standard monochrome receiver is a result of the intercarrier sound technique. Note in the distribution curve in Fig. 37 that the separation between the chrominance subcarrier and the sound carrier is only 920 kc. Consequently, if any sound component enters the video section, it can set up an interference beat with the chrominance subcarrier and cause annoying 920-kc lines to appear on the picture. The sound information, therefore, must be completely blocked from the video channels of the color receiver. To accomplish this, the sound take-off point for a color receiver is not at the video detector or video amplifier, but at one of the video i-f stages preceding the detector.

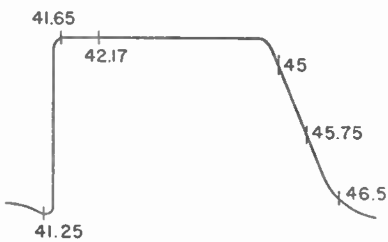


FIG. 38. Typical video i-f response for a color receiver.

Lesson Questions

Be sure to number your Answer Sheet 53B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. Why is partial sideband suppression used in television?

2. In a resonant circuit, how does resistive loading affect (a) the *band width;* (b) the *gain?*

3. What is the function of agc voltage in a video i-f amplifier?

4. What is the difference frequency between sound and picture carriers at the station?

5. What is the difference frequency between sound and picture carriers in the video i-f amplifier?

6. How is adjacent channel interference minimized?

7. What is an absorption trap?

8. Why are un-bypassed cathode resistors used in some video i-f stages?

9. Do we connect the plate or the cathode of a diode detector to the top of an i-f coil to obtain a negative-going composite signal at the output?

10. When adjusting a trap, should you adjust for *maximum* or *minimum* voltage across the video detector?

Get Along With People

"What single ability is most essential to success?"

In a recent study covering the activities of several hundred successful men, this question was asked:

The almost unanimous answer was:

THE ABILITY TO GET ALONG WITH PEOPLE.

You will agree with this, I am sure.

The successful technician—engineer—businessman—must *get along with* other people, if he is to gain the greatest success, and earn the greatest profit from his technical abilities.

Keep this in mind in your everyday life. *Practice getting along with* people. We can all improve on our abilities in this "art"—and will profit by doing so.

VIDEO AMPLIFIERS AND DC RESTORERS

54B

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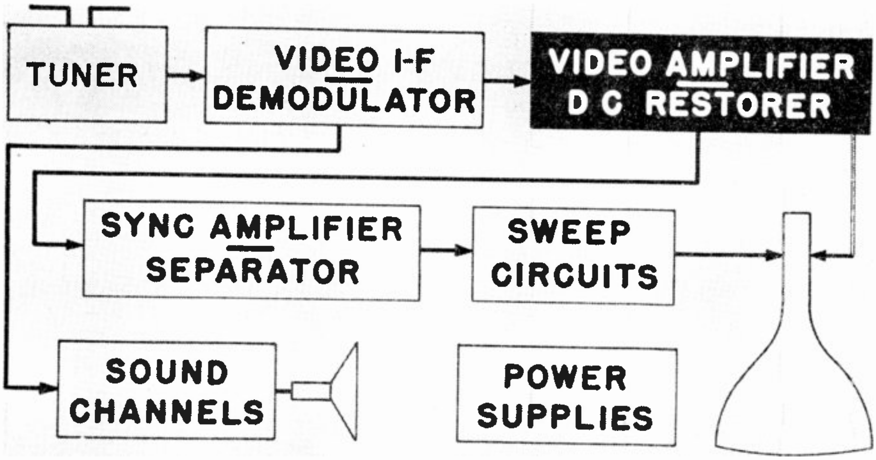
STUDY SCHEDULE NO. 54

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

FM3M1060 **1960 Edition** Printed in U.S.A.



THE VIDEO amplifier of the television receiver follows the video i-f system and the demodulator. It must increase the amplitude of the signal at the output of the video detector to the peak-to-peak voltage necessary to drive the picture tube. It must amplify linearly a range of video frequencies from 30 cycles up to 4 megacycles.

There are a number of other things the video amplifier must do. It must retain the average brightness level of the received picture, and it must reproduce the picture with the proper contrast range. For example, the video information must not be compressed in the white or black regions or the various shades of gray will not be faithfully reproduced.

The contrast and brightness controls are associated with the video amplifier and the grid circuit of the picture tube. The contrast control usually varies the gain of the video amplifier system so that the gain will be high when the input signal is weak, and low when the signal is strong. The contrast and brightness controls are adjusted jointly for the most pleasing picture.

The intercarrier sound take-off point is located in the video amplifier input, and must be planned, as discussed in a previous lesson, to prevent sound interference from entering the video amplifier, and picture modulation components from passing into the sound channel.

The sync take-off point, where part of the composite signal is channeled into the synchronizing circuits, is also located in the video amplifier. The sync take-off circuit, which we will discuss later, must be arranged to supply the composite signal to the sync circuits without causing any loss in picture detail in the video amplifier.

RESISTANCE-COUPLED AMPLIFIERS

Before you study video amplifiers, you must understand how simple resistance-coupled amplifiers work. Let us review a few of the basic facts about resistance-coupled amplifiers so that you will understand the problems of video amplification.

A typical amplifier consisting of a vacuum tube and its associated resistors and capacitors is shown in Fig.

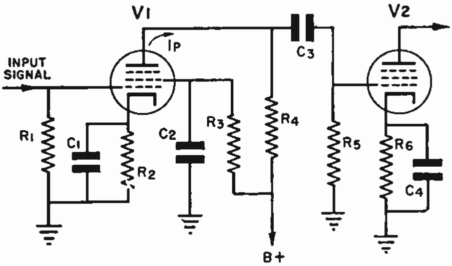


FIG. 1. A typical resistance-coupled amplifier.

1. When a signal is applied to the input of the amplifier it causes the grid voltage to vary. This, in turn, causes a change in the plate current, which flows through the tube, the plate load resistor R4, and the cathode resistor R2. Voltage changes across the cathode resistor R2 are prevented, despite the changing current, by capacitor C1. However, the change in plate current does produce a voltage change across the plate resistor R4. Therefore the plate voltage (voltage between plate and ground) varies to produce a voltage output from the stage.

The gain of the stage depends on the tube, the operating voltages, and the parts values. However, it is determined mainly by the mutual conductance of the tube (Gm) and the value of the plate resistor. The Gm of a tube is a measure of how effectively it changes a grid-voltage variation into a plate-current variation. It is apparent that the greater the plate current variation, the greater will be the output voltage. The size of the plate resistor also determines the output voltage. The larger the value of the resistor (for a given plate current change), the greater will be the output voltage from the stage. You will soon see that the resistance of the plate resistor must be kept low in a video amplifier, so we must use a vacuum tube with a high Gm.

Before we study a video amplifier, let us review the circuit shown in Fig. 1 and the purpose of each of the parts in the circuit.

Grid Resistor, R1—The input signal is developed across the grid resistor, which provides a return path to the cathode for any electrons that strike the grid, thus preventing an accumulation of electrons on the grid from blocking and interfering with the operation of the tube.

Cathode Resistor, R2—The direct current (plate and screen current) that flows through the cathode resistor develops a dc voltage that biases the cathode positive with respect to the grid. (In other words, the grid is negative with respect to the cathode.)

Cathode Capacitor, C1—The cathode capacitor is a filter that prevents any variation in the plate current flowing in the cathode resistor from developing a varying voltage across the cathode resistor. If such a varying voltage did exist across the cathode resistor, it would be out of phase with the signal voltage applied to the grid. This would reduce the effective input voltage and hence the over-all gain.

Plate Resistor, R4—The plate current variation through the plate resistor develops a varying voltage drop across the plate resistor that follows the changes of the grid signal. Since the plate current variations are substantial and the value of the plate resistor is reasonably high, the varying voltage produced between the plate and ground is greater than the input signal applied to the grid. The ratio of the output signal to the input signal is the *gain* of the stage.

Screen Resistor, R3—The screen resistor drops the supply voltage to the proper value for application to the screen grid of the amplifier.

Screen Capacitor, C2—The

screen capacitor acts as a filter that prevents the screen current variation from producing a screen voltage variation that could be degenerative and lower the effective gain of the stage.

Coupling Capacitor, C3—The coupling capacitor provides a low reactance path for the ac signal in the plate circuit of V1 to the grid of V2. The coupling capacitor also prevents the dc plate voltage on V1 from appearing on the grid of the next stage.

Broad - Band Video Amplification

A video amplifier is identical in theory of operation to the vacuum tube amplifier just discussed except for more carefully chosen parts values and the addition of a few other components to improve the performance of the amplifier at frequencies above and below the audio range.

The wide-band response necessary in a video amplifier is obtained by modifying the basic resistance-coupled audio amplifier. A good quality audio amplifier might have a frequency range extending between 100 cycles and 10,000 cycles, but a video amplifier must amplify linearly a span of frequencies from 30 cycles to 4 megacycles—over 400 times the range of the audio amplifier.

We have already mentioned that the frequency range of the video signal covers the frequencies from 30 cycles per second up to 4 megacycles. A good video amplifier must be able to amplify equally any frequencies within this range. In other words, if we have a video amplifier with a gain of 10 and feed a 1-volt signal to the input of the amplifier, the output should be 10 volts, regardless of whether the frequency of the signal is 30 cycles or 4 megacycles.

If the video amplifier cannot amplify the various video frequencies equally, the quality of the reproduced picture will suffer. If the gain of the video amplifier falls off at higher frequencies so that a high-frequency video signal is either lost completely or does not receive the same amplification as the low-frequency or middle-frequency video signals, the reproduced picture will not contain the detail being sent by the transmitter.

If, on the other hand, the video amplifier operates satisfactorily at the middle and higher video frequencies, but the gain falls off at the low frequencies, large objects in the picture will be smeared. In addition, if the synchronizing signal is taken off at the output of the video amplifier, the vertical synchronizing signal will be affected and as a result, the stability of the vertical oscillator will be poor.

A careful examination of the reproduced picture will usually permit you to classify video amplifier defects as follows:

(1) Dead stage.

(2) Poor low-frequency response.

(3) Poor high-frequency response.

The first defect is likely to be caused by the same defects that could cause a similar complaint in an audio amplifier. In other words, you may have a defective tube, an open resistor, a shorted capacitor, no plate or screen voltage on the tube, etc. However, the second and third classes of defects may be somewhat more difficult to localize. In the following sections you will learn how the required broad-band amplification is obtained. You will study the function of the various components in the circuit, particularly the components that limit the video amplifier response, and learn what steps are taken to improve it. When you run into a video amplifier lacking the required broad-band response, once you can identify the defect as either poor high-frequency response or poor low-frequency response, you will know what parts are likely to be causing the trouble.

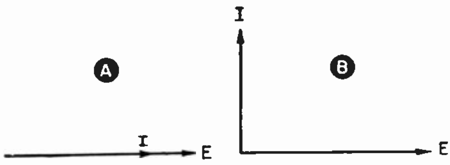


FIG. 2. Vector diagrams of voltage and current. In A, the voltage and current are in phase, but in B, the current leads the voltage by 90°.

AMPLIFICATION OF LOW FREQUENCIES

In amplifying the low-frequency video signals, there are two types of distortion that must be avoided. These are amplitude distortion and phase distortion.

Both of these types of distortion may be caused by the coupling capacitor that feeds the signal from the plate of one stage to the grid of the following stage. The cathode by-pass capacitor may also introduce degeneration in the stage, which will result in a falling off in the low-frequency gain of the stage. Before we go into detail about the steps taken to eliminate the difficulty, let us review a few basic points about capacitors, and circuits consisting of capacitors and resistors in series.

You already know that if a voltage is applied to a circuit that contains pure resistance, the current flowing in the circuit will be in phase with the voltage. In other words, as an ac signal starts at zero and the voltage builds up to a maximum, the current will be exactly in step with the voltage, starting at zero at the same time as the voltage and reaching the maximum when the voltage reaches the maximum.

In a circuit that contains nothing but capacitance, the current flowing in the circuit will lead the voltage by 90°. This means that when the voltage is zero, the current will be at the maximum. As the voltage builds up toward a maximum, the current will decrease until at the instant when the voltage has reached a maximum, the current will be at zero.

For convenience, phase relationships of this type are often represented by means of vector diagrams. Fig. 2A is a vector representation of the current and voltage in a circuit containing only resistance. Since the current and voltage are in phase, the current vector falls on top of the voltage vector. A vector representation of the current and voltage in a capacitive circuit is shown in Fig. 2B. The current leads the voltage by 90°. This is represented by drawing the current vector at an angle of 90° counterclockwise with respect to the voltage vector.

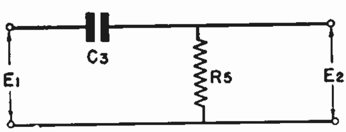


FIG. 3. Capacitor C3 and resistor R5 form a voltage divider so that E2 will be less than E1 when the reactance of C3 becomes appreciable.

In the amplifier shown in Fig. 1, the voltage developed between the plate of V1 and ground is applied to a series circuit consisting of C3 and

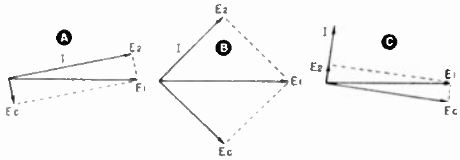


FIG. 4. A vector representation of the attenuation and phase shift in the coupling network of Fig. 3. A shows the relationship between E1 and E2 when the reactance of C3 is small compared to the resistance of R5 and the circuit acts almost like a pure resistance. B shows the relationship when the reactance of C3 is equal to the resistance of R5. C shows the relationship when the reactance of C3 is much larger than the resistance of R5 so the circuit acts almost like a pure capacitance.

R5. This circuit is shown in Fig. 3. The voltage E1 represents the voltage between the plate of V1 and ground, and the voltage E2 represents the voltage between the grid of V2 and ground.

In the circuit shown in Fig. 3, we have a series circuit consisting of C3 and R5. When a voltage is applied to a series circuit consisting of resistance and capacitance, the phase relationship between the voltage and the current flowing in the circuit will depend upon the reactance of the capacitor and the resistance of the resistor. If the reactance of the capacitor is extremely small and the resistance of the resistor is high, the circuit will act almost like a pure resistance circuit, and the current will be almost in phase with the voltage. The voltage is represented by E1 and the current by I in Fig. 4A.

We know that the voltage across the resistance element in the circuit will be in phase with the current. Therefore, we have drawn the vector E2 representing the voltage across the resistor coinciding with the current vector. Since the circuit is almost a pure resistance circuit and the current leads the voltage only slightly, the voltage E2 will be only slightly ahead of the voltage E1. The voltage across the capacitor will lag the current by 90° and therefore Ec is drawn 90° behind the current I and voltage E2.

There are two important things you should notice in Fig. 4A. First, that E2 is almost equal to E1, and second, that it is almost in phase with it. At middle and high video frequencies, the reactance of C3 will be so small that for all practical purposes we can say E2 is equal to E1 and in phase with it.

Now let us investigate what happens when the reactance of the capacitor is equal to the resistance of the resistor. In this case, the characteristics of the circuit will be mid-way between those of a circuit having pure resistance and those of a circuit having pure capacitance. The current will lead the voltage by 45°. This is shown in Fig. 4B. Notice that we have drawn E2 45° ahead of E1 (counter-clockwise), because the voltage E2 will be in phase with the current and therefore it will coincide with the current vector. The voltage Ec is drawn 90° behind E2—the voltage across the capacitor will be 90° behind the current through it.

In comparing Figs. 4A and 4B, there are two things that you should notice in each one. In Fig. 4A, the voltage vector E2, which is the output voltage, is almost equal to the input voltage, E1, and the phase angle between the two voltages is comparatively small. However, in Fig. 4B, E2 leads E1 by an appreciable angle and E2 is considerably shorter than E1. This means that the output voltage E2 is smaller in amplitude than E1 and also that an appreciable phase shift has been introduced.

The vector diagram is Fig. 4C represents a circuit where the reactance of the capacitor is much larger than the resistance of the resistor. The circuit acts almost like a pure capacitor. The current I is almost 90° ahead of the voltage E1. Again, since E2 will be in phase with the current flowing in the circuit, the voltage E2 is drawn coinciding with the current vector and then Ec is drawn 90° behind it. Notice that in this figure, the voltage E2 is much smaller than E1 and that it leads it by almost 90°.

We do not need to go into a great deal of vector theory in order to understand what happens to a circuit similar to Fig. 3. The important thing to understand is that if the reactance of the capacitor is small in comparison to the resistance of the resistor, the output voltage E2 will be almost equal to E1, and it will be almost in phase with it. However, as the reactance of the condenser increases, the output voltage decreases, and at the same time, an appreciable phase angle between E2 and E1 develops.

You will remember that the reactance of a capacitor varies inversely with frequency. In other words, for a given size capacitor, as the frequency of the ac signal decreases, the reactance of the capacitor increases, and conversely, if the frequency increases, the reactance decreases. Therefore, if in Fig. 3, the frequency of the input voltage E1 is high, the reactance of C3 will be low, and E2 will be for all practical purposes equal to E1 and in phase with it. However, if the frequency is low, then the reactance of C3 may be high enough to be either equal to or greater than R5. When this happens, the output voltage E2 will be much smaller than the input voltage E1, and it will lead it by an appreciable phase angle.

If the coupling network consisting of C3 and R5 had to pass only one frequency, we would not have to be concerned about attenuation and phase shift that might be introduced. However, since it must pass a wide range of video frequencies, attenuation and phase shift become a serious problem because they will change as the frequency changes. The lower the frequency of the input signal applied to the network, the greater the attenuation and phase shift will be. This means that there will be a time displacement of the low-frequency video signals. In other words, if low-frequency and high-frequency video signals are fed into the input at the same time, they will not appear across the output at exactly the same instant.

The effect of low-frequency attenuation and phase shift is shown in Fig. 5. Notice, that there is a general displacement of picture information. This is shown in particular by the long trailers that follow low-frequency information (large letters). Phase shift is not difficult to understand if we consider it in terms of the delay it causes between a component of one frequency, and another component of a higher or a lower frequency. Some portions of the signal are displaced with respect to other portions, and information is not po-

FIG. 5. Attenuation and phase shift caused by poor low-frequency response in the video amplifier.

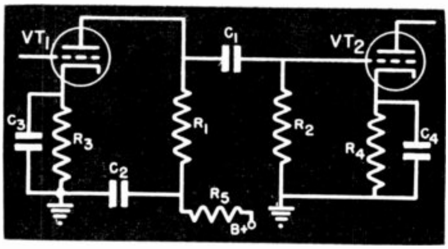


FIG. 6. A circuit that is often used for low-frequency compensation.

sitioned on the picture tube screen in exactly the same order as it was released at the camera.

The cathode by-pass capacitor also causes some difficulty. Its purpose is to by-pass the cathode resistor. At low video frequencies, its reactance may be as high as or higher than the resistance of the cathode resistor. Needless to say, under these conditions it will not by-pass the resistor, and degeneration will occur.

Low-Frequency Compensation. By proper choice of circuits and component parts, low-frequency response can be extended so that satisfactory results can be obtained at the lowest video frequency to be amplified. In the interstage coupling circuit, the value of the capacitor and the resistor must be made sufficiently large to prevent serious degeneration of low frequencies. Usually the results will be satisfactory if the reactance of the capacitor is smaller than the resistance of the resistor. Therefore either increasing the size of the grid resistor, or increasing the size of the coupling capacitor, which will reduce the reactance, will improve the low-frequency response. If it is necessary to use a rather low value of cathode resistor to obtain proper bias for a video stage, that resistor must be shunted by a large value cathode capacitor to maintain a linear frequency response down to the low-frequency limit.

Some video amplifier stages that have a cathode resistor do not have any cathode capacitor. This method of operation prevents low-frequency attenuation, because although the *over-all gain* of the video amplifier *is reduced* by degenerative action, all frequencies are equally affected, and the band width remains essentially linear. When the cathode resistor is left un-bypassed, the size of the resistor is kept small to avoid introducing too much degeneration into the circuit.

It is possible to use a special compensating circuit to emphasize the low-frequency range. Such a compensating circuit is generally in the form of a resistor-capacitor combination in the plate circuit of the video stage as shown by R5 and C2 in Fig. 6.

The values of C2 and R5 are such that at high frequencies the reactance of C2 is negligible so that the load impedance of VT1 is equal to the resistance of R1. When frequencies low enough to be attenuated by coupling and/or degeneration losses are being amplified, the reactance of C2 becomes appreciable, and the load impedance of VT1 consists of R1 and the impedance of the parallel combination of C2 and R5. The increase in load impedance increases the gain of the stage, compensating for the losses due to coupling and degeneration. The capacity and resistance values of C2 and R5 must be carefully selected to provide the correct amount of compensation.

AMPLIFICATION OF HIGH FREQUENCIES

The problem of extending the response of a resistance-coupled amplifier so that it will amplify the high video frequencies is somewhat similar to that of extending the range to amplify low-frequency signals. However,

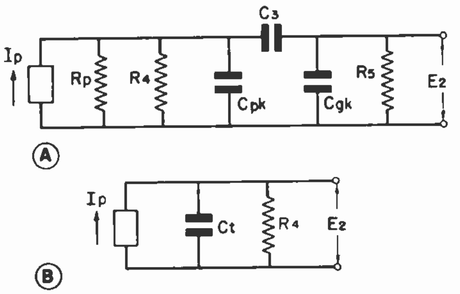


FIG. 7. Equivalent circuit of the amplifier in Fig. 1 is shown in A. Simplified equivalent circuit at high frequencies is shown in B.

the difficulties that are encountered at high frequencies are somewhat different from those encountered at low frequencies, and therefore they must be corrected in a different way.

Attenuation. High frequencies are attenuated by any capacity that shunts or is placed in parallel with the signal path. Thus there is need of low-capacity tubes, low-capacity wiring, and small low-capacity components in a video amplifier stage.

In a video amplifier there are a number of capacities that shunt the signal path. The shunt capacity is made up of the output capacity of the first stage, the input capacity of the second stage, the wiring capacity between stages, the capacity of the individual parts to ground, and any other stray capacities. This capacity must be held to a *minimum* to obtain linear amplification of the wide range of video frequencies.

The effect of the distributed circuit capacity on a typical amplifier can best be seen by drawing the equivalent circuit of the amplifier shown in Fig. 1.

The equivalent circuit of the amplifier shown in Fig. 1 can be shown by using a constant current generator as a source as in Fig. 7A. A constant current generator generates a constant current regardless of the load placed across it. A pentode tube very closely resembles a constant current generator.

In an analysis of this type, the plate load resistor and the tube plate resistance are drawn in parallel with the generator. Similarly, the plate-to-cathode capacity of V1, which is in effect in parallel with R4, is drawn in parallel with the generator.

The plate of V1 is coupled to the grid of V2 by C3, and R5 is connected from the grid of V2 to ground. C3 and R5 are therefore drawn as shown in Fig. 7A, and the grid-to-cathode capacity of V2 is drawn in parallel with R5.

The current from the generator will be Ip regardless of the load, because the generator is a constant current generator. In Fig. 7A, the current Ip divides among Rp, R4, Cpk, and the series parallel combination of C3 in series with the parallel combination of R5 and Cgk.

At middle and high video frequencies, the coupling capacitor C3 acts as a short circuit, and therefore R4, Rp, and R5 are all in effect in parallel. However, the resistance of R5 is usually about 100 times the resistance of R4. Similarly, the plate resistance of the tube is usually 100 times or more the value of the load resistor R4. The total resistance of the parallel combination of R4, Rp, and R5 is equal to R4 for all practical purposes. Cpk and Cgk are also in parallel and therefore we can draw a simplified equivalent diagram as shown in Fig. 7B. In the simplified circuit the generator current flows through R4, and the capacitor Ct is made up of the plate-to-grid capacity of V1, the grid-to-cathode capacity of V2, and any additional capacity to ground that may be present in the circuit.

As long as the generator frequency is not too high, the reactance of Ct will be high, and it will have no shunting effect on R4. However, at the higher video frequencies the reactance of Ct may become quite low, and as a result, the current begins to divide between the capacitor and the load resistor. Eventually, as the frequency is increased, a point will be reached where an appreciable portion of the current will be flowing through the capacitor.

Since the current is generated from a constant-current source, the generator current remains the same at all times. Therefore as a part of the current begins flowing through the shunt capacity, the current flowing through the plate load resistor will decrease. The output voltage, E2, will be equal to the product of the resistance of R4 and the current flowing through it. As you can see, as the current flowing through the resistor decreases, the output voltage will decrease.

Eventually a frequency will be reached where the reactance of the condenser is lower than the resistance of the resistor. When this happens, there will be more current flowing through the capacity than through the resistor, and the output voltage will drop to a very low value.

Phase Distortion. In studying the amplification of low frequencies we pointed out that a phase shift will occur in any circuit containing both resistance and capacitance. This phase shift occurs at high video frequencies, with the result that the high-frequency video information will be displaced so that it does not fall at the proper place in the reproduced picture. This difficulty is even more troublesome than the attenuation of the signal. The phase shift is caused by the lag or time delay in the charge and discharge of a capacitor—in this case, the capacitor is the total distributed circuit capacity.

At the low and middle video frequencies, the total distributed capacity of the circuit is so small that it has a very high reactance, and the voltage variation across the plate resistor follows the plate current variation instantaneously. This can be seen in the vector diagram of Fig. 8A. The reactance of the distributed capacity is so high that all the current flows through the plate load resistor, R4 of Figs. 1 and 7. The output voltage E2, will therefore be the voltage across the resistor. The voltage across the resistor is always in phase with the current flowing through it, and therefore E2 is in phase with Ip.

At high video frequencies, however, the filtering action of the shunt capacity becomes apparent. At some frequency, the reactance of the shunt capacity will be equal to the resistance of the plate load resistor. When this happens, half the plate current will flow through the load resistor and half through the capacitor. This will result in the situation shown in Fig. 8B. Again, the voltage developed across the plate load resistor will be in phase with the current flowing through it. However, the current through a capacitor leads the voltage

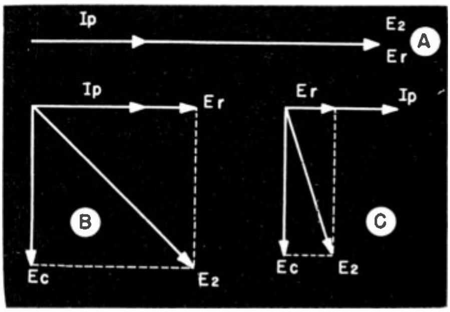


FIG. 8. Vector diagrams showing the phase shift that occurs at high video frequencies.

by 90°. Therefore, the voltage across the capacitor will be 90° behind the voltage across the resistor as shown in Fig. 8B. The resulting output voltage will be the vector sum of the voltages Er and Ec. The sum of these two voltages is the voltage E2, which lags the plate current by 45°.

If the frequency is increased still further, more than half the current will flow through the capacitor, with the result shown in Fig. 8C. Notice that the voltage E2 lags the plate current by an even greater angle than in Fig. 8B and also notice that the amplitude of the voltage is considerably less than it was.

The displacement of the high-frequency video component may cause smearing of the fine detail or a complete loss of the fine detail in the picture. The loss of picture detail is due to the inability of the video amplifier to follow rapid changes or high-frequency changes in brightness.

It is important for the technician to recognize that both high- and low-frequency losses are not confined to the video amplifier. Similar deficiencies in frequency response in the video i-f system, tuner, or antenna system can result in the same degradation of the picture.

IMPROVING THE HIGH-FREQUENCY RESPONSE

In Fig. 8B we have shown, by means of vectors, what happens when the video frequency is high enough for the reactance of the distributed capacities in the output of a video amplified to equal the resistance of the plate load resistor. Notice that the net voltage developed across the circuit, E2, lags the plate current by 45°. It so happens that the output voltage will be equal to .707 of the voltage obtained in the middle video frequency range. If the video amplifier can be designed so that the highest video frequency to be handled receives no more attenuation and phase shift than this, the results will usually be satisfactory.

For a fixed value of capacity in the circuit, the frequency at which the reactance will be equal to the plate load resistance depends upon the value of the plate load resistance. In other words, if the plate load resistor is a 10,000-ohm resistor, and the reactance is equal to 10,000 ohms at a frequency of 1 megacycle, we could increase the frequency at which the reactance will be equal to the resistance simply by reducing the size of the plate load resistor to 5000 ohms. Now the reactance will be equal to the resistance at a frequency of 2 megacycles. From this you can see that the frequency that the video amplifier can handle can be increased by reducing the size of the plate load resistor. Of course, this reduces the gain of the video amplifier at low and middle frequencies, but gain must be sacrificed in order to obtain a wide-band amplifier.

The first step, therefore, in improving the response of the video amplifier is to use a low value of plate load resistor. Let us look into some additional steps that can be taken to give us still better response at high video frequencies.

High-Frequency Peaking. Special inductors, such as L1 and L2 in Fig 9, can be used to boost and improve the gain of the video amplifier in the high-frequency range. The two basic methods of peaking are referred to as shunt peaking and series peaking. In Fig. 9A, inductor L1 is referred to as a "shunt peaking coil" because it is across the signal path. The peaking coil, which at the most has an inductance of just a few hundred microhenrys, has a very low re-

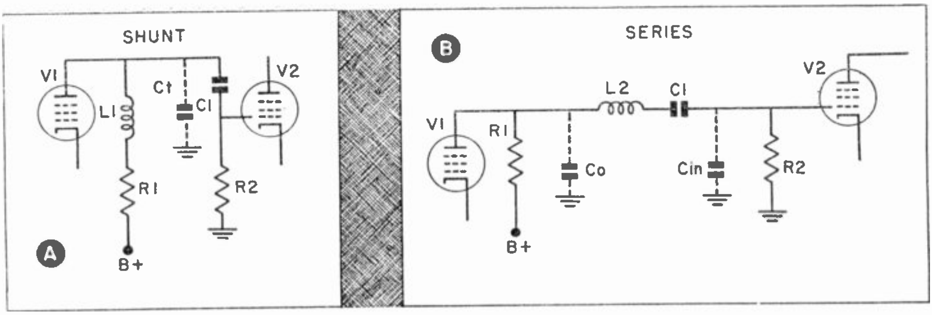


FIG. 9. Circuit arrangement for shunt peaking (A), and series peaking (B).

actance over the middle and low frequency range of the video spectrum. However, at high frequencies, the inductive reactance increases, and adds, in series, with the plate resistor R1. Consequently, the impedance of the plate circuit increases, and the gain of the video amplifier rises.

The peaking coil L1, along with the distributed circuit capacity Ct, forms a circuit that is broadly resonant at the upper end of the video spectrum. This resonant circuit peaks the gain of the amplifier at the high-frequency end. As you have learned, the impedance of a parallel resonant circuit is largely resistive over its band-pass. As a result, the presence of the peaking coil not only adds to the plate impedance to raise the gain of the stage at the high-frequency end, but also reduces the phase distortion introduced by the distributed circuit capacity.

When the peaking coil is inserted in series with the signal path, as in Fig. 9B, it is called a "series peaking coil." A series peaking coil isolates the output capacity of one stage from the input capacity of the succeeding stage. Thus, the total distributed capacity is divided into input and output components, Co and Cin. In fact, a low-pass filter results. This low-pass filter passes all frequency components up to a specific high-frequency limit.

To pass the high end of the video spectrum, inductor L2 and the input capacity of the succeeding stage become series resonant, and permit maximum transfer of signal energy over this spectrum. It might at first appear that the rising inductance of L2 would act as a voltage divider and attenuate the high-frequency segments of the desired video spectrum. However, the series resonant relationship between the inductor and the input capacity permits the voltage across Cin to rise as the frequency is increased, peaking the response over the necessary range to compensate for the presence of the output capacity.

The effective isolation offered by the peaking coil between input and output capacities permits the use of a higher value of plate resistance for a given high-frequency limit than the shunt peaking coil arrangement. Consequently, series peaking not only peaks the video amplifier gain at the high-frequency end of the video spectrum, but also permits an improvement in the over-all gain of the video amplifier stage.

Series-Shunt Peaking. The most common form of peaking in commercial video amplifiers is combination series-shunt peaking. The combination of both types of peaking in a video amplifier, as shown in Fig. 10, permits a higher value of plate re-

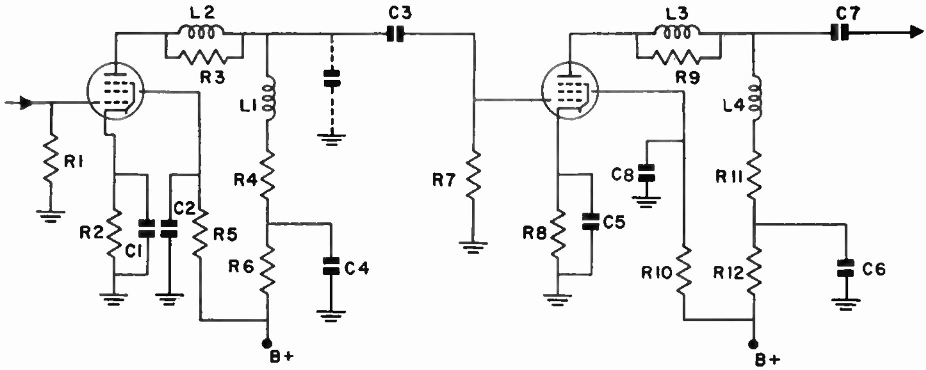


FIG. 10. Two-stage video amplifier with series-shunt peaking.

sistor for a given high-frequency limit, and provides best control of high-frequency response. The higher permissible value of plate resistor results in a higher gain per band width than other types of peaking.

The series-peaking coil, inductor L2 of Fig. 10, is made series resonant with the input capacity of the succeeding stage, at some frequency at the high end of the video spectrum. The shunt peaking coil, inductor L1, is made resonant with the total distributed circuit capacity at a somewhat lower frequency. The combination of both peaking coils gives a linear and extended high-frequency response with substantially higher gain than could be obtained with either of the two types of peaking alone.

The band width and the flatness of the shunt peaking characteristic depends on the loading of the parallel resonant combination by the plate resistor R4. The plate resistor acts as a loading resistance for the parallel resonant circuit, lowering its Q and extending its band width over the high end of the video spectrum without causing a serious resonant peak. The series peaking coil, however, is not loaded by the plate resistor, because of its location in series with the signal path. It could have a very high Q, and therefore it is shunted with a resistor to lower its Q and prevent sharp resonant peaks in the video response curve. The loading of the peaking coil extends the band width and keeps the response flat and linear over the high end of the video spectrum.

Video Amplifier Defects. We have already pointed out that you will encounter defects such as dead stage, low gain, etc., in video amplifiers. These defects are serviced in exactly the same way as similar defects in audio amplifiers. In addition to these defects, there are five dis-

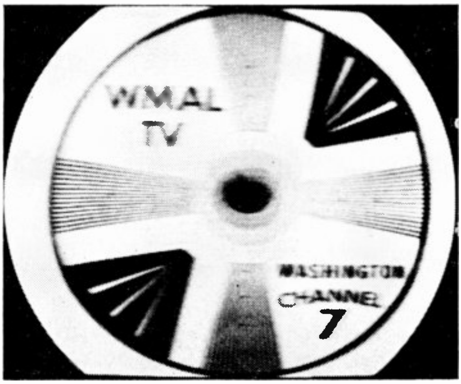


FIG. 11. Loss of fine detail due to loss of high frequencies.

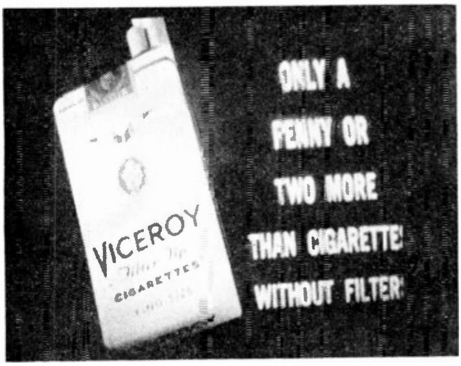


FIG. 12. Grainy appearance and repeat lines caused by emphasis of highs.

turbances that affect the picture resolution. They are the loss of lows, loss of highs, overemphasis of lows, overemphasis of highs, and sharp peaking at some high frequency.

The loss of low frequencies, shown in Fig. 5, can be caused by a defective interstage coupling circuit or inadequate low-frequency filtering at some portion of the circuit. A loss of high frequencies, Fig 11, is most often caused by capacitive loading at some point in the video circuit (tube or a signal take-off point), or a defect in one of the peaking circuits.

It is also possible to have a video amplifier circuit defect that emphasizes the low-frequency components of the video information. Such a defect could be caused by an open or low-capacity decoupling or filter circuit in the supply voltage lead. The same disturbance might also cause additional attenuation of the highs.

Still another defect, as shown in Fig. 12, would be caused by emphasis of certain high frequencies. This effect may be due to peaking circuits with too high a Q, or to a change in loading of the peaking circuits.

A change in the distributed capacity can shift the resonant frequency of one of the peaking components, and produce a high-frequency rise at some point in the response curve. This sharp emphasis of a particular frequency range could make the amplifier subject to transient oscillation in this frequency range. Whenever video signals of this frequency range passed through the amplifier, they would produce a series of oscillations that could contribute added information on the reproduced picture in the form of repeats or echoes as shown in Fig. 13.

It is important to realize that most defects in the video amplifier causing poor resolution are apparent in the reproduced picture. Thus the picture itself is the best indicator for troubleshooting in the video amplifier.

FIG. 13. Echoes and resonant repeats caused by high-frequency peaks.

The Effect of Time Constants on the Video Signal

One of the important factors that engineers must consider in designing video amplifiers is how the various R-C networks will affect the shape of the video signal. As a serviceman, you need not go into the design of these circuits, but you should have a general idea of how the video signal may be affected by these networks so that when a defect occurs, you will have a good idea of what type of trouble to look for.

We have already discussed the effect of the coupling capacitor on the low-frequency response of the video amplifier and also the effect of the shunt capacities on the high-frequency response of the amplifier. Now let us take another look at the video amplifier, and this time consider the time constants of the circuits involved in order to get a better understanding of the factors that limit the response of a video amplifier.

THE VIDEO SIGNAL

In discussing audio amplifiers, we generally consider their response in terms of sine-wave response. This is logical, because the electrical equivalent of a 400-cycle tone is a 400-cycle sine-wave signal. More complex sounds are simply made up of combinations of sine-wave signals.

Video signals are in general much more complex than audio signals. If the scene shown in Fig. 14A is televised, the video signal produced will be a square wave as shown in Fig. 14B. In Fig. 14A, the scene is simply divided into two parts, one black and the other white. To reproduce this scene, as the electron beam scans across the picture tube, we must have a signal that will turn the beam completely off during the first half of a line and then switch it to maximum brightness during the second half of the line. This will require a signal like Fig. 14B where the voltage rises almost immediately to a maximum, then remains constant for the first half cycle and switches polarity almost instantly, remaining constant for the second half and then dropping back to zero.

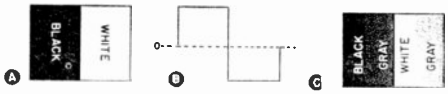


FIG. 14. The video signal resulting from the scene at A is shown in B. The effect of poor low-frequency response on a scene like Fig. 13A is shown at C.

A signal of the type shown in Fig. 14B is usually referred to as a square wave. By means of mathematics, we can show that a square wave actually consists of a fundamental sine-wave plus an infinite number of odd harmonics. Therefore in studying the response of a video amplifier to a wave of this type, we can study the response of the video amplifier to a sine wave and its odd harmonics. This greatly simplifies our study of video amplifiers.

The video signal consists of pulses similar to the pulse shown in Fig 14B. Of course, the pulses may occur at a much faster rate. For example, if the video scene consisted of ten vertical bars, then we would have ten cycles during each line instead of one cycle. Similarly, if there were a hundred vertical lines, we would have a hundred cycles per line.

A video amplifier cannot respond to instantaneous changes like those shown in Fig. 14B. It takes some time for the signal to go from zero to a maximum value. However, the shorter the time required, the better will be the quality of the reproduced picture.

Another important point to notice about the signal shown in Fig. 14B is that both the top and the bottom of the signal are flat. In other words, the signal very closely resembles a dc voltage that has one polarity for the first half cycle and the opposite polarity for the second half cycle. To maintain the top and the bottom of the signal flat, any coupling network used between video amplifier stages must have a good low-frequency response.

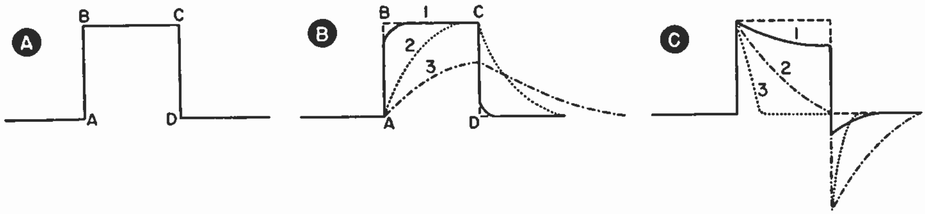


FIG. 15. In a square pulse, the edges are formed by high frequencies, and the top by low frequencies as shown in A. Attenuation of high frequencies slopes the edges (B), and attenuation of low frequencies slopes the top (C).

If the low-frequency response is poor, both the top and the bottom of the square wave will slope. The reproduced picture, instead of being totally black on one side and totally white on the other will be shaded, going from total black on the left to a gray toward the center and then shifting to a white and then again drifting toward a gray at the right side as shown in Fig. 14C.

Of course, in addition to the video signal, the video amplifier must also pass the horizontal and vertical synchronizing pulses. Again, in order to pass these pulses, the video amplifier must be capable of passing a wide band of frequencies.

Let us briefly review what we have learned about pulses and how the video amplifier can affect the shape of the pulse. The high-frequency components of the pulse must be passed to prevent mis-shaping of the leading and trailing edges of the pulse. The leading and trailing edges represent a fast change in voltage in a short period of time; and therefore constitute high-frequency voltage changes.

To prevent changing the shape of the tip or flat top of the pulse, the low-frequency components of the pulse must be passed, because the flat top of a pulse is formed mostly by the low-frequency sine wave. Consequently, as shown in Fig. 15A, the high-frequency response of an amplifier determines how well the sides A-B and C-D are passed; while the low-frequency response of the amplifier determines how well the pulse section B-C is passed.

If the high-frequency response of the amplifier passing the pulse is poor, the leading and trailing edges of the pulse are distorted as shown in Fig. 15B. A slight loss of high-frequency response results in a slight rounding of the pulse at points B and D as demonstrated by curve 1.

A more severe loss of high frequencies causes a greater distortion of the pulse as shown by curves 2 and 3. For example, in curve 3, the high-frequency response is so poor that the leading and trailing edges of the pulse have been lost almost completely. Note that not only is the pulse attenuated and its shape changed, but also, it has been effectively extended and is now a longer signal (lasts longer) than the original pulse. This displacement of the information contained in the pulse is a result of phase shift and time delay. It follows that if a certain part of the video information were spread out as shown by curve 3 of illustration 15B, it would cause a blurred picture because of the presence of additional information to the right of the proper position for the information on the screen.

When the low-freuqency response of the amplifier is poor, it is not possible to hold the constant voltage level represented by the flat top B-C of Fig. 15A. A slight loss of lows causes the flat top to tilt away from point B as shown in curve 1, Fig. 15C, and also a drop of the trailing edge below point D, and then a return to the base line. A more severe loss of low frequency response causes a very decided drop off of the flat top of the pulse as demonstrated in curves 2 and 3. The dotted curve 3 represents a severe loss at low frequencies and a very fast drop off of voltage from point B of the original pulse. It is again to be noted that a loss of low frequencies not only changes the shape of the pulse for the duration of the pulse, but adds information following after the pulse as well. This information, which is again a result of phase shift and time displacement of the signals that make up the pulse, causes additional information and brightness variations following the actual signal.

TIME CONSTANT

The response of an amplifier to pulses can also be interpreted in terms of the time constants of various resistor-capacitor combinations within the amplifier circuit. Time constant is the time required by a capacitor to charge to a prescribed voltage.

You will recall that when a dc voltage is applied to a resistor-capacitor combination such as shown in Fig. 16, a certain time is required for the capacitor to charge through the resistor. The higher the capacity the longer the time required to charge the capacitor to full applied voltage because the larger the capacity the more electrons can be stored. Likewise, the higher the value of the resistor, the longer the time required to charge the capacitor because the resistor retards motion of electrons into the capacitor. The product of the capacitance times the resistance is referred to as the *time constant* of the circuit because the time required to charge the capacitor depends on the values of the capacitor and the resistor.

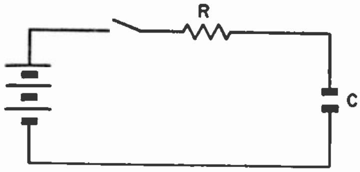


FIG. 16. A series R-C circuit.

When the voltage is removed there is again a time lag before the voltage drops to zero across the capacitor. In other words, the capacitor voltage declines only as fast as the electrons can move through the resistor. Again, the higher the capacity, and the higher the resistance, the longer the time of discharge.

An RC product that is low (small capacitor and low value resistor) is referred to as a *short time constant,* because the capacitor charges and discharges quickly. If the product is high (large capacitor and high value resistor) it is called a *long time constant* because the capacitor charges and discharges slowly.

To understand the action of these resistor-capacitor combinations on pulses better, let us consider a pulse as a dc voltage that is applied to the circuit for only a short time. The leading edge of a pulse is the sudden closing of the switch and the application of the voltage; the trailing edge is the sudden opening of the switch and removal of the voltage. The pulse differs from a switched dc voltage only in the speed of the switching action—switching can occur a great many times in a second.

We have learned that the shunt capacity of a video circuit causes a loss of high frequencies. Another way to consider the same condition is that

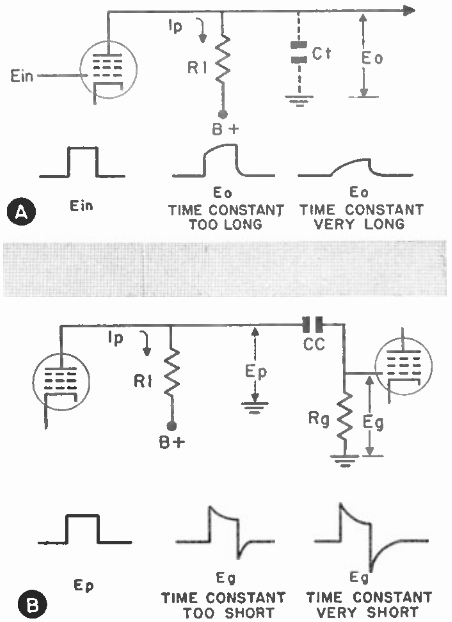


FIG. 17. The R-C circuit made up of the plate load resistor R1 and the shunt capacity Ct in A must have a short time constant to avoid the distortion shown. On the other hand, an R-C circuit such as the one made up of coupling capacitor Cc and grid resistor Rg in B must have a long time constant, to avoid the distortion shown.

the presence of shunt capacity creates too long a time constant. Thus there is a lag between the change in plate voltage and the change in signal current because of the time required to charge Ct as shown in Fig. 17A. The influence of this shunt capacity is more detrimental on the high frequencies, because of the very fast change in signal current that accompanies high-frequency variations. The leading and trailing edges of a pulse represent fast changes in signal or high frequencies. Thus the time of signal change is very short and the time constant of the output circuit must be very fast to follow this signal current change. If there is a lag introduced by the shunt capacity (too long a time constant) the output voltage will not follow the signal current, because the output voltage build-up will not be able to follow the fast rise time of the pulse. Likewise the fast drop off of the pulse will not be followed faithfully because of the time required to discharge the shunt capacity. Consequently, the output voltage will lag behind the trailing edge of the pulse. The manner in which the pulse may be distorted is shown in Fig. 17A.

The time constant of a series combination of resistor and capacitor that must convey the pulse from one stage to another must be long enough to prevent distortion of the low-frequency components of that pulse. For example, in an interstage-coupling circuit such as the one shown in Fig. 17B, it is advisable not to let the charge on the coupling capacitor vary with signal voltage variations because this would represent a voltage across the coupling capacitor that did not reach the grid of the succeeding stage. Thus the time constant is made long enough to prevent the coupling capacitor from charging and discharging during the time of the pulse. If the time constant (t=RC) is made much longer than the duration of the pulse, the capacitor is not able to accumulate an appreciable charge during this interval. Consequently, the pulse will appear in its entirety across the resistor. If, however, the time constant of the coupling combination is too short, a charge does accumulate on the capacitor and substracts from the pulse that should appear across the resistor. This substraction is best shown in the curves of Fig. 17B, which show the drop off of the curve as a charge builds up on the coupling capacitor.

Up to this time we have been discussing the disadvantages and problems created by circuits that may change the shape of a pulse. However,

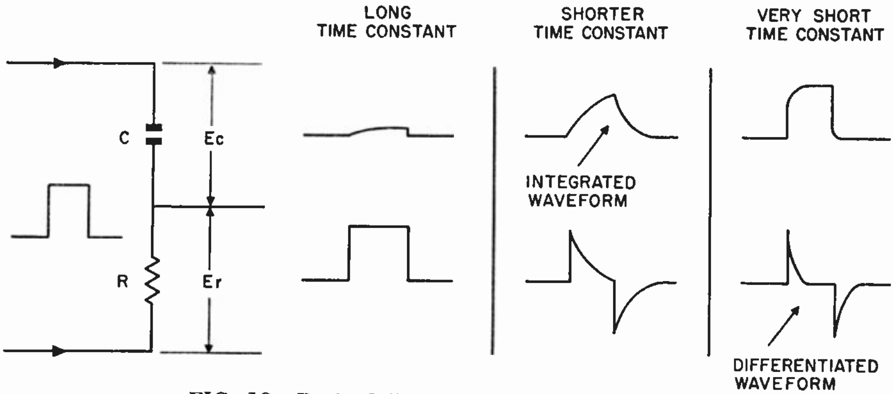


FIG. 18. Basic differentiation and integration.

sometimes the shape of a pulse is intentionally changed by using R-C circuits. The sync pulses are shaped in the sync circuits to obtain positive control of the sweep oscillators. An R-C circuit that can be used to shape a pulse is shown in Fig. 18.

If the series resistor-capacitor combination has a long time constant and a pulse is applied to its input, the pulse is developed almost in its entirety across the resistor, because the time constant is so long that there is not sufficient time for the capacitor to accumulate a charge during the pulse time. If the time constant is made longer than the pulse duration, the pulse can be passed without serious distortion.

When the time constant is shortened, it is possible for the capacitor to charge and discharge a significant amount. As a result, a charge builds up on the capacitor for the duration of the pulse. Whatever charge appears on the capacitor must be subtracted from the pulse and what remains is across the resistor. Consequently, the top of the pulse as it appears across the resistor begins to tilt down. The amount of tilt depends on how much charge accumulates on the capacitor, and this in turn, depends on the time constant of the circuit.

In television we speak of the voltage across the capacitor as being an integrated voltage. Integration is a process used in preparing the vertical sync pulses for proper synchronization of the vertical deflection system. This will be discussed in detail in a later lesson.

When the time constant is very short, the capacitor charges and discharges almost completely during the pulse. (A small capacitor charges quickly through a low value resistor.) The voltage across the resistor is present only when current flows, which is during the rise and fall of the applied pulse. As soon as the capacitor is charged full, current no longer flows, and the voltage across the resistor drops to zero. The leading edge of the pulse in Fig. 18 produces the sharp positive *differentiated pulse* across the resistor as shown. Current once more flows in the resistor when the capacitor discharges at the trailing edge of the pulse. Once it is discharged, current again ceases. The discharge current, of course, flows in the opposite direction through the resistor, and consequently develops the sharp negative spike across the resistor.

The process of differentiation is used in the sync circuits of the television receiver to develop a sharp pulse voltage to synchronize the horizontal deflection system. The horizontal and vertical sync pulses that have passed together through the tuner, the video i-f, the video detector, and part of the sync system can then be separated by differentiation and integration and used separately to synchronize the horizontal deflection system and the vertical deflection system.

Requirements of the Signal Applied to the Picture Tube

The video amplifier is connected between the video detector and the picture tube. It amplifies the weak signal at the video detector output and feeds the amplified signal to the picture tube. The signal can be applied to either the grid or the cathode of the picture tube. However, the signal must be applied with the proper polarity.

SIGNAL POLARITY

When the composite video signal is applied to the grid of the picture tube, the signal must be negative-going so that the blanking level drives the tube beyond beam cut-off. With negative-going sync pulses, the video information has a positive picture phase which will drive the grid in a positive direction (less negative) for white portions of the scene and cause maximum beam current and illumination.

When the video signal is applied to the cathode of the picture tube the composite signal must be positive-going; this drives the grid circuit to cut-off during blanking, as it should. In other words, a positive-going sync signal on the cathode has the same effect as a negative-going sync signal has on the grid.

In the circuit shown in Fig. 19, the video signal is applied to the grid of the picture tube. Therefore the sync pulses must swing negative, as shown, to drive the picture tube to cut-off during the blanking interval. Since each vacuum tube reverses the signal

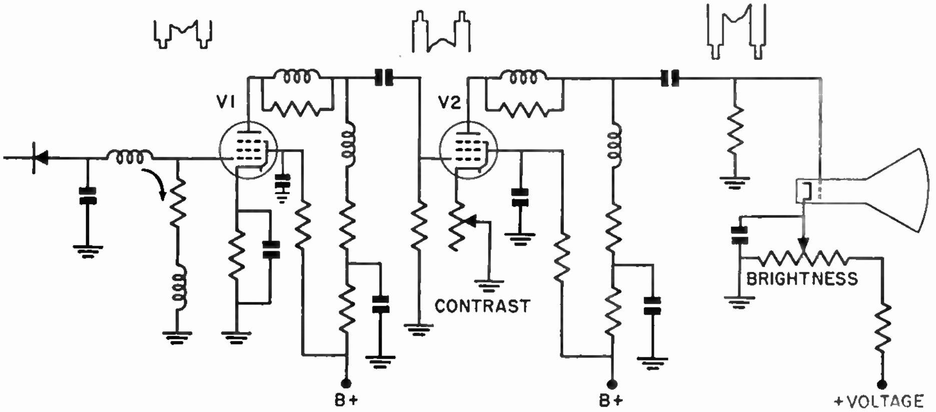


FIG. 19. A two-stage video amplifier connected between the video detector and the picture tube, showing the phase reversal that occurs in each stage.

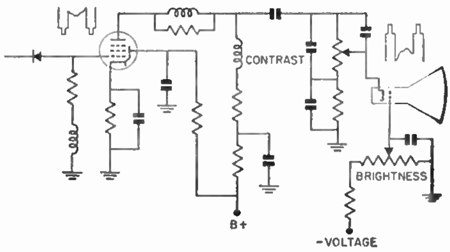


FIG. 20. The output signal of a single-stage amplifier is opposite in phase to the input signal.

phase by 180°, the sync pulse must have the opposite polarity at the input to V2. Similarly, V1 will reverse the signal phase 180° and therefore the input to V1 must be 180° out of phase with the input of V2—this means that the input to V1 must have the same phase as the signal applied to the picture tube. Therefore, the video detector must be connected to develop a negative-going composite signal at its output for application to the grid of the first video stage, V1. When there are two video stages, as there are here, the polarity of the signal at the output of the video detector must be the same as that required at the grid of the picture tube. If in the circuit of Fig. 19 the signal were applied to the cathode of the picture tube, a positive-going composite signal would be needed at the picture tube. This would require a positive-going composite signal at the output of the video detector.

When a single video amplifier stage is used, the composite signal at the output of the video detector must be of *opposite* polarity to that required at the input to the picture tube as shown in Fig. 20. In this example, the composite signal is being applied to the cathode of the picture tube, so it must be positive-going. Therefore, the output of the video detector must be a negative-going composite signal. If the composite signal were being applied to the grid of the picture tube with a single-stage video amplifier, a positive composite signal would be needed at the output of the video detector to give a negative composite signal at the grid of the picture tube.

BRIGHTNESS AND CONTRAST CONTROLS

The brightness control is associated with the picture-tube grid-cathode circuit. It sets the dc component of the bias between the grid and the cathode, and thus controls the over-all brightness of the picture. The brightness control is adjusted to the level required by the room lighting. In a very bright room, the brightness must be set higher. In a darkened room, the brightness should be lower.

Still another requirement for proper picture tube operation is a means of controlling the amplitude of the video signal applied to the grid of the picture tube. The brightness control sets the over-all brightness of the reproduced picture, but a second control, referred to as the "contrast control," regulates the peak amplitude of the video signal applied to the grid circuit. The setting of the contrast control required for best picture will depend on the strength of the signal and on the setting of the brightness control.

If the peak amplitude of the signal is not great enough at the grid of the picture tube, the picture will have an underexposed appearance, with an insufficient brightness range between the brightest part of a scene and the darkest part. If the peak amplitude of the video signal is too high, the picture will have an over-exposed look with excessive contrast. With too much signal, there is a lack of half-tone or gray-scale range in the reproduced picture and the video information is crowded at the very bright range and the very dark range.

The two most common contrast control methods are shown in Figs. 19 and 20. Fig. 19 shows the method of controlling the amplitude of the video signal by using a degenerative cathode circuit. In such an arrangement, the contrast control regulates the resistance between cathode and ground, and thus controls the amount of feedback. When there is a high cathode resistance, the feedback is greatest and the stage gain is at a minimum. With low cathode resistance, the degeneration is minimized, and the video amplifier has maximum gain.

The contrast control system shown in Fig. 20 is simply a voltage divider between the output of the video amplifier and the input circuit of the picture tube. In this type of voltage-divider contrast-control system, it is necessary that the divider arrangement be properly designed to prevent frequency discrimination. In other words, adjusting the gain control should result in equal regulation of the low and the high frequencies in the video signal.

Retaining the DC Component of the Video Signal

The video signal at the output of the video detector is actually a pulsating dc voltage. That is, it consists of voltage variations either above or below a zero reference level, depending on whether the signal is negative or positive-going, but never on both sides of the zero reference level. Such a signal is shown at the left in Fig. 21. Note that the sync tips and the blanking pulses are always at the same voltage level, but the average brightness voltage for each line varies. This same type of video signal voltage must be applied to the picture tube, although in some cases it may be reversed in polarity.

However, if an ordinary resistance-coupled amplifier is used, the signal must pass through coupling capacitors. You will recall that a capacitor, while it provides a path for ac, blocks dc. Therefore, only the ac component of the video signal is passed through a coupling capacitor. The dc components are blocked. The signal at the right in Fig. 21 shows what happens when the dc component is lost.

Note that the zero reference level becomes the average brightness level for all three lines shown. Also, the blanking and sync pulses no longer line up, but are at three different levels. This signal would produce a flat picture lacking in contrast. The background tones in the picture would

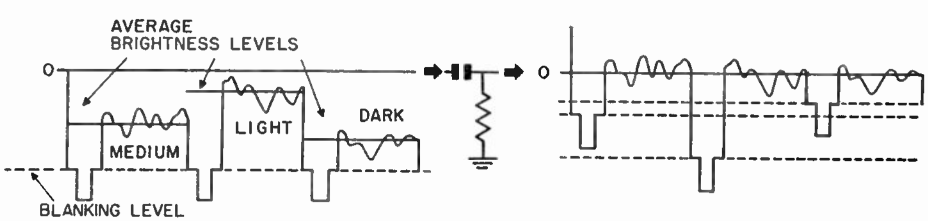


FIG. 21. The pulsating dc signal (left) is changed to an ac signal when passed through a capacitor.

always be the same brightness. Therefore, it is generally considered necessary to retain or restore the dc component of the video signal.

Two general methods are used to retain the dc component. One of the easiest methods is to use a dc amplifier, thereby eliminating the troublesome coupling capacitors. This is quite satisfactory, but in some cases the power requirements for a dc amplifier are quite rigid. The second method is to amplify the ac component with an ordinary resistance-coupled video amplifier and then restore the dc component when the signal is applied to the picture tube. This is called "dc restoration" or "clamping."

There are television receivers that have no provision for either the retention or restoration of the dc component. They are built on the principle that in present studio practice the average brightness of a transmitted scene or sequence of scenes is essentially constant. However, this theory does not take into consideration the transmission of very slow changes in average brightness and other special effects that can be rendered more properly when a dc component is present.

DC AMPLIFIERS

The schematic diagram for a single-stage direct-coupled video amplifier is shown in Fig. 22. Since there is no coupling capacitor at the input of V1, both the ac and the dc components of the video signal will be applied across R1, the grid resistor of V1. The dc component of the signal will add to or subtract from the normal grid bias and faithfully reproduce the proper sync pulse, blanking pulse, and average brightness levels at the plate of V1. The signal will, of course, undergo the usual 180° phase shift in the stage.

In order to use direct coupling between the plate circuit of the video amplifier and the cathode circuit of the picture tube, it is necessary to set up a voltage-divider arrangement so that the proper negative dc voltage is applied between the grid and the cathode of the picture tube, and the proper positive voltage between the plate and the cathode of the video amplifier tube. A voltage divider network consisting of resistors R2 through R6, connects two supply voltage points with each other and then to ground. A + 125-volt source supplies voltage for the brightness control circuit through potentiometer R5 to ground. This arrangement permits proper biasing of the grid as well as a means of controlling brightness. The same + 125 volts is present on the screen of V1 and is also connected through the voltage divider circuit

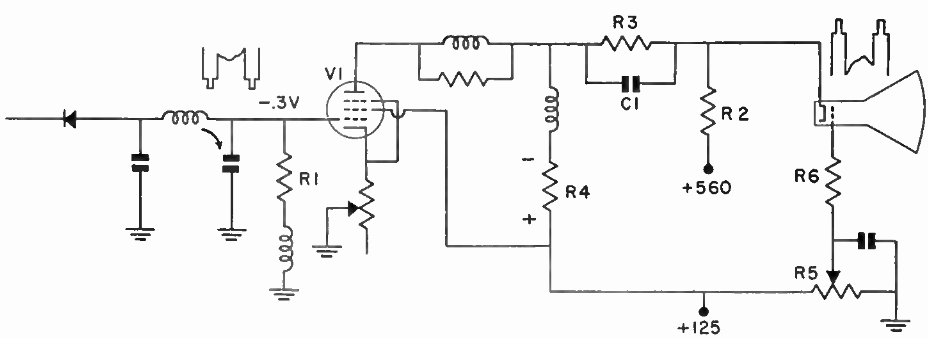


FIG. 22. A single-stage, direct-coupled video amplifier.

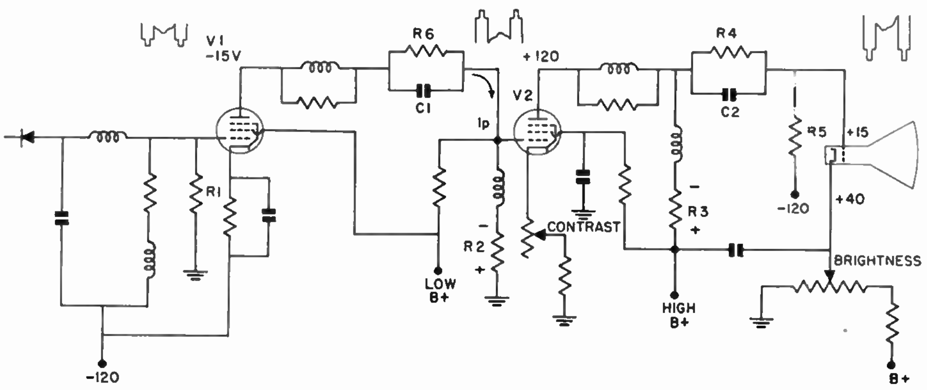


FIG. 23. The direct-coupled equivalent of the video amplifier shown in Fig. 19.

consisting of resistors R4, R3, and R2 to a + 560-volt source. See Fig. 22. This voltage-divider arrangement supplies a positive voltage to the cathode of the picture tube so that the cathode will be positive with respect to the grid, or in other words, the grid will be negative with respect to the cathode. In addition, the positive supply voltage, through divider action, is reduced to the correct value for the video amplifier stage. Capacitor C1 serves as a low coupling reactance for the ac components of video signal, permitting resistor R3 to function simply as a dc divider resistor.

The presence of resistor R4 in the plate circuit of the video amplifier as well as in the voltage-divider circuit of the picture tube, presents the means of transferring the dc component of average brightness to the picture tube. Both the ac and the dc components of the amplified video signal at the output of V1 are developed across R4 and thereby add to or substract from the difference of potential existing between grid and cathode of the picture tube.

Another advantage of a system of direct-coupling is improvement in low-frequency response. If the low-frequency response is poor, as it is with the average resistor-capacitor coupling combination, slow changes in brightness that can occur in a sequence of scenes will not be faithfully reproduced.

In some receivers, a two-stage direct-coupled amplifier is used between the video detector and the picture tube. The major problem in the planning of a two-stage, direct-coupled video amplifier is distribution of supply voltages so that the proper dc bias can be established between grid and cathode and so that sufficient plate and screen voltage is available for each tube. The video amplifier shown in Fig. 19 can be changed over to a direct-coupled version by making the changes shown in Fig. 23.

In the direct-coupled version shown in Fig 23, the output of the video detector instead of being returned to ground, is returned to a -120 volt source. Likewise the cathode of the first video stage is returned to -120 volts. Resistor R1 has a very high value so that the dc voltage on the grid of V1 is just slightly negative with respect to the dc voltage at the cathode. Consequently, the first video stage has the proper dc grid voltage. This dc voltage varies with the average brightness of the signal detected by the crystal diode, while the ac grid voltage also varies instantaneously with the ac components of the video signal.

Since the grid and cathode are at a high negative potential, only a very low supply voltage needs to be applied to the screen and plate of V1. In fact, the plate and screen voltage is slightly negative with respect to ground, because of the voltage-divider network that returns to a low B plus source, and the fact that tube plate current flows in a direction to develop a negative voltage drop across resistor R2. Thus the actual plate voltage of the first video stage is slightly negative with respect to ground, but still more than 100 volts positive with respect to the cathode. At the same time the dc component of the grid voltage on V2 is slightly negative.

The second tube is biased by the cathode circuit and the negative dc voltage is applied to the grid. The second video stage operates almost as a conventional amplifier with a high B plus supplied to its screen and plate circuit, and with the cathode near ground potential. A network of bleeder resistors, R3 through R5, direct-couple the plate circuit of the video amplifier to the grid of the picture tube. Notice that a negative voltage is supplied to the grid resistor R5. The negative voltage is applied to the grid, because the grid must be negative with respect to the cathode. In the single-stage direct-coupled amplifier shown in Fig. 22, the grid resistor is returned to a plus supply voltage source, because the signal is being applied to the cathode.

In Fig. 23, the cathode of the picture tube is returned to a plus voltage source at the brightness control so that the cathode voltage can be adjusted to obtain the negative bias voltage between grid and cathode for proper operation of the picture tube. Capacitors C1 and C2 shunting resistors R4 and R6, permit the low reactance transfer of the ac components of the video signal, and the resistors act as dc voltage dividers.

Insofar as servicing a dc amplifier is concerned, it is somewhat more difficult than servicing a capacitor-coupled amplifier, because a defect does not confine itself to a single stage. If a defect that occurs in the grid circuit of the first video amplifier causes a change in the dc voltage at the grid of the first stage, the voltages throughout the entire amplifier will be affected.

In many receivers, the sync take-off is also direct-coupled to the video amplifier. Consequently, a defect in the first video amplifier stage can be felt as far as the sync circuits and even the agc system. In other words, a defect that might appear to be a fault in the sync or agc circuits might be originating back in the video amplifier.

Stable operation of a direct-coupled system depends to a great extent on power-supply regulation, because slight changes in supply voltage are reflected through the direct-coupled system. Thus, power-supply defects in particular can cause erratic operation of a direct-coupled video amplifier system. A weak low-voltage rectifier tube that causes the output of the low voltage power supply to vary substantially with line-voltage fluctuation is a common trouble-maker.

DC RESTORATION

The process of dc restoration permits reinsertion of a dc brightness level after it has been lost. A technique often used in video amplifiers is to increase the amplitude of the ac portion of the composite video signal, using conventional amplifiers with

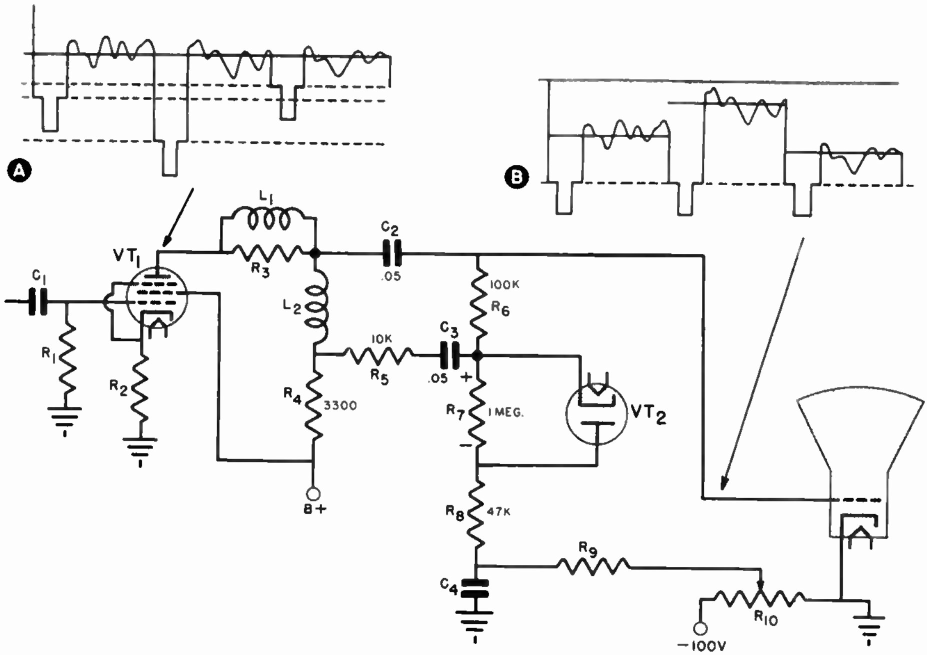


FIG. 24. Diode dc restorer circuit. Note that the sync pulses are not lined up at the plate of VT1, as shown in the waveform at A. The action of the dc restorer VT2 has the effect of aligning the pulses at the grid of the picture tube as shown in waveform B.

capacitive coupling between stages. After the signal has been amplified to a sufficient level, it is applied to a circuit that contains a dc restorer, which evaluates and re-establishes the dc brightness component. It does so by causing the sync tip and blanking levels to line up again. If this is done, the average signal again varies with changes in average brightness, while the blanking and sync tips remain constant.

When the composite video signal is transferred by a coupling capacitor, it loses its dc component as shown in Fig. 21, and the entire signal averages about a single axis. This action in no way affects the peak-to-peak amplitude or ac components of each individual signal. A dc restorer circuit inserted in a video amplifier is able to re-establish the condition where the sync tip and blanking levels line up as shown on the left in Fig. 21.

A typical video amplifier having a diode restorer tube is shown in Fig. 24. After the signal has been coupled by conventional means through the video amplifier, it appears at the plate of the last video amplifier, VT1, with the dc components of brightness lost, as shown in waveform A. Since the composite signal is being applied to the grid of the picture tube, it must have negative polarity. The signal is applied to the grid of the picture tube and to the cathode of VT2, which connects to the grid of the picture tube through R6.

The negative signal applied to the cathode of VT2 causes it to conduct and establish a positive charge on capacitor C3 that is in proportion to the peak amplitude of the composite

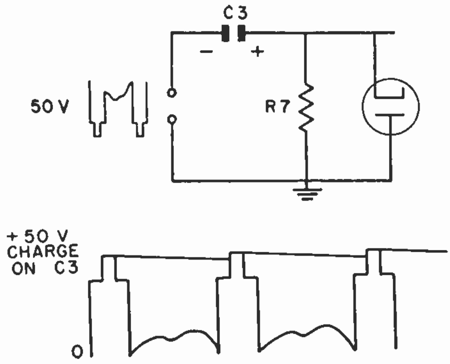


FIG. 25. Action of dc restorer.

signal. Since the peak amplitude of the signal for a high-brightness scene is greater than for a low-brightness scene, a more positive charge is developed on capacitor C3 for the high-average-brightness scene than for the low-average-brightness scene. Thus the voltage across capacitor C3 varies with the average brightness of the scene.

The charge on this capacitor is applied to the grid of the picture tube through resistor R6 causing a change in the picture tube bias. As a result, the dc bias on the picture tube changes with the average brightness of the scene almost as it would if a direct-coupled video amplifier were used.

Let us consider in more detail the action of the dc restorer diode VT2 in Fig. 24. If the peak amplitude of the composite video signal applied to the dc restorer circuit is 50 volts, as shown in Fig. 25, it means that capacitor C3 will charge to 50 volts through the diode. The charging of the capacitor to the peak value of the pulse is almost instantaneous because of the very short time constant presented by the capacitor and the low resistance of the conducting diode. The charge on the capacitor will be positive on the tube side because of the flow of electrons off this side of the capacitor down through the conducting diode.

At the conclusion of each sync tip the diode stops conducting. The tube is cut off by the high positive charge placed on capacitor C3 and on the cathode of the diode. This charge keeps the diode cut off until the arrival of the next sync pulse. The diode is held non-conducting for this interval because the long time constant of C3 and R7 does not permit the charge to leak off C3 before the next sync pulse arrives. The diode itself does not enter into this time constant because it is now in a non-conducting state.

When the next sync pulse arrives, it causes the diode to conduct again. It conducts just enough to restore the original 50 volts on the capacitor, which has declined only slightly during the discharge interval. Thus the charge on capacitor C3 is really a dc voltage, the amplitude of which varies with the average brightness of the received picture. This dc voltage can be used to bias the grid of the picture tube and cause the average beam current to vary with the average brightness of the picture. As a result, the average illumination on the picture tube screen follows the average brightness changes of the received picture.

Now, let us follow the signal through the circuit shown in Fig. 24. When there is a change from a low average brightness signal to a high average brightness signal, the peak amplitude of the composite video signal increases as you see from the plate waveform shown at A. When this signal is applied to the dc restorer, VT2, it causes the dc restorer to conduct and charge capacitor C3. Inasmuch as the peak amplitude of the composite video signal increases in going from the low-average-brightness scene to the high-average-brightness scene, the peak diode current increases and there is a *greater positive* charge placed on capacitor C3.

The charge on capacitor C3, along with the negative voltage at the brightness control, presents a negative net bias between the grid and the cathode of the picture tube. With an increase in average brightness, the charge on capacitor C3 becomes higher. Consequently, the grid-to-cathode bias of the picture tube decreases. With a lower negative dc bias, the beam current increases, and with it the screen illumination. This is as it should be for an increase in brightness of the received signal.

Resistor R6 acts an an isolating resistor and prevents the relatively high capacity of the restorer diode from causing attenuation of the high-frequency components of the video signal. If resistor R6 were not present, the cathode of the diode would have to be connected to the grid of the picture tube and would present a high-capacity load to the video signal components.

Grid-Rectifier DC Restorer. It is also possible to restore the average brightness of the received signal at a stage preceding the grid circuit of the picture tube. When this method is used, the plate of the last video amplifier must be direct-coupled to the picture tube grid circuit as shown in Fig. 26. In this system the grid and cathode of the video amplifier function as a diode producing the restoration action. When a signal is applied to the grid of the video stage, the grid current flow develops a charge on capacitor C1, which acts as the grid bias for the tube. This method of using the signal as a means of generating the dc component of grid bias is referred to as "signal biasing."

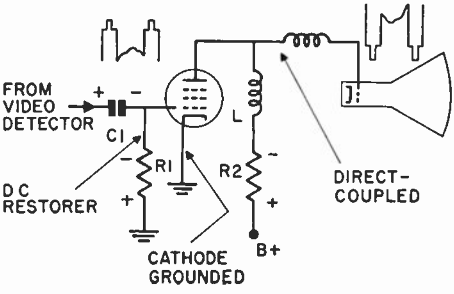


FIG. 26. Rectifier action between grid and cathode of the video amplifier tube may be used for dc restoration.

When the peak amplitude of the signal applied to the grid decreases, so does the grid current and the bias charge placed on the capacitor. This is an ideal condition for the restoration of a video signal, because as the average brightness of the picture changes, so does the dc charge placed on capacitor C1.

A composite video signal with positive polarity applied to the grid ot the video stage causes the peak grid current drawn during the sync tip interval to charge capacitor C1 negatively. Because of the fast time constant presented by the capacitor and the very low resistance of the tube when it is drawing grid current, the capacitor charges to the peak value of the sync tip (as in the previously discussed example using a diode restorer). Between sync pulses, the charge on the capacitor remains essentially constant because the tube is no longer drawing grid current, and the capacitor finds a long time-constant discharge path through the large value grid resistor R1.

If a high average brightness signal is applied to the grid, its peak amplitude places a high negative bias on the capacitor, while a low average brightness scene causes the charge on the capacitor to decrease. The bias created by the capacitor determines the dc component of plate current that flows through resistor R2. In turn, this dc component of voltage developed across R2 serves as bias for the grid of the picture tube. Consequently, when the average brightness of the received signal changes, the dc plate current changes and also causes a change in the dc bias applied to the picture tube. Again we have a dc component transferred to the grid of the picture tube that can control the beam current and the average illumination of the scene on the picture tube screen.

Typical Video Amplifier Systems

There are two basic types of video amplifiers, direct-coupled and capacity-coupled. Each type may have one or two stages. We will now look at several typical video amplifiers taken from commercial TV receivers.

SINGLE-STAGE, DIRECT-COUPLED AMPLIFIER

One of the most common types of video amplifier is shown in Fig. 27. It is a single-stage, direct-coupled video amplifier that supplies a positive-going composite signal to the cathode of the picture tube. Often a crystal-diode detector is used in place of a tube. The video detector supplies a negative-going signal to the grid of the video amplifier stage. The video stage uses a high-gain video amplifier tube. This type of amplifier tube has a very high gain and can build up the weak signal output of the video detector to approximately 60-100 volts of peak video signal.

The output of the video detector is developed across the diode load resistor R1 and peaking coil L2. Excitation for the sound i-f amplifier is removed from across the peaking coil and supplied to the input of the sound i-f stage. The removal of the sound at this low-impedance point prevents degeneration of the high-frequency components of the video signal and permits a low-impedance coupling line to the sound i-f input. To attenuate the sound signal further and prevent its entrance into the video amplifier, a parallel resonant trap, consisting of inductor L3 and capacitor C2, blocks the 4.5-megacycle sound component from the grid of the video amplifier.

The positive composite signal at the plate of the video amplifier is

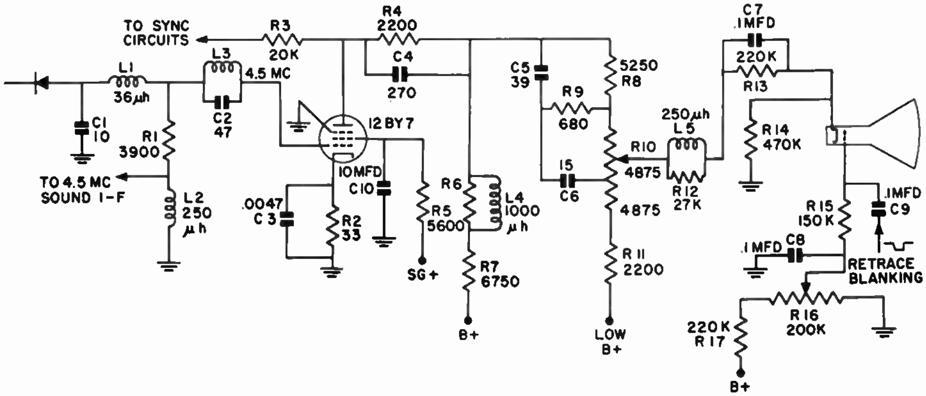


FIG. 27. A direct-coupled single-stage video amplifier.

direct-coupled through the picture contrast control to the cathode of the picture tube. The high frequencies are retained by the shunt-peaking coil L4 and the series peaking coil L5. Both coils are shunted by resistors to broaden the response and to prevent undesired peaking.

The amplitude of the composite video signal is controlled by a special compensating contrast control circuit. The compensating circuit consists of a resistor-capacitor divider which retains a linear video frequency response regardless of the setting of the arm of the contrast potentiometer. Attenuation of highs is further prevented by capacitors C4 and C3. Capacitor C4 presents a low reactance path to the very high frequencies, but a higher reactance at middle and low frequencies across resistor R4, resulting in some attenuation of the middle and low frequencies. Capacitor C3 has a very low reactance at high frequencies and therefore serves as a by-pass for the cathode resistor. It has an appreciable reactance at the middle and low-frequency ranges, and therefore some degeneration in the video stage does exist at these lower frequencies.

A portion of the video signal is also removed at the plate of the video amplifier and, through the isolating resistor, R3, supplies composite signal to the sync circuits of the television receiver. Here the sync pulses are removed and used to synchronize the deflection generator. The 20K isolating resistor prevents the capacity at the input to the sync circuits from being shunted from the plate of the video stage to ground. Any added capacity across the output of the video stage would result in a loss of high-frequency components in the video signal and a loss of picture detail.

Proper plate voltage is obtained for the video amplifier tube through the divider arrangement consisting of the plate load resistor R7, R8, the contrast control R10, and R11. DC voltage for the cathode of the picture tube is also obtained by a divider arrangement which includes resistor R11, and the bottom section of the contrast control along with resistor R13 and resistor R14. The dc bleeder arrangement permits the changes in voltage drop across the plate resistor R7 to be conveyed at proper level to the cathode of the picture tube. The divider arrangement makes certain that the picture tube bias does not change over too great a range. The divider also prevents excessive voltage between the cathode and the heater. This could cause picture tube defects and leakage between cathode and heater. Capacitor C7 across resistor R13 serves as a low reactance path for the ac components of the video signal, but at the same time permits resistor R13 to function as a dc voltage divider.

The brightness control is in the grid circuit of the picture tube. The proper voltage is obtained from a positive supply source. It is adjusted to give the proper bias between grid and cathode.

A vertical blanking pulse is applied to the grid of the picture tube through capacitor C9 and appears across resistor R15. This pulse is obtained by properly shaping the vertical waveform present at the output of the vertical deflection circuit. The pulse occurs during the retrace time of the vertical deflection circuit and consequently coincides with the vertical retrace motion of the scanning beam in the picture tube. The pulse biases the picture tube beyond cut-off during the vertical retrace interval, thus eliminating any possibility that the retrace lines will appear.

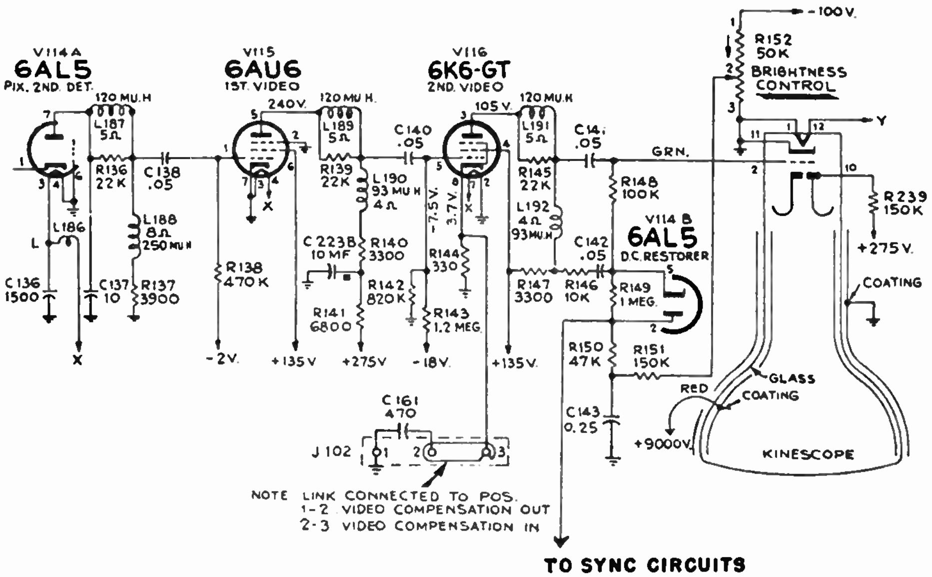


FIG. 28. A two-stage dc restorer type of video amplifier system.

TWO-STAGE, CAPACITY-COUPLED AMPLIFIER

An example of the dc restorer type of video amplifier system using two video stages is shown in Fig. 28. The output of the video detector is coupled through C138 to the grid of the first video amplifier stage. The receiver from which this circuit was taken uses the dual-channel sound system, and since sound traps are located in the video i-f amplifier, they are not needed in the video amplifier. The bias for the first video stage is obtained from a 2-volt tap on the power supply.

The plate circuit of the first video stage employs series and shunt peaking and conveys the positive-going composite signal to the grid of the second video stage through capacitor C140.

A conventional diode dc restorer is used to re-establish the dc component of the signal. We have already discussed this circuit in this lesson. The sync take-off point is in the dc restorer circuit. Resistors R148 and R149 effectively isolate the input of the sync circuits from the output of the second video amplifier stage.

You will notice that there is no contrast control in this video amplifier. In the receiver that used this circuit, contrast was controlled by varying the bias on the video i-f stages. Many older sets used this system, but practically all modern sets use agc to control the gain of the i-f stages, and put the contrast control in the video amplifier stage.

SINGLE-STAGE AMPLIFIER WITHOUT DC RESTORATION

A typical capacitor-coupled video amplifier without a dc restorer is shown in Fig. 29. The negative-going composite signal at the output of the video detector is applied to the grid of the single-stage video amplifier. The grid is biased to near zero by returning resistor R1 to a low B plus voltage. This arrangement permits peak gain in the amplification of a weak signal and also permits the use of the full transfer range of the tube characteristic with the amplification of a strong signal. Thus, it is less likely to compress or clip off the sync pulses. A degenerative contrast control circuit is located in the cathode of the video amplifier.

The plate circuit of the video amplifier has series-shunt peaking, using inductors L1 and L2. They are shunted by resistors to obtain the proper broad high-frequency response. A 4.5-megacycle transformer is also located in the plate circuit of the video amplifier. It functions both as a 4.5-megacycle take-off transformer for the intercarrier sound, and as a parallel resonant trap to prevent the appearance of 4.5-megacycle interference on the picture.

The sync take-off is made across resistor R4 and supplies the composite video for the synchronizing circuit through the proper isolating filter. The composite video signal is coupled to the cathode of the picture tube through capacitor C1. The brightness control is located in the cathode circuit, and negative vertical blanking pulses are applied to the grid of the picture tube to prevent the appearance of vertical retrace lines on the screen of the picture tube.

Let us see how capacitor C1 and resistor R5 in the cathode circuit of the picture tube work together to change the overall brightness of the picture according to the video content.

The brightness control is set so that the screen is a very dark grey when no signal is received. The white peaks of the video signal at the cathode are negative going. When the video signal is applied to the cathode, these negative peaks lower the voltage at the cathode, which increases the beam current. The increased beam current increases the voltage drop across R5, and reduces the charge on C1. C1 and R5 have a long time constant, which prevents the charge on C1 from following the video peaks. Instead, the charge on C1 stays at the average cathode potential. This charge on C1 sets the bias on the picture tube.

If the average white level of the picture is increased, the average drop across R5 will be increased, and the average charge on C1 will be decreased. This reduces the bias on the picture tube, increases the average beam current, and makes the overall

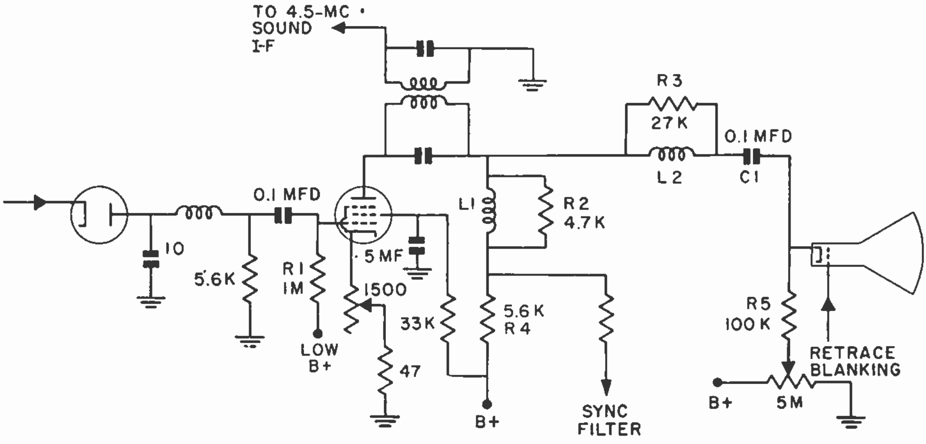


FIG. 29. Single-stage video amplifier without dc restorer.

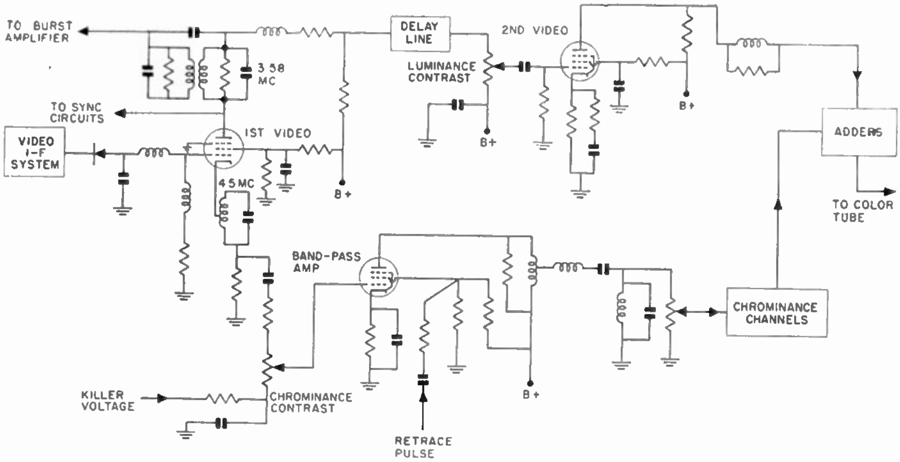


FIG. 30. Video amplifier section of color receiver.

picture brighter. If the average white level of the picture is reduced, the drop across R5 is reduced, and the bias is increased. The average beam current is reduced, and the overall picture is darkened.

C1 and R5 together give the same result as a dc restorer in the cathode circuit.

COLOR TELEVISION VIDEO AMPLIFIER

In your lesson on video i-f systems, you traced the luminance and chrominance as far as the video detector in a color receiver. You learned that the luminance information carries the brightness variations and picture detail, while the chrominance (color) information is on a separate 3.58-megacycle sub-carrier. Consequently both the luminance and the chrominance information are demodulated by the crystal video detector and appear on the grid of the first video amplifier, shown in Fig. 30. The frequency response of the first video amplifier is shown in Fig. 31A, and it is able to amplify both the luminance and the chrominance information.

The first video amplifier has four separate outputs to supply the various sections of the color television receiver with signal. First, there is an output taken directly off the plate of the video amplifier, which supplies composite video signal to the sync circuits of the receiver. The next output in the plate circuit is via a double-tuned resonant transformer tuned to 3.58 meyacycles. This resonant circuit is sharply tuned and emphasizes the 3.58-megacycle sine-wave burst that rides on the back porch of the horizontal blanking pulse. The 3.58-megacycle burst is the signal that synchronizes the color channels of the television receiver. It is first supplied

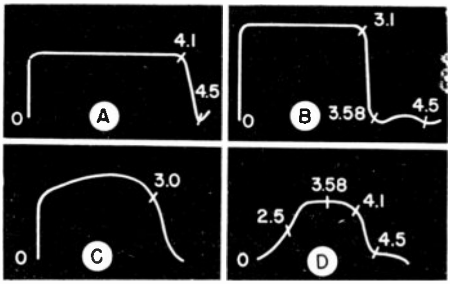


FIG. 31. Video amplifier response curves. A, first video amplifier response. B, video response after burst take-off. C. overall video response. D, bandpass amplifier response.

to a so-called burst amplifier, which removes the color synchronization information for application to the color synchronizing circuits of the receiver.

A third output of the first video amplifier supplies the luminance signal through a delay line to the second video amplifier. The frequency response of the first video amplifier after the burst take-off point is shown in Fig. 31B. Notice that the presence of the burst transformer causes the frequency response of the rest of the amplifier to fall down sharply at the 3.58-megacycle point. Consequently, the luminance signal detail extends out linearly to a frequency of only 3.1 megacycles.

The function of the delay line is to delay the luminance picture detail a specified amount so that upon arrival at the color picture tube it is still in phase with the chrominance or color signal components. The output of the delay line is supplied to a contrast control and then into the second video amplifier. The grid circuit control regulates the contrast of the luminance or brightness components of the color television signal. The output of the second video amplifier supplies luminance information to the adder system in which the luminance and chrominance component of the signal are added together before they are applied to the picture tube. The over-all video response of the two video amplifier stages is shown in 31C.

The fourth output is the chrominance information taken off the cathode circuit of the first video amplifier. First there is a 4.5-megacycle trap in the cathode circuit which supplies degeneration at the intercarrier sound frequency to keep any trace of the 4.5-mc sound signal out of the color video amplifier system. The excitation for the chrominance channel is removed from the cathode resistor and supplied to the chrominance contrast control. This control is ganged with the luminance contrast control to permit over-all adjustment of chrominance and luminance contrast on the color picture tube screen.

The band-pass amplifier amplifies the chrominance signal, and its response is as shown in Fig. 31D. Note that it is centered in the chrominance carrier and sideband range, at about 3.58 megacycles. Thus the band-pass amplifier has a poor response at the low video frequencies and assists in keeping the luminance information out of the chrominance channel. The output of the band-pass amplifier supplies the signal to the chrominance channels of the color receiver. In the chrominance channels, the hue and saturation information are released from the two color signals. The color synchronization burst arrives through the burst amplifier and color synchronization circuits. The output of the chrominance channels is also applied to the adder. As mentioned, the signals are arranged properly for excitation of the color picture tube in the adder circuits.

Two additional signals are supplied to the band-pass amplifier. One signal is in the form of a horizontal retrace pulse that cuts off the band-pass amplifier during the horizontal retrace period. Consequently the synchronizing pulses do not pass through the band-pass amplifier and enter the chrominance channel. A second signal that can be applied to the band-pass amplifier is the so-called killer voltage or bias, which also turns off the band-pass amplifier whenever a standard monochrome signal is to be received. Thus there is no interference from the chrominance channel in the reception of a monochrome signal.

Troubleshooting in the Video Amplifier

Video amplifier defects are not usually difficult to locate. The picture tube itself serves as the indicator for proper video amplifier operation. As in all electronic servicing, the tubes should be tested before any other steps are taken to isolate trouble. Perhaps the most difficult task in troubleshooting a video amplifier is to isolate the trouble to the particular section of the receiver. Many video amplifier troubles create a picture tube disturbance that could just as well be caused by defects in other sections of the receiver.

A typical example of this condition is 60-cycle hum in the picture as shown above in Fig. 32. This defect could just as well have its origin in the video i-f or tuner sections of the receiver as in the video amplifier. An oscilloscope is helpful in pinning down this type of disturbance because the presence of hum in the video will also make itself apparent on the waveform of the video signal as shown below in Fig. 32. To ascertain if the hum is originating in the video amplifier or at some previous stage in the receiver, the oscilloscope can be attached to the output of the video detector. If no hum exists at this point, it indicates that the hum pickup occurs somewhere between the output of the video detector and the picture tube.

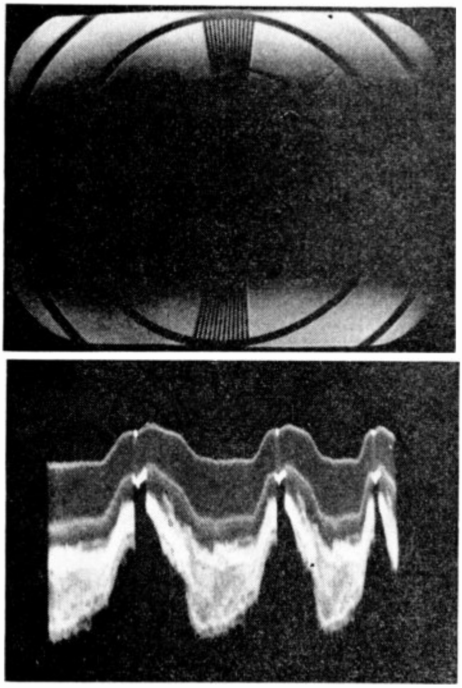


FIG. 32. Hum in picture (above), and on video signal (below).

A loss of gain and a weak picture can be caused by a defect in the video amplifier, the video i-f section, the tuner, or the antenna system. To isolate the loss of gain to the video amplifier, it is again only necessary to attach the oscilloscope to the output of the video detector. If sufficient signal strength is available at this point, the loss of gain must occur in the video amplifier or picture tube circuit. In fact, an oscilloscope that has calibration facilities (either internal or external) can be used to measure the gain of the video amplifier. First the video signal is measured at the output of the video detector and then at either the grid or the cathode pin of the picture tube socket. With the contrast control set to maximum, the peak voltage obtained at the picture tube socket divided by the peak voltage measured at the input of the video amplifier equals the gain of the video amplifier.

Often a deterioration in the picture tube itself gives an indication of a weak and washed-out picture of poor contrast and brightness. If the amplitude of the video signal at the picture tube socket is normal, and the picture tube electrode voltages are normal, the picture tube itself is at fault.

ISOLATION OF DEFECTS IN RESOLUTION

Defects affecting the resolution of the picture can exist in any portion of the receiver between the antenna and the picture tube. Thus the first job is to isolate the resolution defect to its proper section. If the antenna system or the tuner is at fault, the resolution is generally poor on one or two channels, but is acceptable on others. Consequently, by observing each station and carefully checking the resolution of the picture, you can usually decide whether the antenna system or the tuner is at fault. If the resolution is good on any one of the channels, it is almost certain that the video amplifier is *not* at fault if the received signals are strong enough for a picture with good detail.

If picture resolution is poor on all stations, the trouble is generally in the video i-f system or in the video amplifier. The video i-f section can be isolated as a possibility by a check of the over-all response curve of the video i-f section.

If the defect is apparently confined to the video amplifier, the picture tube itself can be used as the indicator in attempting to isolate defective components. The photographs shown in Figs. 5, 11, and 12 are a clue as to what is possibly defective. A knowledge of what component parts influence the response of the video amplifier to certain video frequencies, can help you decide what part to check first.

Voltage measurements sometimes assist in locating the defective part in the video amplifier. Measurements with a vacuum tube voltmeter can be of particular help in locating troubles in the direct-coupled type of video amplifier.

Testing the Video Amplifier. The gain of the video amplifier can be checked using a calibrated oscilloscope and a received signal. The resolution performance of the video amplifier can be ascertained by observation of the reproduced picture. If a calibrated oscilloscope is not available, a gain measurement can be made by using a 60-cycle sine wave of low amplitude (2 to 5 volts peak to peak) applied to the video amplifier input. An accurate and high-impedance 60-cycle meter can then be used to measure the amplitude of the 60-cycle sine wave at the picture tube socket.

The response of a video amplifier can also be checked with sweep alignment equipment. Although this would be of only occasional help in the servicing of modern monochrome receivers, it is quite possible that video sweep equipment can be of considerable help in the adjustment and test of the various video sections of a color television receiver.

A video response curve can be obtained with the usual type of service equipment. If, as shown in Fig. 33, a sweep signal generator and marker generator are attached across the video detector i-f coil, an actual video

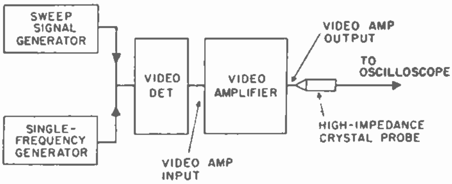


FIG. 33. Interconnection of equipment for video sweep alignment.

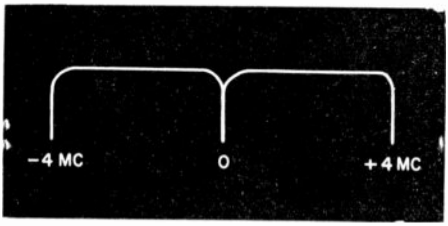


FIG. 34. Video response curve obtained with test equipment connected as shown in Fig. 33.

response can be obtained by attaching an oscilloscope through a crystal detector probe at the picture tube socket. In using this method, it is a good idea to shunt a 300-ohm resistor across the video detector i-f coil to prevent its response from distorting the video response. The detector probe should also have a high impedance so as not to attenuate the high-frequency components of video at the point where the response curve is removed (output of the video amplifier).

In performing the sweep alignment, the sweep signal is adjusted to the center frequency of the i-f range. The marker generator is set to exactly the same frequency. Consequently, there is a heterodyning beat between the sweep signal and the marker signal. As the sweep signal deviates over its range, difference frequencies from a very low frequency up to 4 or 5 megacycles are present at the output of the video detector. The video frequency spectrum is then passed through the video amplifier, and because it recurs at a 120-cycle rate, the response pattern of the video amplifier can be interpreted by attaching a crystal detector probe at the output of the video amplifier.

Actually there is a deviation on each side of the zero beat frequency, and consequently the response pattern appears as illustrated in Fig. 34 with the zero frequency point at the center, and high frequency points at each end of the response curve. The pattern can be shifted away from the center by adjusting the sweep generator center frequency slightly. Low frequency markers can also be inserted to calibrate the response curve.

Lesson Questions

Be sure to number your Answer Sheet 54B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next Lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of lessons before new ones can reach you.

1. What two capacitors in a resistance-coupled amplifier cause attenuation of lows?

2. What capacity limits the high-frequency response of a resistance-coupled amplifier?

3. What disturbance does phase distortion cause in the picture?

4. How does high-frequency attenuation affect the picture?

5. What effect does reducing the value of the plate resistor have on the high-frequency response?

6. What type of video amplifier prevents loss of the dc component of average brightness?

7. What information does the dc component of the video signal carry?

8. How can the average brightness component be re-established?

9. What is meant by a direct-coupled video stage?

10. What four separate signals are removed from the first video amplifier of a color receiver?

TAKE TIME

Here is a quotation from the "Santa Fe Magazine" which appealed to me as containing much good, common sense. I hope you too will enjoy it—perhaps profit by it:

"Take time to live. That is what time is for. Killing time is suicide.

"Take time to work. It is the price of success.

"Take time to think. It is the source of power.

"Take time to play. It is the fountain of wisdom.

"Take time to be friendly. It is the road to happiness.

"Take time to dream. It is hitching your wagon to a star.

"Take time to look around. It is too short a day to be selfish.

"Take time to laugh. It is the music of the soul.

"Take time to play with children. It is the joy of joys.

"Take time to be courteous. It is the mark of a gentleman."

J. E. Smith

TV SWEEP CIRCUITS

55B

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE No. 55

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the facts firmly in your mind. Study each other step in this same way.

☐ **1. Introduction . . . . Pages 1-7**

The general function of the sweep system as it works in conjunction with other receiver sections is discussed here.

☐ **2. Formation of a Sawtooth Wave . . . . Pages 7-18**

In this section, you learn the various methods used in TV receivers to produce the sawtooth wave, which is necessary for proper beam deflection.

☐ **3. Magnetic Deflection Amplifiers . . . . Pages 19-32**

In modern TV receivers, the magnetic deflection amplifier is the output section of the sweep system. An explanation of how these amplifiers work is given here.

☐ **4. A Typical Sweep System . . . . Pages 33-39**

In this section you apply what you have learned in previous sections to the study of a complete sweep system. The deflection and convergence systems of a color receiver are also discussed.

☐ **5. Adjusting and Troubleshooting in the Deflection System . . . . Pages 40-44**

Adjustments and troubleshooting will be studied in detail in later lessons, but a brief outline of the proper procedures is given here.

☐ **6. Answer the Lesson Questions.**

☐ **7. Start Studying the Next Lesson.**

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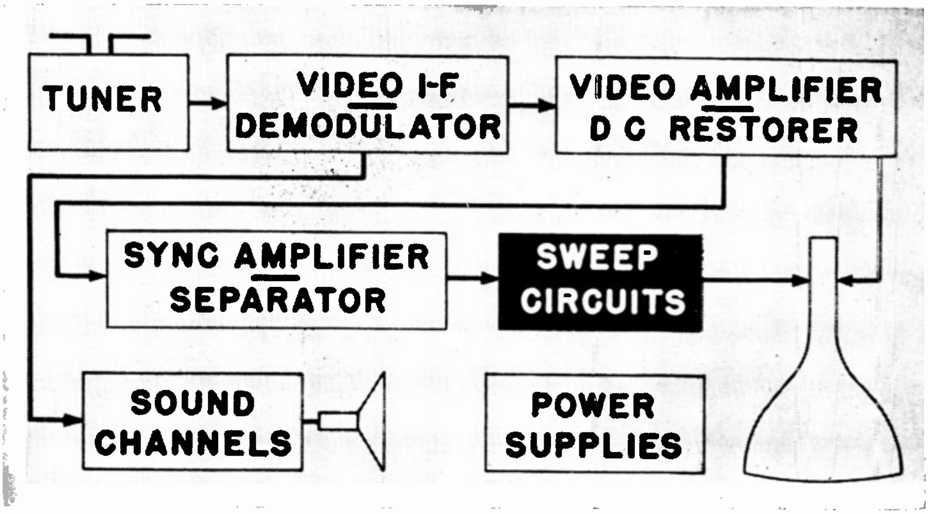


THE sweep, or deflection, system of the television receiver generates the voltage or current waveforms that move the scanning beam across and down the fluorescent screen of the picture tube. When no signal is being received, the sweep system forms a "raster" of almost 500 individual lines from top to bottom of the screen. The individual lines that form this raster glow with a uniform brightness. When a signal is applied to the grid or cathode of the picture tube, it varies the number of electrons in the beam, and as the scanning beam is moved across each line by the sweep system, the brightness along the line changes.

Each variation in the applied signal represents a brightness change in the scene being picked up by the camera tube. This signal change causes brightness variations on the fluorescent screen in the particular section toward which the beam is directed at that instant.

The sweep system in the television receiver must generate the series of lines that form the scanning raster. The process of synchronization, which will be discussed in detail in another lesson, locks in the sweep voltages so the position of the scanning beam on the picture tube is in exactly the same position as the camera tube beam scanning the televised scene at the station. Thus, if the camera tube scanning beam is covering a brightness change at the top right side of the image, the scanning beam at the picture tube will also be directed to the top right part of the raster.

A block diagram of a sweep system is shown in Fig. 1. The sweep system is responsible only for the motion of the scanning beam and the formation of a synchronized raster. The brightness variations along the individual lines of the raster are caused by the video signal applied to the grid-cathode circuit of the picture tube. An understanding of this relationship is necessary in rapidly locating troubles in the television receiver.

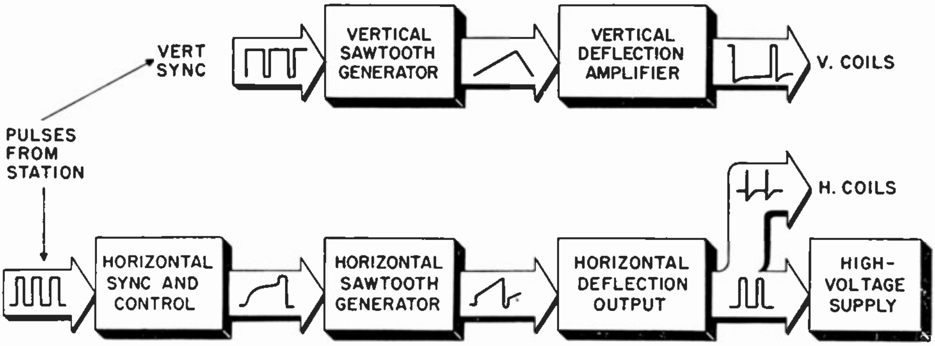


FIG. 1. Block diagram of a sweep system.

HOW THE SCANNING RASTER IS FORMED

The formation of a scanning raster can be best understood by recalling the formation of figures and patterns on an oscilloscope screen. Oscilloscope tubes, and even some of the earlier small-screen picture tubes, use electrostatic deflection. There are two pairs of plates—horizontal and vertical. When equal voltages are applied to both horizontal plates, and equal voltages are applied to both vertical plates, the scanning beam will strike the center of the scope or picture tube screen. Applying a more positive dc voltage to the right deflection plate than to the left plate moves the beam to the right center of the screen. By applying proper voltages to the various deflection plates, the beam can be moved to any point on the screen.

If a sawtooth voltage is applied to the right-hand horizontal deflection plate, the beam will move from left to right across the screen and then, during the much faster sawtooth retrace interval, return quickly to the left-hand side again, forming a single horizontal line as in Fig. 2A.

If the sawtooth wave is removed from the horizontal plate and applied to the bottom vertical plate, a single vertical line will be formed on the screen, as shown in Fig. 2B. More important, if at the same time a positive sawtooth is applied to the right plate and a sawtooth of the same frequency and phase is applied to the bottom plate, a diagonal line running from top left to lower right results as shown in Fig. 2C.

If we increase the frequency of the horizontal sawtooth so that it is five times as high as the frequency of the vertical sawtooth, a number of individual diagonal lines or horizontal scans are traced before the beam can be moved from top to bottom of the screen as shown in Fig. 2D. Consequently, a number of horizontal lines tilted from left to right are formed on the screen. Notice also that fainter lines run from right to left to interconnect the diagonal lines. The heavy, or bright, lines are formed by the slow rise of the horizontal sawtooth wave and are called "trace" lines, and the faint lines running from right to left occur during the fast return (steep side) of the sawtooth wave and are called "retrace" lines. In an actual television system the horizontal blanking pulses that arrive at the grid circuit of the picture tube cut off the scanning beam during the horizontal retrace time so that the retrace lines are not visible.

As the frequency of the horizontal sawtooth is increased above the frequency of the vertical sawtooth, more and more horizontal lines are formed. With the horizontal frequency so many times higher than the vertical, the lines appear almost as horizontal lines as shown in Fig. 3. The actual tilt of the line is not discernible, although there must be some slight tilt to permit the formation of one line beneath the preceding one.

A television raster often has bright lines streaking from bottom to top. These lines occur during the vertical

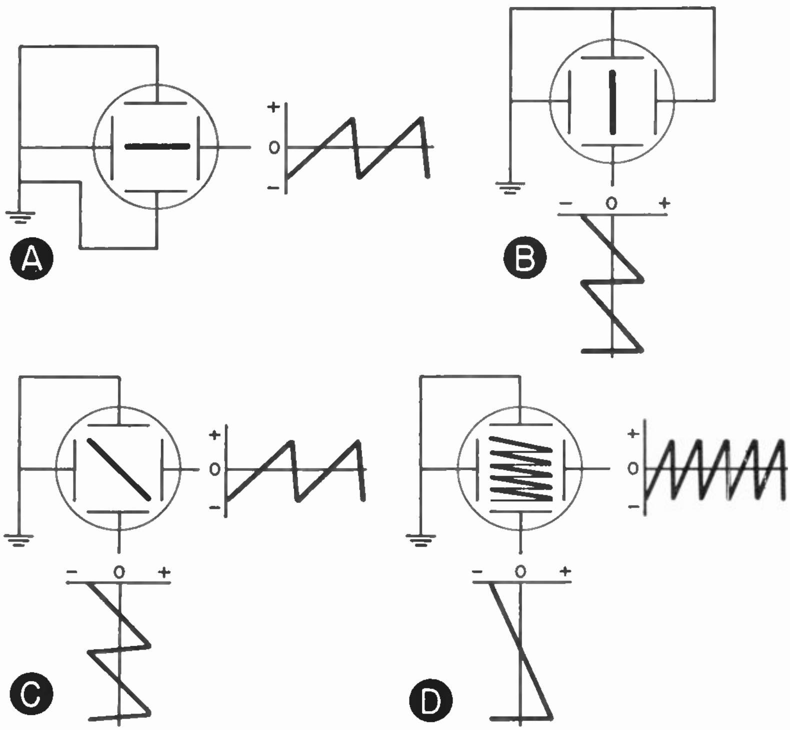


FIG. 2. How a raster is formed.

In a television receiver, the horizontal sawtooth frequency is 15,750 cps and the vertical sawtooth frequency is set at 60 cps so that 262½ horizontal lines are formed. However, you will recall that some of the lines are not visible because of the relatively long vertical blanking period. With the retrace period when the scanning beam is returning to the top of the raster before beginning a new set of scanning lines. Since the *vertical retrace period is longer than the time required to scan a number of horizontal lines,* the beam does not return directly from bottom to top of the raster but weaves

Courtesy Admiral

FIG. 3. This enlargement of a section of a TV picture shows that it is made up of a series of lines of varying brightness separated by fine black spaces. (Look at it from ten feet away, and you will see that the lines blend together.)

back and forth from bottom to top. These retrace lines are visible on the screen of many television receivers when no signal is being received or when the brightness control on the receiver is set too high.

Magnetic Deflection. It is possible to form a scanning raster with a changing magnetic field as well as a changing electrostatic field. In fact, for a picture of a given area, it is possible to position the picture tube screen nearer to the electron gun when magnetic deflection is used. Thus a shorter picture tube can be made. Therefore, the picture tubes used in most modern television receivers use magnetic deflection.

You have already become familiar with the principles of magnetic deflection from your study of previous lessons, and we will not go into detail on them here. However, there are a few important facts that you should remember when studying sweep systems.

First, beam deflection is at right angles to the magnetic field, therefore the horizontal deflection coils are mounted above and below the neck of the tube and vertical deflection coils are mounted on each side.

Second, to achieve linear motion of the electron beam, the sweep system must supply sawtooth *currents* to the deflection coils—not sawtooth voltage, as with electrostatic deflection.

Third, the raster is formed in much the same manner as with electrostatic deflection. Voltages are applied across the horizontal deflection coils to produce a sawtooth current in them at the rate of 15,750 cps and across the vertical coils to produce a sawtooth current at the rate of 60 cps. In this manner, sixty 262½-line fields are produced per second. You will recall that there are two fields per frame so that the complete raster has 525 lines. However, slightly less than 500 are visible because of the relatively long vertical blanking period between fields.

SYNCHRONIZATION

In the television receiver the video and blanking pulses are used at the grid circuit of the picture tube to modulate the intensity of the scanning beam. The synchronizing pulses are also used to synchronize the deflection system. The deflection sawtooth waves are generated continuously, whether a signal is being received or not. Consequently, when the television set is turned on, a scanning raster should always appear, indicating that the horizontal and vertical deflection systems (or sweep systems, as they are usually called) are operating.

The arrival of the horizontal and vertical synchronizing pulses at the input of the deflection system locks in the generation of the vertical and horizontal sawtooth components so that they operate in phase with, and at the same frequency as, the horizontal and vertical oscillators at the camera tube. The horizontal sync pulse occurs at the start of the horizontal retrace portion of the sawtooth wave, as shown in Fig. 4. In fact, the horizontal sync pulse is responsible on for a period of time after the sync pulse. The blanking pulse arrives at the grid of the picture tube and shuts off the scanning beam just before the start of the retrace period.

We generally speak of beam retrace in discussing the scanning process. However, if the receiver is working properly, the actual beam does not retrace, because the blanking pulse has biased the tube beyond cut-off so that there is no beam. What actually takes place is that the deflection

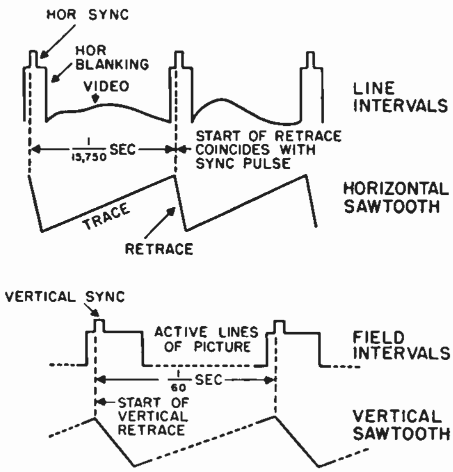


FIG. 4. Comparing the horizontal and vertical sawtooth pulses with respect to received pulses.

for the start of the horizontal retrace period. Thus, the horizontal sawtooth has the same frequency as the arriving sync pulse and also has the proper phase relationship. The vertical sync pulse coincides with the vertical retrace interval and is responsible for the proper cycling of the vertical deflection system. Note that the sync pulses ride on top of the blanking pulses. The blanking pulse starts just ahead of the sync pulse and continues magnetic fields are reshaped during the retrace times. As a result, when the beam is turned on once again, at the end of the blanking pulse, it is at the proper position to start a new trace.

To understand the relationship between the deflection sawtooth waves and the arriving pulses, let us consider how the picture is reproduced on the picture tube. During the horizontal trace period, the scanning beam is moved from left to right across the screen. At the same time, the video signal is applied to the grid of the picture tube and modulates the scanning beam in accordance with the brightness variations along this single line of picture information. The blanking pulse arrives just before the synchronizing pulse, and shuts off the scanning beam at the right-hand side of the raster. Next, the horizontal sync pulse arrives, at which time the horizontal deflection field is reshaped to start the next horizontal line. Reshaping the deflection field involves changing the field from a maximum value of one polarity to a maximum value of the opposite polarity.

If the scanning beam were turned on, the reshaping of the field would cause it to return rapidly to the left side of the screen, and it would produce a visible line from right to left across the screen, and cause a deterioration in the quality of the picture.

The blanking pulse continues after the synchronizing pulse to allow sufficient time for complete reshaping of the deflection field. At the end of the horizontal blanking pulse, the scanning beam is turned on again, and starts its motion across (left to right) to form the next line.

The second horizontal line appears below the preceding one, because of the action of the much slower vertical sweep, which is slowly pulling the beam down the screen. The vertical sweep causes the beam to move from top to bottom of the screen at a 60-cycle rate so that approximately 250 visible horizontal lines are traced down the screen during the vertical trace period. Just before the arrival of the vertical sync pulse, a vertical blanking pulse arrives at the grid circuit of the picture tube and cuts off the scanning beam as it reaches the last line at the bottom of the raster. During the vertical retrace period the vertical sync pulse arrives. During the vertical retrace interval, the vertical fields are reshaped so that, at the conclusion of the vertical blanking pulse, the scanning beam will start a new field beginning at the top of the raster. The vertical retrace period is approximately equal to the time required to transmit 20 lines, and there are two vertical retrace periods for each complete picture. Consequently, our television picture contains about 485 lines instead of 525.

The vertical blanking pulse continues after the vertical sync pulse to allow time for reshaping the vertical deflection field. At the conclusion of the vertical blanking pulse, the beam is turned on once again and appears at the top of the raster, ready to begin a new field. The equalizing pulses that appear before and after the vertical sync pulses insure precise timing and stable interlace. They will be discussed in more detail in the lesson on synchronizing systems.

An understanding of what occurs in the deflection system, and the relationship between the generated sawtooth waves and the received pulses is very helpful in isolating receiver defects. For example, even if no signal is being received, it should still be possible to obtain a normal raster on the picture tube screen, because the sync pulses influence the timing of the deflection waveform only, and do not actually generate the deflection energy. If the raster is normal, but it is not possible to lock it in with the sync pulses, you know there is a sync defect in the receiver. If the raster locks in normally, but the picture information does not appear or is very weak, there is some defect that prevents the arrival of the full amplitude video signal to the grid circuit of the picture tube. Knowing where each signal goes and what it is supposed to do is a great help in rapid isolation of receiver defects.

Formation Of A Sawtooth Wave

The sawtooth voltage is the basic deflection waveform. After shaping and amplification, the sawtooth voltages are used to excite the deflection output stages. These form the sawtooth current waves in the two pairs of deflection coils to produce horizontal and vertical motion of the scanning beam.

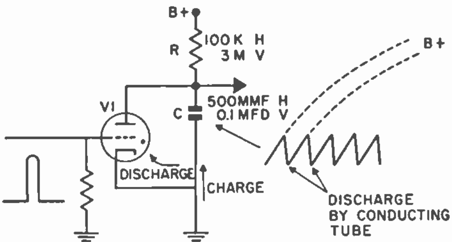


FIG. 5. A simple sawtooth generator.

A sawtooth voltage can be formed by using the simple arrangement shown in Fig. 5. The gradual rise of voltage across a capacitor charging through a resistor can be used to form the long side of a sawtooth trace. Thus, in the circuit shown, a capacitor C is placed across the plate and cathode of a special tube. This capacitor attempts to charge to the supply voltage (B+) through resistor R. The rate of charge decreases as the total charge increases, making the charging curve "fall off," forming an exponential curve as shown by the dotted lines of Fig. 5. If all of this curve were used, the scanning would not be linear. Therefore, only the lower portion, which is almost a straight line, is used. The tube is of a special gas-filled type. The gas becomes *ionized* (becomes conductive) at a certain critical voltage. At this point it provides a low-resistance shunt through which the capacitor can discharge very rapidly, forming the retrace portion of the sawtooth. When the voltage drops sufficiently, the tube again becomes non-conductive, and another charging cycle is started. The time required for charging is controlled by the time constant of the resistor and capacitor combination. This is made long as compared to the period of the trace so that only the initial linear part need be used.

The sync pulse arriving at the grid of the tube supplies a trigger action. By suddenly increasing the voltage, it "trips" the tube, making it conductive at the proper scanning frequency.

The vertical trace is much longer than the horizontal trace, so the time constant required is also much longer. Fig. 5 shows typical values for using the circuit as a horizontal sawtooth generator and as a vertical sawtooth generator.

SAWTOOTH OSCILLATOR

Although the circuit shown in Fig. 5 represents the simplest method of producing synchronized sawtooth voltages, it has been found that other circuits operating on similar principles are more stable and more economical.

The basic sawtooth oscillators are the blocking oscillator and the cathode-coupled multivibrator. The more complex oscillators used in modern TV receivers are modifications of these two basic types. The feedback cycle of this type of oscillator is such that the tube conducts for a short time and is cut off or non-conducting for a much longer time.

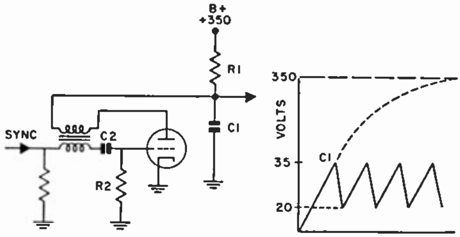


FIG. 6. Blocking-tube sawtooth generator.

Blocking Tube Oscillator. A blocking tube oscillator is shown in Fig. 6. Let us assume that the tube is beginning to conduct and the grid voltage is swinging in the positive direction. The positive grid voltage causes a further increase in plate current and, at the same time, a drop in plate voltage. This drop in plate voltage produces a negative voltage across the transformer primary. The voltage is coupled to the secondary with the polarity necessary to cause an additional rise in grid voltage in the positive direction. As a result, the feedback cycle drives the grid positive rapidly until it reaches the level where a further increase in grid voltage causes no further change in plate current. This point of no further increase in plate current, with an attempted rise in grid voltage, is the level at which the grid draws current and counteracts the attempted rise in grid voltage.

Consequently, for a short interval of time, there is no plate voltage change to produce feedback, and the grid voltage begins to slide back. As soon as it does, the plate current decreases, and the plate voltage begins to increase. This plate voltage change, now in the opposite direction, initiates a fast feedback cycle of opposite polarity. The increase in plate voltage across the transformer primary causes a secondary voltage that drives the grid in the negative direction, resulting in a further decrease in plate current and rise in plate voltage. This new feedback cycle drives the grid rapidly to cut-off and beyond, because the tube and the transformer have amplified the initial grid voltage change and, assisted by the collapsing field about the transformer (tube has been cut off), drive the grid far negative.

The high negative charge on capacitor C2 (result of feedback cycle and grid current flow) holds the tube at cut-off until the capacitor has discharged through resistor R2, to the extent that the negative bias on the grid of the tube declines to the point at which plate current can flow again. The length of time, and therefore the frequency of the oscillator, is determined by the time constant of resistor R2 and capacitor C2. The longer the time constant of this combination, the lower the frequency of the oscillator, because of the greater time required to discharge capacitor C2 to the level at which the tube begins to conduct. Thus, when a blocking tube oscillator is used to generate a vertical sawtooth, the time constant in the grid circuit will be longer than when it is used to generate a horizontal sawtooth.

After the grid capacitor C2 has discharged to the conduction level of the tube, the plate current begins to flow and the plate voltage to decrease once again. This initiates another feedback cycle that drives the grid in the positive direction once again, and a new cycle of operation begins. It is apparent that the blocking tube oscillator is free-running and continues to oscillate and form an output signal.

The transformer, C2, and R2, function to make V1 serve essentially the same purpose as the gas tube in Fig. 5. When the blocking tube in Fig. 6 is non-conducting, capacitor C1 charges toward the B+ voltage through resistor R1. The time constant of R1 and C1 is chosen so that the charge that accumulates on the capacitor during the trace interval reaches a peak value of approximately 35 volts, or 10% of the supply voltage. Consequently, the capacitor will build up voltage only during the more linear portions of the exponential charge cycle. At about the time that the capacitor C1 charge reaches 35 volts, the grid capacitor C2 has discharged to a level where the tube begins to conduct and originates a feedback cycle.

During the conduction time of the tube, the low resistance of the tube is shunted across C1, discharging it rapidly. It does not discharge to zero volts, however, because the conducting tube has a specific resistance which depends on the tube type and the operating potentials. Let us assume that the plate voltage on the tube, when it is conducting, is 20 volts and, consequently, the capacitor C1 can discharge only to this level as shown in the waveform drawing in Fig. 6. At the end of the short conducting period of the tube, the grid capacitor C2 has been once again charged to a negative voltage. Beyond this interval the sawtooth-forming capacitor C1 begins to charge toward the B+ supply potential. It is again interrupted by the conduction of the tube after it has reached a potential near 35 volts. This starts a new feedback cycle and sawtooth retrace.

Sawtooth Amplitude and Frequency. The frequency of the sawtooth oscillator is controlled mainly by the grid time constant; the sawtooth amplitude is regulated by the sawtooth-forming time constant. Typical blocking tube waveforms are illustrated by drawings A, B, and C of Fig. 7. Waveform A is the grid waveform, showing the discharge of capacitor C2 through resistor R2 until the conduction point is reached. At this instant the grid voltage swings positive to the saturation and limiting level, and then sharply negative beyond cut-off. Consequently, during the pulse portion of the grid waveform, the tube is conducting and the feedback cycle occurs. A negative pulse is developed in the plate circuit that

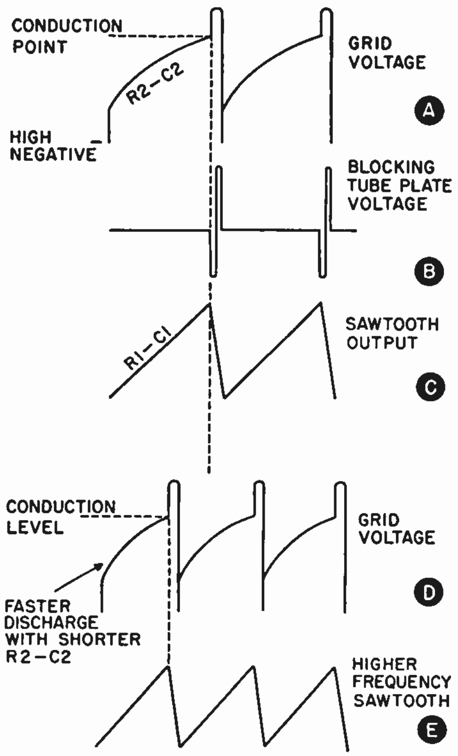


FIG. 7. Blocking-tube waveforms and frequency change.

corresponds in time position to the positive swing of the grid voltage, as shown in Fig. 7B. There is also a sharp positive pulse in the plate circuit that occurs during the collapse of the field about the blocking tube transformer, and is instrumental in driving the grid circuit far beyond cut-off.

Waveform C represents the sawtooth wave as it is developed across capacitor C1. During the cut-off period of the tube, capacitor C1 is charging through resistor R1. However, at the instant the grid swings into the conduction range, the low resistance of the blocking tube discharges capacitor C1. As a result, the retrace portion of the sawtooth wave is formed.

To increase the frequency of the blocking tube, the time constant in the grid circuit is reduced; to decrease the blocking tube frequency, the time constant is increased. When there is a lower grid time constant, such as can be obtained by reducing the value of capacitor C2 or resistor R2, there is a faster discharge of the voltage on capacitor C2. Usually the frequency of the blocking tube is regulated by varying the value of resistor R2. When an increase in frequency is desired, resistor R2 is reduced in value. Consequently, capacitor C2 will lose its cut-off voltage at a faster rate, and the conduction level of the tube will be reached in a shorter interval of time, as shown by waveform D of Fig. 7. The blocking tube will be driven into conduction earlier than shown in waveform A. The retrace will occur sooner, and the new trace will begin earlier. As shown in waveforms D and E, the shorter time constant in the grid circuit causes the generation of a higher frequency sawtooth wave.

The grid time constant also has some limited influence on the amplitude of the sawtooth wave formed in the plate circuit. If the discharge time is faster, the amplitude of the sawtooth wave is not quite as high because it is not allowed as much time to charge. Consequently, in making receiver adjustments, there will be interaction between control settings, particularly with relation to the frequency, linearity, and amplitude adjustments of the sawtooth waves.

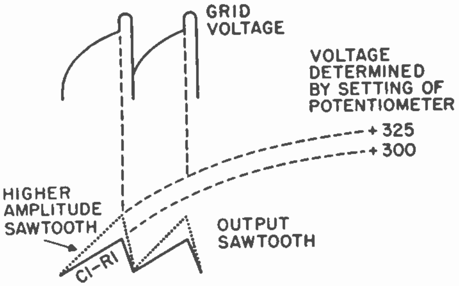


FIG. 8. Control of sawtooth amplitude.

The amplitude of the sawtooth wave is most often controlled by regulating the B+ value toward which the sawtooth-forming capacitor attempts to charge. For example, if a potentiometer were connected in the B+ circuit of Fig. 6, it would be possible to control the amplitude of the generated sawtooth wave as shown in Fig. 8. During the discharge cycle of the grid waveform, the sawtooth capacitor C1 is charging toward the B+ voltage. With a fixed amount of time for the charge, the actual amplitude of the final voltage on the capacitor depends on the supply voltage toward which the capacitor is attempting to charge. For example, for this solid-line sawtooth wave, the capacitor is attempting to reach a supply voltage of plus 300 volts; for the dotted-line sawtooth wave, it is attempting to charge to plus 325 volts. By regulating the voltage supplied to the sawtooth-forming circuit, it is possible to include a means of regulating the sawtooth amplitude. The frequency of the sawtooth wave remains essentially constant, and the amplitude changes only with changes in the supplied voltage.

In a TV receiver, the controls that regulate the amplitude of the sawtooth generators are referred to as width and height or "size" controls, while the controls that set the frequency of the generated sawtooth waves are called the frequency or "hold" controls.

Cathode-Coupled Multivibrator. Another basic sawtooth generating circuit is the cathode-coupled multivibrator illustrated in Fig. 9. In this circuit the sawtooth voltage is developed across capacitor C1, and the frequency of the multivibrator is determined mainly by capacitor C2 and resistor R2. The second section of the triode functions very much the same as the blocking tube, because the sawtooth trace is formed on capacitor C1 when the tube is non-conducting, and the retrace is formed when the tube conducts and discharges capacitor C1. The cut-off time of the tube is controlled by the time constant of the grid capacitor C2 and grid resistor R2, just as in a blocking oscillator. In fact, the first section of the multi-

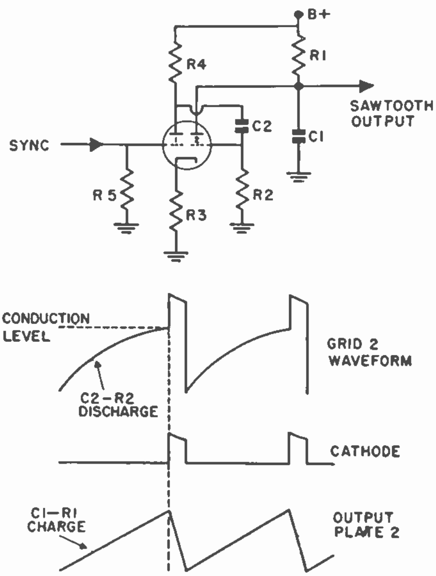


FIG. 9. Cathode-coupled multivibrator.

vibrator has the same purpose as the transformer of the blocking tube oscillator—mainly to initiate a feedback cycle.

The cycle for the cathode-coupled multivibrator is as follows: Let us assume that capacitor C2 is discharging and the grid voltage has reached the level at which the second section of the tube begins to conduct.

The rise in plate current, when the second section of the tube conducts, develops a more positive voltage across cathode resistor R3. The higher cathode voltage results in an increase in negative bias on the first section. The plate current of the first section decreases, and its plate voltage increases.

The plate circuit of the first section is coupled through capacitor C2 to the grid of the second section. Therefore, the rise of plate voltage on the first section causes a further increase in positive grid voltage on the second section.

This feedback arrangement causes the grid voltage of the second section to rise rapidly and almost instantaneously, driving the grid of the first section toward cut-off and the grid of the second section positive to the level where a further increase in grid voltage causes no further increase in the plate current of the second section. At this instant, no further feedback occurs, because there is no change in plate current in the second section. With no feedback to support it, the grid voltage of the second section begins to slide back and reverses the feedback cycle.

This time the grid voltage of the second section decreases, causing a decrease in plate current, and a less positive voltage across the cathode resistor R3. Thus, the bias on the first section of the tube begins to decrease and there is an increase in the plate current of the first section. The resultant decline in the plate voltage of the first section drives the grid of the second section further in the negative direction. In fact, feedback operation, assisted by the amplification by the first section, drives the second section beyond cut-off. As a result, the second section is held at cut-off by the high negative charge placed on capacitor C2, just as the negative charge placed on the grid capacitor of a blocking tube holds it at cut-off. The second section remains cut off until capacitor C2 discharges through resistor R2 to the bias level at which the second section of the tube begins to conduct again. As soon as the second section begins to conduct, a new feedback cycle is originated.

During the interval that the second section is held at cut-off by the charge on capacitor C2, capacitor C1 charges toward the B+ voltage through resistor R1. At the instant the second section conducts, this same capacitor is discharged through the tube, forming the sawtooth retrace interval. The frequency of the generated sawtooth is controlled by the grid time constant (capacitor C2 and resistor R2), which determines the rate of discharge of capacitor C2, as shown in the grid 2 waveform. The faster the time constant, the higher the frequency of the sawtooth generated, as explained in the blocking tube oscillator discussion. The amplitude of the sawtooth wave is again controlled by the plate-circuit time constant (resistor R1 and capacitor C1), and the supply voltage toward which capacitor C1 charges.

The feedback characteristic of the first section of the triode is illustrated by the cathode waveform. This cathode waveform is developed by the plate current changes in the second section. An amplified version of this same waveform appears at the plate of the first section, and therefore serves as the strong feedback pulse that is fed to the grid of the second section. Thus, the first section of the multivibrator has the same task as the blocking tube transformer; namely, to supply the necessary feedback pulse that triggers the sawtooth-forming second section.

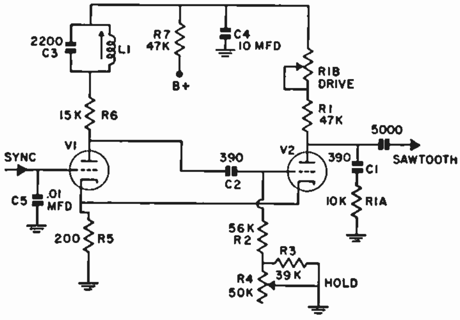


FIG. 10. The addition of a resonant circuit, C3 and L1, stabilizes the multivibrator.

Stabilized Multivibrators. It is possible to improve the frequency stability of a cathode-coupled multivibrator by inserting a tuned circuit in the plate circuit of the feedback tube, as shown in Fig. 10. The resonant circuit, consisting of inductor L1 and capacitor C3, is tuned to a frequency near the synchronized frequency of the multivibrator. Except for the resonant circuit and a special modifying resistor in the sawtooth output circuit, the multivibrator is the same as the one shown in Fig. 9.

The frequency of a multivibrator is controlled by the time constant in the grid circuit of the second tube. Resistor R4 is variable and acts as a horizontal hold control to adjust the multivibrator frequency as close as possible to that of the incoming horizontal sync pulses. The values shown are typical for a multivibrator that must operate at a line rate of 15,750 cycles. The sawtooth voltage is developed across capacitor C1 as it charges through the R1 series of resistors. The retrace portion of the sawtooth is formed when the second tube conducts.

The resonant circuit, C3 and L1, improves stability by adding a sine wave to the regular grid waveform of the multivibrator. The sine wave voltage is developed across the resonant circuit by the sharp change in plate current of the first tube, and is coupled through capacitor C2 to the grid of the second section. Also present on the grid of the second section is the standard multivibrator waveform that results from the discharge of capacitor C2. The two waveforms

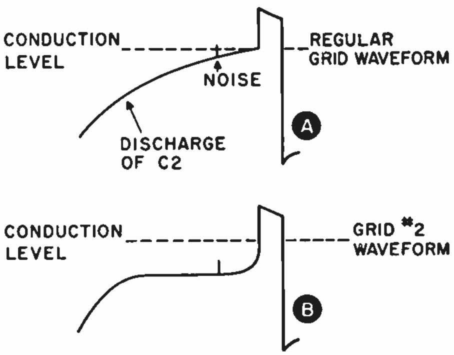


FIG. 11. The sine wave voltage developed across the resonant circuit combines with the regular multivibrator grid waveform (A) to produce the modified form at B.

combine to form the resultant waveform B of Fig. 11. The advantage of this type of grid waveform is that the discharge cycle of capacitor C2 near conduction time is separated by a substantial voltage from the conduction level of the second tube. For example, if a small burst of noise reaches the grid of the second section, as shown in Fig. 11A, it may reach the conduction level and start the second tube conducting before the true synchronization time. This will start the retrace portion of the sawtooth too soon, and the next line of video information will be displaced on the scanning raster. However, with the discharge portion of the waveform substantially below the conduction level, as shown in waveform B, the same burst of noise does not reach the conduction level and trigger the multivibrator incorrectly.

Thus, the resonant circuit improves the stability of the multivibrator by preventing stray noises and circuit variations from causing a shift in frequency and phase of the sawtooth output of the multivibrator.

Formation of a Modified Sawtooth Wave. In almost all magnetic deflection systems, it is necessary to modify the sawtooth wave with the addition of a pulse component in order to obtain a linear sawtooth current in the deflection coil. The addition of a pulse to the sawtooth wave can be accomplished at the sawtooth-forming circuit as shown in Fig. 12. When the sawtooth trace is formed, capacitor C1 charges slowly toward the B+ potential through the R1 group of resistors. Since the actual charging current is small, it does not develop any great voltage across resistor R1A, connected between the capacitor C1 and ground, because its resistance is comparatively low. At the time of discharge, however, the second section of the multivibrator is conducting, and the discharge path is through resistor R1A, resistor R5, and the resistance of the conducting tube. This is a short time constant discharge path, so there is a high discharge current which flows down through resistor R1A and develops an appreciable negative pulse as shown in the waveforms of Fig. 12.

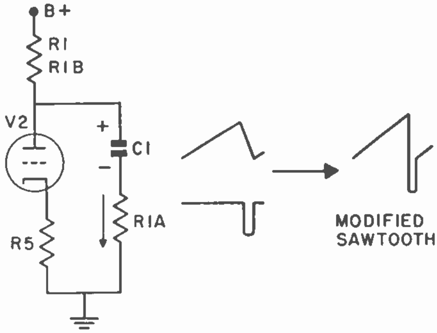


FIG. 12. When R1A is added in series with C1, a modified sawtooth voltage is produced across the series combination.

SYNCHRONIZATION OF SAWTOOTH OSCILLATORS

A horizontal sawtooth oscillator can be set at the line rate frequency and a vertical sawtooth oscillator to the field rate frequency of the television receiver, but adjusting each oscillator to the correct frequency is not enough to obtain a stationary, locked-in picture. The oscillators must be held rigidly to a specific frequency and must maintain a definite phase relationship with the scanning beam at the camera tube. Consequently, it is necessary to convey sync pulses from the transmitter to the receiver, and to introduce these sync pulses into the deflection system of the receiver. The sync pulses lock in the frequency and phase of the sweep oscillator. The sync pulses do not generate the sawtooth wave or determine the frequency of the sawtooth wave. They serve to hold the oscillator rigidly at the required frequency and phase.

This very characteristic is often helpful in determining whether a defect is in the synchronization or the sawtooth generating sections of a TV receiver. Generally, when there is a sync defect, it is possible to lock in the picture momentarily by varying the frequency controls. However, with improper sync, the picture remains locked in just for a short time and then drifts out again. Usually, if there is a sawtooth generating defect, it is not possible to tune the defective oscillator to the correct frequency.

The process of synchronization is discussed in detail in a later lesson. However, a brief introduction to synchronization here will give you a better understanding of the operation of the deflection system in a television receiver. There are two basic methods of establishing rigid control of the frequency and phase of a sawtooth oscillator—by application of the sync pulses to the oscillator and by the establishment of a dc voltage at the sawtooth oscillator that depends on the incoming sync pulses.

When a sync pulse is introduced into the grid circuit of a blocking tube oscillator, and the hold control is adjusted to bring the frequency of the oscillator near to that of the arriving sync pulses, synchronization occurs as shown in Fig. 13A. The sync pulse, which is very much lower in amplitude than the normal grid waveform of the blocking tube oscillator, is applied to the grid. When the oscillator is properly adjusted, the positive sync pulses will extend above the trigger level and drive the blocking tube into conduction, thus initiating the retrace portion of the generated sawtooth wave.

A hold control is necessary to permit adjustment of the frequency of the oscillator to the frequency at which the sync pulses can establish rigid control of the oscillator. The direct application of the vertical sync pulses to the vertical blocking oscillator is the most common method of synchronizing the vertical deflection system.

The horizontal deflection system is more often synchronized by a dc voltage. This dc voltage is established initially by comparing the frequency of the sync pulses with the frequency of the horizontal deflection waveform. When there is any difference in frequency or phase between the two signals, the dc voltage changes, causing a correction in the frequency of the sawtooth oscillator. The manner in which this dc voltage is produced is discussed in more detail in your lesson on the sync system.

With this method of synchronization it is not necessary to apply the sync pulses to the sawtooth oscillator directly. Instead, the sync pulses are applied to the comparison circuit that develops the dc voltage. This voltage is then applied to the oscillator, as shown in Fig. 13B.

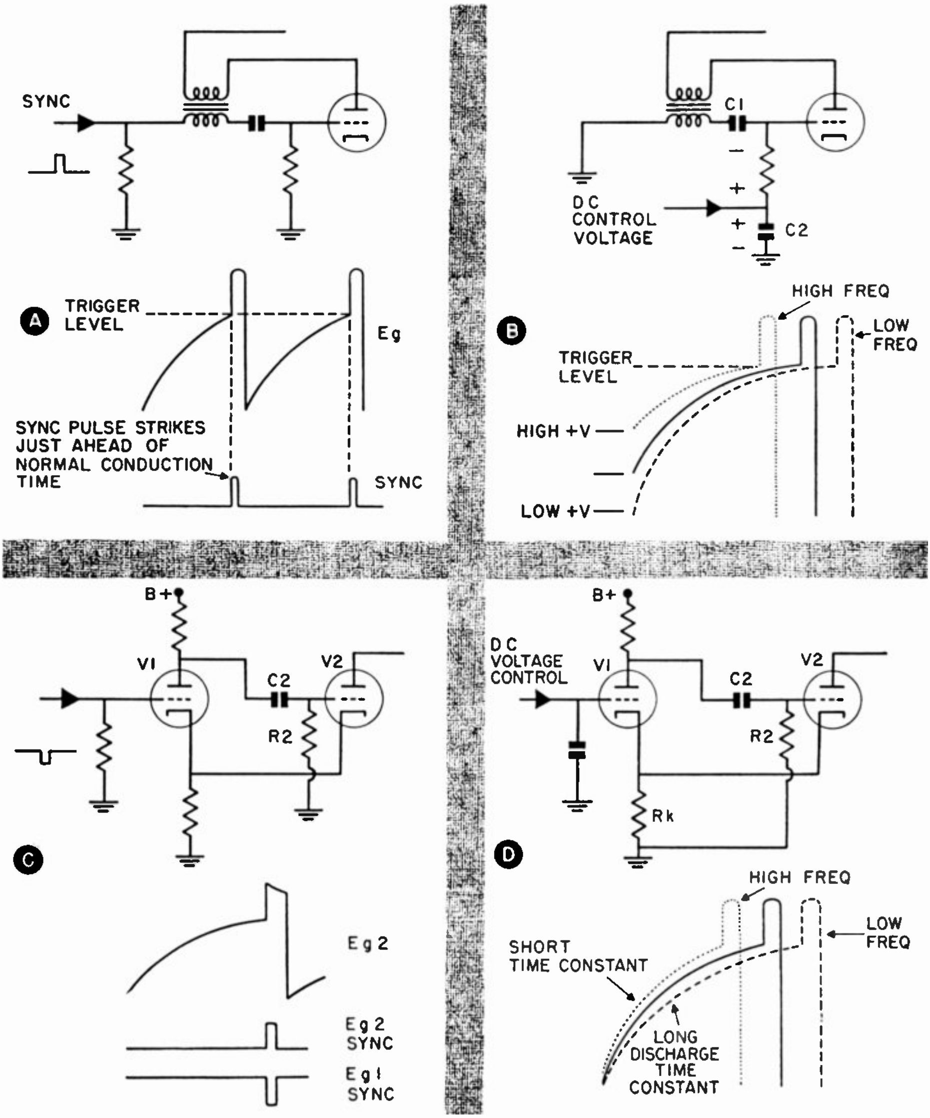


FIG. 13. Synchronization of sawtooth oscillators.

The waveforms in Fig. 13B illustrate how a dc voltage can be used to vary and correct the frequency of a blocking tube oscillator. The negative charge placed on the grid capacitor C1 establishes a bias voltage that must be discharged to the conduction level before the blocking tube again conducts. If a dc voltage is introduced in conjunction with this negative capacitor charge, the time required to discharge to the conduction level can be altered. For example, when a high positive dc voltage is supplied, the capacitor discharges from a less negative voltage, and it reaches the conduction level earlier. Inasmuch as the discharge time has been made shorter with the introduction of the positive voltage, the frequency of the blocking tube rises.

If the applied dc voltage is now reduced, the capacitor discharges from a higher negative voltage, and the time of discharge to reach the conduction level is longer, lowering the frequency of the blocking tube.

Thus, limited changes in an introduced dc voltage vary the frequency of the oscillator over a limited range to permit it to follow the frequency and phase of the sync pulses.

Just as in the blocking tube oscillator shown in Fig. 13A and 13B, it is possible to control the frequency of a multivibrator either with the direct application of sync pulses or with the use of a dc control voltage. When a multivibrator is synchronized directly with pulses, they arrive as small positive spikes at the grid of the second section as shown in Fig. 13C. Again they add to the normal grid waveform of the multivibrator and start the retrace portion of the generated sawtooth by driving the second section into conduction at the instant of their arrival.

The schematic diagram in Fig. 13D shows how the frequency of the multivibrator is controlled by a dc voltage applied to the grid of the first section. A dc voltage so applied acts as a grid bias and determines the plate current of the first section. The plate current in turn determines the voltage drop across the plate load resistor, and hence the voltage level to which C2 must discharge. A positive voltage on the grid of the first section will cause the plate voltage to drop to a lower value, and hence C2 must discharge to a lower value. This will increase the time required for C2 to discharge to a level that will permit V2 to conduct, and hence will increase the time constant of the circuit and reduce the oscillator frequency. When a negative voltage is applied to the grid of V1, the opposite effect is produced and the oscillator frequency will increase.

In some of the earlier TV receivers, sine-wave oscillators were often used in the horizontal deflection system. The sine-wave output of this oscillator was compared with the incoming sync pulse, and the resultant comparison voltage was used as grid bias on a reactance tube. The reactance tube in turn controlled the frequency of the sine-wave oscillator so that it would be the same as that of the incoming horizontal sync pulses. The sine-wave oscillator, shown in Fig. 14, also controlled the generation of the sawtooth wave.

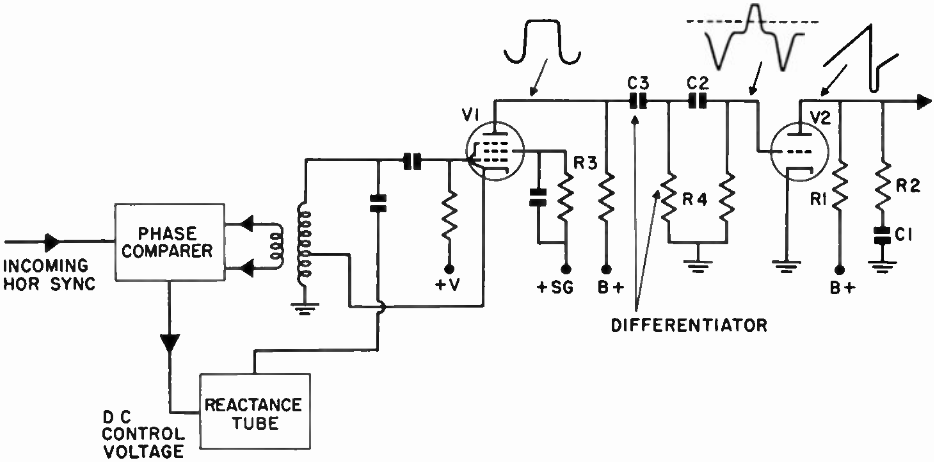


FIG. 14. Sine wave sweep generator.

The sine-wave oscillator is basically an electron-coupled oscillator with the screen grid, control grid, and cathode forming a Hartley oscillator. The strength of the oscillations and the biasing of the oscillator tube are such that the plate current reaches saturation on the crest of the sine-wave cycle. Thus, the top of the sine wave as it appears across resistor R3 has been flattened into a crude square wave. This signal is then applied through a differentiating circuit consisting of capacitor C3 and resistor R4 to the grid of the sawtooth-forming discharge tube. The differentiated waveform appears as shown in Fig. 14, at the input of V2.

The positive spike of the differentiated signal corresponds to the retrace time, and triggers the discharge tube into conduction. When the discharge tube conducts, the sawtooth-forming capacitor C1 is discharged. Between positive grid spikes, the discharge tube is held at cut-off, and the sawtooth trace is formed on capacitor C1, as it charges through resistor R1, toward the B+ supply voltage. Thus the sine-wave output of an oscillator, if properly shaped, can be used to trigger a discharge tube.

Magnetic Deflection Amplifiers

The purpose of the deflection amplifiers (horizontal and vertical output stages) is to produce sawtooth *current* waves in the deflection coils. The deflection coils are attached around the neck of the tube so that their magnetic fields penetrate the glass envelope and deflect the electron beam. The excitation or drive for the deflection output stages is the modified sawtooth voltages generated by the sawtooth oscillators.

The deflection or sweep output stage is similar in some respects to an audio output stage. It consists of a power amplifier tube and an output transformer system in which the plate current change in the tube causes a substantial current change in the deflection coil. The large current change is necessary to create a changing magnetic field of sufficient strength to deflect the scanning beam as it passes along the neck of the picture tube toward the screen. Since the horizontal scanning rate is much higher in frequency than the vertical scanning rate, much more output power is required for horizontal than for vertical deflection. In addition, at the higher-frequency horizontal rate, there are added circuit and transformer losses to be overcome. The power required for horizontal deflection is generally several hundred times greater than that necessary for vertical deflection.

To obtain the necessary peak efficiency in the deflection output circuits, it is necessary to use a transformer or an auto-transformer arrangement, as shown in Fig. 15, to reflect the proper load to the output tube from the low-impedance deflection coils.

The technician must realize that the high efficiency and high power required by the output stages make them subject to defects caused by minor disturbances in the operation of the sawtooth generators or in the power supply system of the television receiver. Improper excitation or improper voltages in the deflection output circuit influence the size and

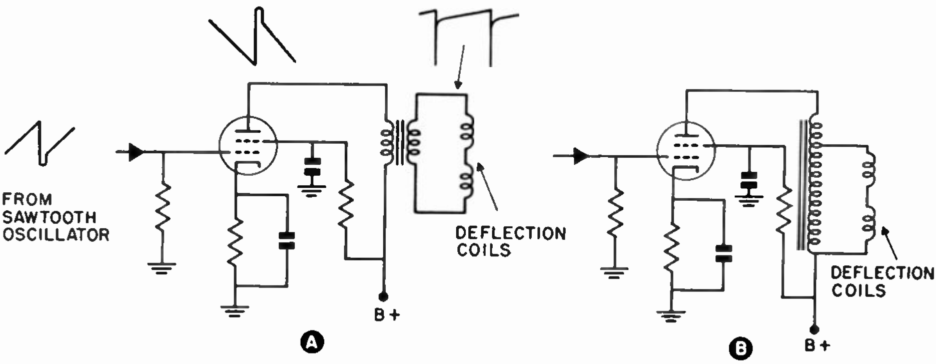


FIG. 15. Basic magnetic deflection amplifiers (A) using transformer in output, (B) using auto-transformer.

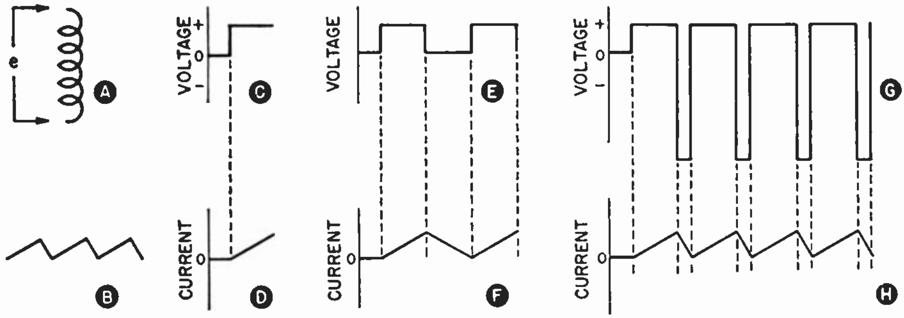


FIG. 16. How a sawtooth current can be made to flow in a perfect coil.

linearity of the picture. A very common defect in television receivers is a weak rectifier tube in the low-voltage power supply. This tube is perhaps the first tube to check and replace when the picture does not fill the entire screen. A power supply defect can cause an appreciable change in picture size with just minor fluctuations in line voltage, whereas if the power supply is operating properly, the line voltage changes usually will not cause any noticeable change in picture size.

TRAPEZOIDAL WAVES

Since the deflection field in an electromagnetic system is proportional to the current through the coils, we need a sawtooth current to produce the proper deflecting action. Because a coil resists sudden changes in voltage, such a sawtooth current cannot be produced by applying a sawtooth voltage to the coil. Let's see what shape the applied voltage must have to make the coil current a sawtooth current.

Let's suppose we have a perfect coil (no resistance) as shown in Fig. 16A and want the sawtooth current shown in Fig. 16B to flow through it.

If we apply a dc voltage (Fig. 16C) to a coil, the current through the coil will build up as shown in Fig. 16D. The rate at which this current rises depends on the inductance, on the voltage, and on how long the voltage is applied. In a perfect coil, this current could reach infinity if the voltage were applied long enough.

If we apply the voltage for just a short period of time, then cut it off for an equal period of time (Fig. 16E), we will get the triangular current flow shown in Fig. 16F. We can change this into a sawtooth current by finding some way of making the right-hand edge of the wave more nearly vertical.

A voltage having the form shown in Fig. 16G will do the trick. The high, short negative pulse will make the coil current drop suddenly, producing the sawtooth current in Fig. 16H.

The voltage shown in Fig. 16G is very similar to the output from a blocking oscillator or multivibrator. Therefore, if the output of one of these devices could cause enough current to flow, and if the coil had negligible resistance, we could get a sawtooth coil current without using a discharge circuit.

However, the coils with which we are dealing have appreciable resistance (which, as we shall show later, is needed to damp out oscillations). A practical coil, therefore, is like the combination shown in Fig. 17A.

A voltage having a rather unusual wave shape must be applied to get a sawtooth current to flow through this combination. A voltage having the form shown by curve 1 of Fig. 17B must be used to create a sawtooth current in an inductance, and one having the shape shown by curve 2 must be used to create such a current in a resistance; therefore, the two voltages must be combined, producing the "trapezoidal" wave shown in Fig. 17C, to create a sawtooth current through a combination of inductance and resistance.

The proportion of pulse voltage to sawtooth voltage needed in the trapezoidal wave depends on the relative proportions of inductance and resistance in the coil. Therefore, the circuits used to shape this trapezoidal wave must be designed to suit the particular deflection coils to be used with them and may be widely different in parts values in different receivers.

VERTICAL DEFLECTION SYSTEM

Since the vertical deflection coil must produce a linear deflection at a low frequency, a high inductance and its corresponding higher resistance is used. In the modern receiver, the excitation voltage for the vertical output tube consists of both a pulse and a sawtooth component. A vertical deflection output stage fed by a sawtooth oscillator is shown in Fig. 18. The modified pulse-sawtooth wave is formed across capacitor C1 and resistor R1B. This combined waveform is coupled through capacitor C2 to the grid of the vertical output stage. A long time-constant grid circuit is required to prevent mis-shaping of the very low-frequency vertical sawtooth.

The output of the vertical sawtooth amplifier is transformer-coupled to the vertical deflection coils. The

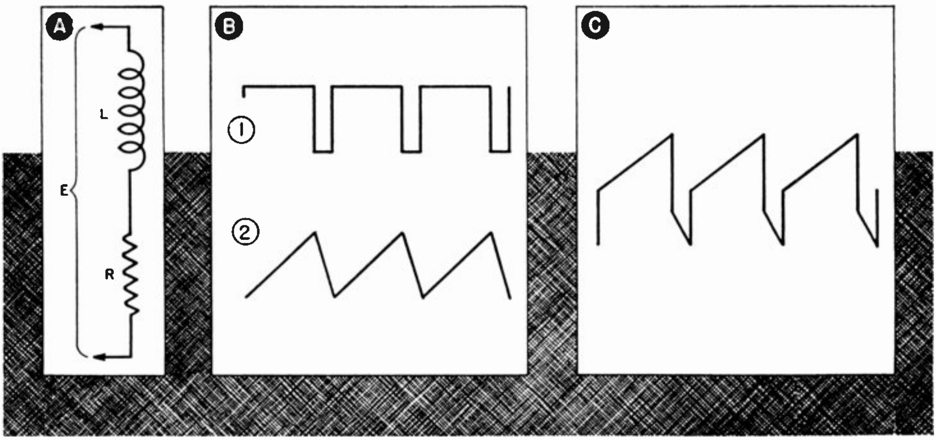


FIG. 17. A trapezoidal voltage wave must be applied to a practical coil to produce a sawtooth current.

transformer ratio is chosen to reflect the proper load to the output tube from the low-impedance deflection coil. During the long trace period of the vertical deflection cycle, it is possible that the sawtooth may curve instead of rise linearly because of the non-linear charge on the sawtooth-forming capacitor, or because of poor low-frequency response in the coupling circuit. To correct for any distortion that might occur in the vertical trace, a vertical linearity control is inserted in the cathode circuit of the vertical output tube.

The vertical linearity control, as shown in Fig. 19, permits the biasing of the vertical output stage on the non-linear part of the characteristic curve. By moving this bias point with the linearity control, it is possible to choose a point of curvature on the curve that will match the rounding of the applied sawtooth wave. Therefore, a linear sawtooth is developed at the plate of the output tube, with the non-linearity of the tube compensating for the non-linearity in the shape of the grid sawtooth wave.

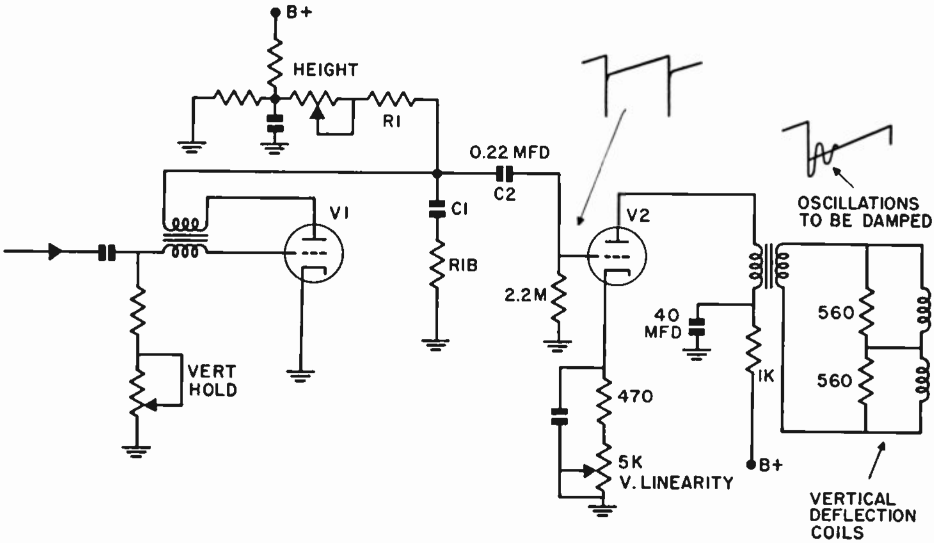


FIG. 18. A blocking tube oscillator (V1) used for vertical deflection fed into a vertical deflection output stage (V2).

At times distortion of the sawtooth occurs in the deflection output system, and the linearity control must adjust the shape of the sawtooth wave before the actual distortion occurs. Although you might think that if the sawtooth applied to the grid of the amplifier is linear no linearity control would be necessary, the linearity system may be necessary to correct for distortion later in the deflection system.

In some vertical output circuits the low side of the peaking resistor is often returned to the cathode of the vertical output amplifier, as shown in the optional connection of Fig. 19. This connection picks up a low amplitude waveform at the cathode circuit, which has an opposite curve to that

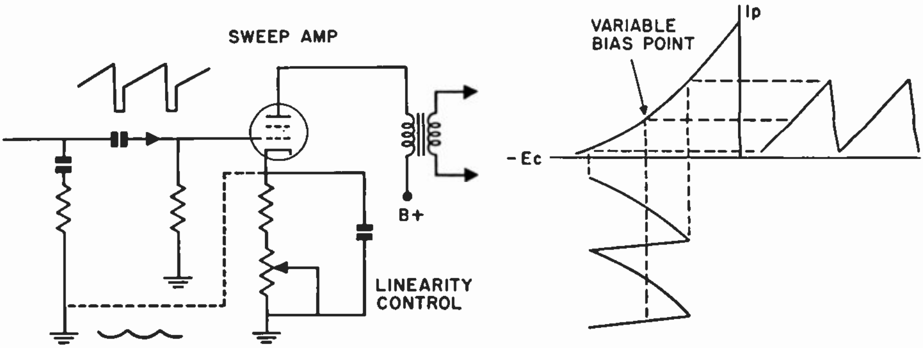


FIG. 19. A curve in the trace portion of the sawtooth current may be eliminated by adjusting the "Linearity Control" to select the proper bias point on the sweep amplifier transfer curve.

of the generated sawtooth wave. The addition of the two components through the feedback connection produces further improvement in the sawtooth linearity.

With a linear sawtooth applied to the grid of the vertical output amplifier, the plate current of the tube rises linearly, resulting in the transfer of the combined waveform to the secondary of the output transformer. However, the step-down transformer (the voltage is stepped down but the current is stepped up) can have a ratio of approximately 10-to-1. Therefore, a change in sweep amplifier plate current might result in a change ten times as large in the secondary of the output transformer. Thus, at the time that the applied sawtooth has reached its peak, a very high peak current is flowing in the deflection coil, and a strong magnetic field surrounds the coil. At the peak of the sawtooth wave the grid excitation is removed suddenly as the tube falls to cut-off. Consequently, there is no energy to support the magnetic field surrounding the deflection coil, and it collapses rapidly. In so doing it starts the vertical retrace, which reshapes the vertical deflection field quickly. However, the rather high resistance and inductance in the deflection coil circuit extend the retrace time so that it continues over an appreciable segment of the vertical blanking period.

The rapid collapse of the magnetic field can cause high amplitude oscillations at the self-resonant frequency of the deflection circuit, or at other leakage self-resonant frequencies. To prevent these oscillations from being generated and continuing over into the trace portion of the vertical period, some damping is required, otherwise they could cause non-linearity in the vertical scanning cycle.

You have learned that the strength and the duration of oscillations depend on the Q of the resonant circuit across which they occur. Also you know that the insertion of resistance in a resonant circuit can lower the Q, and if the Q is made low enough, it can stop the oscillations abruptly. Serious oscillations in the vertical deflection circuit can be reduced by the insertion of resistance. The vertical deflection coils are shunted by damping resistors connected across the coils and also by the low resistance of the output triode which begins to conduct again soon after the magnetic field collapses. The resistance damping is such that the oscillations are suppressed, but the loading is light enough to permit full vertical retrace to occur during the vertical blanking period.

Multivibrator Output. A common vertical deflection system in the modern TV receiver consists of a combination multivibrator sawtooth generator and deflection output stage. The multivibrator consists generally of a triode first section and a pentode second section, as shown in Fig. 20. The pentode second section also serves as the vertical deflection output stage.

The triode section serves as the frequency-controlling and sawtooth-forming stage; the pentode, in addition to driving the deflection coil circuit, serves as the feedback tube for the multivibrator section. An arrangement is used in which the feedback signal goes from the plate of the pentode to the grid of the triode, instead of the common-cathode arrangement discussed earlier. The sawtooth-forming circuit consists of capacitor C1, which charges through resistor R1 and the height control R2. Resistor R3 serves as the peaking element to form the modified sawtooth waveform used to excite the grid of the output section. The peaking resistor is returned to the cathode of the output tube to improve linearity. Linearity can be adjusted precisely with the cathode-bias control.

The frequency of the multivibrator is determined mainly by the grid time constant of the triode section, consisting of capacitor C2, resistor R4, and the frequency control potentiometer R5. This time constant determines the discharge time of capacitor C2; and therefore the length of time that the triode is held cut off. During the cut-off period of the triode section, the sawtooth wave is present on the grid of the pentode, and the tube plate current is increasing linearly.

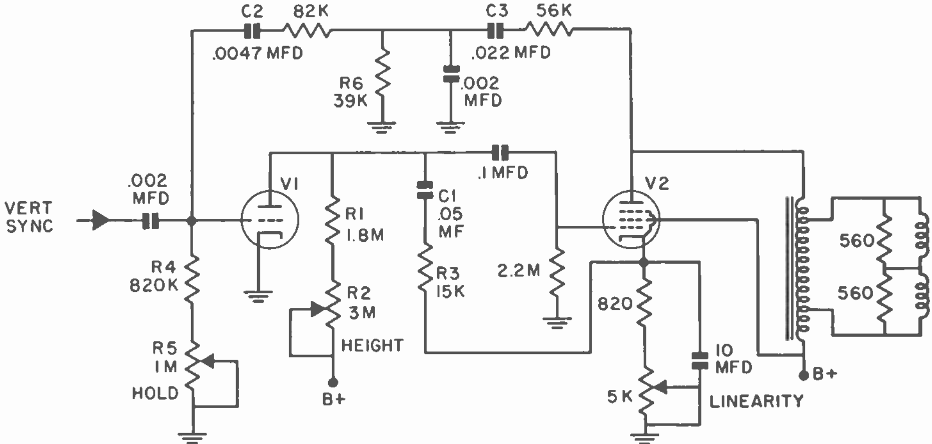


FIG. 20. The pentode section of a multivibrator (V2) also serves as a vertical output stage.

The output of the pentode section is coupled through the vertical output transformer to the vertical deflection coils.

Since the waveform at the plate of the pentode is trapezoidal, it is differentiated by capacitor C3 and resistor R6 so that only the pulse portion is fed back to the grid of the first section. This pulse is of proper polarity to support the feedback cycle during the conduction time of the first tube. When the triode section conducts, capacitor C1 discharges, and the retrace portion of the generated sawtooth wave is formed. In addition to forming the feedback pulse, the network between the plate of V2 and the grid of V1 attenuates the pulse so that it is of proper amplitude to excite the triode section, and shapes it so as to establish the best synchronization with relation to the incoming vertical sync pulses.

HORIZONTAL DEFLECTION SYSTEM

The horizontal output stage has some basic characteristics that are similar to those of the vertical output stage. However, there are a number of added features associated with the horizontal sweep amplifier. A typical horizontal output stage contains a beam power output tube and circuit, a horizontal deflection output transformer or direct-drive auto-transformer, a damper system, and a high-voltage supply.

In a horizontal output stage, which deflects the beam very rapidly, a small inductance will make the inductive reactance of the coil sufficiently high. To operate efficiently, it is necessary to keep resistive losses and stray capacities at a minimum. In fact, the horizontal deflection system presents an inductive load to the output tube. Despite the very low resistance, a very high current is required, and it is still necessary to use a slightly modified sawtooth voltage as excitation for the output stage.

The rise of plate current in the output tube during the sawtooth trace develops a constant high voltage across the secondary, insuring a constant rise of current through the deflection coil. At the conclusion of the trace, the horizontal output tube is suddenly cut off, and the field about the deflection coil collapses. Because this is a strong magnetic field, and the deflection coil along with its distributed capacity is resonant to a high frequency (approximately 75 to 100 kilocycles), the abrupt collapse of the field causes the secondary to go into oscillation.

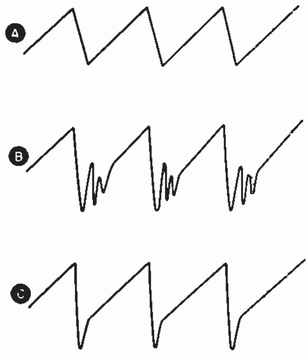


FIG. 21. The sawtooth current waveform (A) is distorted by oscillations at the resonant frequency of the deflection coil circuit (B), but with proper damping, one-half cycle of these oscillations is utilized to assure rapid retrace (C).

If allowed to run freely until overcome by the circuit resistance, these oscillations would cause distortion in the trace portion of the sawtooth current waveform as shown in Fig. 21. Therefore, some method of damping is essential. However, you will note that the effects of this oscillation are not all bad. If you will compare the waveform shown at Fig. 21A carefully with that shown at Fig. 21B, you will see that when the oscillations exist, the initial negative swing is more rapid in Fig. 21B. This rapid decline in current would assure complete retrace within the allotted blanking period, if there were some way of eliminating the undesirable oscillations in the following trace portion. A damping system that does just this is utilized. The oscillation is stopped after the first half cycle so that a current waveform similar to the one shown at Fig. 21C is obtained.

The multiple functions of the horizontal output circuit can be better understood if we follow a step-by-step analysis of its operation. This analysis is made with reference to the circuit shown in Fig. 22.

A modified sawtooth voltage, which is a combination pulse and sawtooth waveform, is developed across capacitor C1 and the peaking circuit by whatever type of sawtooth generator is used. The sawtooth voltage is coupled through capacitor C2 to the grid of the horizontal output tube V1. Capacitor C3, the horizontal drive control, regulates the amplitude and proportions of pulse to sawtooth of the grid waveform. It assists in the adjustment of picture width, linearity, and over-all brightness.

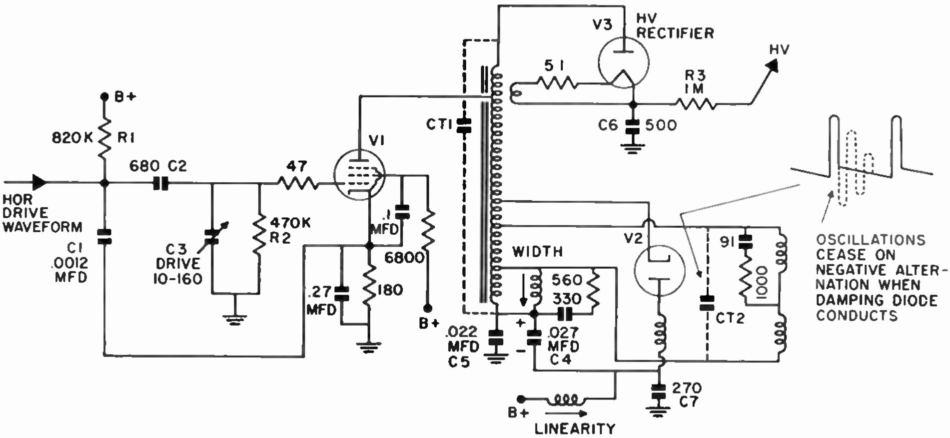


FIG. 22. Horizontal output stage.

In the usual horizontal deflection system, the actual plate current does not begin to flow until the grid waveform has risen to almost the mid-point of its trace. The horizontal output tube is so biased that a substantial portion of the applied grid waveform, including the initial part of the trace, is below cut-off, as shown in Fig. 23A. This does not mean that there is no rising current in the horizontal deflection coil during the initial trace time. As will be discussed later, the damping circuit supplies the energy for the initial portion of the rising current in the deflection coil.

A largely inductive load is presented to the output tube during the trace interval (motion of the beam from left to right across the screen). The output transformer functions as an inductive transformer reflecting the proper load to the tube from the deflection coil. As the plate current of the output tube rises at a linear rate, it produces a square-wave voltage and causes a decline or drop-off of the square-wave voltage. However, the plate current, which rises with the rising grid waveform of the horizontal output tube, continues to supply this loss, so there is a linear rise of current in the coils.

The deflection coil current continues to rise as the grid is driven more and more positive by the signal from the horizontal oscillator. After the grid waveform has risen to its peak, it drops sharply negative and cuts off

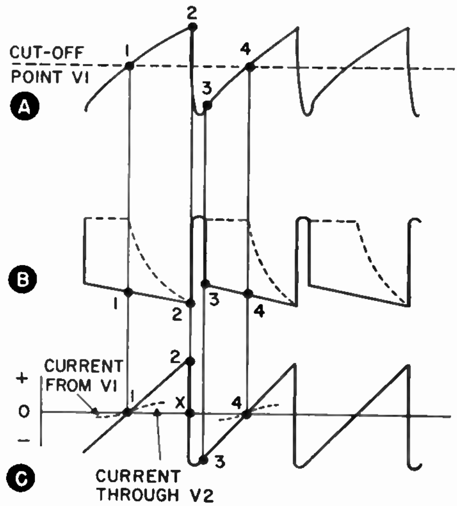


FIG. 23. (A) Drive voltage applied to the grid of the horizontal amplifier. (B) Square wave voltage that appears across the deflection coils. (C) Sawtooth current in the deflection coils.

age (negative polarity) across the inductive load, as shown in Fig. 23B. This square wave across the secondary of the deflection coil circuit causes a linear increase in current in the deflection coils. As the deflection current builds up, the IR drop due to the resistance of the transformer, deflection coils, and damping circuit tends to reduce the amplitude of the output tube. Consequently, there is no supporting voltage to sustain the build-up of current in the deflection coil, and the energy stored about the coil is now released.

Although it is characteristic of an inductor to attempt to keep the same current flowing when the source of voltage is removed, the current falls rapidly to a low value through the series resistance of the deflection circuit. The very rapid collapse and release of energy in the deflection coil develops a very sharp positive voltage across the distributed capacity of the deflection circuit as shown in Figs. 22 and 23; in fact, the abrupt change in current in the deflection coil circuit tends to produce a series of high-amplitude oscillations at the self-resonant frequency of the deflection coil and the total distributed capacity.

One alternation of this transient oscillation is permitted to occur because the initial sharp positive alternation rapidly reshapes the horizontal deflection field. In fact, the resonant frequency of the inductance and the distributed circuit capacity must be made sufficiently high (75 kilocycles or higher) to have the positive alternation occur in a time interval which is shorter than the horizontal retrace period. Thus the half-period of the oscillation must be less than the horizontal retrace time between the leading edge of the sync pulse and the conclusion of the horizontal blanking pulse.

If the oscillations are not suppressed adequately after the first alternation, a series of oscillations will ride on the deflection-current sawtooth, causing the beam to weave back and forth as it moves across the screen, producing vertical bars on the left side of the picture. In fact, improper suppression of these oscillations by a defect in the damping circuit can produce such vertical bars right across the screen.

The damping diode must suppress the oscillations after the first sharp positive alternation that is used to reshape the deflection field. As the oscillation starts on its first negative alternation, the damping tube conducts because its cathode is driven negative, as shown in Fig. 22. Thus, after the first positive half-cycle of oscillation, further oscillations are prevented by the conduction of the damper tube. The damping tube presents a low resistance and heavy load across the deflection coil. Thus a long time-constant circuit is presented and the energy is released from the coil into the damping circuit at a slow rate.

The slow release of the stored energy into the damping circuit after the damping tube begins to conduct forms a part of the active trace of the picture tube beam, because the release of current is linear. It is in the proper direction to start the formation of the magnetic field that moves the beam from left to right. Thus, the energy stored in the deflection coil at the end of the previous trace is put to use in the formation of the start of a new trace. The resulting conservation of power reduces the power requirements of the output tube and circuit.

The flow of current from the deflection circuit energy is linear over the initial part of the release, but current rise gradually tapers off. At this point the output tube begins to conduct, as shown in the waveform of Fig. 23C, and supports the rise of current in the deflection coil.

For a more complete understanding of the manner in which the square-wave voltage and the sawtooth current are obtained at the deflection coils, let us again study the waveforms shown in Fig. 23 for the circuit shown in Fig. 22. The waveform in Fig. 23A represents the voltage applied to the grid of V1. Since approximately half of this excitation, or drive voltage, falls below the cut-off point of V1, only the upper portion of this modified sawtooth is amplified by V1. If the plate load on V1 were a pure resistance, its output voltage would take the shape indicated by the dotted lines in the voltage waveform shown in Fig. 23B. Only the upper half of the sawtooth input would be amplified and appear at the output in essentially the same shape as before, but 180° out of phase with the input.

However, the load on V1 is largely inductive rather than resistive; therefore, the voltage output appears to be very nearly a square wave. The portion of the square wave shown between points 1 and 2 in Fig. 23B is produced by the horizontal amplifier tube V1. The current rise produced by this section across the deflection coils is shown between points 1 and 2 in Fig. 23C.

At point 2 in Fig. 23A, the drive voltage drops sharply below the cut-off point of V1. The consequent rapid drop of current through V2 initiates oscillations. The first half cycle of these oscillations appears as the positive voltage pulse between points 2 and 3 in Fig. 23B.

At point 3 in Fig. 23B, the voltage on the cathode of the diode damper tube, V2, becomes negative with respect to its plate, and V2 begins to conduct. When the diode damper tube, V2, conducts, it acts as a low shunt resistance to prevent further oscillation and presents a long time constant for the discharge of the energy placed in the field of the deflection coils by the *high positive peak* between points 2 and 3. That portion of the square-wave voltage in Fig. 23B between points 3 and 4 is the result of current induced in the coil by the collapse of the magnetic field around it and flowing through the long time constant of the circuit formed by the conducting damper tube and the distributed resistance of the circuit. This current is shown between points 3 and 4 of Fig. 23C.

Now let us see what happens in the picture tube when the current between points 1 and 4 of Fig. 23C is flowing through the deflection coils. At point 1 there is no horizontal magnetic field through the neck of the tube, and therefore the electron beam is centered mid-way between the left and right-hand sides of the tube. As the current increases from point 1 to point 2, the strength of the magnetic field through the neck of the tube increases proportionately, pulling the electron beam to the right.

At point 2, the electron beam has reached the right-hand side of the tube, and a horizontal blanking pulse has cut the beam off. The current through the coils rapidly decreases, changing direction at point X and increasing until it reaches its negative peak just ahead of point 3.

Thus, at point 3, a strong magnetic field of opposite polarity to the one that existed at point 2 is present in the neck of the picture tube, and when the blanking pulse has passed, the beam is directed at the left-hand side of the picture tube. Since there is no sustaining voltage being applied to the deflection coil at point 3 (remember, V1 is cut off), the magnetic field surrounding the deflection coils begins to collapse and produce the current shown between points 3 and 4. This current, and, consequently, the magnetic field that produces it, is reasonably linear in its decline between points 3 and 4 because of the time constant of V2 and the distributed circuit resistance. At point 4, the current available from the collapse of the magnetic field begins to taper off and no magnetic field is present at the zero level. At that instant V1 begins to conduct again, and the current again increases in a positive direction, producing a linearly increasing magnetic field of opposite polarity.

The length of the horizontal scanning line (picture width) is controlled by a tunable inductor that shunts the lower part of the auto-transformer. The width control has the effect of adjusting the turns ratio of the auto-transformer. Therefore, it regulates the amplitude of the voltage developed across the output section and the rise of current in the deflection coil.

The linearity control permits adjustments in the shape of the plate current drawn by the horizontal output tube during the interval when the scanning beam is moving from the center of the raster to the right side. Both the plate current for the horizontal output tube, and the current from the damping tube circuit flow in the linearity control. The linearity control regulates the shape of the damping circuit discharge waveform and can be used to make the necessary adjustments in the current drawn by the horizontal output tube to obtain a linear trace.

Voltage Boost. In addition to using some of the deflection coil energy of the previous line interval for initiating the first half of the trace of the succeeding line, the damping current can be used to develop additional supply voltage and energy for the horizontal output tube. In such a system, the damper circuit voltage is added in series with the B supply voltage to supply an additional 50 to 150 volts to the horizontal output tube. As shown in the circuit of Fig. 22, the dc component of the damping tube current places a charge on capacitors C4 and C5, which is added in series with the supply voltage applied through the linearity control In many receivers the boosted supply voltage available at the damper circuit is also used to supply higher plate potentials to other stages in the receiver.

High Voltage Generator. Still another purpose of the horizontal output circuit in a modern television receiver is to form the high voltage for the picture tube anode. As mentioned earlier, the initial collapse of the magnetic field about the deflection coil at the end of the active trace, when the output tube is driven to cut-off by the grid waveform, causes a high voltage oscillation to be developed in the secondary. Remember that at the instant it is developed, the damping tube is also cut off, and there is only a very light load across the resonant circuit; as a result, the peak positive voltage pulse developed across the deflection circuit can be a thousand or more volts. Since the output transformer is an auto-transformer, the voltage across the deflection coil is stepped up to ten to twenty thousand volts across the entire transformer. Consequently, a high voltage rectifier placed at the high side of the transformer can be used to rectify the pulse and form a very high dc voltage.

The current drawn by the high voltage rectifier, V3 in Fig. 22, develops a dc voltage across capacitor C6 with a value almost the same as the peak amplitude of the transient pulse. The high dc voltage is filtered by capacitor C6 and resistor R3. The high frequency of the horizontal circuit also permits filtering by a simple, low-value resistor-capacitor network. The filament voltage for the high-voltage rectifier is obtained by a single-turn loop that surrounds the horizontal deflection transformer.

Two-Winding Transformer. A horizontal output stage using a two-winding output transformer instead of an auto-transformer is shown in Fig. 24. The output of the sawtooth generator is coupled through capacitor C1 to the grid of the horizontal output tube. The grid waveform is controlled by the horizontal drive capacitor C2,

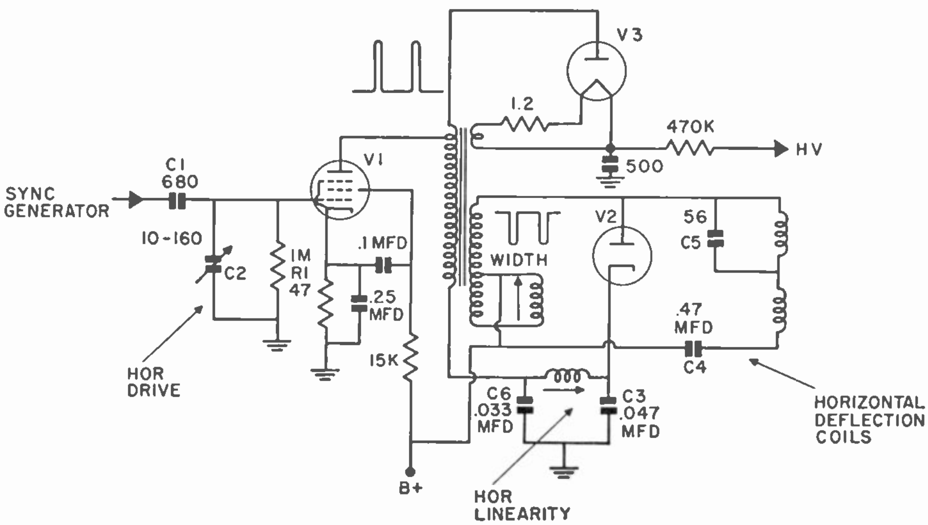


FIG. 24. Horizontal output stage using a two-winding transformer.

low current requirement of the television picture tube permits the use of this very simple type of voltage supply, using just a small high-voltage diode and a capacitor-resistor filter. The low current requirement means that just a very light load is placed on the horizontal deflection circuit by the high-voltage supply system. The

which is adjusted for satisfactory picture width and peak high voltage without disturbing the linearity of the raster or introducing vertical bars. Since a regular horizontal output transformer with primary and secondary windings is used, there is a reversal of the plate waveform, and the trace portion of the deflection voltage is positive across the secondary. The collapsing field about the deflection coils at the end of the trace generates a negative pulse that serves as the retrace cycle of the horizontal deflection field. The positive half cycle of the oscillation is damped by the conducting diode (positive voltage on its plate causes the damping diode to conduct) which prevents the generation of a series of oscillations. Notice that the polarity for the damping diode is opposite to that for the auto-transformer arrangement shown in Fig. 22 and discussed previously.

There is an inductor linearity control and a voltage booster arrangement. The conducting damping circuit develops positive charges on capacitors C6 and C3 which add in series with the B+ voltage supplied to the horizontal output tube through the primary of the horizontal output transformer. Capacitor C4 in the deflection coil circuit prevents the flow of any dc current component in the deflection coil which could de-center the reproduced raster. The actual centering of the raster is controlled by proper location of the focus coil on the neck of the picture tube or by an external centering magnet on the neck of the picture tube. Capacitor C5 balances the capacities of the two halves of the deflection coil windings with respect to ground, so that the linearity of the magnetic field is the same for both sections of the horizontal deflection coil, and a linear motion of the scanning beam is retained. The balanced arrangement prevents interference between horizontal and vertical signals in the yoke.

The high-voltage rectifier and output circuit is connected to the primary of the horizontal output transformer where a positive pulse is available. The pulse developed across the secondary is of negative polarity but is reversed and stepped up in amplitude by the horizontal output transformer when it is transferred from the secondary to the primary. A pulse with an amplitude of eight to fifteen thousand volts is applied to the plate of the high-voltage rectifier tube. Filament voltage for the high-voltage rectifier is derived from a single-turn loop around the core of the horizontal output transformer.

A Typical Sweep System

In the preceding section, various types of deflection amplifiers and sawtooth generators were discussed. You will find, however, that although the basic types are more or less standardized, manufacturers use numerous circuit variations and modifications of the basic systems. Receivers differ in the type of sawtooth oscillator used, the method of synchronization, and the technique used in the output stages. However, the variations are minor enough so that you will have no difficulty in tracing defects if you have a thorough understanding of the operation of the fundamental systems.

A typical commercial sweep system with its waveforms is shown in Fig. 25. This model has a multivibrator oscillator and amplifier in the vertical system shown in Fig. 25A, and a stabilized cathode-coupled multivibrator and pentode output stage in the horizontal system shown in Fig. 25B.

Vertical Circuit. In the vertical circuit, the sawtooth trace is developed across capacitor C1 as it charges through resistors R1 and R2 toward a B+ voltage. Consequently, the first section or first tube of the multivibrator conducts for just a short interval of time during the vertical retrace period to discharge capacitor C1. It remains cut off for a long interval of time during the charging cycle of capacitor C1. The grid waveform shows the long cut-off period and the short conduction period, when the grid swings sharply positive. The frequency of the multivibrator is controlled by this grid circuit, and is determined largely by the time constant of capacitor C2 and resistors R3 and R4.

The proper spike is added to the sawtooth waveform by peaking resistor R5 in the return path to the cathode of the output tube, as illustrated by the waveform at the grid of the output section.

Notice that the peak amplitude of the required signal at the grid of the output tube is almost 100 volts. The synchronizing pulse is also applied to the same grid and has a peak amplitude of about 20 volts. Vertical sync is being applied through the integrator circuit shown in the dashed-line block. Since the shape of the grid waveform of the output tube has an influence on the linearity of the reproduced picture, a bias type of linearity control is inserted in the cathode of the output tube.

An auto-transformer transfers the signal from the plate of the output tube to the low-impedance vertical deflection coils. The vertical deflection coils are damped by the two shunt resistors. Despite the damping system, a high voltage is generated and is fed back to the plate of the output stage via the auto-transformer. Notice that the peak amplitude of the waveform on the plate is 1200 volts. Therefore, a high voltage capacitor is used to couple the signal back to the grid of the first section of the multivibrator. The network between the plate of the output tube and the grid of the first section attenuates and shapes the feedback waveform properly for stable excitation of the grid of the first section.

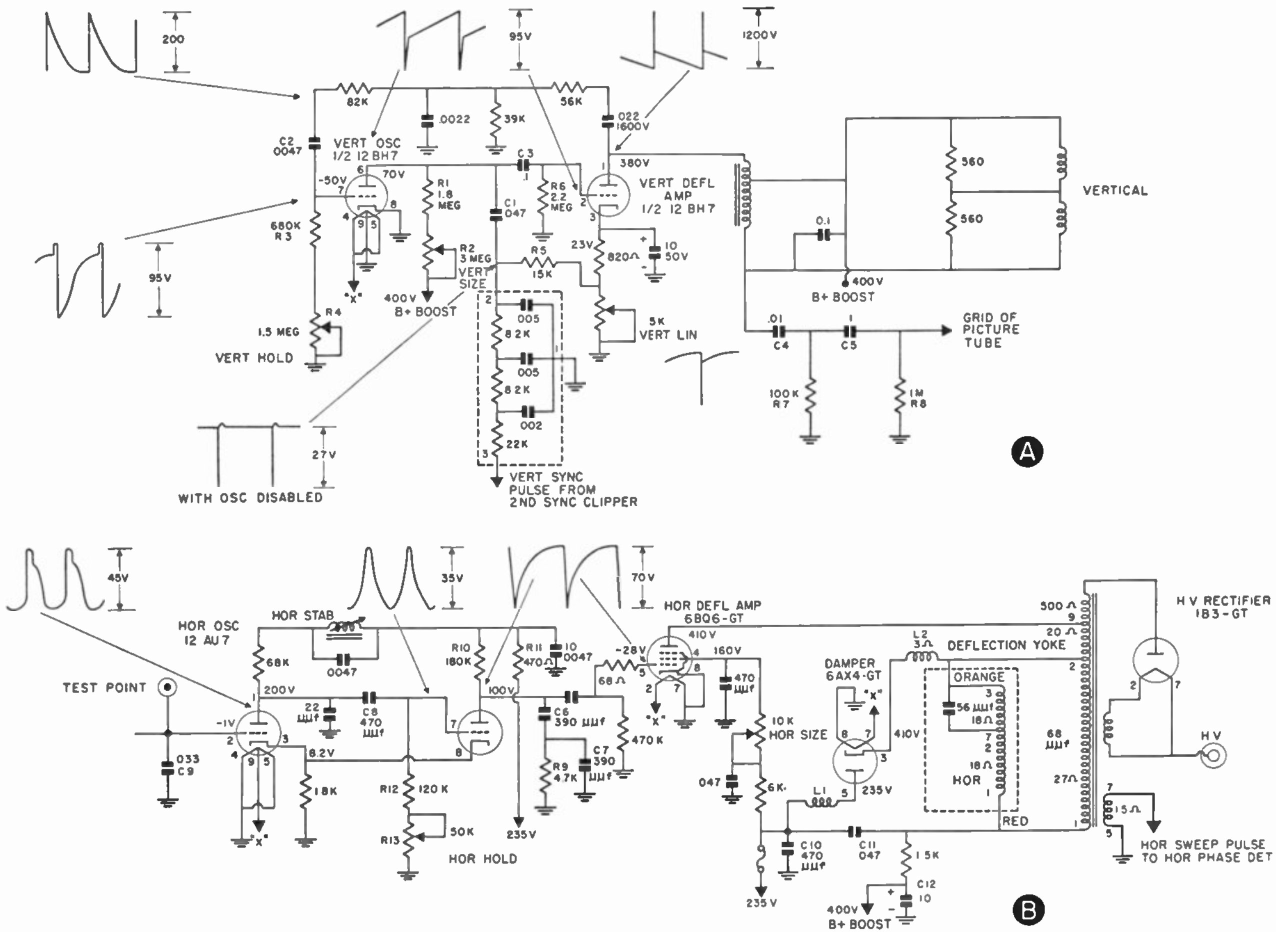


FIG. 25. Typical sweep system. The vertical system is shown at A, and the horizontal system at B.

A pulse is removed from the bottom section of the auto-transformer and is supplied through a differentiating circuit to the grid of the picture tube. Actually, this waveform, after it is shaped properly, can be used as a negative vertical blanking pulse for the picture tube. This technique is referred to as "retrace blanking." It permits more versatile adjustment of contrast and brightness without the appearance of retrace lines in the picture. Such versatility is helpful in receivers with no dc restoration. In fact, even when the received vertical blanking interval is quite distorted, no retrace lines will appear because of the effective blanking provided by this technique.

Horizontal Circuit. A stabilized multivibrator is used in the horizontal sawtooth generating circuit, the sawtooth voltage being developed across capacitor C6 and the shaping network consisting of capacitor C7 and resistor R9. The capacitor charges toward the supply potential through resistors R10 and R11. The frequency of the multivibrator is controlled in the grid circuit of the same tube and is determined by the time constant of capacitor C8 and resistors R12 and R13. Notice the much shorter time constants used in the horizontal circuit than in the vertical circuit.

The stabilizing resonant circuit is in the plate circuit of the first section. It shapes the feedback signal for best stability and synchronization. The actual synchronization is in the form of a dc voltage that is developed on capacitor C9, at the grid of the first section, by a phase detector circuit.

The horizontal deflection amplifier consists of a pentode output stage, an auto-transformer, a diode damper, and a diode high-voltage rectifier. The width control for the output circuit is in the screen-grid circuit of the pentode. The gain of the amplifier, and therefore the peak amplitude of the deflection waveform at the plate of the amplifier, is controlled by this potentiometer. This method of control has a high efficiency because it does not affect the current and the impedance ratio of the auto-transformer.

When the damping tube conducts, an actual boost voltage is developed across capacitors C11 and C12, which adds almost 200 volts to the supply potential. This same voltage is used as a supply source for the vertical deflection oscillator-amplifier as well as the plate of the horizontal output stage. Inductors L1 and L2, along with capacitor C10, function as filters in the damper circuit, to prevent radiation of horizontal frequency components or their feed-through into the power circuit.

The plate of the high-voltage rectifier receives a high-amplitude pulse from the top of the transformer and rectifies it for use as anode voltage for the picture tube. A separate winding on the transformer supplies filament voltage for the high-voltage rectifier. In addition, another winding on the transformer picks up a pulse that is fed back to the phase detector for comparison with the incoming sync pulses to establish the dc component of the sync control voltage.

TRIODE DAMPER

In some of the older TV receivers a triode damper tube is used, as shown in Fig. 26, to establish better control over the linearity of the sawtooth current. The higher resistance of the triode, however, causes additional loss of stored energy in the deflection output stage. The bias for the damper tube is developed by grid current flowing from the grids back to the cathodes through resistor R3. The combination of resistor R2 and capacitor C3 compensates for the non-linear portion of current decline when the energy in the deflection coil is released, generating the first part of the active trace. The R-C combination in the grid circuit compensates for the non-linear portion of the current supplied by the amplifier tube by applying an oppositely shaped voltage waveform to the grid of the damper tube. Potentiometer R5 permits adjustment of the damping correction. High-frequency transients are applied through capacitor C2 to the grid of the damper tube, developing an opposing waveform in the plate circuit which cancels out by degeneration, the initial transient voltages. This cancellation can be regulated with R5.

In some of the older receivers a negative pulse is removed from across the secondary of the output transformer and fed back to the input of the horizontal amplifier stage to shape the grid-driving waveform and add a spike component to it. In still other receivers, a feedback pulse from the horizontal output transformer is used, after proper shaping, as a phase comparison pulse in the horizontal sync control system. In many modern receivers a pulse is derived from the horizontal output circuit for AGC.

DEFLECTION AND CONVERGENCE SYSTEMS OF A COLOR TV RECEIVER

A color television receiver contains the same basic type of horizontal and vertical sawtooth oscillators and output stages as a monochrome receiver.

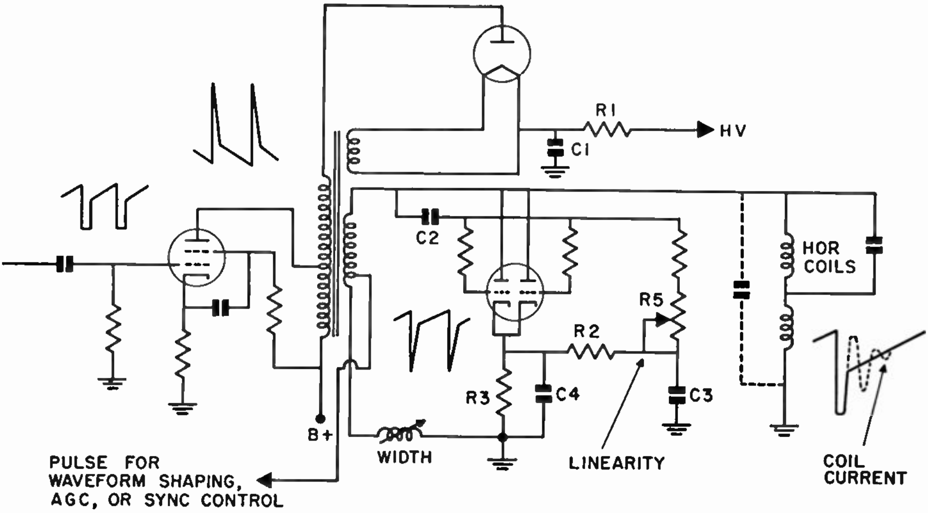


FIG. 26. A triode damping system.

In the color receiver the tolerances are more exacting than those for a monochrome receiver. An in-focus beam, and a linear motion of that beam, is of utmost importance in rendering true color hues. It is more than a matter of moving a single scanning beam, because in the usual color picture tube there are three separate scanning beams representing the three primary colors. Thus, the task of a color deflection system is to move all three beams from left to right and down the screen.

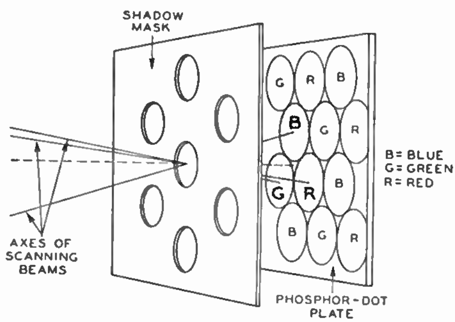


FIG. 27. Scanning action at the screen of a color picture tube.

All three scanning beams must be moved linearly, and held in focus over the entire area of the picture tube screen. In addition, the three beams must have a uniform relationship with respect to each other and must converge at a shadow mask, as shown in Fig. 27, and strike the exact center of the individual color phosphor dots on the picture tube screen. For example, the red scanning beam must not only be brought to focus, but also must converge properly with respect to the other beams at the hole in the shadow mask. It must pass through the hole and strike the red phosphor dot.

Thus, the sweep system of a color receiver must have not only the conventional deflection circuits, but also the proper convergence circuits. The static convergence voltage is a dc potential supplied to the convergence electrode of the color picture tube. There must also be a dynamic convergence component to maintain the proper convergence between the three beams at all parts of the screen. It is in the form of a correction waveform, derived from the output stages, designed to take into consideration the fact that the scanning beam has to travel a greater distance between the gun and the outer portions of the screen than between the gun and the center of the screen. There is also a dynamic focus waveform to keep each beam in focus individually over the entire screen.

Deflection and Convergence Circuits. The vertical sawtooth generator and vertical output stages for the color receiver are similar to those found in a monochrome receiver except for the convergence waveform taken off at a take-off point in the cathode circuit of the vertical output tube, as shown in Fig. 28A. The waveform at the cathode has the necessary shape to be used as the vertical dynamic convergence and focus waveform after suitable amplification. A means for electronic centering is also incorporated in the deflection system of the color television receiver. It is in the form of a dc source of voltage and a potentiometer that can control the amount and direction of the direct current flow through the vertical deflection coils.

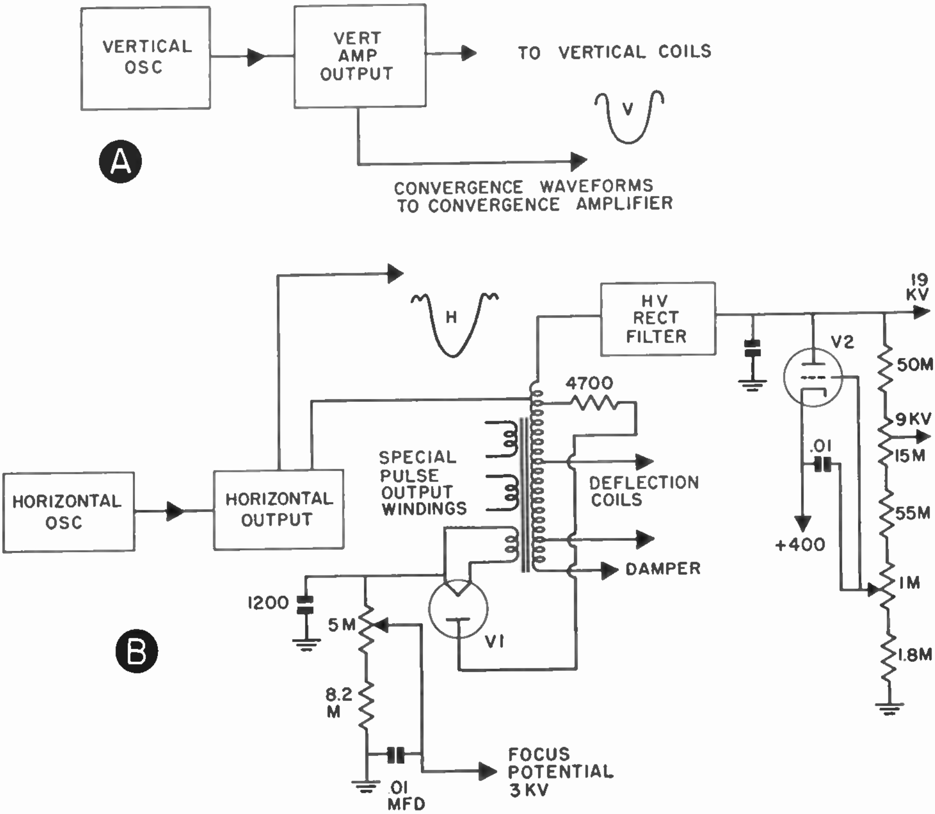
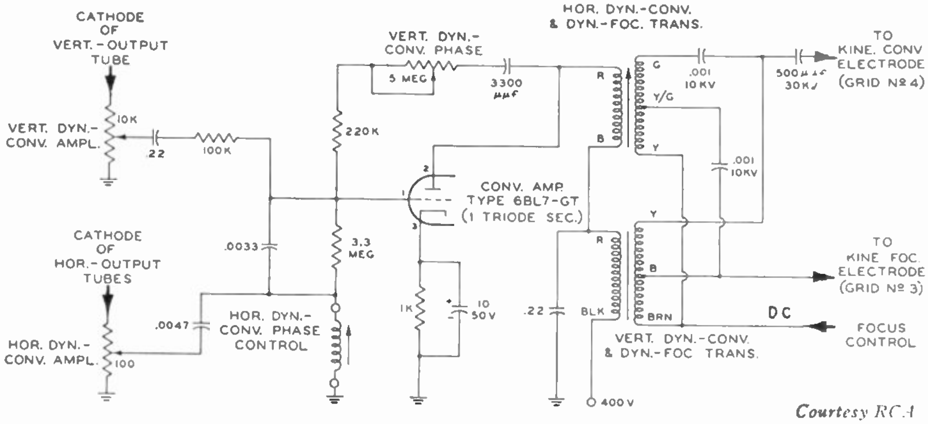


FIG. 28. Plan of a sweep system of a color receiver.

In the horizontal sawtooth oscillator and deflection output stages, the following additional facilities must be provided as shown in Fig. 28B: a take-off point in the cathode circuit of the horizontal output tube for the horizontal dynamic and focus convergence waveform; a voltage regulator for the high-voltage output; a special horizontal output transformer with multiple taps for supplying horizontal waveform components to various sections of the receiver; a focus rectifier (V1) and filter system for obtaining the proper focus voltage; and an electronic centering control for adjusting the direct current in the horizontal deflection coils. The focus voltage rectifier circuit is similar to the rectifier system used for obtaining the anode voltage, with the exception that the pulse take-off is at a lower potential point on the horizontal output transformer. The pulse is rectified and filtered and supplies the voltage required by the focus electrode.

The high-voltage rectifier and filter supplies high voltage to a bleeder network and a voltage regulator tube (V2). Approximately 10,000 volts are made available for the picture tube anode, and 9000 volts for the convergence electrode. The regulator tube acts as a variable resistance across the output of the high-voltage circuit. If the voltage along the bleeder network decreases, there is less positive voltage on the grid of the regulator tube. This increases the resistance of the regulator tube and reduces the load on the output of the high-voltage rectifier and filter. Consequently, the output voltage rises to compensate for its attempted decline.

electrode. The dc voltage, however, has been modulated by the vertical and horizontal waveforms developed across the lower half of the two transformer secondaries. Thus, both a horizontal and a vertical correction waveform have been added to the dc focus potential. Higher amplitude components of the same correction voltage are also capacitively coupled to the



Courtesy RCA

FIG. 29. The conversion circuits of a color receiver.

A typical dynamic convergence and focus circuit is shown in Fig. 29. The convergence amplifier increases the amplitude of both the horizontal and vertical correction waveforms to the peak amplitude necessary to modulate both the dc component of the focus voltage and the dc component of the convergence electrode voltage. One of the output transformers favors the low-frequency vertical waveform, and the other favors the higher-frequency horizontal-correction waveform. The dc component of the focus voltage is applied to the low side of the secondary windings of both transformers, and is conveyed via the center tap of the lower transformer to the focus convergence electrode. These correction waveforms have peak amplitudes of a few hundred volts to obtain suitable correction.

It is necessary to regulate both the amplitude and the phase of the convergence waveform. The amplitude of the convergence waveform establishes a uniformity of correction from the center to the outer portions of the fluorescent screen. The convergence phase adjustment phases the correction waveform properly with respect to the scanning period. As a result, there is the same uniformity of correction (both focus and convergence) on all sides.

Adjusting And Troubleshooting In The Deflection System

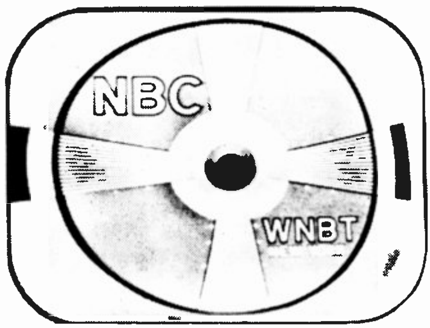
In the deflection system of a television receiver there is a close link between proper adjustments and scanning defects. Often what appears to be a defect is only an improper adjustment. At other times, improper picture size, linearity, or drive adjustments are the result of a defect in the deflection system. The technician should realize that many minor raster disturbances are caused, not by component defects, but by adjustments that have drifted or have never been made properly. In fact, troubleshooting in a deflection system for a minor disturbance should proceed in the following order: adjustments, tube check, and finally, if necessary, a localizing procedure to find a defective component.

In many cases minor picture defects could be caused by misadjustment of either deflection circuit controls or controls on the neck of the picture tube. Therefore, it is advisable to check the adjustment of the ion trap, the focus coil, the deflection yoke, and the pincushion magnets before proceeding with any adjustments in the deflection circuits.

DEFLECTION CIRCUIT ADJUSTMENTS

Once the accessories on the neck of the picture tube have been properly adjusted, it is time to proceed with the adjustment of the deflection circuits. The horizontal oscillator and agc system must be functioning properly before you proceed with the adjustments. A recommended procedure for adjusting the width, drive, and horizontal linearity controls is outlined below.

(a) Adjustment of the horizontal drive control affects the picture tube high voltage as well as the shape of the grid waveform driving the horizontal output tube. Adjust the horizontal drive trimmer for maximum drive (minimum capacity) consistent with a linear raster. This will give the highest possible voltage and hence the brightest and best focused picture. Compression of the raster due to excessive drive can be seen as a white vertical bar or bars in the right half of the picture. Besides compression caused by excessive drive, another item to watch for is the change in linearity (at the extreme left) with changes of brightness control setting. By proper adjustment of the linearity control, the changes in linearity with changes in brightness can be made negligible.



Courtesy RCA

Poor horizontal linearity.

(b) Set the width control to mid-position. Set the linearity control near minimum inductance. Set the drive capacitor in the maximum drive position.

(c) If the raster is cramped or shows compression bars on the right half of the picture, turn the drive capacitor clockwise until this condition is just eliminated.

(d) Adjust the linearity control coil clockwise until you get the best linearity with maximum deflection, or the best compromise.

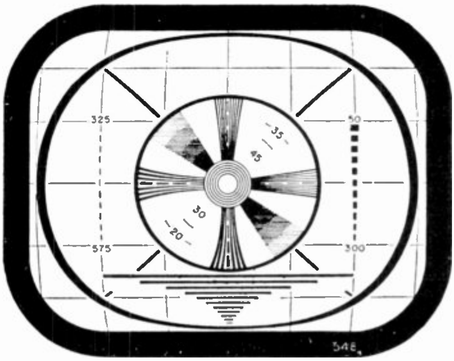
(e) Retouch the drive capacitor to obtain best linearity and maximum width if necessary.

(f) Check the horizontal linearity at various settings of the brightness control. There should be no compression at the right half and no appreciable change in linearity, especially at the extreme left of the picture. If there is an objectionable change, readjust the linearity control and repeat the test.

(g) Adjust the width control until the raster fills the entire mask.

(h) Many receivers have a special width control or power circuit adjustment to permit correction for a low or high line voltage so that it is possible to obtain full picture width with proper linearity.

Height and Vertical Linearity Adjustments. Adjust the height control until the picture fills the mask vertically. Adjust the vertical linearity control until the test pattern or picture is symmetrical or linear from top to bottom. A readjustment of either control often requires a readjustment of the other. In fact, in many receivers, if it is necessary to readjust the linearity or height over a substantial range, it is also necessary to readjust the vertical frequency for best stability.



Courtesy Belmont

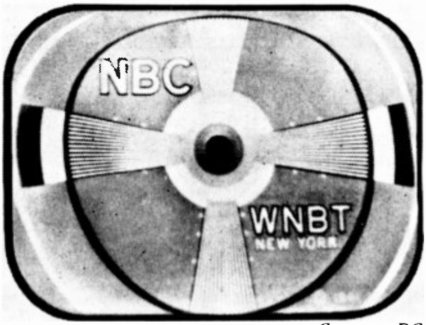
Picture too large horizontally.

Focus. Adjust the focus magnet for maximum definition in the vertical wedges of a test pattern or best focus in the white areas of a scene. Recheck the position of the ion trap magnet to make certain that there is maximum brightness. If necessary, readjust the centering to align the picture with the mask.

TROUBLE LOCALIZATION PROCEDURE

The localization of most sync and sweep system defects to a stage or two can be accomplished very quickly by observation of the picture tube screen. If the picture size is normal, but it is not possible to maintain synchronization either horizontally or vertically, the defect is generally ahead of the deflection system. If only the horizontal or the vertical synchronization is affected, the instability can be caused by a defect in the horizontal or vertical oscillator. However, most synchronization disturbances occur before the actual sawtooth generators and deflection output stages.

When there is a serious vertical oscillator or vertical amplifier defect, only a single horizontal line will appear on the picture tube screen, or the height of the raster will be very much reduced. A serious horizontal failure in either the sawtooth generator or the output stage results in the complete removal of the raster, because the picture tube anode receives its high voltage from the horizontal output stage. When the horizontal output stage does not work properly, the high voltage is not developed.



Courtesy RCA

Poor vertical linearity.

The oscilloscope is the most useful test instrument when localizing both major and minor disturbances in the deflection system. For example, if the raster is completely gone, attaching the oscilloscope at the grid of the horizontal output tube will tell the technician immediately whether the horizontal sawtooth generating system is operating properly. If there is no signal, or only a very weak and distorted signal at the grid of the horizontal output stage, there is a defect ahead of the horizontal output stage. A normal grid waveform at the horizontal output tube indicates a defect in the horizontal output stage or a defect in the damper or high-voltage supply source.

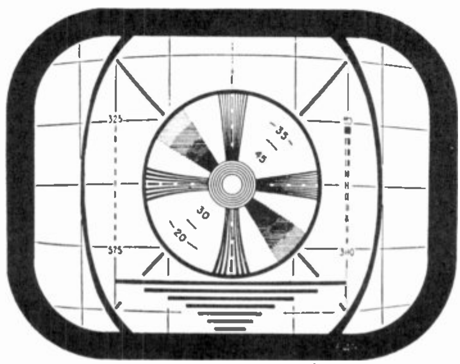
Reduced Picture Size. One of the most common disturbances in a television receiver is reduced picture size—horizontally, vertically, or in both dimensions. Perhaps the most common defect that causes loss of picture size is a weak low-voltage rectifier. Thus, a check of the low-voltage supply voltage under load is the first step in localizing the trouble. Often a weak rectifier tube or trouble in the power circuits makes the supply voltage vary appreciably with changes in line voltage. Consequently, the complaint will be that the picture is sometimes normal, but is reduced in size during the time that the greatest load is being placed on the local power main. If the supply voltages are normal, the next step is to check the boost voltage coming from the damper circuit of the horizontal output stage. It is important for the technician to know that in many receivers the boost voltage is supplied not only to the horizontal tube, but to the vertical sawtooth generator and amplifier as well. Consequently, a loss of boost voltage reduces the vertical as well as the horizontal size of the picture. In other receivers where the boost voltage is used only in the horizontal circuit, only the horizontal size of the raster would be reduced.

Horizontal size and linearity are influenced greatly by the waveform at the grid of the horizontal output tube. The grid waveform, when checked with an oscilloscope, should have the shape and peak amplitude indicated by the manufacturer. If there is a serious departure, the technician should look for trouble in the sawtooth-forming and generating circuit. An improper grid waveform can also affect the boost voltage, which would reflect the defect into the vertical channel of many receivers as well.

Horizontal and Vertical Linearity. The horizontal and vertical output tubes operate at almost their peak capacity in developing the necessary power to cause deflection of the scanning beam. Three defects can cause a non-linear picture. These three defects are in tubes, supply voltages, and grid waveforms. Since the tubes are often strained to obtain the high peak current necessary to give full deflection on a large picture tube screen, a minor tube defect can cause loss of full picture size. This same tube might check normal on a conventional tube checker, but still not be able to deliver the peak current required to reach the far right or bottom of the scanning cycle. Low supply voltage will also cause a lack of full deflection. A defective waveform either at the grid of the horizontal output tube or at the grid of the vertical output tube can result in a loss of picture size and linearity because the grid will not be driven satisfactorily as the plate current rises toward its high peak value.

Poor linearity, accompanied by vertical bars on the raster, is caused by improper adjustment of the horizontal drive and width control, improper drive voltage, or a damper circuit defect.

Hum Defects. Hum occasionally enters the deflection system when there is a filter or by-pass defect. When there is hum in the vertical deflection circuit, the picture becomes unstable vertically and moves in and out of interlace. A loss of interlace results in a coarse line structure because the effective number of lines in the picture is halved whenever the receiver is out of interlace. Generally, a minor disturbance will cause the picture to change, being sometimes in interlace and sometimes out of interlace. Hum in the horizontal circuit causes the picture to weave and irregular vertical sides on the raster.



Courtesy Belmont

Picture too large vertically.

Often by-pass and filter circuit defects as well as improper placement of leads after repairs have been made can cause a cross-modulation of horizontal and vertical signal components. If horizontal sync components feed through into the vertical circuit, they can cause interlace disturbances; vertical components in the horizontal circuits can cause raster distortion or horizontal instability.

Testing With an Oscilloscope. The oscilloscope and its voltage calibrator are a most effective combination for tracing defects of the more obscure types in the deflection system. The oscilloscope can be used to check waveforms through the vertical generating and amplifier circuits, and through the horizontal circuits up to the grid of the horizontal output tube. Servicing diagrams include the proper waveforms that should be obtained at the various test points as shown in Fig. 25.

The scope can also be used at certain low-voltage points in the actual deflection output circuit when indicated by the receiver manufacturer. However, do not use the oscilloscope indiscriminately beyond the grid of the horizontal output tube; the high peak voltages can result in damage to the test instrument. If waveform observations beyond the grid of the horizontal output tube are recommended, follow the exact procedure and precautions presented by the manufacturer of the particular model.

The high voltage can be checked using high-voltage probes that are available as accessories for most vacuum tube voltmeters. The presence of high voltage at various points in the circuit can be checked by touching the tip of a well-insulated screwdriver to the various points and observing the arc drawn. With experience in working with the high-voltage circuit, you will be able to tell by the length of the arc if there is approximately normal voltage. All high-voltage checks should be made carefully for safety reasons and to prevent a low resistance shunt from damaging some of the high-voltage components which are designed to carry only a small current.

Lesson Questions

Be sure to number your Answer Sheet 55B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next Lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of Lessons before new ones can reach you.

1. Which type of deflection, electrostatic or magnetic, is used in modern television picture tubes?

2. Which do you apply to the deflection coils in a receiver using electromagnetic deflection, a sawtooth current or a sawtooth voltage?

3. What are the two basic sawtooth oscillators?

4. Should you increase or decrease the time constant in the grid circuit of a blocking oscillator to increase the frequency of the oscillator?

5. Why is a tuned circuit used in the plate circuit of the feedback tube in a multivibrator?

6. What voltage waveform is needed to produce a sawtooth current in the deflection coils?

7. Why are damping resistors used across the vertical deflection coils?

8. A series of vertical bars on the left side of the picture indicates a defect in which circuit in the horizontal sweep?

9. What circuits in addition to the deflection circuits make up the sweep system of a color receiver?

10. What is a common cause of reduced horizontal and vertical picture size?

ASK WHY

The ability to observe *intelligently*—to learn—to gain information—depends greatly upon your willingness to ask WHY.

Don't simply take things for granted. Get in the habit of asking other people WHY. And most important of all, *ask yourself* WHY—then find out the answers!

Be a *student* for the rest of your life—be a person who seeks knowledge—be a person who *wants to know*—be a man who *asks* WHY!

Thomas Edison became rich and famous because he was curious about the *reasons* for this and the *reasons* for that. He asked himself and others WHY. Alexander Graham Bell was able to invent the telephone, because he asked WHY. Marconi discovered much about Radio because he had the habit of asking WHY.

And so I advise you—a man who wants to know more and more about Radio and TV—to develop the lifetime habit of asking WHY. This will contribute much to your eventual success.

PRACTICAL TRAINING IN TV SERVICE

HOW TO RECOGNIZE AND LOCATE DEFECTS IN TV RECEIVERS

REFERENCE TEXT 55BX

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL · NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE 55BX

This text is not intended as a regular study lesson—it outlines a Practical Training Plan for getting practical experience in television servicing. We recommend that you follow this plan if you expect to do TV service work.

FM3M760 **1960 EDITION** Printed in U.S.A.

HOW TO RECOGNIZE AND LOCATE DEFECTS IN TV RECEIVERS

THIS IS the second section of your Practical Training in TV Servicing. In this part we will review troubleshooting methods and you will conduct experiments on your receiver.

Before going on with this section, let's review what you have learned in the first section of your practical training. You now have your set removed from its cabinet and mounted on the workbench in a position that is convenient to work on. You have analyzed the circuit diagram of your set, and have a good working knowledge of its circuits. You know how to adjust your set and know the effects of misadjustment of any of the controls. Finally, you are familiar with the physical layout of your own particular set and consequently with that of a good many other sets. You know how to locate the tubes and components of the various circuits. In short, you now have the same general knowledge that the outside serviceman must have.

In most television servicing organizations, the outside serviceman, who goes to the customer's home, will make adjustments, test tubes by substitution and analyze the complaint to determine whether the set can be repaired in the home. If it must be taken to the shop, the outside serviceman must be able to remove the chassis, picture tube and speaker from the cabinet. The first section of your Practical Training in TV Servicing has enabled you to perform these jobs on your own set.

The purpose of this section of your practical training course is to give you experience in troubleshooting your receiver on the bench; that is, performing the benchman's duties in the TV service organization. To accomplish this you will conduct a series of experiments on your own set, introducing defects into the various circuits and observing their effects. Then you will locate these defects to practice professional servicing methods.

RF and i-f alignment are not covered here for several reasons. First, most sets can be repaired without realignment. Second, it is best that you do not delay your practical training for lack of the test equipment necessary for this work. There is also a tendency on the part of the inexperienced serviceman confronted by a difficult troubleshooting problem, to attempt to repair sets by alignment when alignment isn't necessary. The omission of alignment experiments will help you to avoid this tendency. The manufacturers' service data contain detailed alignment instructions. These instructions should be read before any attempt is made to align a receiver. The alignment procedure varies so much for different sets that there is no point in giving general instructions here.

If you have the necessary equipment and wish to practice alignment on your set, it is recommended that you wait until you have received your regular lesson on TV alignment and then proceed to align your set in accordance with the manufacturer's instructions. Later on, we will briefly discuss the equipment used for alignment.

Before you begin to conduct experiments on your receiver, you should review professional troubleshooting techniques and equipment.

Troubleshooting Equipment

The best tools for troubleshooting are a thorough knowledge of television circuits, and experience in applying professional troubleshooting methods. However, other basic items are required to put these initial tools to use. You probably already have on hand most of the equipment necessary to conduct the experiments. This equipment will be discussed here along with some additional equipment that is standard for any efficient service shop. Also, in this section, TV troubleshooting methods are reviewed. Many of these are identical to the radio methods you have already used; others may be new to you.

EQUIPMENT REQUIRED

In addition to your TV receiver and the manufacturer's data sheet there are five items of equipment which are necessary to carry out the experiments in this lesson. It is quite possible that you may be able to conduct a number of experiments without having all the items, but to get the most benefit from this lesson you should have the following equipment:

1. Multitester or vacuum tube voltmeter.

2. High voltage probe for our multimeter.

3. A small soldering iron.

4. Assorted resistors and capaciters.

5. Test cables and jumpers.

Multitester. Since it will be necessary in the course of your experiments to test both voltages and resistances, you will need a multitester of reasonably high sensitivity. Any standard service instrument of this type may be used. It should have at least 20,000 ohms-per-volt sensitivity and be capable of measuring voltages up to 1000 volts and resistances up to 10 megohms with reasonable accuracy. A standard vacuum tube voltmeter is the best meter for all kinds of service work.

High Voltage Probe. In at least one experiment it is desirable that you measure the high voltage applied to the television tube. This voltage is far beyond the range of any ordinary multitester. However, it may be measured with a common meter by means of a special probe that has a built-in multiplying resistor. Such probes are available for most commercial multitesters and vacuum tube voltmeters. Unless you obtain such a probe you will be unable to measure the high voltage. Probes must be matched to the meter. Make sure that the probe you buy is the one recommended for your meter. You cannot make accurate measurements using a probe built for a different model of meter.

Soldering Iron. In a few experiments, you will be asked to unsolder parts or leads. You will do this to imitate parts failures. Any small electric soldering iron of 35 to 75 watts rating will be satisfactory.

Resistors and Capacitors. It will probably be unnecessary for you to buy any resistors or capacitors for these experiments if you already have an assortment on hand. Throughout the experiments, various values of resistances and capacities will be recommended for use in the experiments. The values are usually not critical, therefore if you have anything reasonably close it can be substituted for the recommended value. If you have no resistors or capacitors, the following list of those mentioned in later experiments will serve as a guide for obtaining them. These are all common values and therefore can be used as replacements in any service work that you may do later.

1 2.7-ohm, 1-watt resistor
1 5-ohm, 1-watt resistor
1 500-ohm, 20-watt resistor
1 1000-ohm, 1-watt resistor
1 5000-ohm, 1-watt resistor
1 10,000-ohm, 1-watt resistor
1 50,000-ohm, 1-watt resistor
1 100,00-ohm, ½-watt resistor
1 1-megohm, ½-watt resistor
1 100-mmf, 400-volt capacitor
1 400-mmf, 400-volt capacitor
1 .001-mfd, 600-volt capacitor
1 .005-mfd, 600-volt capacitor
1 .05-mfd, 600-volt capacitor

Test Cables and Jumpers. In order to conduct the experiments as easily as possible it is essential that you have a good assortment of test

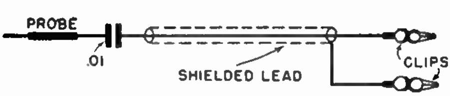


FIG. 1. A simple test cable.

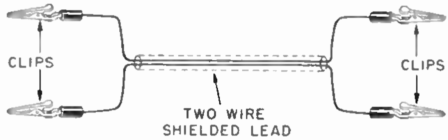


FIG. 2. Test lead for substituting components.

cables and jumpers. These can be made easily from test clips and hook-up wire, or in some cases shielded lead.

Fig. 1 shows a simple test cable that can be constructed from a piece of shielded lead, two clips, a capacitor and a test probe. This cable is very convenient for signal tracing and signal injection tests. A .01-mfd capacitor prevents dc coupling but will pass any signals from the audio frequencies upward. This capacitor should have a 600-volt dc rating. The shielded lead will help prevent pickup of the signal in circuits where it is not desired. In order to avoid possible short circuits the cable used should have a rubber or plastic coating outside of the shielding. This test cable should be long enough to reach any point of the underchassis wiring from any other part, but no longer than that.

Fig. 2 shows another test cable that will be very convenient if you wish to make it. This is simply a two-conductor shielded cable with clips on the wires at both ends. This cable may be used to substitute components such as resistors or capacitors without soldering them in place. This cable should be kept very short, not over six or eight inches in length. It need not be shielded, but shielding may prevent some stray pickup if the lead is very long. Another method of accomplishing this same purpose is shown in Fig. 3. Here test clips

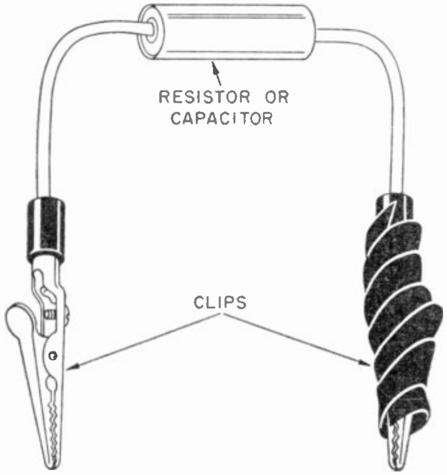


FIG. 3. Method of attaching test clips to parts for substitution in circuit.

are simply attached to the pigtail leads of the component, making it easier to make temporary connections. Recommended clip-on parts are a .05-mfd, 600-V capacitor, and 1000-ohm, 100,000-ohm and 1-megohm resistors.

Also handy in these experiments are simple jumpers made of hookup wire with test clips at each end. You will find it convenient if you make up several of these in lengths varying from six inches to two feet long. These you may consider as a permanent part of your test equipment for they are always handy when servicing radio or television receivers.

It is good practice to wrap all but the very tip of the clips with plastic insulating tape as shown in Fig. 3. This will help avoid short circuits when the clip is used in close places. Wrap the tape firmly but do not stretch it, then, when the clip is squeezed, the tape will stretch and allow a connection to be made.

A very useful test piece for temporarily detuning an i-f stage or sound trap is shown in Fig. 4. To make this "gimmick" capacitor you need only two clips and 6 inches of hookup wire. Fasten a 3-inch piece of insulated hookup wire to each clip. Twist the free ends of the wire together for a distance of about 1½ inches. Five or six half turns will be enough. This will give you a 2 to 5-mmf capacitor.

ADDITIONAL EQUIPMENT

All of the experiments may be made with the equipment just listed, however, there are two other items of equipment that may be considered very nearly indispensable to any efficient service shop. These are the oscilloscope and the sweep signal generator. They are not required for this lesson, but the use of the oscilloscope for locating defective parts and circuits will be described. Since these two instruments are explained in more detail in your lesson on alignment and the reference text on TV test equipment, only a brief explanation of their use is given here.

The Oscilloscope. An oscilloscope

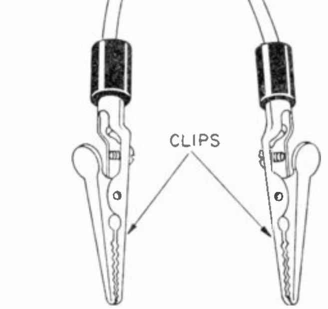


FIG. 4 "Gimmick" capacitor for detuning i-f amplifiers and sound traps.

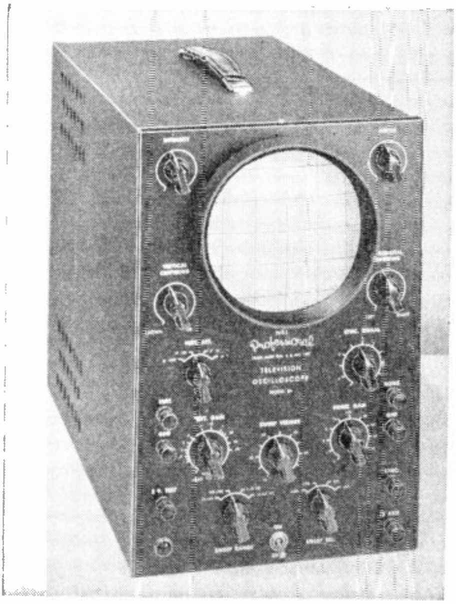


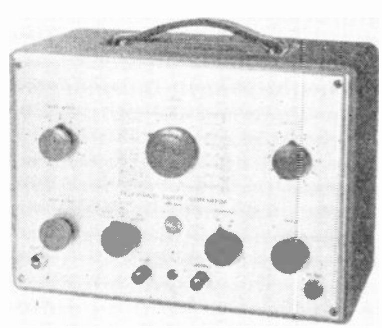
FIG. 5. Serviceman's oscilloscope designed specifically for TV Service.

enables its user to look at a signal anywhere in the TV set. The advantage of the oscilloscope in signal tracing is obvious. In television we deal with a video signal rather than a sound signal and the best indication of whether or not the signal is of the proper shape and magnitude is a visual one such as is given on the oscilloscope. Many manufacturers' schematic diagrams use sample waveforms to show what the signal should look like at various points in the circuit. If you have an oscilloscope, and your manufacturers' schematic gives such waveforms, it is recommended that you use your oscilloscope to check the signal at the points indicated by the manufacturer.

A typical oscilloscope designed primarily for TV service work is shown at Fig. 5.

Next to a good vacuum tube voltmeter, the oscilloscope is the TV serviceman's most important piece of test equipment. A reference text later in the course will describe the features of a good scope and tell you how to select one for your own shop.

Sweep Signal Generators. The sweep signal generator puts out a signal that varies in frequency at a rapid rate over a band of frequencies. Thus this instrument enables you to check the response of the television receiver over an entire channel. In addition to its obvious usefulness in alignment, the sweep signal generator may also be used for signal injection in troubleshooting tuners and i-f strips. A typical sweep signal generator such as is used in TV service work is shown in Fig. 6.



Courtesy RCA

FIG. 6. Sweep signal generator for TV alignment.

Troubleshooting Methods

One of the big differences between the professional and the amateur serviceman is that the professional must make a living wage from his time. The amateur, on the other hand, has no specific value set on his time and need not show a profit on his labor. When the professional accepts less for his time than his normal rate, because he has wasted time by making an incorrect diagnosis, he ceases to be a professional.

One of the keys to successful servicing lies in systematic troubleshooting methods. It is not possible to apply these methods without a good basic knowledge of TV receiver circuits and operation. Anyone with a basic knowledge of electronics and unlimited time can eventually shoot trouble by the cut-and-try method. However, the professional does not have unlimited time and must apply systematic methods to cut servicing time to a minimum. Only in this way can he handle enough sets to pay his shop upkeep with the profit from replacement parts.

Rapid, systematic troubleshooting is based upon effect-to-cause reasoning, using knowledge gained through experience and study. The effect-to-cause reasoning process is applied first in analyzing the customer's complaint. Always check the complaint yourself. The customer will describe the effects in his own words, but you and the customer probably speak different languages where TV is concerned. Always base your reasoning on your own observations.

After observing the effects of the trouble you can decide which major sections the trouble is apt to be in. This will give you a starting point for testing, and you can then test the most likely of these sections. The choice of stage to test first will be determined largely by past experience. When testing the major sections you will apply effect-to-cause reasoning again to determine which smaller sections or stages the trouble might be in. After this analysis you test the stage that is suspected of being defective, and again through an effect-to-cause reasoning process analyze the results of your tests. This last analysis, or application of effect-to-cause reasoning, narrows your probable cause down to several components. The last stage of your troubleshooting process is testing these parts to determine which is causing the trouble.

The troubleshooting process, then, may be broken down into six distinct steps as follows: (1) analyzing the complaint through effect-to-cause reasoning, (2) testing the suspect major sections, (3) analyzing the results of these tests to determine which stage or smaller section the trouble might be in, (4) testing that stage, (5) analyzing these tests to determine which parts may be causing the trouble, and (6) testing those parts.

Caution. Effect-to-cause reasoning can only be used effectively after the schematic for the set has been carefully studied and analyzed in order to see the paths through which the signal and supply voltages travel. Circuit variations might mislead you. A good example of this is in B plus supply distribution. In many sets it is common practice to obtain two levels of B plus supply by placing

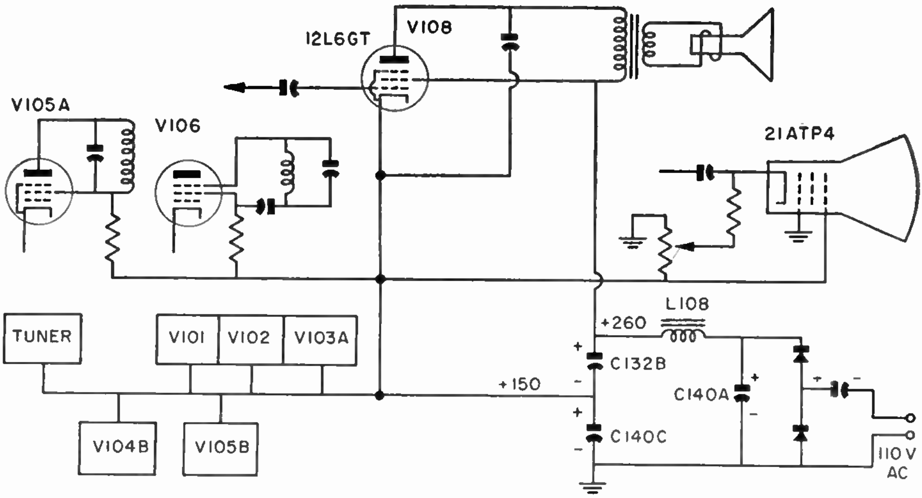


FIG. 7. Simplified diagram of circuit in which audio output tube is used as voltage divider for audio and video i-f's, tuner, and focus electrode of CRT. Loss of conduction in V108 will disable all of the tubes connected in its cathode circuit.

two tubes in series. These two tubes may be in different sections of the TV receiver. Where such an arrangement is used, a failure in one section of the receiver may disable another section and the effects observed would lead to incorrect reasoning. A simplified schematic showing this type of distribution is shown in Fig. 7.

In order to avoid being led astray in a circuit like this, check schematics for unusual plate supply circuits and for dc cathode paths that are grounded through some other tube.

ANALYZING THE COMPLAINT

In analyzing the complaint, there are three things that you should notice about the operation of the set. These are sound, picture, and raster. A distinction is made between picture and raster, because, although there may be no picture, the raster still can exist and will indicate that sweep and picture tube circuits are working properly. However, it is obvious that you cannot have a picture without the raster. These three items may show defects in any one of seven possible combinations. They are as follows: (1) dead set, no sound, no picture, no raster, (2) sound, no picture, no raster, (3) picture, no sound, (4) sound, raster, no picture, (5) raster, no sound, no picture, (6) distorted picture, (7) distorted sound. In every case of trouble, the combination of defects gives you very definite clues pointing to the cause of the trouble.

Dead Set. A dead set is one in which nothing works—no sound, no picture, no raster. The most likely cause of a dead set is some form of power supply failure. If the set uses series filaments, the failure of any tube filament in the string could cause a dead set. Likewise, it is a good idea to check the line voltage. The cause may be something entirely outside the set, such as a blown house fuse. A fuse in the set may also be blown. If external power is coming to the set then there may be a B+

power supply failure.

Sound, No Picture, No Raster. This condition tells us that there is nothing wrong with the sound section, power supply or the i-f section of the receiver. Since there is no raster, the most likely place to suspect trouble is in the high voltage power supply or in the picture tube itself.

Here again it is necessary to check the schematic. In most modern sets, failure of the horizontal oscillator, horizontal amplifier or damper tube will cut off the high voltage.

Picture, No Sound. If the picture is all right but there is no sound, the trouble is obviously in the sound section of the receiver. If the set is of the intercarrier type, i-f trouble is unlikely and the trouble will usually be found in the sound detector or amplifier circuits. If separate channel i-f's are used, the sound i-f must be checked.

Sound, Raster, No Picture. Here again your first application of effect-to-cause reasoning will depend upon whether your set is of the intercarrier type or of the separate channel i-f type. If the set is of the intercarrier type, the existence of sound indicates there is no trouble in the i-f sections and the raster eliminates the possibility of trouble in the sweep circuits or picture tube. Thus the most likely place to look for the trouble would be in the video detector and amplifier sections. If the set is of the separate channel type, the trouble could be in the picture i-f section as well as the video detector and amplifier.

Raster, No Sound, No Picture. The failure of both sound and picture, but the existence of a raster, indicates that the trouble probably lies in the tuner or i-f sections of the set if it is of the intercarrier type. If it is of the separate channel type the most likely place for trouble to occur will be in the tuner or any of the i-f sections common to both sound and picture.

Distorted Picture or Raster. The most frequent cause of picture distortion will be found in the sync and sweep circuits. However, the frequency response of the video section may, if it is poor, cause some picture distortion. You will recall from the first section of your practical training that picture distortion may also result from misadjustment of controls or components on the picture tube neck. In your experiments you will find that most of the effects produced by misadjustment can also be caused by circuit defects.

Distorted Sound. Sound distortion may be traced to a failure in the audio section of the receiver. However, the adjustment of the tuner may cause hum in the sound and should be checked in the event that hum exists. Likewise, if the tuner is not properly adjusted sound bars may appear in the picture.

PROBABILITY OF FAILURE

You must rely on past experience and knowledge of the circuit of the set to indicate the most likely of several possible causes of any failure. There are some characteristics of electronic circuits in general that may be of help in determining the most likely cause. This applies not only to the first effect-to-cause analysis but also to succeeding analyses in locating the individual stage and individual part that may have failed.

As soon as the outside serviceman makes his first analysis of a customer's complaint, he checks the vacuum tubes in the suspect section by substitution. This is common practice for two reasons: (1) tubes may be checked in the home easily and usually without removing the set from the cabinet, and (2) approximately 60% of all failures in TV receivers are caused by failure of the tubes themselves. Thus, the most probable cause of failure in a TV receiver is the failure of a vacuum tube.

The second most probable cause of failure in TV circuits is the failure of capacitors. This applies in particular to the paper type. Paper capacitors fail due to heat and moisture. They become leaky after 1 to 3 years of operation. This will be particularly true of sets in basement recreation rooms or in damp climates. The failure of mica and ceramic capacitors is much less frequent.

Probably the third most frequent cause of failure is the failure of resistors. Resistors may burn out completely or may change value with age. However, a burned out resistor usually means excessive current being drawn because of the failure of some other component—a shorted tube or capacitor.

Testing Methods

Before going on with your experiments it is best to review some of the methods used in conducting tests to locate the troubles that you will insert into your set.

SIGNAL INJECTION

Signal injection consists of feeding a signal to different stages in a receiver and observing the response. If the set is dead or weak, a signal of the proper freqeuncy is introduced near the output and the output noted. If the output is normal then the signal is introduced at points further back toward the input of the set. When the output changes or is lost the bad stage has been passed.

For dead or weak receivers, almost any signal generator can be used as a source. It must only generate a frequency that will pass through the section being tested. Another form of signal injection is the circuit disturbance test. In a TV receiver using a power transformer, a disturbance test can be carried out by removing and replacing tubes. In the audio portion of the set, this should cause a click or thump in the speaker; and in the video portion it should cause a flash of light on the screen of the picture tube.

In sets having series filament strings, removing any tube will break the filament string and cause a dead set condition. On such receivers a different form of circuit disturbance must be used. Touching a tube grid terminal with the point of an insulated screwdriver will usually inject all the signal necessary.

The circuit disturbance test can normally be applied only to the circuits that carry the signal; it does not work in checking the sweep or sync circuits or power-supply circuits. Also, it won't work very well on many TV receivers because of interaction between circuits; the signal may travel around a defective stage, thus giving a false indication. In other instances, particularly when you are working in the video circuits, you may get almost as much of a flash on the raster when disturbing a defective stage as when disturbing a good one. You will have to learn by experience just how far you can go in depending upon tests of this kind. This is one point where experience really counts. Try each of these tests that applies to your receiver and note the results. The sooner you learn, the better you'll be.

Signal injection works well on sets that are weak or dead, but circuit disturbance is not as reliable as in radio servicing. Signal injection is not so helpful for signal distortion unless a special signal source is used.

SIGNAL TRACING

In signal tracing, a signal is applied to the input of the receiver and traced through the receiver. This input signal can be from a signal generator, or it can be a signal from a TV transmitter.

The best test instrument to use in signal tracing is either a vacuum-tube voltmeter or an oscilloscope designed for TV service work. The oscilloscope is particularly useful because most manufacturers' schematics are prepared with the assumption that it will be used and the proper waveforms at various points in the circuits are shown.

By the use of rf probes with the vtvm and oscilloscope, it is possible to follow the signal through at least some of the i-f stages, although the signal level may be too low to measure in the first stage. When you get to the video stages, an ordinary ac voltmeter or a cathode-ray oscilloscope can be used to follow the signal right up to the grid of the picture tube.

The scope may be used to trace the sync pulses through the sync amplifier and clipper stages, as well as to trace the sweep voltages through the sweep circuits. However, you must be careful about the sweep outputs where the voltage levels may be very high. The blocking capacitor used with your scope will break down at the high voltages on the plate of the horizontal amplifier; therefore, it is not advisable to check sweep voltages at the plates of the sweep output amplifiers. The waveform can be safely checked at the deflection yoke.

The ac vtvm will tell you whether or not there is a signal present in the sweep circuits. It cannot tell you anything about the frequency, wave shape, or peak voltage and so is of little value in these circuits.

In the sound channel, the same devices can be used for signal tracing —a vtvm with an rf probe can be used to follow the signal through the sound i-f stages, and an ac voltmeter or an oscilloscope or even a signal tracer may be used to follow the audio signal through the audio stages.

STAGE BLOCKING

If the complaint is noise, oscillation, or a similar internal condition which develops an interference pattern on the screen, blocking is sometimes an effective test. In a way, this is a form of signal tracing. The interfering signal is present, and you block stages to find out where it originates.

As an example, suppose that noise is being produced in one of the sound i-f stages. If you block any of the stages between the origin of the noise and the loudspeaker, the sound will disappear, but it will not disappear if you block stages farther from the loudspeaker than the noise source. Thus, if you block or cut out the first sound i-f stage, and the noise is still present, you know that it is produced in one of the later stages. By blocking the next stage, you can determine whether the noise is introduced in that stage or not. If it disappears, you know that it is being introduced in that stage, but if not, that it is in one of the later stages.

There are several methods that might be used for blocking a stage. On receivers that operate with the filaments in parallel, the simplest method is to pull out the tube of the stage to be blocked. This test cannot be done on a set in which the tube filaments are in a series or series-parallel string. In such a case, the simplest way is to shunt a large by-pass capacitor between the grid of the stage to be blocked and ground. This works very satisfactorily in the rf and i-f stages. In the audio stages, the noise may only be reduced by this method, as any practical bypass capacitor may not provide a complete block. A capacitor of about .05 mfd is usually satisfactory for this test.

ISOLATION OF DEFECTIVE PART

If your first analysis of a complaint locates the defective major section, the next step is to isolate the stage in which the trouble has occurred. Assuming that the vacuum tubes have already been checked, this is best done by checking the output of each stage by signal tracing or signal injection.

Once the defective stage is located, the next step is to check components to find out which of the parts in that stage has failed. An examination of the parts in the stage may disclose the defect. You may be able to see that a part is burned or that a connection is loose. However, generally it is necessary to resort to a voltage or resistance check to localize the defect exactly.

When using a voltmeter, it is important that the meter have high sensitivity. Many TV circuits have very high resistances, so any additional current drawn by the voltmeter may upset the readings considerably. Most manufacturers' voltage and resistance tables give the sensitivity of the meter used to obtain the values in the table. Unless you have a meter of the same sensitivity, your readings are going to be higher or lower in high-resistance circuits than those of the manufacturer.

An ohmmeter can be used to check the resistance of a complete circuit, a portion of the circuit, or an individual part. When using an ohmmeter on a TV receiver, observe the same precautions as in a radio set—you must never use an ohmmeter in a live circuit. You should also discharge the filter capacitor even after the set is turned off.

Be cautious when you check parts not to jump to the wrong conclusions. Examine the circuit or the diagram; there may be a number of parts in parallel, in which case it may be necessary to disconnect one lead of the part being checked in order to get an accurate indication of its resistance. Once the defective part is located, the troubleshooting procedure is completed.

Experiments

Now that you have reviewed professional servicing methods and obtained the necessary equipment, you are ready to proceed with your experiments.

Since it is impossible to cover every set in exact detail, the instructions given here are for typical receiver circuits. These have been selected to include the maximum number of commercial TV receiver circuits in use today. Your set will probably be a combination of the circuits used in the experiments outlined in this section. Select those which most nearly resemble the circuits in your set and follow the instructions for them.

After performing each experiment, return the set to normal and check it for proper operation.

After you have read the directions **for each of the experiments** you should check your diagram carefully to see what portions of the circuit will be affected. Try to figure in advance what symptoms will be apparent on the picture tube and in the sound. Then when you have made the experimental changes in your receiver you can observe the effects and compare them with those that you expected. If the effects were not what you expected, think back over your reasoning and try to determine where you made your mistake.

In your servicing work you will apply effect-to-cause reasoning after seeing the effect of trouble on the signal. In doing these experiments, you start with a known cause, and from this cause you should be able to determine in advance the effect that it will have on the picture. It will be necessary for you to think ahead in the set and determine every stage that can be affected by the change you have made in the receiver.

You will of course know the cause in advance in each of the experiments that you perform. However, you should still apply effect-to-cause reasoning as if the cause were unknown to you. When you decide that some particular circuit or stage is not the cause and could not be the cause of the trouble, verify this fact with your voltmeter, oscilloscope or by signal tracing or signal injection.

Whenever signal injection or signal tracing are indicated as part of your troubleshooting procedure, do not select the one of these two methods which will get you to the known fault in the quickest manner. Try both of these methods in every case. In this way you will become much more rapid in each type of troubleshooting. Remember that in actual service work you will not know where a fault in the i-f strip is located. You will have to use testing methods to determine that.

Safety Precautions. Before beginning your first experiment, review the following safety precautions. If you follow these rules you will avoid the possibility of receiving an unpleasant shock or of damaging any of your equipment.

1. Don't work on "hot" circuits unless absolutely necessary.

2. After disconnecting your set, before working on it, discharge any capacitors that might hold a charge.

3. Stand on a dry insulated surface while working on your set.

4. If you must work on a "hot" circuit, use insulated tools and keep one hand in your pocket.

5. When measuring voltage, be sure to select a range on your meter that is higher than the expected voltage reading.

6. Do not attempt to make high voltage measurements without a probe.

7. Use extreme caution to avoid bumping or tapping the picture tube in your set. The implosive force of a broken picture tube can cause serious injury.

VOLTAGE TESTS

Your first experiment is to measure the voltages at all of the tube sockets in your set. There are two good reasons for doing this first; it enables you to become accustomed to working underneath the chassis and it will give you a set of reliable voltage readings for reference during your troubleshooting experiments.

It is quite possible that the manufacturer of your set has supplied you with a table or chart giving all of the tube socket voltages. A table of this type is shown in Fig. 8. This table is for the Crosley chassis 434. The voltages were measured with a vacuum tube voltmeter from tube socket pins to ground. The set was operating on 117 volts, 60-cycle ac with no signal input.

Even if you have the manufacturer's table, you should check the readings yourself and make corrections in the table where your values differ by 10% or more. Your readings may differ from the manufacturer's because of the differences in meter accuracy and sensitivity, and differences in conditions under which the readings are made.

The most useful readings will be those taken with your own meter and with the set in good operating condition. You can then compare them with readings taken with the same meter when the set is not operating properly to locate a defective part.

If you do not have a table of tube socket voltages, make one like the one shown in Fig. 8. To obtain the voltage readings, proceed as follows:

1. Turn the set on and adjust for good picture and sound. Then disconnect the antenna to remove the signal input.

2. Connect the negative lead of your voltmeter to receiver ground (usually the chassis).

3. Check the schematic diagram of your receiver to get an idea of what the voltage should be at each of the pins on the first tube socket you wish to test.

4. Set your meter to a scale which covers a range well beyond the estimated voltage and touch the test probe to the first pin to be tested. CAUTION: Be sure to check the schematic and set your meter for ac, +dc or –dc, whichever the schematic indicates for a given tube socket pin.

5. Check the voltages at all accessible tube socket pins as outlined above and record the voltage readings in the table. Note: In some sets the tube socket pins in the tuner cannot be reached without disassembling the tuner. However, the important voltages are brought to test points that are accessible from the outside of the tuner. Make such tests as you can at the test points provided. For the physical and electrical location of test points consult the manufacturer's service data for your set. Do not attempt to measure the high voltage at the high voltage rectifier

TABLE OF SOCKET VOLTAGES

The following voltages were measured with an electronic voltmeter while the set was operating on 117 volts, 60 cycle a.c. with no signal input, antenna terminals shorted, Station Selector set to channel 3, and the Brightness and Contrast Controls at minimum setting. Electronic voltmeter connected between socket lug and chassis. * = AC. voltages. Voltages may vary depending upon the setting of other controls.

Nominal D.C. current at junction of L108 and C132B, with contrast control in the maximum counter-clockwise position, 190 ma. With contrast set at maximum clockwise position, D.C. current at this point is 200 ma.

SYMBOL	TYPE	PIN 1	PIN 2	PIN 3	PIN 4	PIN 5	PIN 6	PIN 7	PIN 8	PIN 9
V101	3CB6	-0.6	+0.5	*44.3	*41.1	+140	+141	0	---	---
V102	3CB6	-2.8	+0.6	*41.1	*37.9	+140	+141	0	---	---
V103	5AV8	0	-0.7	-0.7	*33.15	*37.9	0	+1.9	+134	+135
V104	6AW8	0	-1.1	+108	*26.85	*33.15	+9.2	+1.7	+230	+240
V105	5AV8	0	-0.2	+51	*22.1	*26.85	---	+0.8	+61	+61
V106	3BN6	+1.9	---	*22.1	*18.9	+100	---	+114	---	---
V107	6SN7GTB	-20	+60 to +120	-7.6	-75	+210	0	*12.6	*6.3	---
V108	12L6GT	---	*65.15	+250	+266	+144	---	*52.25	+150	---
V109	12CU6	---	*77.75	---	+125	---	---	*65.15	0	---
V110	12BH7A	+480	+83	+105	*18.9	*18.9	+73	-21	0	*12.6
V111	12AX4GTA	---	---	+520	---	+265	---	*77.75	*90.35	---
V112	1X2B	High Voltage -- Do not measure with electronic voltmeter.								
V113	17AVP4	*0	0	---	---	---	Gnd. or +150	Pin 10 +302	Pin 11 +150	
	21ATP4	*0	0	---	---	---	Gnd. or +150	Pin 10 +302	Pin 11 +150	
V1	3BC5	-1.0	0	*44.3	*47.5	+140	+135	0	---	---
V2	5U8	+105	-2.6	+150	*47.5	*52.25	+132	0	0	-2.6

Courtesy Crosley

FIG. 8. Table of socket voltages for TV receiver.

unless you have a high voltage test probe for your meter. Do not attempt to measure the voltage at the horizontal amplifier plate cap.

When you have completed your tests you should have a table similar to the one shown. Save the table you have made. It will become part of the service data for your receiver.

POWER SUPPLY

The next section of your receiver on which you conduct experiments is the power supply. Power supply failures do not show up as the failure of any single stage or section, but cause the failure of all or a number of sections.

Therefore, if the troubles noted in a defective receiver indicate that the trouble could be caused by a power supply failure, a voltage check is the first step in the troubleshooting process.

Line Voltage Failure. The simplest form of power supply failure is the failure of line voltage; this results in no power reaching the set. This failure may be in the house wiring, the line cord, interlocking connector, or On-Off switch. To simulate this failure disconnect your set from the power line and remove the incoming power lead from the On-Off switch (usually on the back of the volume or contrast control). Tape the end of the lead. Plug the set in and turn it on. Note that the set remains completely dead—no sound, no picture, no raster, and the tube filaments do not glow.

To localize the cause of this trouble, start checking for line voltage at the receptacle into which the set was plugged and proceed to check line cord, chassis connector and On-Off switch until the defective part is found.

Filament Supply Failure. The effects of a failure of the filament supply voltage are almost identical to those of a line voltage failure. However, the manner in which you simulate this failure depends upon the type of power supply circuit your set uses.

There are three possible types of filament supply wiring: series, series-parallel, and parallel. If your set has a transformer type power supply, the filaments undoubtedly will be wired in parallel. If your power supply is of the transformerless type, the filaments will be wired in series or in some series-parallel combination. Check the schematic diagram of your set to determine which type power supply and filament wiring your set uses and then follow the directions given here for that type of supply.

Transformer Type. To simulate filament supply failure in a transformer type power supply, locate the filament leads or terminals on the power transformer of your set, and disconnect all connections to the ungrounded side of the filament winding. Plug the set in and turn it on. You will note the same effect on the set that line voltage failure caused—a completely dead set. Therefore, your first step in localizing the trouble may be to measure the line voltage across the primary of the power transformer. Finding the primary voltage present, your next step would be to measure the voltage across the output windings and discover that there was no voltage across the filament winding.

On most transformer type sets there would be an indication that line voltage was present and you would not waste time checking it. Almost all sets using a power transformer use a B+ rectifier having a 5-volt filament and a separate winding is provided to supply it. Therefore, if you see that the rectifier filament is glowing but none of the other filaments are, you would immediately conclude that the fault is in the filament supply wiring. You would make tests only to find the nature of the failure.

Many sets use a power transformer with a 12-volt center-tapped filament winding. In these sets the center tap is usually grounded and half of the filaments connected from each side of the winding to ground. If this is the case in your set, you will have to disconnect both sides of the winding to simulate complete filament supply failure.

Transformerless Type. The receiver containing a transformerless type power supply will have the tube filaments connected in series or in some series-parallel combination so that the total voltage drop across the filaments is equal to the line voltage. In some cases there will be a voltage dropping resistor in series with the filaments. The most common cause of filament failure in this type power supply is an open filament in one of the tubes. To simulate this defect, simply remove one of the tubes. If your set has its filaments wired in a series-parallel combination, be sure to remove a tube whose filament is in series with all of the other filaments rather than one whose filament is in one of the parallel branches.

To localize this trouble you could check the continuity of the filament string from point to point until the open filament is located, or, with the set on, check the voltage across each filament in turn until the line voltage is indicated on the meter. When voltage is read across the filament terminals of a tube, the filament of that tube must be open. If more than one filament is open, the second method will not locate either one.

In professional servicing you would use a filament continuity checker. With this test instrument, you do not have to remove the chassis from the cabinet to check open filaments.

B+ Supply Failure. Your receiver will have either a transformer or voltage doubler type of B+ supply.

The same general effects on the operation of the set will be noted in the event of failure of the B+ supply in either case. The failure of the audio tube in a circuit like Fig. 7, will give the same effect as a failure of the B+. The method of simulating a B+ failure will depend on the type of supply your set uses.

Transformer Type. If your set uses a transformer type power supply it probably has a full-wave rectifier tube such as the 5U4. To disable the B+ supply, remove this tube. The effects of no B+ will be no sound, no picture, no raster. The fact that the tube filaments glow will indicate that line voltage and filament supply are present. This defect is localized by checking the rectifier output with a dc voltmeter.

Voltage Doubler Type. If your

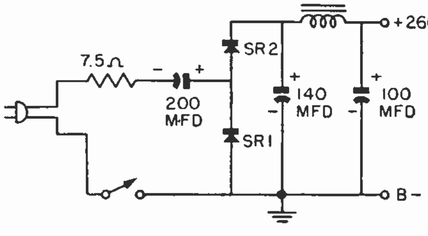


FIG. 9. Transformerless half-wave voltage doubler power supply.

set uses a voltage doubler type of supply similar to the circuit shown in Fig. 9, it probably uses dry disc rectifiers instead of vacuum tubes. To simulate B+ failure in this type supply you must disconnect the lead from the output side of the rectifier in your set that corresponds to SR2 in Fig. 9. The effects noted should be the same as for the transformer type supply, and again the trouble will be localized by measuring the dc voltage output of the rectifier.

A loss of B+ voltage may be caused by defective rectifiers, open choke coil, shorted or open filter capacitors, or a blown fuse. Many sets incorporate a small fuse in the B+ supply. The wire is usually so fine in these fuses that they must be checked with an ohmmeter rather than by observation.

Frequently the B+ failure in either transformer or voltage doubler type supplies is not complete. A rectifier may become weak and cause the B+ voltage to be low, a filter or by-pass capacitor may become leaky and overload the rectifier causing low B+, or the input filter capacitor becomes open. To simulate low B+ voltage, disconnect the lead between the rectifier and the filter input. Connect one end of a 50-ohm, 20-watt resistor to the rectifier output. Connect the filter input to the other end of the resistor. A number of effects might be observed under this condition depending on how much this resistor drops the voltage in your particular set. In general it will lower the gain of all stages in the set. Sound and picture will be weak, picture size small, and the picture may go out of sync. If the voltage has been dropped too much there may be no picture at all and only weak sound, or a dead set like that produced by a total lack of B+. If the latter situation exists in your set, shunt the first resistor with another of approximately the same value and observe the effect.

Another way to simulate low B+, is to disconnect the positive lead of the input filter capacitor. This reduces the output of the rectifier. An open filter capacitor is a common receiver defect. This also reduces the filtering action and may put hum bars in the picture.

Localizing these troubles is a matter of checking plate supply voltage. However, the combination of effects produced by low B+ will indicate by effect-to-cause reasoning that the trouble cannot be due to a defect which can affect only a single section of the receiver. Therefore, it must be caused by something common to a number of sections, such as the power supply or B+ wiring. This reasoning will lead you to check supply voltages.

High Voltage Supply Failure. Although the high voltage power supply is usually a part of the horizontal deflection system, it is still a power supply and in many early TV sets it was a power supply independent of the horizontal deflection system. Therefore, an experiment illustrating the effect of a loss of high voltage is given here rather than in the section on sync and sweep circuits.

Regardless of what type of high voltage power supply your set uses it will have a rectifier tube. This tube will have the plate connected to the top cap. To disable the high voltage supply, remove the clip from the cap of the tube and tape it well away from the cap and any parts of the set that may be grounded. Caution—

be sure to ground the plate and filament of the rectifier carefully before touching the cap.

Turn on the set and note the effect of a lack of high voltage. You should be able to get normal sound but no picture and no raster. Loss of the raster indicates that there must be trouble either in the picture tube, sweep circuits, or high voltage. Since there is sound, there must be B+ and filament supply.

If you have a high voltage probe so your meter will measure voltages up to 20kv, you can check for high voltage failure with your meter. If not, you will have to use the screwdriver method. This is the method used by auto mechanics to check for sparks at the spark plugs on an engine. Use a screwdriver with a well insulated handle. Holding it by the handle, touch the blade to the chassis and bring the shaft close to the cap of the rectifier. If an arc is drawn you know that you are getting high voltage ac to the plate of the rectifier. Repeat the process, but this time bring the shaft close to the filament connection. If an arc is drawn the second time you know that there is high voltage dc at the output of the rectifier. This method is not as good as a voltage measurement because it only tells you that there is or isn't high voltage, and gives no indication of the amplitude of that voltage.

Loss of high voltage is most often caused by a defect in the horizontal sweep system, the high voltage rectifier, the high voltage filter capacitor, or an arc to ground from the high voltage lead. A high voltage arc is easy to detect by the sound it makes.

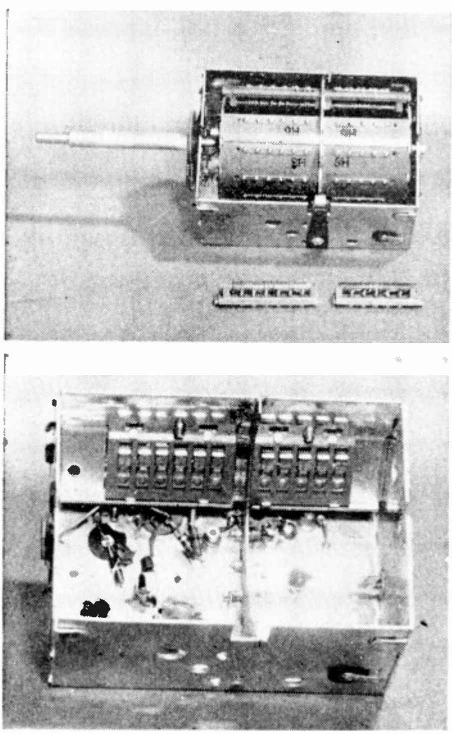
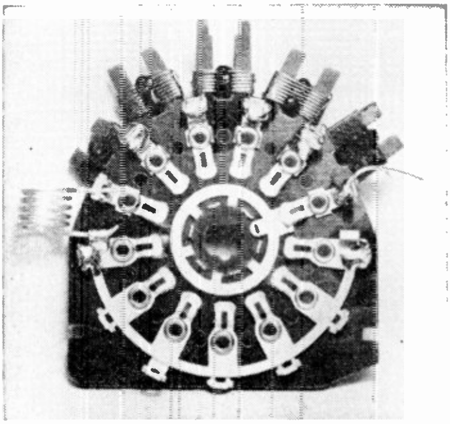


FIG. 10. Above: Photo of Turret tuner showing drum mounted in place, and one set of strips removed. Below: Photo of the inside of a turret tuner chassis showing the stationary contacts.

TUNER

Now that you have conducted your voltage tests and noted the effects of power supply failures, you will proceed to conduct experiments in the other sections of the TV receiver. Failures in these sections will be such that they can be localized rapidly to a single major section or stage. Your experiments will be conducted in the same order as the path of signal flow. You will start with the tuner and go through the i-f section, the video section, the audio section and the sync and sweep sections, conducting experiments on each section in turn.

Your tuner may be any one of several different types. However, regardless of which type tuner your



Courtesy of Radio Maintenance Magazine

FIG. 11. One of the switch decks used in a wafer switch type of step tuner.

set may have, the procedure for conducting these experiments will be the same. The major types of tuner are described briefly here so that you may identify the type your set uses.

Tuners may be divided into two major classifications: the step type and the continuous tuning type. The step type tuner allows the operator of the TV receiver to select the channel to be received in separate steps. It usually contains a fine tuning device to tune for best picture and sound after the proper channel has been selected.

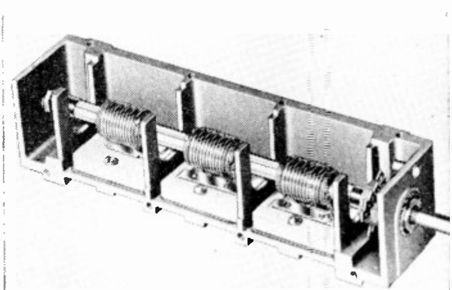
Fig. 10 shows a turret-type step tuner. In this type tuner, separate coils for each channel are mounted around the sides of a drum which can be rotated to select the proper channel. Spring contacts bearing on the drum connect the selected coils to the rest of the tuner circuit.

Fig. 11 shows a step tuner of the wafer switch type. Here the coils are mounted on switch wafers and the wiper arms of the switch select the proper coil connections.

Fig. 12 shows a continuous tuner. Here there are no separate steps for selecting the channels; the set is tuned the same as an ordinary radio receiver. The stages are turned by rotating the coils while sliders ride back and forth on the coils as they turn.

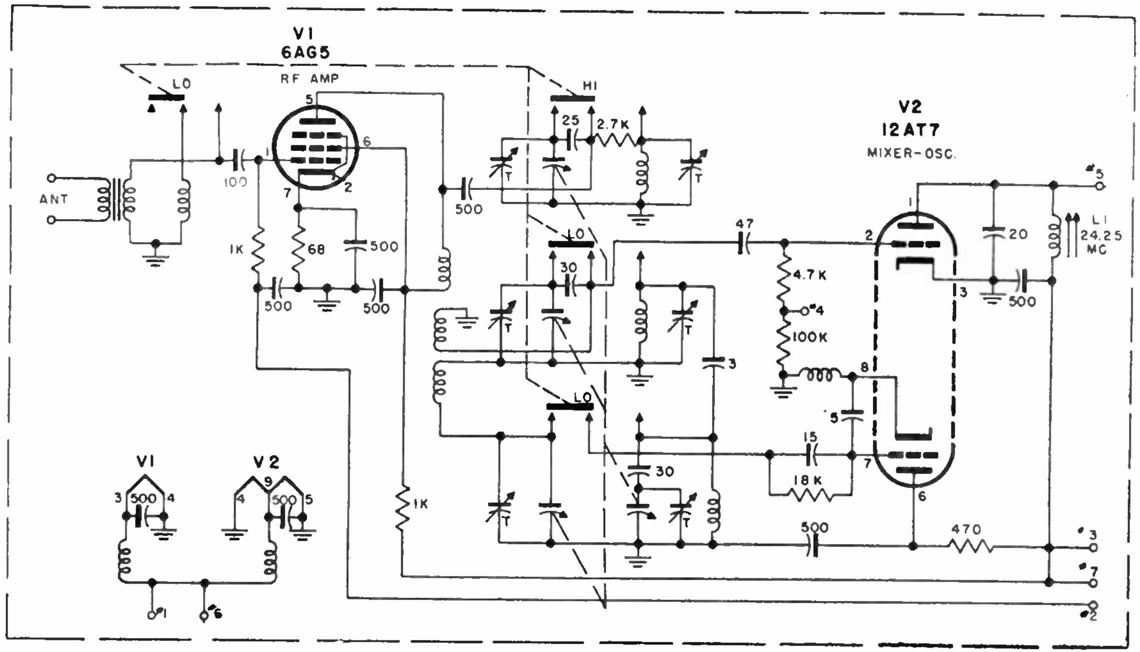
Still another type continuous tuner uses variable capacitance rather than variable inductance. The schematic diagram of such a tuner is shown in Fig. 13. While this is a continuous tuner it actually operates in two bands. While tuning the range of capacitor values that resonate on channels 2 through 6, the switch remains in the low position as shown in the diagram. When approaching the values of capacity for resonance at chanel 7 the switch automatically moves into the high position placing other values of capacity and inductance in the circuit. The switching is automatic as the tuning knob is turned.

All the tuners that have been described above rely upon some form of mechanical device—sliding contacts, switches, or spring contacts, to complete the resonant circuits in the tuner. These contacts are the most common cause of trouble in tuners. The contacts become dirty or the springs lose their tension and the result is intermittent tuner operation.



Courtesy of P. R. Mallory & Co., Inc.

FIG. 12. Rotary coil type of continuous tuner.



Courtesy Capehart

FIG. 13. Capacitively tuned continuous tuner.

Disabling The Tuner. In order to study the effects of a defective tuner section it is necessary to create a condition in which no signal is received from the tuner. To do this, study your schematic diagram to see which lead connects the tuner output to the first i-f stage input. The best way to be sure that you have the right lead is to first trace it out on your schematic from the grid of the first i-f stage to the tuner. Note which terminal it is connected to and disconnect this lead. Tape the end of the lead as close to the tuner as possible and as far from the i-f circuits as possible.

Next, turn on your set and attempt to tune in a channel and obtain a picture. You will note that there is no picture and no sound but there is a raster on the picture tube. The presence of the raster tells you that the picture tube and sweep circuits are operating properly. Since both sound and picture are missing you know that the trouble must be in some stage that is common to both. This will narrow your trouble down to the tuner or one of the first i-f stages, if your set uses separate channel i-f's. If your set uses the intercarrier i-f, the trouble could be in the tuner or any of the i-f stages.

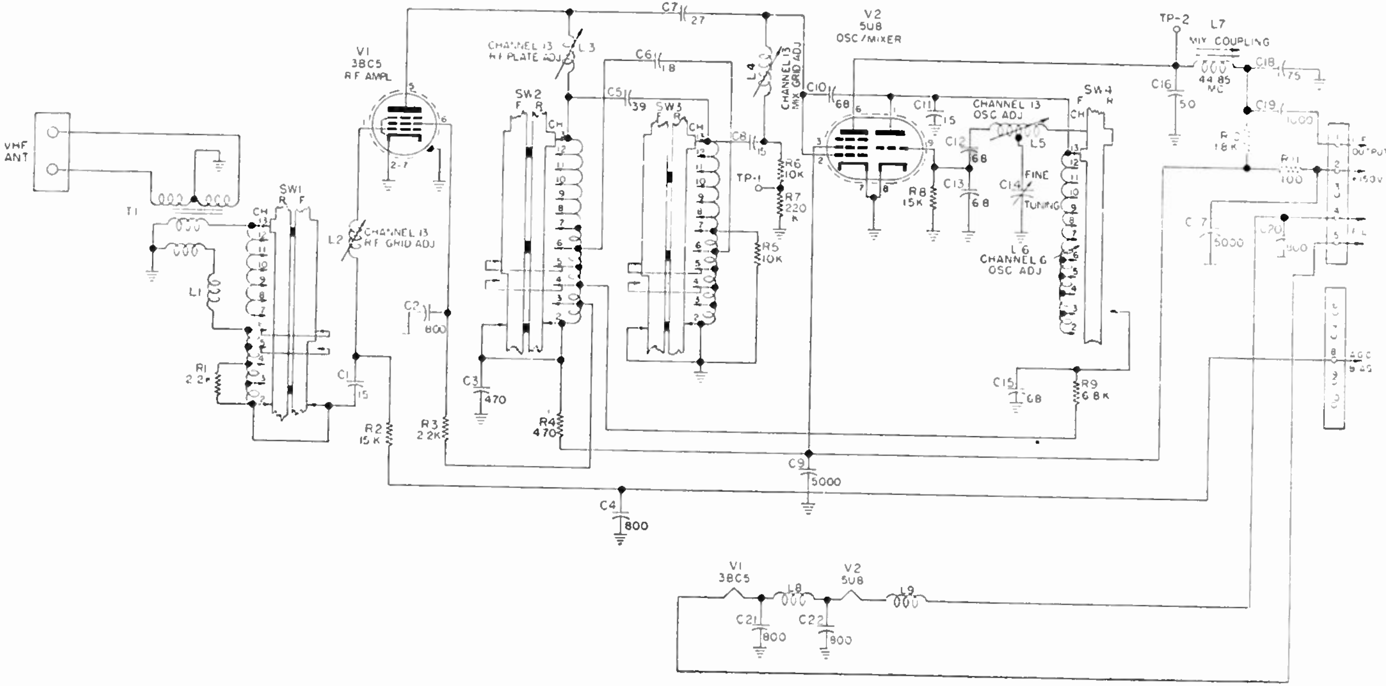
This trouble could be localized by means of the signal tracing or the signal injection methods previously outlined in this manual. Stage-by-stage signal tracing or injection would quickly lead you to the defective tuner. Tube failure is the most likely cause of an inoperative tuner. The tuner normally contains three vacuum tube stages: the rf amplifier, the mixer, and the oscillator. The failure of any one of these stages will disable the tuner.

If your set uses a parallel filament hookup, you can verify this by removing any of the tubes in the tuner and noting the effect. Do this with the normal connection to the first i-f amplifier restored. First remove the rf amplifier tube and note the effect, then if your set uses a combination mixer and oscillator tube, remove that and again the tuner will be disabled. If your set uses separate mixer and oscillator tubes these may be removed separately and the effects noted. The removal of any tube should produce the same effect as disabling the tuner by disconnecting it from the i-f amplifier.

Weak Tuner Output. Another common tuner defect is weak output. Sometimes this varies with the channel selected. In many sets the oscillator tube will operate well on the lower channels but not at higher frequencies. As the tuner vacuum tubes grow older, their efficiency will be decreased and the tuner output will be weakened.

Before you can simulate the condition of weak tubes in the tuner, it will be necessary for you to study the diagram of the tuner of your receiver. You can duplicate the weak tube condition by reducing the plate voltage on one or more of the tubes in the tuner.

The tuners in most common use have only one B+ connection. This lead supplies plate voltage to the rf amplifier, the mixer and the oscillator. If you connect a 1000-ohm, 1-watt resistor in series with this lead, you will reduce the plate voltage on all three stages of the tuner. A few tuners apply plate voltage to the mixer through the transformer at the input of the first i-f amplifier. The resistor may be inserted in the lead



Courtesy Crosley

FIG. 14. Schematic of a selector switch type of step tuner.

between B+ and this transformer to simulate a weak mixer tube.

A very few tuners use different B+ leads to the three stages. If you have a tuner of this type, you may place the resistor in each of the three B+ leads in turn and in this way determine the effect of a weak tube in any one of the three stages.

A 2.7-ohm, 1-watt resistor in the filament lead to the tuner will also give the effect of a weak tube by lowering the emission of each of the three tubes. This method of simulating weak tubes will of course work only in the case of a transformer type power supply which feeds the tube filaments in parallel. This method should not be attempted in cases of series filament strings.

Many tuners provide a test point on the outside of the case for measurement of the rectified grid current in the mixer tube. This rectified grid current is a measure of the strength of the oscillator output. As you make any of the tests to simulate a weak oscillator tube you should measure this rectified grid voltage to determine how weak the oscillator may be and still allow the set to function.

After adding the voltage dropping resistor, turn on your set and note the effects produced. If the effect is the same as a completely disabled tuner, decrease the value of the resistor that you added and again note the effect. The raster should be weak, and sound should be weaker than normal. It is quite possible that a weak tuner output will cause an unstable sync condition in the picture also.

Since most tuners are separately encased units, once a defect has been traced to the tuner it is usually the best practice to check the tubes in the tuner by substitution to see if one of them is defective before attempting to remove the tuner from the set and disassemble it.

Frequently, analysis of the effect of the trouble will help to localize the trouble within the tuner. For instance, if the tuner operates properly on some channels and not on others, and the inoperative channels are all above a certain frequency, it is safe to assume that the trouble is probably in the rf oscillator. Check that tube by replacement. On the other hand, if the tuner works only on the higher channels and not on some lower channels, it is more probable that a mechanical defect exists in the switching arrangement.

The schematic in Fig. 14 shows a typical selector switch type of step tuner. Note that in this tuner successive coils on the switch are connected in series to form the total inductance in a resonant circuit for all three stages. Should one of these coils become open the tuner would operate at all positions of the switch above that coil but operate at none of the positions below that coil. Therefore, if a set uses this type of tuner and operates normally on some channels but will not operate on lower bands it would be a reasonable guess that one of the coils is open.

In turret tuners, one channel only may fail while all the others work normally. In this case the trouble would be in the coil strips for that channel. Correcting the trouble might require only adjustment of the oscillator tuning slug. If tuning does not correct the condition, the strips for that channel can be replaced.

It is not recommended that you attempt to simulate these defects that would require you to go into the tuner and remove or open coils because of the difficulty you might experience in trying to realign the tuner without the proper test equipment. However, these effects and their causes are mentioned here as points of information.

Whenever you have to work on a tuner, remember that lead dress is very important. Moving some leads as little as one quarter inch can detune these circuits.

On completing your experiments with the tuner, restore all connections to their normal condition and check to see that your set is operating properly.

I-F SECTION

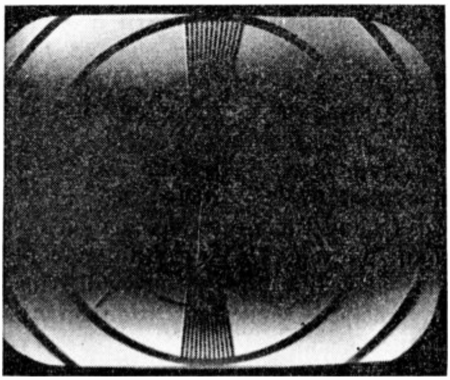
The first step in conducting your experiments in this section is to determine whether your receiver uses separate channel i-f's for sound and picture or whether it uses an intercarrier system in which both sound and picture are carried through all i-f stages to the video detector. This is also one of the first things you should do in servicing a receiver.

If the sound take-off in your receiver is at any i-f stage ahead of the second detector, you have a separate channel system. Study the schematic of your receiver. Locate the first sound i-f and trace the input of this tube back to determine the location of the sound take-off point. Once this is located, you can tell whether you have a separate channel or an intercarrier system.

The most common failure in a television receiver i-f strip will be the loss of emission of one of the tubes. The complete failure of a tube in a receiver with parallel-wired filaments may be simulated by removing the tube from the socket. In sets using series filaments, you can simulate a complete loss of emission in the tube by disconnecting the cathode bias resistor from the cathode pin at the tube socket.

Once effect-to-cause reasoning leads you to the i-f strip, the fastest procedure in localizing the trouble is by means of either signal tracing or signal injection. Once the stage in which the trouble is located has been found, voltage checks at the tube socket will further localize most of the troubles. In this case you would find that the plate voltage and screen voltages were slightly higher than normal and that the cathode voltage was quite high. Actually, a tube which had lost its emission would show practically no voltage on the cathode. The reason for a voltage on the cathode in this case is that the tube does have emission but there is no ground return.

Another trouble which occurs in the tube is heater-to-cathode leakage. You can obtain the effect of heater-to-cathode leakage by connecting a .05-mfd, 600-volt capacitor between the ungrounded heater terminal and the cathode pin of the tube. The presence of 60-cycle hum on the



Courtesy RCA

FIG. 15. Hum bar in picture caused by heater-to-cathode short in video i-f stage.

cathode will give you a very light or a very dark band across the face of the picture tube. A dark band due to hum is shown in Fig. 15. The fact that there is only one light or dark band shows that it is 60 cycles and must be due to leakage from the heater circuit.

This trouble can be cured without removing the chassis from the cabinet by substituting new tubes through the video amplifier and video i-f strip until the faulty one has been replaced.

You introduced the trouble at the socket so tube replacement will not correct it in this experiment. This is a good place to try signal tracing methods. Stage blocking will not work; the hum bar will only show when a signal is being received. A carrier is necessary to get the 60 cycles through the i-f stage.

Occasionally an i-f coil will become either shorted or open. To show the effect of a shorted primary in an i-f transformer, you can connect a short jumper between the plate and screen pins on an i-f tube socket. The effect of this short is to block the i-f strip at that stage. Since you have a "no picture" condition, signal tracing or signal injection will be the fastest way to determine the faulty stage. When you test the tube voltages in this stage you will find that they are all approximately normal. Signal tracing methods will show that there is a signal present at the grid of this tube but no signal at the plate. The tube has been checked or a substitute tried and it is known that the tube is good.

This is one of the more difficult types of trouble to locate; the resistance of the i-f coil is very low and it will be difficult to detect the short with an ohmmeter. In some cases connecting the plate to the following grid through a 100-mmf mica capacitor and substituting a 1000-ohm, 1-watt resistor for the plate coil may pass a signal. This would indicate that the trouble was in the i-f coil. In a case of this type you would probably have to check your estimate of the trouble by substitution of a new i-f coil.

Another defect in these i-f coils is that a lead will break and they become open circuits. This condition can be copied by disconnecting the B+ from the i-f coil. In this case, once you have located a defective stage, a voltmeter test at the tube socket will indicate immediately that B+ is not getting to the plate. As you check back along the circuit with your voltmeter, you will come to the point at which it is broken.

Occasionally a screen by-pass capacitor will become leaky. The current flowing through this capacitor will increase the voltage drop across the screen resistor. Reduced screen voltage on the tube will lower the gain of this stage considerably. The effect of this on the picture tube is a reduced brightness caused by loss of sensitivity of the set.

Connect a 5000 to 10,000-ohm, 1-watt resistor between the screen terminal on the tube socket and ground. This will increase the drain through the screen dropping resistor in the same fashion that a leaky capacitor would. Note the effect on both the picture and the sound of your receiver. This condition would be detected by a voltmeter check at the tube socket.

If your set uses separate i-f channels for audio and video, it is suggested that you try these measures on i-f stages both before and after the audio take-off point.

If you do not wish to open circuits and break connections in your receiver, you can block individual stages with the .05-mfd, 600-volt capacitor. If the capacitor is used for stage blocking it is recommended that you block some stages at the grid and some stages at the plate so as to obtain experience in signal tracing through the interstage coupling circuits.

Naturally you know where the trouble was introduced in the set, but when you start troubleshooting forget where it is. Satisfy yourself in each case that you can localize the trouble to one section of the receiver by effect-to-cause reasoning.

I-F Frequency Response. Unless you are thoroughly familiar with your lesson on TV receiver alignment and video i-f amplifiers, and have the necessary equipment for the alignment of your set, it is not recommended that you detune any circuits to note the effect of poor i-f frequency response. However, it is possible to observe some of the effects.

If you connect a "gimmick" capacitor like the one shown in Fig. 4, across any of the i-f coils of your receiver, you will lower the resonant frequency of that circuit. In the i-f stages of a receiver, the video carrier is at a higher frequency than the audio carrier. This means that lowering the resonant frequency of a tuned circuit will accentuate the highs in the video information and cause a reduction in the low frequencies. In many cases, this reduction in the low frequencies will be sufficient to reduce the amplitude of the sync pulses and cause the picture to be unstable. The most common effect will be that shown in Fig. 16. The picture will become smeared and large black areas will be blacker on the left than on the right.

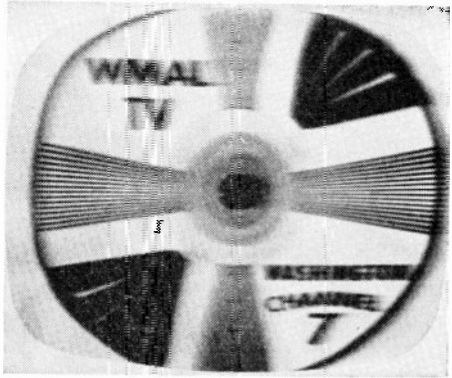


FIG. 16. Smearing of picture due to loss of low frequencies and phase shift of lows.

It is impossible to accurately predict the result that you will obtain by use of this "gimmick" capacitor in any given receiver. The effect will depend upon the values of the parts in the circuit, the sensitivity of the stage and the amount of shielding that is used in the receiver. In some cases, there will be sufficient coupling between adjacent stages and this "gimmick" capacitor to cause oscillation in the i-f strip. This oscillation will most likely appear as irregular white or black patches extending into the picture from the left-hand edge. In some cases the oscillation may be strong enough to cause the picture to reverse in polarity; that is, the white parts will appear black and the black parts will appear white. Oscillation due to feedback in the receiver is not an uncommon complaint. In most cases, it is due to the failure of plate decoupling capacitors. If these capacitors fail, the signal in the plate circuit of a stage may flow through a resistor which is common to more than one

FIG. 17. Poor high frequency response. Note that only fine detail on vertical lines is lost.

stage. This common resistor then functions as a feedback element between two stages.

If your set uses stagger-tuned i-f's, connecting a 1000-ohm carbon resistor across the stage which is tuned to the lowest frequency, will reduce the gain of this stage sufficiently to cause an over-all reduction in high frequency response in the picture. The effect of loss of high frequency response is shown in Fig. 17.

Connecting the "gimmick" capacitor across a parallel-tuned sound trap will detune the trap. This detuning will allow audio to pass through to the video amplifier and on to the picture tube. This will give rise to sound bars in the video. These sound bars will have the appearance of the pattern shown in Fig. 18. Sound bars of this type are present only during periods of audio modulation. They are easy to detect, since they come and go with the audio portion of the program. The louder the audio, the more intense the sound bars. The faster the audio, the closer spaced the bars will be.

Connecting the "gimmick" capacitor across only the coil of a series-tuned sound trap, will raise the frequency of this trap. Raising the frequency of the trap in this manner will reduce the response in the portion of the video passband which carries the high frequencies. The effect of this on the picture tube will be a combination of loss of detail in the fine line vertical portions of the picture, and the presence of sound bars. Both of these effects will occur at the same time.

In any of these experiments in the i-f strip, be very careful not to disturb the position of parts or the lead dress of the wires to and from the i-f coils. These stages are quite critical as far as stray capacity is concerned. If the lead dress is disturbed badly, it may become necessary to completely realign the receiver.

VIDEO SECTION

In this section, you will conduct experiments in the video detector, the video amplifier, and the agc circuits of your receiver. There are a great number of variations of these three circuits. However, the general principles and the effects of failures of the major parts will be practically the same in all sets.

Video Detector. In the first part of your practical training lessons you located and analyzed the video de-

Courtesy RCA

FIG. 18. Sound bars in video.

tector of your receiver. Now we will disable the detector and note the effects on the sound, the picture and the raster.

There will be very few cases in which you can disable the video detector by removing a tube from the socket. Most of the vacuum tubes used as video detectors are dual section tubes and removing the tube would also disable another section of the receiver. In the case of some crystal diode detectors, however, the diode is mounted on the i-f transformer in a simple clip mount. If your set uses this type of detector it is very easy to remove from the circuit. Be sure to check the polarity, so that you can replace the diode correctly.

The simplest way to disable all types of diode video detectors, whether crystal or vacuum tube, is by connecting your .05-mfd capacitor from anode to cathode. The effect of disabling the video detector of your set will depend upon whether or not your set uses intercarrier i-f's. In any case, a raster but no picture should be obtained.

If your set uses separate channel i-f's, you may use either signal tracing or signal injection between the point of sound take-off and the picture tube grid. This will enable you to locate the defective stage. If your set uses intercarrier i-f, effect-to-cause reasoning will tell you that the trouble occurs between the antenna and the video detector. If the failure were in the video amplifier, you should have sound on your receiver.

One of the quickest tests that you can make when you have found raster but no video, is to check for a rectified voltage across the load resistor of the detector diode. If the detector and i-f are working, you will have a voltage across this resistor to ground. If this voltage is present, the fault will lie between the detector and the picture tube grid. If this voltage is not present the fault will lie in the detector or the i-f strip. By making this voltage test you have eliminated one or more stages from consideration and will use only one frequency for signal injection tests.

When you have isolated the defect to the video detector stage itself, the best test is to substitute a new detector. In the case of a vacuum tube detector, a new tube would be plugged in; in the case of a crystal rectifier, a new unit would be used. If a new detector does not correct the trouble, it will be necessary to use resistance and continuity tests to locate the defective part.

Video Amplifier. The video amplifier of your TV receiver will use either one or two stages, and may be either direct-coupled or capacity-coupled. Failure of the video amplifier can result in loss of sync, loss of picture, or distortion of the picture. The distortion can take three forms. These are loss of highs, loss of lows and clipping of either the white peaks or the sync.

You can stimulate a dead video amplifier stage by any of the methods used to block the video i-f stage with the exception of a short across the peaking coils of the video amplifier.

Try shorting around the peaking coil in the video amplifier with one of your straight jumpers. This will result in the loss of high frequency response in the amplifier. In service work this condition could arise either from a direct short across the entire coil or from the presence of several shorted turns within the coil. The picture will have the same general appearance as Fig. 17. An increase in resistance of the plate load resistor of the amplifier, or the diode load resistor in the detector will have the same effect. You should become familiar with the appearance of the picture under these conditions.

Another way to simulate a defect in the video amplifier which will result in the loss of high frequency response is to connect a 100-mmf capacitor between plate and ground of the video amplifier.

In either the input or the output of the video amplifier you will find a coupling capacitor which will probably have a value of .1 mfd. Remove the capacitor—it doesn't matter whether at the grid or plate of the amplifier—and substitute in its place a .001-mfd capacitor. This will result in considerable loss of lows and is a common defect in TV receivers. This gives a smeared picture, as seen in Fig. 16. You should become familiar with the appearance of a picture in these conditions.

In many receivers, the sync takeoff point for the sync separator and amplifier is located in the plate circuit of a video amplifier tube. When severe loss of low frequencies occurs in this amplifier stage, the sweeps will frequently be quite unstable. The sync pulses which control the sweep generators are at quite low frequencies and the loss or reduction of these pulses in the video amplifier can lead to a vertical rolling. Since the vertical sync pulses are at lower frequencies, the vertical sweeps will suffer most from this condition.

AGC System. All modern sets use some form of automatic gain control. The simpliest and most economical form used in TV receivers is a direct copy of the avc circuits used in radio. A circuit of this type is shown in Fig. 19A. In this circuit, the dc component of the rectified carrier is **built up across resistor R116. The** fluctuating portions of the signal are filtered out by means of R117 and C111. This filtered voltage is negative with respect to ground and is applied through a chain of decoupling and filtering resistors to the first and second i-f's and the rf tube.

This agc circuit may be disabled in either of two ways. You will note the lead between resistor R117 and

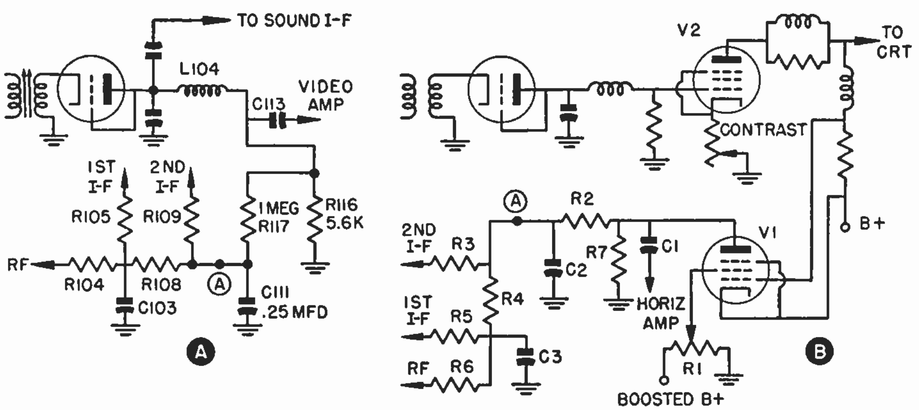


FIG. 19. Two basic types of TV agc circuits. (A) Simple agc using rectified video carrier from video detector. (B) Typical gated or keyed agc.

resistor R108 is marked with a circle and the letter A. You may either break the circuit at this point or short the bus to ground across capacitor C111. Either method will completely remove the agc voltage from the rf and i-f tubes. If you live in a region of high signal strength, the picture will be distorted due to overload of the last i-f or of the video amplifier. It is suggested that you try both methods of removing the agc.

When the circuit is broken at point A the grids of the rf tube and of the two i-f tubes are left floating, that is, they have no dc return to ground. When they are operated this way, each of the grids must take on a negative voltage which is caused by electrons striking the grid. This voltage will apply some bias to the tube and the overloading will probably not be as great. However, when point A is connected to ground the tubes operate with only the very small bias developed across the cathode resistor. The overload in this case will be considerably greater.

This is the simplest and most basic of all the agc circuits. There are several variations of this in common use today. In one variation the diode used to obtain the agc voltage is not the same as the diode used for detection. The two are both connected, however, to the last i-f transformer. By using a separate diode, it is possible to construct the circuit for maximum efficiency as an agc rectifier, and not have to worry about its efficiency as a video detector. The use of a separate diode also allows application of a small positive voltage to the cathode of the diode. A positive voltage at this point will prevent the diode from conducting until the signal is larger than the bias. This is known as delayed agc. This method is particularly effective since it does not reduce the sensitivity of the set on low level signals.

Another variation of the simple circuit is to insert, at point A on the diagram, a triode or pentode direct-coupled amplifier. In this manner the agc potential can be increased and the set can then handle a greater range of signal strengths. When a direct-coupled amplifier is used in this manner, it is necessary to obtain the agc voltage from the cathode of the diode. The phase reversing properties of an amplifier tube require a positive-going voltage at the grid of the tube in order to obtain a negative-going voltage at the plate. Delay bias is usually applied to the diode when an amplifier is used.

The second form of agc is the "gated" or "keyed" circuit. A form of keyed agc is shown in Fig. 19B. The reasons for the use of this circuit and its advantages over the simple circuit were explained in the first part of your practical servicing lessons. This is an improved form of amplified agc. In "gated" agc the amplifier tube is biased to cut-off except when sync pulses are applied to one of the grids.

This circuit may be disabled by opening or shorting the circuit to ground between resistors R2 and R3 at point A on the diagram. The effect of doing this will be the same as opening the agc bus or shorting to ground in the simple circuit of Fig. 19A. This type circuit is subject to all the defects and difficulties of the simpler one with the additional possibility of tube failure.

The circuit in Fig. 19B also shows the means used to reverse the polarity of the signal applied to the grid of V1, which is actually an amplifier tube. The video amplifier tube V2 reverses the polarity of the signal received from the diode detector. This is reversed again in tube V1 and the polarity on the agc bus is then the same as at the output of the detector. In this case, failure of the video amplifier could cause failure of the agc circuit. Note that varying the contrast control varies the agc voltage by changing the gain of the video amplifier.

The most likely cause of failure of this circuit is the failure of tube V1. Failure of this tube can be simulated by removing the tube from the socket, in the case of parallel heater strings, or by reducing the screen voltage, which in most cases will be adjustable by a potentiometer similar to part R1 in the diagram. Another cause of failure of this stage would be for capacitor C1 to become open. Since this stage derives its plate voltage only during the horizontal sync interval and this plate voltage is in the form of pulses, failure of capacitor C1 would remove the plate voltage of the tube and the stage would stop working.

In some circuits, the grid of tube V1 receives its voltage from the sync separator-amplifier tube. In this case the voltage at both grid and plate would be in the form of pulses. A failure of the sync separator amplifier tube in this case would cause a failure of the agc circuit.

You can see from the above discussion of the failures possible in this circuit, that in most cases the only apparent sign of a failure of the agc circuit will be an overload of the video i-f or video amplifier. Even though failure of the horizontal oscillator, horizontal sweeps, video amplifier or sync separator tubes would stop agc action in some sets, you would not notice the failure since you would have no picture on the tube anyway.

For these reasons the most likely part failures here are open coupling capacitors to the plate of the gated tube, shorted capacitors to ground on the agc bus or open resistors in the filter circuit for the agc voltage.

A very few sets have been constructed in which a separate narrow band i-f stage was used to supply the signal to a separate agc rectifier. The operation of this type of circuit is the same as the simple agc circuit.

Another variation in the manner of obtaining the agc voltage was to rectify a portion of the audio signal. There were, however, few sets made with this circuit. The idea behind this circuit is that TV broadcast stations are required to maintain both audio and video signals at the same average power. Since there is no amplitude modulation on the audio carrier, the agc voltage will be constant for any fixed carrier strength. If you should encounter a set of this type, the operation will be the same as the simple agc circuit.

The best check on an agc system is to measure the bias on the grids of the controlled tubes with no signal received, and then with signals of different strengths. The bias should increase as the signal becomes stronger.

SOUND SECTION

The sound section of a television receiver from the point of sound i-f take-off, follows the standard practices used in FM receivers. The troubles you meet and the methods of correcting them are exactly the

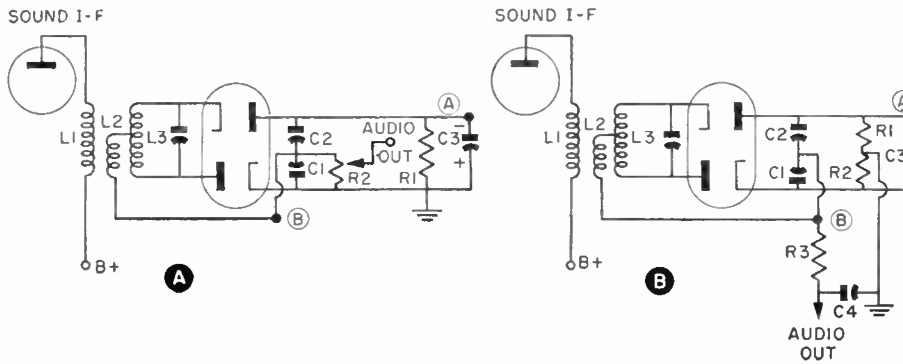


FIG. 20. The two common variations of the ratio detector circuit. (A) Unbalanced ratio detector. (B) Balanced ratio detector.

same as you would use in FM receiver service practice. With one exception, therefore, we will not go into trouble in the sound i-f amplifiers. The experimental methods of introducing defects in these circuits are exactly the same as the methods that we used with the video i-f strip.

The single exception which we will discuss here is that of the limiter-discriminator type of FM demodulator. You learned in the first section of your practical servicing training that the i-f stage immediately preceding a discriminator is used to limit the peak amplitude of the signal. This is accomplished by operating the tube at low screen and plate voltages. If the screen and plate resistors of this stage should drop in value, higher plate and screen voltages would be applied. With these higher voltages the tube would operate as a normal i-f stage. When this stage does not limit, noise impulses in the i-f are carried through the discriminator and will appear in the audio output at the speaker.

If the input signal at the grid of the limiter is too low, limiting action will not take place and again noise impulses will appear at the speaker. This situation is easy to detect from the operation of the receiver controls. If the signal is so low at the limiter grid that noise impulses get through, it will be necessary to turn the audio gain control much higher than normal in order to have room level output.

Ratio-Detector. The Most common type of FM demodulator in use in television sets today is the ratio detector. There are two basic forms of this circuit. They are shown in Fig. 20. Any ratio detector circuit which you encounter in practice can be redrawn in the form shown in either the A or B part of this figure.

In discussing possible failures, we will study Fig. 20A first. The first and most obvious failure is of course the failure of the detector tube. The next simple failure would be a short across capacitor C1, which would remove all audio voltage from the output.

In troubleshooting a complaint of picture but no sound, the first test you should make would be to measure the voltage at point A on either the balanced or the unbalanced ratio detector. If a signal is rectified in the detector and R1 is not shorted, there will be a negative voltage at point A. The value of this voltage will depend upon the value of the incoming signal.

Using one of your jumper wires, short capacitor C3. You will note that no voltage appears at point A and no signal is apparent in the output. Only four things can cause a loss of this rectified voltage at point A. They are, loss of incoming signal, failure of the tube, shorted or open resistor R1 or shorted capacitor C3. Once you have established the fact that no voltage is present at point A, you have localized the failure to the ratio detector or the sound i-f.

If the rectified voltage is present at point A, the next check is for dc voltage at point B. This voltage would disappear if there were an open circuit in coil L2 or a short circuit in capacitor C1 or resistor R2. If the rectified voltage is present at point B, you know that the failure in the circuit is between the detector and the loudspeaker. In this case you would use signal tracing methods through the audio amplifier.

If you disconnect one end of resistor R1 in either ratio detector, no audio output will be obtained. This is because there is no dc path between the two halves of the detector tube. In a few cases, leakage through C1, C2 and C3 may be great enough to give a high resistance dc path. In this case the audio will be very weak and distorted and the voltage at point A very low.

If you parallel R1 with a 10K-ohm resistor, you will find that noise pulses come through with the audio. This is because of the reduced time constant R1-C3. It is the long time constant of this resistor-capacitor combination which gives this circuit its immunity to noise impulses. Disconnecting one side of C3 to open this circuit will have exactly the same result; noise pulses will come through the same as in AM radio.

If one side of coil L3 is disconnected from the diode tube at the socket, the audio that comes through will be weak and distorted. The voltage at "A" will be reduced or missing, depending on which side of the coil is disconnected. The circuit no longer operates as a ratio detector but as an AM detector. This is slope detection and always results in noisy and distorted audio.

In the balanced ratio detector circuit shown in Fig. 20B, if either R1 or R2 becomes open the dc path around the rectifier and coil loop will be broken and no audio output will be obtained. If resistor R1 is shorted there will be no voltage at point A, but weak, noisy audio may be heard.

R3 and C4 in Fig. 20B are the de-emphasis net. The high frequencies are increased in the transmitter before they are broadcast. R3 and C4 reduce the level of the highs in the receiver output to compensate for this. If C4 becomes open, the audio will sound high and shrill.

Gated Beam Detector. If the receiver you are using for your practical training uses a gated beam FM detector, there are several experimental tests you can make on this

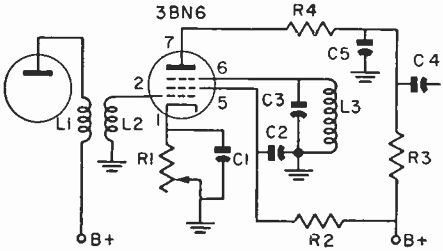


FIG. 21. Gated beam FM detector.

unit. Your "gimmick" capacitor can be connected across coil L3. This will detune the circuit and result in noisy, distorted detection or no intelligible audio at all. The effect of the change will depend upon the exact value of the capacitor you place across it. Failure of this tube can also be simulated by removing the lead from resistor R2 to pin 5 on the tube socket shown in Fig. 21. This will remove the screen voltage from the tube and will simulate a tube failure.

If your receiver uses an audio circuit such as that shown in Fig. 7, where the cathode return of the audio amplifier tube is through the i-f stages, you may disconnect the lead from the screen of the audio amplifier tube. This will greatly reduce the plate current through the audio amplifier tube and will simulate the loss of emission in the audio tube. You should note very carefully the effect on the picture, on the sweeps, and on the audio while making this change. The failure of this tube will give the same effects as a B+ power supply failure.

SYNC CIRCUITS

In order to reproduce the picture on a home receiver, the beam of the picture tube must be deflected across the screen exactly in step with the beam of the camera tube at the transmitter. The necessary information to assure this condition is transmitted along with the picture information. In order to use this information it must be separated from the picture forming signal, and the horizontal and vertical sync pulses must be separated from each other. These jobs are performed in the sync circuits.

Fig. 22 shows a typical sync separator-amplifier circuit. The sync information is separated from the picture information in the two triodes V1 and V2. The horizontal and vertical sync pulses are separated from each other in wave-shaping networks. The resistive-capacitive network composed of R1, R2 and R3, and C1, C2 and C3, pass the vertical sync pulses but block the horizontal passed in the differentiator circuit pulses. The vertical pulses are eliminated and the horizontal pulses C4-R4.

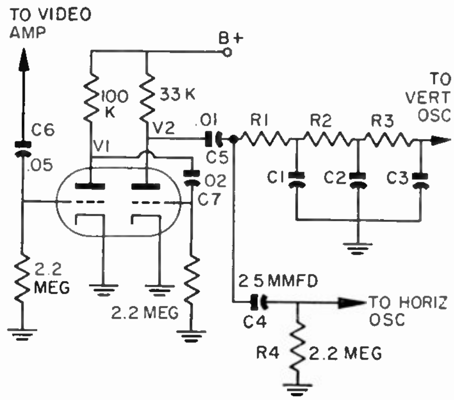


FIG. 22. Sync separator-amplifier circuit with differentiator and integrator networks.

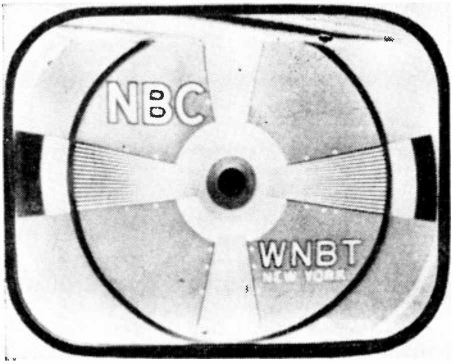
The first part of your practical training described the operation of V1 and V2 in removing the video information from the sync pulses. We will not go into that again here.

As in all electronic equipment, the most common failure is the failure of tubes. If the cathode emission of either tube becomes low, the clipping action will be incomplete and part of the video information will be transmitted to the oscillators. This video information can trigger the sweep oscillators at the wrong time and destroy the picture synchronization.

If the signal arriving from the video amplifier is weak it will also make the clipping action incomplete. It is possible to simulate this condition by changing the value of capacitor C6 from .05 mfd to .005 mfd. In addition to reducing the over-all signal level this change will reduce the vertical pulses more than the horizontal pulses. Changing this capacitor may cause the vertical to roll without having any great effect on the horizontal. The exact effect will depend largely upon the particular receiver and the condition of its tubes and other components.

Incomplete clipping action can also be obtained by connecting a 100,000-ohm resistor across the 2.2 meg resistor between the grid of triode V1 and ground. This will reduce the bias on this section and allow considerable video information to get through. The same effect would be obtained by shunting the 100,000-ohm resistor across the 2.2 meg resistor between the grid of the second section and ground. The effect of this change would be most apparent on the horizontal. This would probably cause tearing of the picture if not complete inability to lock the horizontal oscillator. This is shown in Fig. 23.

Complete loss of emission of either



Courtesy of RCA

FIG. 23. Horizontal tearing.

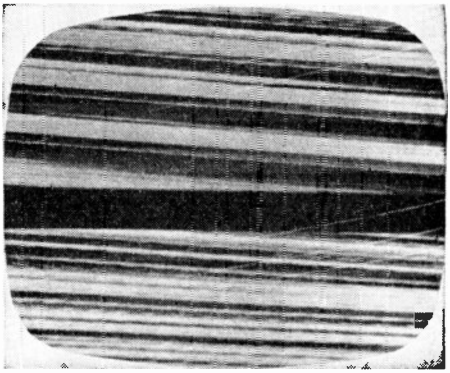


FIG. 24. No horizontal or vertical sync.

section of this triode can be simulated by connecting a .05-mfd, 600-volt capacitor between plate and ground of either section. This would block all sync pulses and would cause complete loss of sync as in Fig. 24. Reduction of the value of either of the two plate resistors would increase the voltage on the plate of that particular stage and would also reduce the clipping action.

If any of the three capacitors C1, C2 or C3 become shorted to ground, vertical sync pulses will no longer arrive at the oscillator and the vertical oscillator will not lock in. A short in capacitor C1 would also reduce the height of the horizontal sync pulse and cause complete loss of sync. A reduction in the value of capacitors C5 and C7 would tend to make the vertical oscillator unstable.

In servicing defects in the sync separator-amplifier circuits, an oscilloscope is almost a necessity. Effect-to-cause reasoning can lead you to these circuits, but it cannot always distinguish between the sync separator circuit and the individual sweep oscillators. The shape of the waveform is as important as the amplitude of the pulses in these circuits. Servicing is much more rapid and systematic when an oscilloscope is used to observe the waveforms throughout the circuits.

This discussion of these circuits shows you that it is possible for failure in the sync circuit to have greater effect on either the vertical or the horizontal amplifier. In general, failure of this section will effect both the horizontal and the vertical. Because one oscillator may be affected more than the other it is frequently impossible in initial effect-to-cause reasoning to determine whether the failure has taken place in the sync circuits or in a sweep oscillator.

In cases of failure of both the horizontal and the vertical to lock with the incoming signal, it is safe to assume that the failure is in the sync circuits. You cannot, however, eliminate the possibility of a sync circuit fault, when only one of the two sweep oscillators will not lock.

SWEEP OSCILLATORS AND AMPLIFIERS

There are three parts to each of the sweep sections of any receiver. These parts are the sweep oscillator, the sweep amplifier, and the deflection coils. Each of these three parts is subject to its own characteristic failures. In some cases effect-to-cause reasoning will lead you directly to the faulty stage; in other cases it will lead you only to the over-all sweep section. In the latter case, it is necessary to check the operation of each stage of the circuit.

As in the case of the sync section, the most systematic way to test these circuits is by checking the waveform on an oscilloscope. It is possible, however, to make many tests by means of your vtvm, and in most cases to isolate the defect to one particular stage. Even when the oscilloscope is used for waveform analysis, it is generally necessary to use the vtvm in locating the particular component which is defective.

Nearly all of the sweep oscillators in use today in either horizontal or vertical circuits are variations of one of two types. These two types of oscillators are called the blocking oscillator and the multivibrator.

A third type of circuit was used as the horizontal oscillator in many of the very early television receivers. Since these were basically good receivers many of them are still found in use today. The variation used in this case was a sine wave oscillator at the horizontal rate. This sine wave oscillator was locked in frequency and phase with the incoming sync signals by means of an afc discriminator. The sine wave output of the oscillator was used to control a discharge tube which generated the necessary trapezoidal waveform.

To study the effects of failures we will consider each of the three types of oscillator circuits separately. Each of the examples given will have the proper component values for either horizontal or vertical sweep frequency. However, by changing the RC networks which control the frequency, it is possible to use these

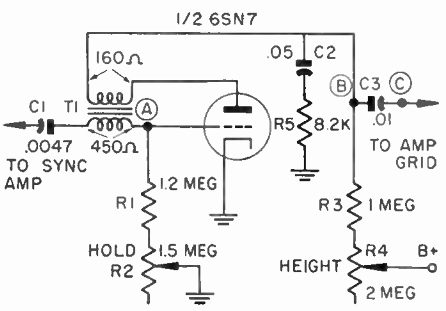


FIG. 25. Typical blocking oscillator sweep generator. Parts values shown are for vertical rate.

basic circuits at either frequency. The defects which would occur at one frequency are just as likely to occur at the other.

Blocking Oscillators. The blocking oscillator is the commonest form of vertical sweep generator. It uses relatively few parts and is quite simple to adjust. For this reason it is favored by many manufacturers. A simplified diagram of a typical blocking oscillator sweep generator is shown in Fig. 25.

Failure of this oscillator can be simulated by connecting a .05-mfd, 600-volt capacitor between point C and ground. This effectively short-circuits the output and will prevent any signal reaching the vertical amplifier. You will find when you do this that the only raster apparent on the face of the tube is a narrow horizontal line at the center of the tube. Do not leave the set operating in this condition for any length of time since an undeflected beam may damage the coating on the face of the tube.

When this condition is seen on a service call, effect-to-cause reasoning leads to the vertical sweep section. Two simple tests may be made at the vertical oscillator to determine whether or not it is working. The first test is to measure the voltage at point A. This voltage should be negative and its presence indicates oscillation. The only bias on this tube is obtained by feedback from the plate to the grid circuit through transformer T1, and rectification of this feedback signal between grid and cathode. If bias appears at point A, the tube must be in oscillation. The second test would be a waveform test with an oscilloscope at point B. This is a check on the output. A second check on the other side of capacitor C3 at point C would also show that the signal was reaching the amplifier grid.

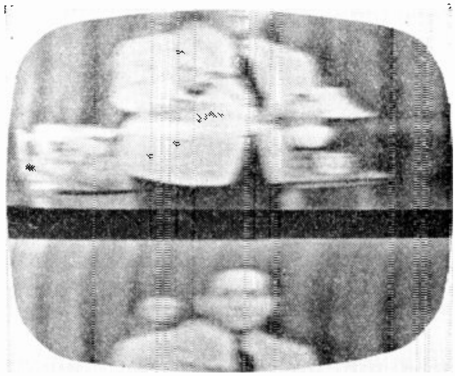


FIG. 26. Above: Vertical oscillator operating at half the correct frequency. Below: Vertical Oscillator operating at too high a frequency.

Any large change in the value of either capacitor C1 or resistors R1 and R2 will result in operation at the wrong frequency. If C1 becomes smaller the frequency will become greater; and if R1 and R2 become smaller the frequency will also become greater. Either of two simple changes in the circuit may be made to demonstrate this fact. One would be to connect a 1-megohm resistor between point A and ground. This would reduce the value of resistance

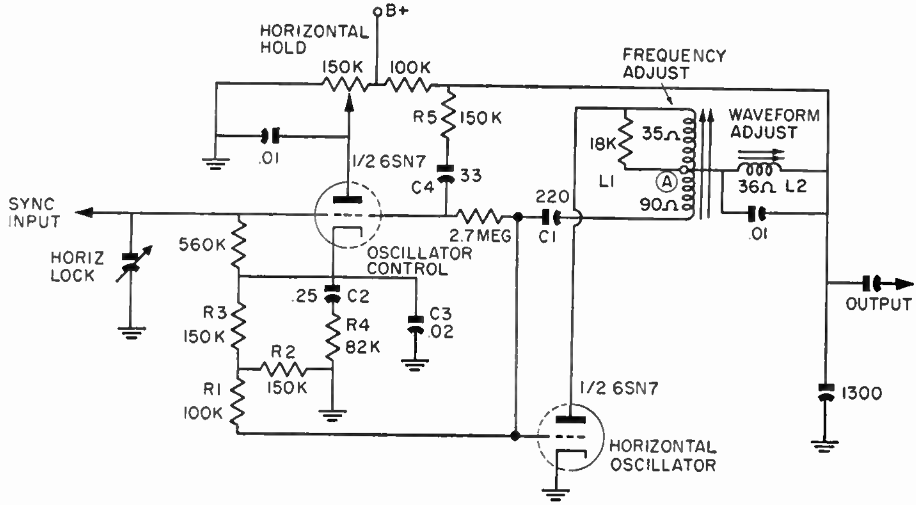


FIG. 27. Synchroguide horizontal sweep oscillator and control tube.

between point A and ground to half its normal value. It should be possible in this condition to adjust the hold control so that two pictures appear, one on top of the other, on the picture tube. The effect of making this change is shown below in Fig. 26. If capacitor C1 is removed and a capacitor of about .002 mfd is inserted in its place the same condition will be obtained.

Paralleling capacitor C1 with a .005-mfd capacitor will roughly halve the frequency at which the stage operates. This will result in two pictures one above the other on the picture tube as shown above in Fig. 26. An increase in value of R1 and R2 so that the total resistance to ground from point A is approximately doubled would lead to the same condition.

If either winding of transformer T1 becomes open, the circuit, of course, will not operate. A simple check for this would be by means of an ohmmeter across the terminals of each of the coils. If the primary winding is open, no plate voltage will appear. In some cases a failure of a blocking oscillator is due to internal shorts in one of the windings. This condition can generally be detected by an ohmmeter reading. The resistance of these windings is high enough that any short will be apparent by an ohmmeter check. If either winding of T1 shorts to the core, the oscillator will not work. This condition can also be checked with an ohmmeter.

It is possible that this oscillator may be working and still not be locked to the incoming picture. To determine whether or not sync pulses are arriving at the grid of the blocking oscillator you would remove the 6SN7 from its socket and check the waveform at point A with an oscilloscope. It is necessary to remove the tube or otherwise disable the blocking oscillator so that the pulse it generates at its grid will not mask the incoming sync pulse.

The condition of insufficient height of the picture could be due to an increase in resistance of either R3 or R4. A jumper around the 1-megohm resistor in the plate circuit could be used to simulate the reduction in resistance of either R3 or R4 and would result in a picture which was too high and non-linear.

Failure of resistor R5 would result in a non-linear vertical sweep. The resistor R5 is the wave-shaping resistor which changes the sawtooth wave which would normally be generated by capacitor C2 to the trapezoidal form necessary for magnetic sweeps. Connecting a shorting jumper across resistor R5 will show this effect on a picture tube screen.

This simple type of blocking oscillator has rarely been used for horizontal sweep generation. However, a common form of blocking oscillator used today as a horizontal sweep generator is shown in Fig. 27. This is the Synchroguide horizontal oscillator circuit. The frequency of this oscillator is controlled by the inductance of coil L1 and by the time constant of capacitor C1 and the resistors R1 and R2. Changing the value of this time constant can change the frequency of the oscillator.

This form of sweep oscillator is extremely stable over long periods of time. Changes in component values or loss of emission of the tubes, however, can cause it to fail. No detailed directions will be given here for any experiments on this circuit. It is quite difficult to set up properly, requiring the use of an oscilloscope. Manufacturers' instruction sheets for receivers using this type of circuit will always give the proper setup instructions.

There are four adjustments in this oscillator to obtain proper frequency and lock; all of these adjustments interact to a certain extent. The proper operation of the circuit is determined by observation of the picture and of the waveform appearing at point A as seen on an oscilloscope.

The effect of a complete failure of this oscillator can be simulated by connecting a .05-mfd capacitor across the output and ground. This will effectively block the sweep signal from the horizontal amplifier.

This circuit has appeared in sets of some manufacturers for a number

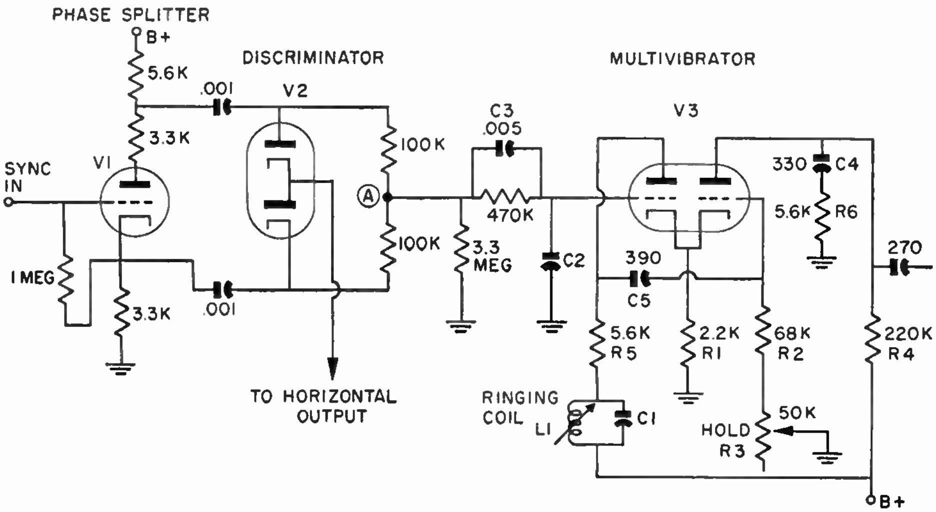


FIG. 28. Multivibrator horizontal sweep generator with phase detector afc.

of years. However, other manufacturers have avoided using it because of the difficulty in adjusting this oscillator in the field.

Multivibrator Sweep Generators. The most common form of horizontal sweep generator is shown in Fig. 28. The oscillator of this circuit is a cathode-coupled multivibrator. The operating frequency is determined by the time constant of capacitor C5 and resistors R5, R2, and R3. The tuned circuit L1-C1 is parallel-resonant at the oscillator frequency. The purpose of this circuit is to shape the wave appearing at the plate of the first section of the tube in order to give more positive lock with the incoming sync pulses.

This oscillator is maintained in sync with the incoming sync pulses by comparing the output of the oscillator, usually obtained at the horizontal output tube, with the incoming sync pulses. This comparison takes place in discriminator tube V2. If the output of the horizontal oscillator is not in phase with the incoming sync pulse, a voltage is built up at point A. This voltage is filtered through a low pass RC filter and applied to the grid of the first section of the multivibrator V3. Changing the bias of this section changes the conduction point of the tube and therefore the frequency of the oscillator.

The time constant of the multivibrator may be altered by connecting a 400-mmf capacitor across capacitor C5. This will lower the frequency of the oscillator. The frequency of the oscillator may be increased by connecting a 100,000-ohm resistor across resistors R2 and R3 to ground.

You can simulate the effect of a failure of the discriminator circuit by shorting across capacitor C2 to ground. This will remove the dc control voltage from the grid of the first section of V3. The multivibrator will continue to operate, but the frequency will be incorrect and it will be impossible to lock the picture on the screen. An open in either of the capacitors between the phase splitter and the discriminator tube can be simulated by opening the circuit at that point. Again the multivibrator will operate, but it will be impossible to bring it to the correct frequency. Loss of sync pulses may be simulated by removing tube V1 or disconnecting the lead to its grid.

It is also possible to simulate a failure of the oscillator by shorting across resistor R1, the common cathode resistor. This resistor is necessary to provide feedback from the second section of V3 to the first section. The oscillator will not work without this resistor. Connecting a short across resistor R6 to ground will cause nonlinearity of the horizontal sweeps. Resistor R6 performs the same job as the similar resistor in the blocking oscillator; that is, it transforms the sawtooth wave into the trapezoid necessary for linear magnetic deflection.

Once effect-to-cause reasoning has led you to one of these stages, voltage checks on all tubes and resistance readings of the components will generally find the faulty part very quickly.

The description here has been for a horizontal sweep generator system. However, a few sets have used multivibrators for the vertical sweep generator. When a multivibrator is used for vertical sweep generation the discriminator, V2, and phase splitter,

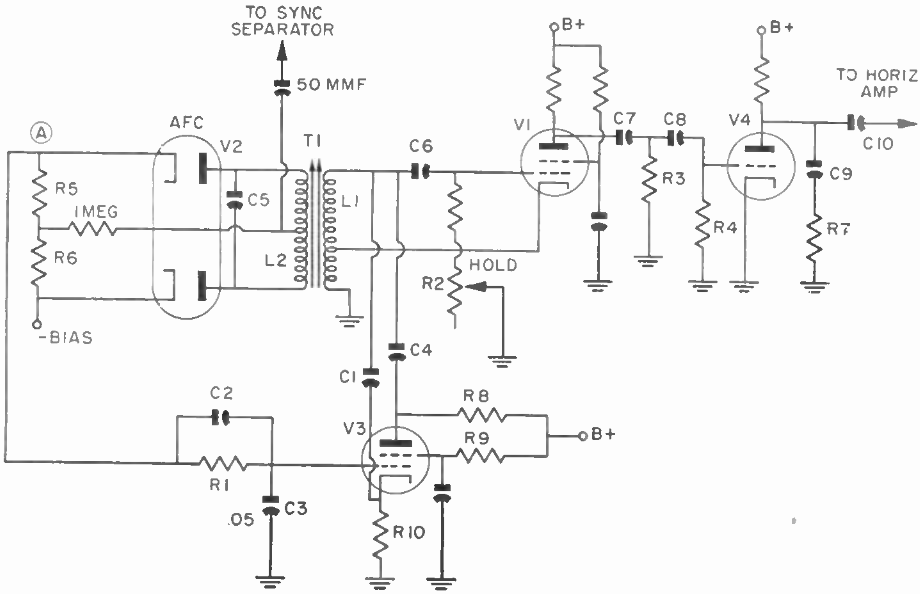


FIG. 29. Simplified circuit of a sine wave horizontal sweep generator.

V1, are not used and the resonant circuit L1-C1 is not necessary. The output of the sync separator-amplifier stage is coupled directly to the grid of the first triode section through the integrator network. It is possible to use the received sync pulses to control a vertical oscillator directly, since its lower frequency makes it much easier to sync. The more complex methods are necessary only at the line frequency.

Sine Wave Sweep Generator. This very common circuit appeared in many of the early TV sets. It is extremely stable and locks well under conditions of high noise level. A simplified diagram of the circuit is shown in Fig. 29. In this circuit, tube V1 is a sine wave oscillator. The frequency is determined by the resonant frequency of coil L1 and capacitor C1. Small variations in frequency can be made by adjusting resistor R2 in the grid circuit of the oscillator which is of the Hartley form with the screen of the tube acting as the plate of the oscillator. The tube is operated so that the positive peaks of the sine wave are flattened at the plate of V1. This flattened sine wave is then passed through a differentiator composed of capacitor C7 and resistor R3, and capacitor C8 and resistor R4. This differentiator changes the flat-top sine into a sharp spike which is used to trigger the discharge tube V4.

A portion of the signal in the oscillator grid circuit is coupled from coil L1 to coil L2 of transformer T1. This signal is applied in push-pull to the two plates of the afc tube V2. At the same time sync pulses obtained from the sync separator through a differentiating network are applied in parallel to the two plates of the tube V2. When the sine wave coupled from the oscillator to the afc tube is of the same frequency and in proper phase with the sync pulses arriving from the sync separator, the voltages across resistors R5 and R6 are equal and opposite. The voltages then cancel each other and the only voltage appearing at point A is that due to the negative bias. This bias is applied through a low-pass filter, composed of resistor R1 and capacitors C2 and C3, to the grid of V3. This tube is connected across coil L1 to ground in such a manner that it acts as a reactance across the coil. The presence of this reactance changes the frequency of oscillation from the natural resonant frequency of L1 and C1 alone. The amount of reactance represented by V3 is changed by changing the mutual conductance of tube V3. This change in mutual conductance is accomplished by varying the bias on the first grid.

There are two horizontal frequency adjustments here; one, the inductance of coil L1 is changed by moving the core, and the other is the resistor in the grid of the oscillator. Coil L1 is set to the proper frequency with the hold control at its mid-point, then the hold control is adjusted for best stability. Any change in oscillator frequency will change the potential at point A and hence the bias and mutual conductance of V3. This change in mutual conductance changes the effective reactance due to V3 changing the tuning of the oscillator circuit to bring it into lock with the incoming sync pulses.

In this circuit, failure of V1, of course, stops all oscillation. Failure of V2 or V3 will make it impossible to lock the horizontal oscillator with the incoming picture.

If the set which you are using for your practical training uses this type of oscillator you have already experimented with adjustments of coil L1 and the horizontal hold control R2. You can simulate failure of tube V2 by removing it from the socket. In this case it will be impossible to maintain the horizontal oscillator in lock. Likewise the failure of V3 may be simulated by removing this tube from the socket.

For proper operation, resistors R5 and R6 should be nearly equal. If you shunt either one of these resistors with a 100,000-ohm resistor the circuit will become unbalanced and the bias on tube V3 will be changed. This change in bias on V3 will shift the frequency of oscillator V1, and the picture will no longer be locked on the screen.

In this circuit V4 is the sweep discharge tube. Capacitor C9 and resistor R7 form the wave-shaping net. It is possible to simulate the failure of tube V4 by removing it from its socket.

Shorting across either capacitor C7 or C8 will modify the waveform of the signal appearing on tube V4 and leads to horizontal tearing in the picture.

The large value of capacitor C3 makes this circuit relatively immune to noise. If this capacitor becomes open, noise pulses will be able to get to the grid of tube V3 and cause momentary changes in the frequency of the oscillator. This condition will result in several lines of the picture being torn out each time a noise pulse is received. Disconnecting one end of this capacitor will show you the effect on the screen of the tube.

A change in value of resistors R8 or R9 will change the mutual conductance at which tube V3 operates. If this change is great enough, it may

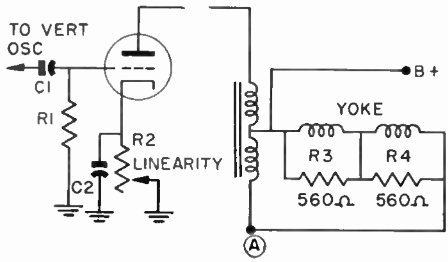


FIG. 30. Vertical sweep amplifier using an auto-transformer for impedance matching.

be impossible to lock the oscillator with the incoming signals without readjusting L1. This condition could be simulated by shunting either of these resistors with a 50,000-ohm resistor. This increases the voltage on that tube element. An increase in value of resistor R10 in the cathode circuit of V3 will also change the mutual conductance of the tube but in the opposite direction.

This resistor is also part of the phase-shift net which is used to make V3 act like a reactance across the tank circuit. So a change in value of this resistor could detune the grid of V1 even if the actual conductance of V3 did not change. In practice this resistor may be found either open or shorted.

Vertical Sweep Amplifier. The vertical sweep amplifier used in most TV sets uses the same circuit arrangement and many of the same components as a single-ended audio amplifier. In practically every case the output of the amplifier will be coupled to the deflection yokes by means of a transformer. This transformer is necessary to match the relatively low impedance of the deflection yokes to the higher impedance of the tube plate. A typical circuit, which uses an auto transformer for impedance matching, is shown in Fig. 30.

This circuit is simple and straightforward and practically all failures in this circuit are easy to locate and correct. One common failure is that coupling capacitor C1 becomes leaky. To show the effect that this has on the circuit, connect a 1-megohm resistor across capacitor C1. This will place a positive voltage on the grid of the tube, and distortion of the sweep will result. Fig. 31 shows the effect on the picture of this distortion which appears as nonlinearity. The simplest method to check within the stage for this fault is to measure the voltage at the grid of the tube. In a normally operating stage there is no voltage, either positive or negative, present; if capacitor C1 is leaky, a positive voltage will appear at the grid of the tube.

A second possible cause of difficulty in this tube is due to a heater-to-cathode short within the tube. You can simulate this condition in a receiver using parallel-connected filaments, by connecting a short jumper wire between the cathode and the grounded side of the heater. The effect of this short is to remove resistor R2 from the circuit and re-

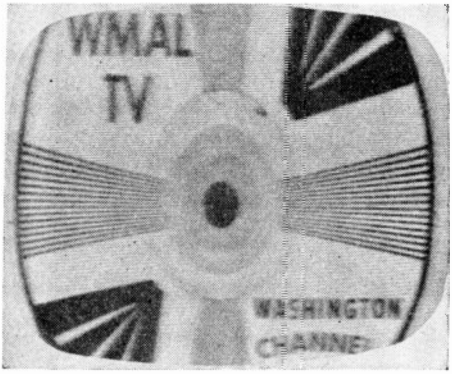


FIG. 31. Non-linearity of vertical sweep caused by leaky coupling capacitor between vertical oscillator and vertical amplifier.

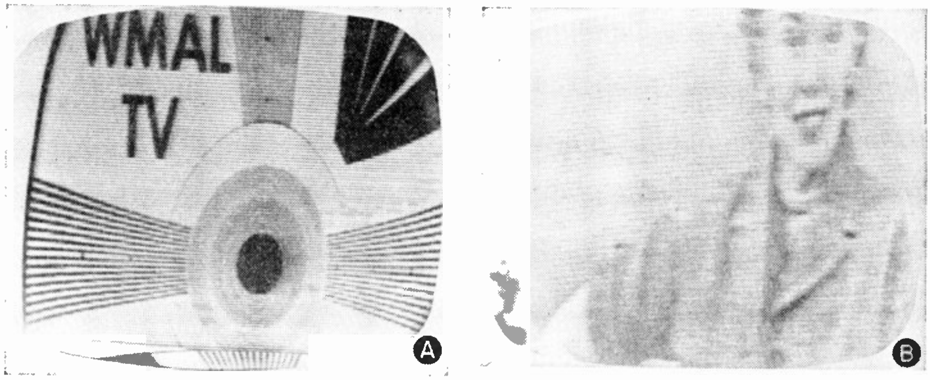


FIG. 32. Picture distortion caused by heater-to-cathode short in vertical amplifier.

move the bias from the tube. Changing the operating point of the tube in this manner increases the height of the picture and causes distortion of the sweeps. The effect of this short and the distortion of the sweeps it causes is shown in Fig. 32.

Internal shorts sometimes occur in the output transformer. You can show the effect of these by connecting a short-circuiting jumper across either winding of the transformer. The result in either case will be a complete loss of vertical sweep. Do not operate the set long in this condition since the narrow horizontal line may burn the face of the tube and ruin it.

If you connect a short across either section of the yoke you will obtain a picture similar to that in Fig. 33. You will have full width but the height will be reduced and the picture will be trapezoidal in shape. The broader side of the trapezoid may occur on either the left or the right-hand side of the picture and will depend on which section of the yoke is shorted. Shorts of this type are relatively common in home receivers.

Occasionally the damping resistors across the yoke will become open. This will cause ringing in the vertical circuit. The condition can be simulated by disconnecting one end of one of the resistors at the yoke.

If you have an oscilloscope you might like to check the current waveform through the yokes. To do this it is necessary to break the deflection yoke circuit at point A on the schematic of Fig. 30. Insert a 5- to 10-ohm resistor so that it is in series with the yoke lead and the transformer winding. When you connect your oscilloscope across this resistor the waveform that you see will be the current wave through the yoke. One caution in performing this experiment, however—in the circuit

FIG. 33. Trapezoidal sweep resulting from a short across one section of vertical deflection coil.

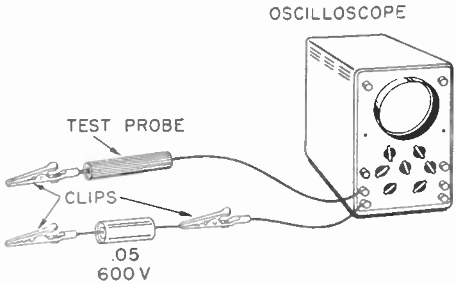


FIG. 34. Capacitor added to ground return lead of oscilloscope to keep set B+ off oscilloscope chassis and cabinet.

shown in Fig. 30, B+ is present at both sides of the yoke. In order to prevent this B+ from flowing to the chassis of your oscilloscope on the ground lead, it will be necessary to connect a .05-mfd, 600-volt capacitor in series with ground lead from the oscilloscope. The proper method of making this connection is shown in Fig. 34.

In some cases capacitor C1 between the vertical oscillator and the vertical amplifier will become open. When this happens there will be no drive on the amplifier grid and no output at the yoke. Effect-to-cause reasoning will lead you to the vertical sweep section but will not tell you which section has failed. The tests that you perform on the vertical oscillator will show that the oscillator is working. However, no dc voltage measurements on the amplifier tube will detect the presence of the signal. It will be necessary to make a measurement with an ac voltmeter at the grid of the tube to show whether or not the sweep signal is applied to this stage.

Many forms of distortion of the raster are possible due to changes in value of components in both the vertical oscillator and the vertical amplifier. To locate these quickly, or to study the effect of these changes, it is necesary to use an oscilloscope to observe the waveforms at various points through the two stages. All cases of troubleshooting in the sync and sweep circuits of a television receiver are greatly speeded up by the use of an oscilloscope for waveform observation.

Horizontal Sweep Amplifier. The horizontal sweep amplifier and its output circuits are probably the most complex in a TV set. This stage not only provides the horizontal sweeps but also the high voltage for the pic-

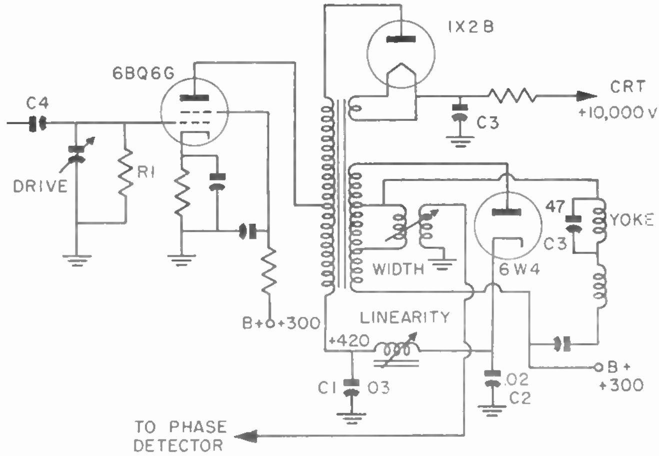


FIG. 35. Horizontal amplifier showing damping circuit and hi-voltage rectifier.

ture tube and an increased B+ which is used on the horizontal amplifier plates and in some cases on the vertical amplifier and oscillator. From this stage also is obtained the comparison signal used in the horizontal phase detector for controlling the frequency of the vertical sweeps. Fig. 35 shows a typical circuit.

When performing experiments on this stage it is necessary to observe all safety precautions. Before making any circuit changes, turn the equipment off and discharge all filter capacitors.

Do not touch the horizontal amplifier tube, the high voltage rectifier, the picture tube, or the horizontal output transformer while the receiver is operating.

Do not connect the oscilloscope to the receiver or move the scope input lead from one circuit to another while the power is on.

Discharge the high voltage filter capacitor and the picture tube before handling the picture tube or working on the high voltage circuits. In these high voltage circuits, do not expect to completely discharge a filter capacitor by merely shorting it once quickly with a screwdriver. It is necessary to short it two or three times before the capacitor is completely discharged. For your own safety and the safety of your test equipment, one of the most important experiments you can perform on this stage of your receiver is to shut off the power and then short the filter capacitor two or three times and note that a spark can be drawn at least twice.

The voltage generated across the output transformer of this stage is very high. However, due to the nature of the circuit, its current is very low. In spite of the high voltage, it is unlikely that the current this power supply can provide would be sufficient to cause death or even serious injury. However, the accelerating anode of the picture tube and the filter capacitor of the high voltage power supply are both capable of storing a large charge at high voltage. When they discharge rapidly, the current from them can be very high; if this discharge were passed through your hand, the current could easily be enough to temporarily paralyze your hand.

The danger of working around this circuit when it is in operation is stressed, not to give you the impression that it is unsafe to work on, but to impress upon you the necessity for taking all possible safety precautions. If proper precautions are taken, this circuit is as safe to work on as a flashlight.

Partial failure or low emission of the horizontal sweep amplifier tube may cause a number of secondary effects in the receiver. The direct effect, of course, would be a reduction in the horizontal sweeps. The possible secondary effects are reduced brightness in the picture and even reduced vertical sweep. The output of this tube provides the pulses from which the high voltage is obtained and also a portion of this output is added to the B+ in order to boost the voltage at the plate of the tube. In some sets this boosted voltage is also applied to the vertical sweep amplifier tube. If the horizontal sweep amplifier tube loses its emission, its output becomes low and the plate voltage supplied to the vertical sweep amplifier will also be low. This will cause a reduction in vertical sweeps as well as a reduction in pic-

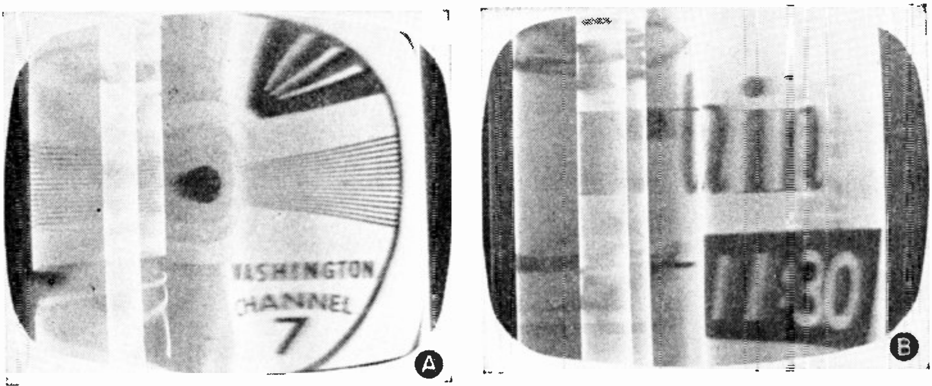


FIG. 36. Picture distortion caused by open capacitor at input of linearity coil filter.

ture intensity.

There are a number of non-operating adjustments in this circuit. In the first part of your practical training you experimented with each of these and noted the effect on the picture tube.

Reduced emission of the high voltage rectifier tube will lead to a low accelerating potential on the picture tube and this in turn will give low brightness pictures. The best test for this reduced voltage is to measure the high voltage at the picture tube.

Reduced emission in the damper tube of this circuit can give reduced boosted B+. You can simulate reduced emission in this tube if your set uses parallel filaments, by placing a 1- or 2-ohm, 1-watt resistor in series with one side of the filament. This will effectively reduce the cathode temperature and limit the emission of the tube.

It is not unusual in circuits of this type for capacitors C1 or C2 to become open. If you disconnect one side of capacitor C2 you will find that the boosted B+ voltage is reduced, the picture becomes quite narrow and has foldover on the left-hand side. The effect of this foldover is shown in Fig. 36. A check of the voltage at the cathode of the damper tube or at the far side of the linearity coil will show reduced boosted B+.

If capacitor C1 becomes open, the picture will become quite non-linear and will be compressed on the right. This effect is shown in Fig. 37. You learned in the discussion of this circuit in the first part of your practical training, that capacitors C1 and C2, together with the linearity coil, form a low-pass filter and phase shift net. An open or large drop in value of either one of these capacitors will change the phase shift through the net and the peak plate voltage will not arrive at the horizontal sweep amplifier at the right time to obtain linearity.

Once effect-to-cause reasoning tells you that either the horizontal oscillator or horizontal amplifier has failed, one quick check to localize the stage in which the difficulty occurs is to measure the dc voltage appearing at the grid of the horizontal sweep amplifier. This tube is over-driven and the grid goes positive with respect to the cathode during a portion of the sweep cycle. During

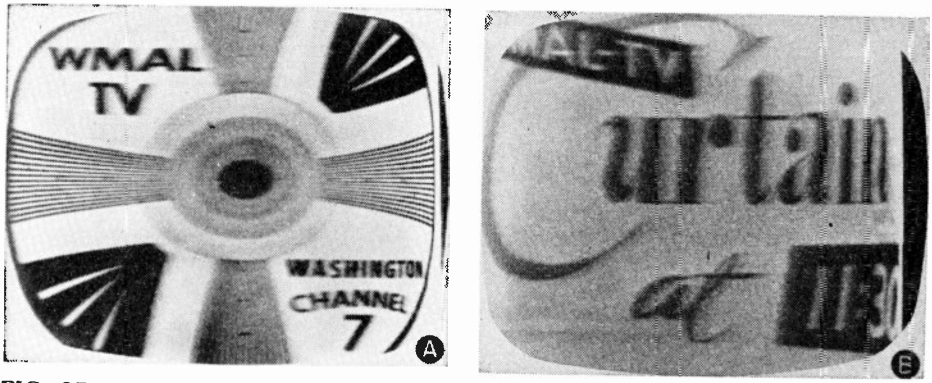


FIG. 37. Picture distortion due to open capacitor at output of linearity coil filter.

the time the grid is positive, rectification between the grid and cathode takes place and a negative voltage is built up at the grid of the tube across the grid resistor R1. If the tube is being driven, this voltage will appear. In the absence of drive, the grid of the sweep amplifier tube will be at ground potential.

In cases of complete failure of the horizontal sweep section, it is possible to localize the trouble to one stage and to a particular component or tube by tube substitution and voltage and resistance measurements in the circuit. However, in cases of horizontal sweep distortion it is usually necessary to use an oscilloscope to observe the waveforms in the various parts of the circuit. The presence of a sweep signal can always be detected by an ac voltmeter, but this measurement gives you no indication of the peak amplitude or shape of the wave. In some cases there may be a large change in the value of a component, and in this case it would be possible to detect the failure by voltage or resistance measurements. However, in most cases slight changes in values, too small to be detected by voltage and resistance measurements, can cause a large distortion of the raster. As in the case of the vertical sweep amplifier, there is no substitute for a good oscilloscope in checking the horizontal sweep circuits.

PICTURE TUBE CIRCUITS

The cathode-ray picture tube is subject to the same defects as any other type of vacuum tube. This tube may fail due to a burned-out filament, loss of emission from the cathode, or inter-electrode shorts. Any of these defects will have a definite effect on the picture and most of them will result in either no picture or no raster.

It is possible to check the emission of a picture tube either with a special picture tube tester or by means of an adapter which can be used with an emission type of receiving tube checker. A quick first check of the tube can be made by simply observing whether or not the filament of the tube glows. However, if the tube has been in use for some time, the fact that the filament glows is not a guarantee that there is emission or that there is no interelectrode short within the tube.

Any check of the cathode-ray tube circuits should include a check for proper operating voltages on all elements of the tube gun. These voltage checks not only assure you that the tube has proper operating potentials applied but also serves as a check for interelectrode shorts. Many interelectrode shorts in picture tubes as well as receiver tubes do not show up until the tube filament is heated or until anode voltages are applied. This type of intermittent short will, however, change the voltages on the elements of the picture tube gun.

There are two ways in which the video signal may be applied to the picture tube; these are on the cathode and on the grid. The usual way is on the cathode. Figs. 38A and 38B show a picture tube directly coupled to the plate of the video amplifier and a picture tube capacitively coupled to the video amplifier plate. You will note that in the case of direct coupling the brightness of the tube is controlled by varying the grid potential. Both the cathode and the grid are above ground but the cathode is at the higher positive voltage.

In the direct-coupled circuit, any variation in current through resistor R1 and the video amplifier tube will change the voltage at the cathode of the picture tube. If the video amplifier draws excessive plate current, the voltage drop through resistor R1 will become excessive and the voltage on the cathode will be reduced. If the brightness control is not changed, the reduction of voltage on the cathode will reduce the bias on the grid and the tube will become much brighter. On the other hand, if the current passed by the video amplifier becomes less than normal, the bias on the grid of the picture tube will become greater and the brightness will be reduced.

In some receivers the video detector is direct-coupled to the video amplifier and the video amplifier is direct-coupled to the cathode of the picture tube. In this case, changes in incoming signal strength will change the brightness of the picture tube. As the incoming signal changes, the rectified component appearing across the detector load resistor will change; this changes the bias on the video amplifier. As the bias changes on the video amplifier, the plate voltage on the amplifier is changed. This change in dc level is amplified by the video tube. For this reason,

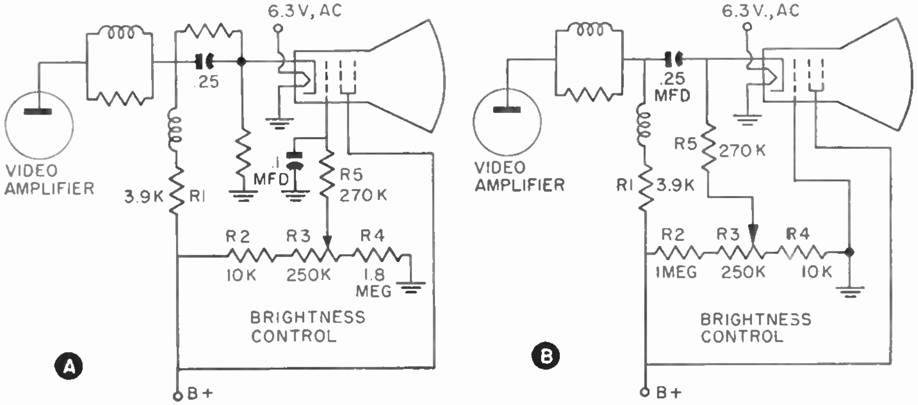


FIG. 38. (A) direct-coupled picture tube showing brightness control connections. (B) Capacitively-coupled picture tube showing brightness control.

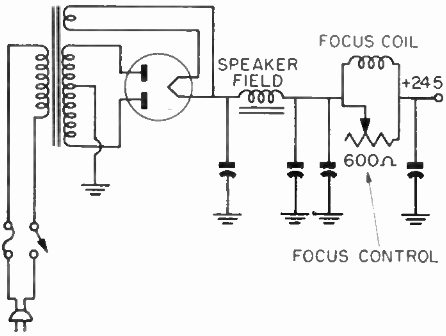


FIG. 39. Focus coil connected in series with high side of power supply.

a very small change in incoming signal strength can cause a large change at the cathode of the picture tube. In a circuit of this type it is necessary to readjust the brightness control when tuning from station to station.

In the capacitively-coupled circuit, the brightness is controlled by varying the bias on the cathode, holding it positive with respect to ground. The grid in this case is grounded and hence is more negative than the cathode. In this circuit, variations in video amplifier plate current have no effect whatsoever on the brightness.

Occasionally a complaint is made by a receiver owner that it is impossible to control brightness with the brightness control. This complaint is in many cases due to an internal short in the cathode-ray tube. The best way of detecting this type of short is by means of voltage measurements at the socket of the cathode-ray tube while varying the brightness control.

Many of the earlier receivers used electromagnetic focus picture tubes. The focus coil for these tubes requires around 100 milliamperes for proper operation. The operating current for these coils was normally obtained by connecting the focus coil in series with the high side of the power supply as shown in Fig. 39, or by connecting the focus coil between the chassis ground and the center tap of the power transformer. The second connection, which is shown in Fig. 40, was frequently used when a source of low negative voltage was required for the receiver. The voltage drop across the focus coil and its control were used as a bias source. In both of these circuits the focus coil is paralleled by a variable resistor. This connection divides the load current between the focus coil and the focus control. As the focus control resistance is reduced, less current is passed through the focus coil.

In some sets it may be impossible to achieve proper focus at any setting of the focus control. This condition can be traced to either too much or too little load on the power supply. In the case of a low emission rectifier, there will not be enough current through the focus coil to achieve proper focus. In some cases leaky by-pass capacitors or even leaky filter capacitors draw excessive current from the power supply and it is impossible to reduce the current

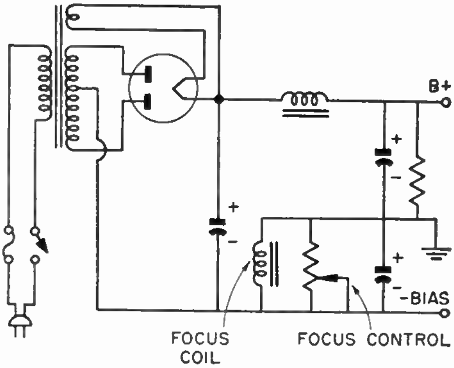


FIG. 40. Focus coil in transformer center tap as dropping resistor for bias supply.

through the focus coil sufficiently to achieve proper focus. In trouble of this type, it is necessary in almost every case to make point-to-point voltage checks to determine where the excess current is drawn. If the rectifier tube has low emission, the B+ voltage will be low and the current will be low.

EXTERNAL TROUBLE

All cases of poor picture are not caused by failure of the TV receiver. Troubles outside the set can also cause poor reception. These outside troubles may be divided into three groups: (1) power source troubles, (2) antenna troubles, and (3) outside interference.

In the section of this book on power supply troubles, it was suggested that you check the ac power source in all cases of dead sets. Where a set appears to have weak pictures for no good cause the power source may also be at fault. In some cases, a set will be taken into the shop for repair with a complaint of weak pictures or poor sync, the set is worked over in the shop and some minor difficulties are found and the set is brought to perfect working condition. Then the set is returned to the home and it is found that it does not operate satisfactorily. This would indicate that either the power line voltage was low at the home or that the antenna was poor. The check for this would be to test the ac line voltage and to make an inspection of the antenna and lead-in systems. It is possible also to check the antenna system by temporarily erecting a second antenna and using that with the set.

Occasionally a customer will complain that a set works fine all day but doesn't work well in the evening. This, in many cases, is due to poor line voltage regulation. During the evening the lights of the house are on and the electrical appliances are in use and draw considerable current. This higher drain will frequently overload the house electrical wiring causing a loss in line voltage at the set. Low line voltage will have the same effect upon a receiver as low B supply voltage.

Occasionally the complaint will be made that there are black streaks or horizontal tearing in a receiver during a windstorm. In most cases, complaints of this type can be traced to loose connections in the antenna or lead-in.

There are many types of outside interference which can destroy picture reception. Automobile ignition interference, interference from radio stations, FM stations, other TV receivers, or amateur stations can all spoil a picture.

ADDITIONAL EXPERIMENTS

You need not limit your experiments to the instructions given here. You may note the effects of a failure in every part in your set if you wish, but if you conduct experiments in addition to those given in these instructions be sure to follow a cautious experimental method. A shorted component may be simulated easily by connecting a jumper across the part and an open may be simulated by disconnecting the part. A change in the value of a part may be simulated by adding another component in series or in shunt, depending on whether you wish an increase or a decrease in value. Shunt a resistor to decrease its value and connect another resistor in series with it to increase its value. The opposite is true of a capacitor—shunt to increase and connect in series to decrease its value.

The general method for conducting additional experiments is as outlined in the following step-by-step procedure:

1. Select the part in which you desire to simulate a defect.
2. Carefully analyze your circuit diagram to make certain that the introduction of defects will not cause damage to any other parts in the set. For example, shunting filaments or series voltage dropping resistors in a filament string may place excessive voltage on other filaments and burn them out.
3. Try to determine in your circuit analysis what effect the introduced defect will have on the picture or sound.
4. If you have determined that it will not cause damage to other parts of the set, introduce the defect and observe its effect.
5. If the effect is different from what you expected, recheck the schematic diagram to see if you can find out why.
6. Remove the defect and restore the set to normal operation.

By following the procedure given above you can gain maximum benefit from any additional experiments you may wish to make, and you can make them without damaging your set. However, it is recommended that you perform as many of the experiments given in this manual as you can before you attempt to devise additional ones of your own. The experience gained in conducting the regular experiments will be of great help to you in devising additional ones.

Hints on the use of the oscilloscope were given in some sections of this book. If you did not have an oscilloscope available when you did these experiments, you should repeat all the experiments in the video detector and amplifier, and in the sync and sweep circuits using an oscilloscope, as soon as you can obtain one. You will use an oscilloscope constantly in your service work. Your practical training is not complete until you are familiar with circuit checking by means of waveforms.

LOOKING AHEAD

By performing the experiments in this book, you will be able to acquire in a few short months the same practical experience in the servicing of television receivers that you would get in several years of apprenticeship in a television repair shop.

Many servicemen waste a great deal of time servicing TV receivers because they fail to realize immediately in what circuit a defect is located. It is not always possible to study the performance of the receiver and then decide definitely that the trouble is in one circuit or another. However, in most cases it is possible to decide that the trouble must be in one of two or three different stages.

You might be able to isolate the trouble immediately to one stage. If this is possible, so much the better. The smaller the section of the receiver to which you can isolate the trouble, the better off you will be.

After you have applied effect-to cause reasoning and isolated the trouble to as small a section of the receiver as possible, you should select a test instrument to isolate the trouble further. If you are able to isolate the defect to the vertical sweep circuit, you have two stages to check. Probably the easiest thing would be first to use your oscilloscope to check the output of the vertical oscillator. With the oscilloscope, you should be able to quickly isolate the trouble to either the oscillator or the amplifier stage. On the other hand, if you can definitely isolate the trouble to the vertical oscillator from the performance of the receiver, you should not need the oscilloscope, and you should start right in taking voltage and resistance measurements.

When you can isolate the trouble to one stage by effect-to-cause reasoning before you start the actual work on the receiver, take a few extra minutes and try to determine what parts in that stage could be causing the trouble. Try to figure out what could be wrong with the components that would cause the type of trouble you have encountered. The small amount of extra time you spend in analyzing the performance will be well worth while and will usually cut down the total time you must spend to repair the receiver.

There are servicemen who go to another extreme. They use effect to-cause reasoning to isolate the trouble to one stage or possibly a group of two or three stages, and then instead of going ahead from that point and trying to isolate the trouble rapidly to one part, they waste too much time confirming their diagnosis by trying different tests. Avoid falling into this habit of over-testing. Try to develop the habit of using a servicing procedure that follows a logical sequence, and avoid overlapping tests. For example, if you check a receiver and discover that you have voltage on one side of a coil and no voltage on the other side of the coil, you have a pretty good idea that the coil is defective. If after removing the coil and installing a new one in the receiver, the receiver operates, you can be sure that the coil was defective. That should be the end of it as far as the coil is concerned, but many servicemen will waste time performing elaborate tests on the coil they removed from the receiver. There is no point in making tests of this type. The fact that the new coil cleared up the trouble, indicates that the old coil was causing the trouble, and any further study that you may make of it is simply a waste of time insofar as the repair of the receiver is concerned. This may seem like a small thing, but if you embark on a project of this type each time you repair a receiver, you may find that at the end of a day you have fixed only five or six sets, when it might have been possible for you to fix seven or eight. The more work you can turn out, and the more sets you can repair, the more you will earn.

Don't let your practical training stop here. Spend a little extra time on each new circuit you see. Make sure you understand it thoroughly. The time you save on other sets with the same circuit will more than make up for the extra time on the first one.

Study new circuits as they are developed. Learn to analyze circuits for yourself. If you wish, perform experiments just as you did on your training receiver. Above all, be systematic and thorough when trouble-shooting.

LEARNING NEVER ENDS

More and more it becomes evident that learning is a continuous process—that it is impossible to break the habit of studying without slipping backward. Look around you at all the marvelous developments of the last twenty years. You have the advantage of having "grown up" with them—yet I'll bet that there are many things you wish you knew more about. Then, consider what can happen in the years ahead if you do not keep abreast of the stream of new things that are bound to come!

Your NRI Course is preparing you for the problems of today and tomorrow, but what about the day after tomorrow? In five or ten years, will you still be up-to-date? Yes, if you plan your future. Resolve now—that you WILL keep up. You have the fundamentals; keep them fresh in your mind by constantly reviewing. Read and study technical literature and textbooks; join in discussion groups and listen to lectures; take advantage of every possible educational opportunity. Then, and only then, can you face the future unafraid, no matter what technical developments the future may hold.

J. E. Smith

TELEVISION SYNCHRONIZING CIRCUITS

56B

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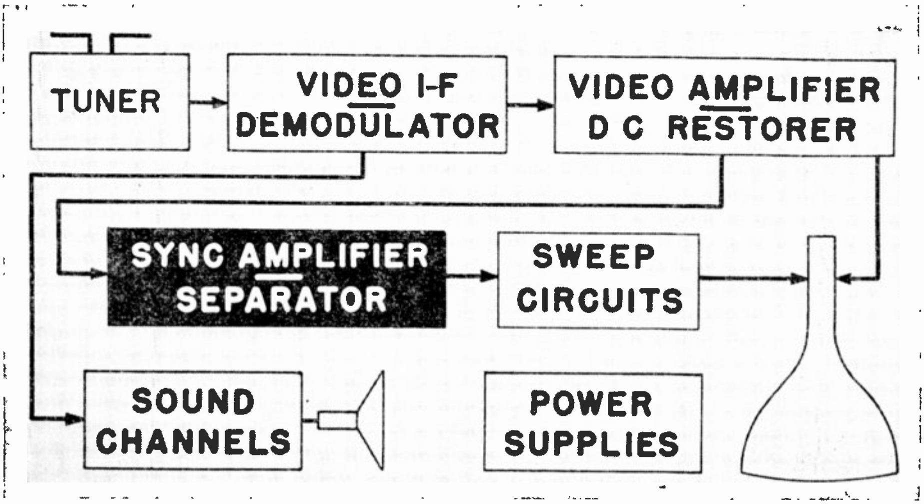

TELEVISION pictures are reproduced on the picture tube screen in a definite orderly manner—element by element, and line by line. To reproduce the original scene faithfully, the scanning beam, which paints the picture on the picture tube screen, must follow exactly the path taken by the scanning beam of the camera tube at the station. The camera tube scanning beam releases the picture information in a definite orderly sequence. The scanning beam at the receiver that is reproducing the picture must be synchronized with the scanning beam at the camera tube. The synchronizing or timing information is sent in the form of pulses, which are called the horizontal and vertical synchronizing pulses. These pulses are used to control the receiver circuits that generate the sweeps, which move the electron beam over the face of the picture tube.

In previous lessons you have followed the television signal from the antenna to the grid of the picture tube. You have also studied sweep circuits. You learned that the signal applied to the grid or the cathode of the picture tube contains video and blanking information, and modulates, *but does not move*, the electron beam. The movement of the electron beam is controlled by the energy developed in the form of sawtooth currents in the horizontal and vertical deflection coils. This motion *must be synchronized* by the sync pulses from the station. Consequently, the television signal present in the video amplifier is also applied to the sync amplifier-separator circuit. The synchronizing circuits must extract the sync pulses from the composite video signal, and prepare them properly for synchronizing and controlling the sweep generating circuits of the receiver.

A number of operations must be performed to separate and shape the pulses for control of the sweep generators. A block diagram of this section of a TV set is shown in Fig. 1. First, the composite video signal must be fed from some takeoff point in the video amplifier to the sync separator. The sync removal must not disturb the operation and frequency response of the video amplifier. Next, the sync is separated completely from the video and blanking signal. In succeeding amplifier and clipper stages, the sync pulses are leveled (the base line and sync tip levels are made flat and free of video information) and made as free of noise impulses as possible. Leveling or clipping at the top and bottom gives the same amount of stable synchronization regardless of the strength of the received signal.

sync amplifiers after the sync segregating circuits, before the individual sync pulses are applied to the sweep oscillators.

The final step in the synchronizing process is to use the pulses to control the sweep generators. As you have already learned, the sweep generators are free-running; they generate the sawtooth currents that deflect the electron beam, whether sync pulses are present or not. Thus, the scanning

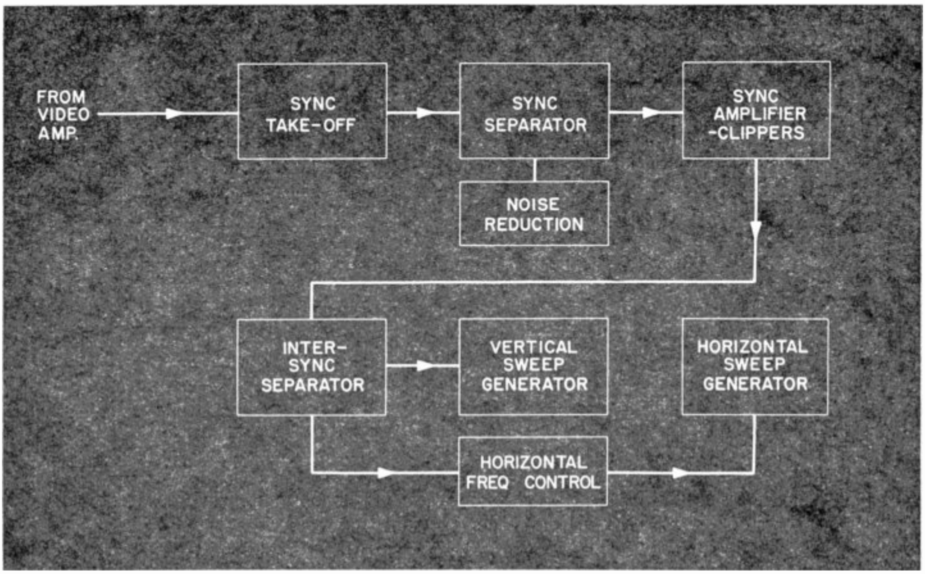

FIG. 1. Functional block diagram of synchronizing circuits.

The next step in the preparation of the sync pulses is to segregate the horizontal components from the vertical components. This must be done so that the vertical sync pulses will go to the vertical sweep generator, and the horizontal sync pulses to the horizontal sweep generator. Clean segregation prevents interaction between horizontal and vertical components, and minimizes the influence of noise impulses on both synchronizing circuits. Sometimes there are additional

raster is always present, but only with the arrival of the sync pulses does the raster lock in so the scanning beam moves in exact synchronism with the scanning beam at the camera. *It is important to realize that the sync pulses do not themselves cause the scanning beam to move, but only control the frequency and timing of the waveforms that do move the scanning beam.*

The expert technician does not consider the operation of circuits and the

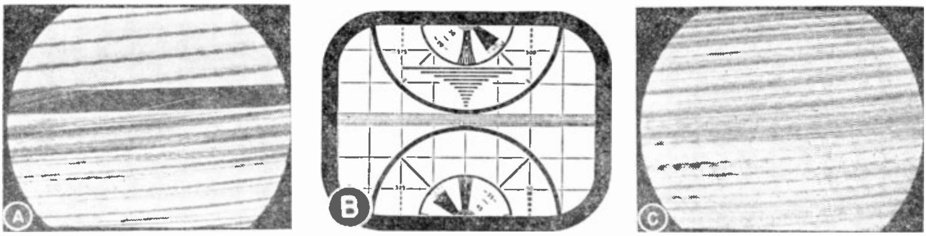

FIG. 2. Sync circuit defects. A, loss of horizontal and vertical sync; B, loss of vertical sync; C, loss of horizontal sync.

servicing of circuits separately. It is his understanding of circuits that permits him to identify and repair defects rapidly. He must therefore train his thoughts to associate the operation of a circuit with the effects of trouble within that circuit and the influence such defects have on over-all operation of the receiver. For example, at this very point and with only a limited knowledge of the sync circuits, your *fundamental understanding of the reasons for having the sync circuits would permit you to isolate trouble to the sync circuit.* If there is a failure in the sync circuit, the horizontal and vertical sawtooth generating circuits will run free, wandering in frequency and phase with respect to the incoming video information, as shown in Fig. 2A. A failure in the sync circuit does not in any way affect the video and blanking information applied to the grid circuit of the picture tube. Therefore, the scanning beam will still be modulated by the video information and will cause brightness variations on the picture tube screen.

If the sync circuit defect affects just one of the sync signals, the disturbance on the screen will guide you to it. For example, if the defect is in the vertical synchronization, the picture *will roll,* as shown in Fig. 2B, and although it will be possible to adjust the vertical hold control to lock in the picture vertically, the picture will soon drop out of vertical synchronization, but it will remain synchronized horizontally. If the defect is in the horizontal synchronizing section only, the picture will remain locked in vertically, but *will tear out* horizontally as in Fig. 2C.

SYNC CIRCUIT WAVEFORMS

To gain more complete understanding of the general operation of the sync circuits, let us study the typical waveforms shown in Fig. 3. First the sync information along with an appreciable level of blanking and video information is removed at a convenient point in the video amplifier and applied to the sync circuit. This composite signal fed to the sync separator is shown in Fig. 3A. Next, the composite signal is applied to the sync separator, which almost completely removes all signal information below the blanking level so that only the sync pulses remain, as in Fig. 3B.

In the composite signal, the amplitude of the synchronizing information is greater than that of the video and blanking information. For example, in Fig. 3E, if the amplitude of the combined horizontal sync and blanking signal is 20 volts at the input to the sync separator, the sync information itself, which is just the upper 25% of the total signal, is only a five-volt peak component. In the process of *sync separation* the rest of the signal (video and blanking) is dropped, leaving only the sync pulses at the output of the separator.

Succeeding amplifier stages remove any extraneous signal and properly flatten both the tips of the pulses and the base line to a prescribed voltage level, which is reasonably constant for a wide variation in applied signal strength.

Now the combined sync information (horizontal and vertical sync pulses) is applied to a sync segregator or inter-sync separator that separates the horizontal from the vertical sync information. One section selects the horizontal pulses from the combined information and, at the same time, blocks out the vertical pulses. A second section accepts the vertical pulses and rejects the horizontal. Finally, the horizontal and vertical information is properly shaped and used to control the frequency and phase of the sweep oscillators.

The location of defects in the sync circuit is a task that can be performed well by an oscilloscope. The disap-

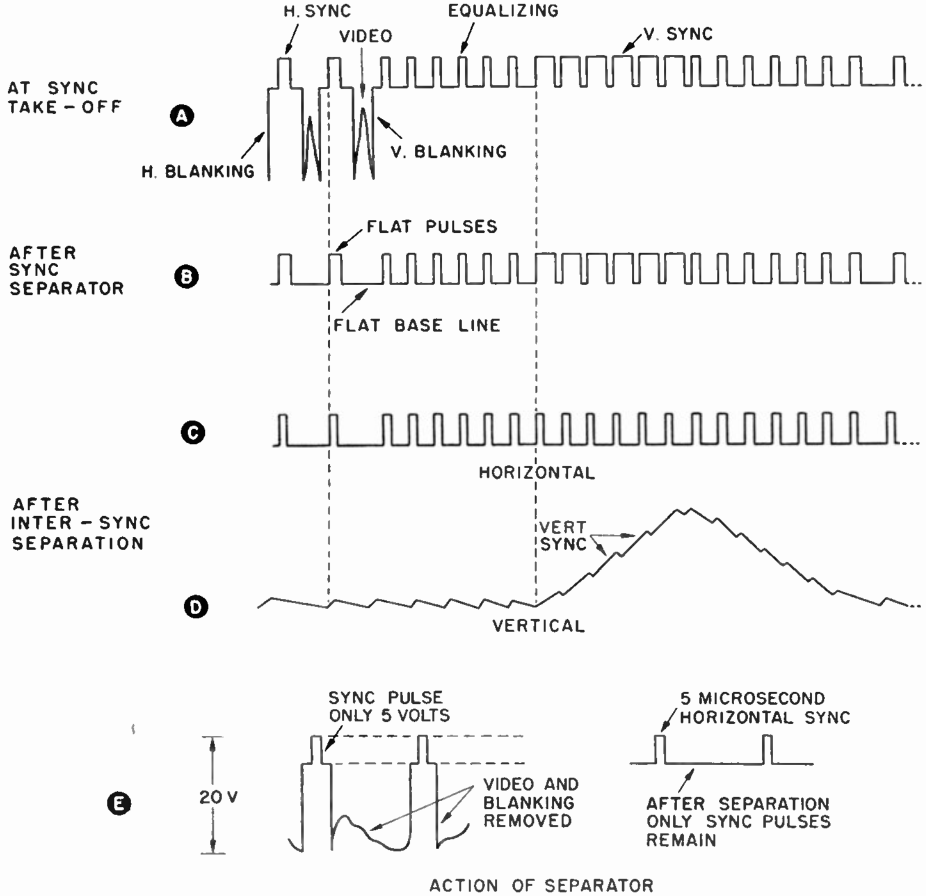

FIG. 3. Sync circuit activities as shown by waveforms.

pearance, reduction in amplitude, or change in shape of various waveforms can be observed at key points. You should remember, however, when using an oscilloscope in the sync circuits, that the sync information itself is of very low amplitude and can often be obscured by the higher voltage deflection waveforms that are also present in the latter sections of the synchronizing system. Thus, in signal tracing through the latter sections of the sync system, it is preferable to turn off or remove the sweep generating tubes. For example, it is not possible to check for the presence of the vertical sync pulse at the grid of the vertical blocking oscillator when it is operating, because the waveform produced by the blocking oscillator is much higher in amplitude than the vertical sync pulse.

SYNC TAKE-OFF

Let us now consider the individual functions of the various sections of the sync circuits in detail, starting with the removal of the synchronizing information at the take-off point in the video amplifier.

The signal in the video amplifier of the receiver is shown in Fig. 3A. It contains the picture information that is used to vary the brightness of the spot, as well as the horizontal and vertical blanking pedestals. On top of the blanking pedestals ride the synchronizing pulses. There is one set of pulses for horizontal or line synchronization, and a second set for vertical or frame synchronization. A portion of this composite video signal must be supplied to the sync circuits from the take-off point without any deterioration of the video information passing through the video amplifier to the picture tube.

There must be no loss of the high-frequency components of the video information, which determine the picture detail. Some typical sync take-off methods are shown in Fig. 4. They demonstrate the use of isolating resistors to prevent deterioration of the high-frequency response of the video amplifier. Resistor R1, in each example shown, prevents the input capacity of the sync separator circuits from causing high-frequency loss in the video amplifier stage.

Of course, the presence of the series resistor between the video amplifier and the sync circuit input causes attenuation of the video signal. However, this is not important, because the video signal at the point of take-off in the video amplifier is higher in amplitude than required by the input circuit of the sync stages. If the sync take-off is at the video detector, as in Fig. 4C, the sync information is often applied to an amplifier before separation, to compensate for the weaker signal amplitude at the output of the video detector compared to that at the output of one of the video amplifier stages.

In circuit 4A the sync information is removed at the junction of the shunt peaking coil and the plate load resistor. It is applied to the grid of the sync separator through an isolating resistor and a noise-filter network. In the take-off system shown in Fig. 4B, the sync information from the video amplifier is separated into individual horizontal and vertical sync channels. Again, an isolating resistor is used in each circuit to reduce the influence of the input capacities of the sync amplifiers on the high-frequency components of the video signal passing through the video amplifier. Also, there is a noise reduction filter

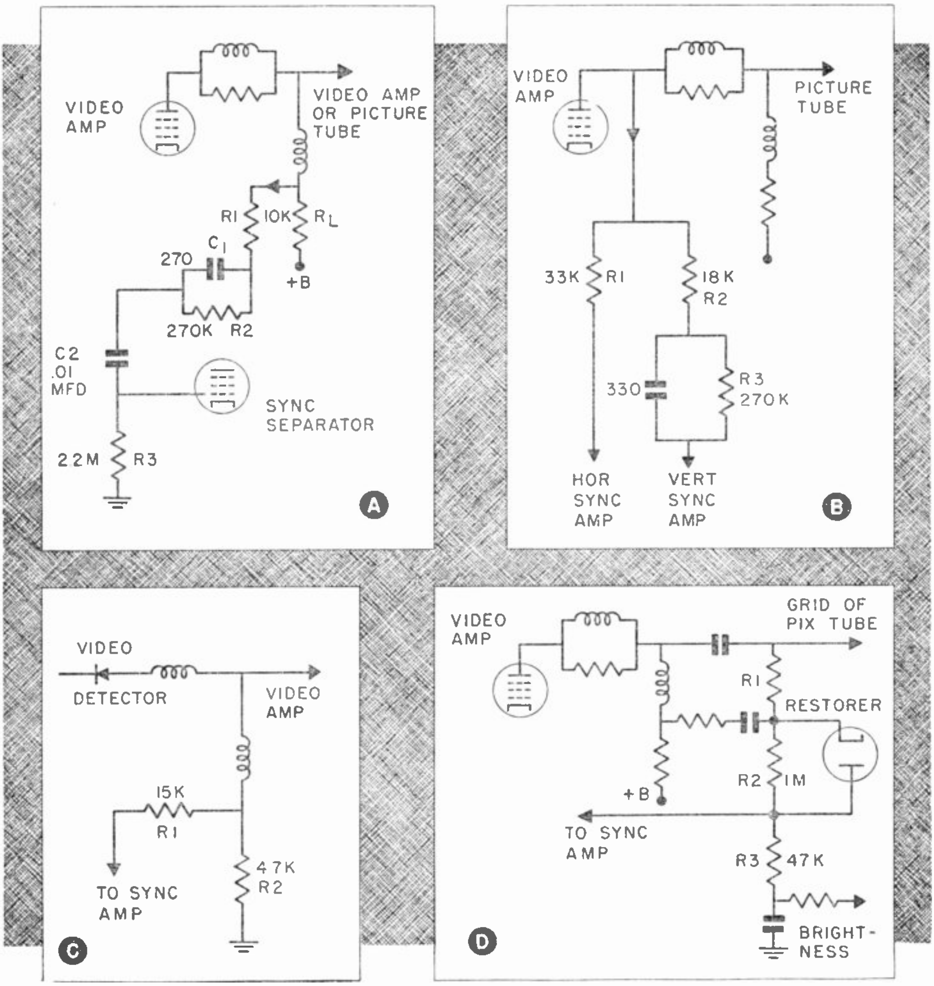

FIG. 4. Sync take-off methods.

in the signal path to the vertical sync amplifier.

In the take-off system shown in Fig. 4C, the sync information is removed from across the diode load resistor and applied to a sync amplifier through an isolating resistor.

In the three systems mentioned, both the sync and the video information at the take-off point are applied to the first synchronizing stage. However, the presence of the isolating resistor and network reduces the amplitude of this signal. Therefore, if you are tracing the signal with an oscilloscope, you can expect the amplitude of the composite signal at the input of the sync circuit to be about 1/3 to 1/4 the original amplitude at the take-off point.

The fourth take-off method, shown in Fig. 4D, is used in some of the older receivers with dc restorers. In this system, the synchronizing information is removed from resistor R3 inserted between the plate of the dc restorer and the return to the brightness control. Resistor R1 isolates the capacity of both the restorer circuit and the sync amplifier input circuit from the video amplifier. At the same time, resistor R1 serves as a dc return path for the grid circuit of the picture tube. Because of the non-linear characteristics of the restorer diode and the fact that the current change through resistor R3 is greater during the sync pulse intervals, the amplitude of the signal between blanking and sync tip is greater than between blanking and the white level of the video information. Thus, the sync pulse is emphasized before its application to the sync separator.

SYNC SEPARATOR

After the composite video signal is taken from the video amplifier it is fed to the sync separator. The sync separator must remove the portion of the composite television signal below the blanking level so that the only signal appearing in the output will be the sync pulses. Sync separators can be diodes, triodes, or pentodes.

The sync separator is biased to permit the tube to conduct only on the portion of the composite signal between blanking and sync tip. If the applied signals were of a constant amplitude, this separation could be accomplished with the use of external bias as indicated in Fig. 5A. For example, if the applied video signal were of a constant 12-volt amplitude, and the cut-off bias for the tube were —3 volts, it would be possible to set the bias far enough beyond cut-off with a battery or another external bias source so the tube would conduct only on the portion above the blanking level. Thus, a pulse would appear in the output of the separator for each

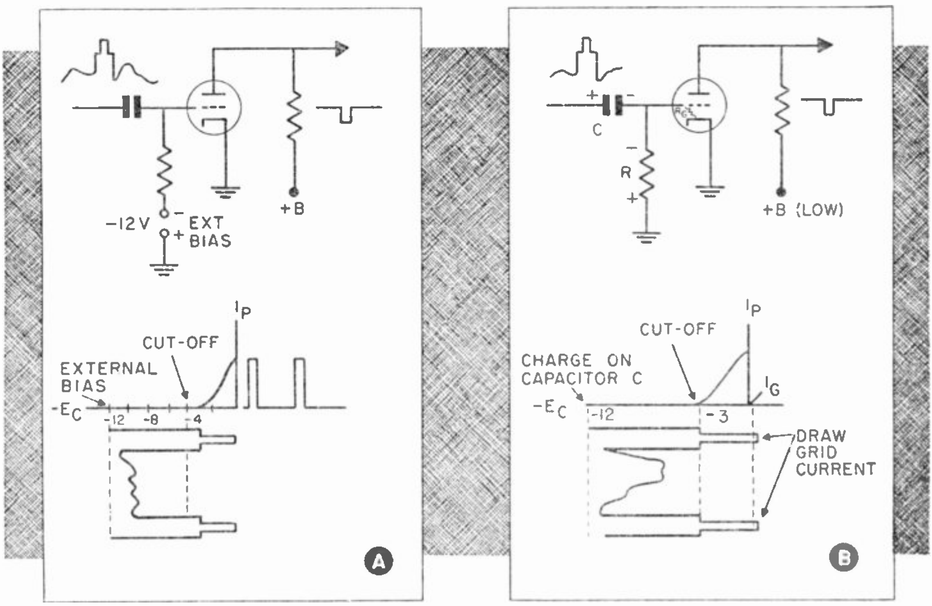

FIG. 5. Operation of triode sync separator.

arriving sync pulse, and the other information below blanking level would not be present, because the signal would not be strong enough to drive the tube into the region of plate current flow.

However, the television signal amplitude changes in accordance with the received signal strength and with the average brightness of the picture. Consequently, the external bias system is not able to accommodate the range of signal level variation. Some method of signal-biasing must be used to obtain true sync clipping.

When signal bias is used, the amplitude of the sync pulses sets the separator bias as shown in Fig. 5B. When the sync pulse drives the grid positive, the stage draws grid current, which charges capacitor C with the polarity shown. The charge is placed on the capacitor very quickly because of the fast time constant of the grid capacitor C and the low grid-to-cathode resistance of the tube. This resistance can be as low as 1,000 ohms in a triode drawing grid current.

With an applied 12-volt peak signal, the grid current flow charges capacitor C to 12 volts. When the pulse is ended, the grid current ceases, and the capacitor begins to discharge. Because the grid current flow has stopped, the capacitor must discharge through the high value grid resistor, R. The discharge time constant, however, is so long that only a slight discharge occurs before the next sync pulse comes along and recharges the capacitor to 12 volts with another burst of grid current. As a result, the charge on the capacitor has an average dc value near 12 volts and the stage has been "signal biased."

With the proper choice of circuit values, and a low value of plate voltage, the *tube cut-off bias can be set at —3 volts.* It is important to note that the charge on capacitor C has the stage biased beyond cut-off. As a result, the tube plate current flow cannot start until the applied signal is more positive than 9 volts. (The bias on the tube is 12 volts, which is 9 volts beyond cut-off bias. Therefore, the signal must have an amplitude of at least 9 volts to drive the grid to the region of plate current flow.)

The applied signal in Fig. 5B *does not reach beyond positive 9 volts except during the sync pulse.* Consequently plate current flows only during the sync pulse time when the signal is between 9 and 12 volts. The flow of plate current reduces the plate voltage during the sync pulse time, and develops a negative sync pulse in the output.

In television transmission, the dc component of signal bias varies with

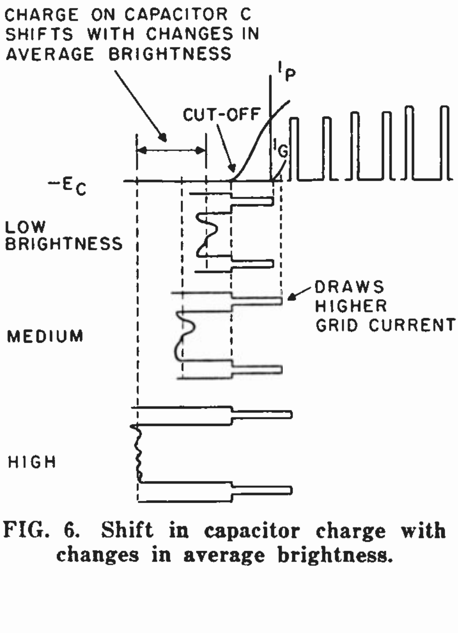

FIG. 6. Shift in capacitor charge with changes in average brightness.

the strength of the incoming composite signal as shown in Fig. 6. The operation of the sync separator is quite similar to that of a dc restorer, because the actual bias placed on the grid capacitor is dependent on the peak amplitude of the sync tip.

Actually, the charge placed on the capacitor by grid current flow forms the dc bias of the separator stage. This bias is established by each arriving sync pulse and is held constant between sync pulses (when grid current is no longer drawn) by the much longer time constant of the capacitor and the large value grid resistor. If the amplitude of the composite video signal decreases (as with a decrease in average brightness) the charge on the capacitor becomes less negative, keeping the blanking level at cut-off as shown in Fig. 6. When the amplitude of the composite signal increases with an increase in average brightness, the negative charge on the capacitor increases, and maintains the blanking level constant. Thus, as you can see, with the signal bias system, the dc component of the bias changes, but the dc levels of the blanking and sync tip remain constant. As a result, the self-bias separator is self-compensating over a substantial range of amplitude changes in the incoming signal. It maintains a sync pulse of essentially constant amplitude at the output of the separator, and removes all portions of the video signal below the blanking level.

The blanking level will be properly positioned at cut-off bias if the amplitude of the signal is high enough and if the correct plate voltage is applied. The amplitude of the applied signal must be sufficient to drive the tube substantially beyond cut-off and cause the blanking level to be at cut-

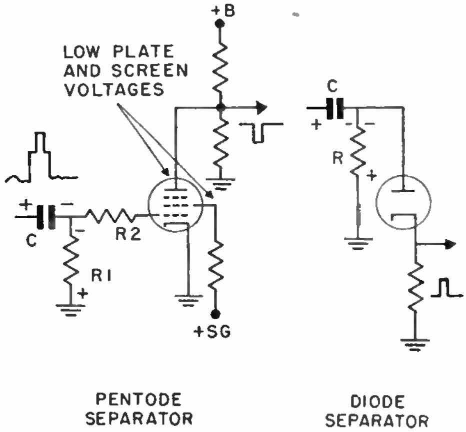

FIG. 7. Pentode and diode separators.

off. If possible, the sync tip level should be near saturation. For the limited change in amplitude that accompanies variations in average brightness, the separator will be self-regulating and will keep the amplitude of the sync pulse output constant.

The plate voltage on the separator is generally lower than for normal operation. A low plate voltage permits cut-off earlier, or at a low negative voltage, giving a narrower voltage range between cut-off and saturation, which permits better clipping and a more constant pulse amplitude at the output.

A signal-biased pentode is shown in Fig. 7. This stage is an excellent sync separator when the plate and screen voltages are low. Again, the grid current drawn during the sync tip interval sets the bias on the tube at the proper level to cut off all portions of the signal below the blanking level.

A pentode separator will work well because there is a narrow grid voltage range, just a few volts between cut-off and saturation. It also produces a strong output signal that is constant for a wide range of applied signal amplitudes. The sync pulse developed in the plate circuit depends on the grid voltage change between cut-off and the positive grid voltage at which grid limiting occurs. Thus, if the plate voltage is held constant, the sync amplitude in the plate circuit also remains constant, despite substantial variations in peak signal amplitude at the separator grid. In addition, the better limiting action in the grid circuit of a pentode operating with low screen and plate voltages means that any noise impulses greater in amplitude than the sync tip are clipped off, minimizing improper synchronization of the deflection generators.

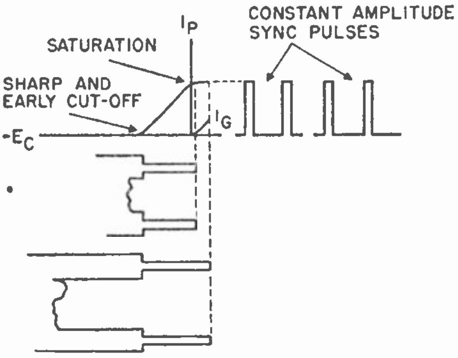

FIG. 8. Pulse clipping by pentode separator.

The advantages of both early cut-off and early saturation are demonstrated in Fig. 8. As you can see, the sync pulses will cause plate current flow, but reach an early saturation amplitude where any further rise in grid voltage will cause no additional increase in plate current. Therefore any variation in sync tip level is leveled off, and the sync voltage output remains constant.

A series resistor, R2 in Fig. 7, is often added between the grid and the grid resistor to produce an instantaneous opposing voltage whenever very strong noise pulses reach the grid of the separator. This instantaneous opposition to grid current flow prevents the grid capacitor from being charged to an excessively high value of bias by noise bursts. Such a high bias could result in the loss of a number of the succeeding sync pulses, and produce sync instability.

Even the simple diode circuit shown in Fig. 7 can be used as a sync separator (as it was in a number of earlier receivers). When the positive-going composite signal is applied to the diode plate, the sync tip peak draws maximum diode current, charging capacitor C to a peak value. Again the charging of capacitor C is rapid because of the short time constant of the capacitor and the very low resistance of the conducting diode. Capacitor C discharges through resistor R, developing a voltage across the resistor having the polarity shown. This voltage biases the diode and prevents conduction when the signal falls below the blanking level. The only portion of the signal developed across the diode load resistor occurs when the diode is conducting. The diode conducts only for signal amplitudes higher than the blanking level, and therefore only the sync pulse itself appears across the diode load.

The disadvantages of the diode separator are that no amplification and only minor noise rejection are possible.

Noise Rejection In Sync Circuits

We have considered the source of sync take-off and actual removal of sync information from the composite video signal. Now let us consider the methods used to reduce the influence of noise in the sync separator and amplifier stages.

Two basic techniques are used singly or together to make synchronization less subject to noise interference. One method, called noise rejection, is to make certain that noise pulses greater in amplitude than the sync tips are removed and that noise pulses occurring between sync pulses do not trigger the sweep circuits erroneously. A second method of noise reduction uses the principle of cancellation. In this system, noise pulses are taken from two points in the receiver and then combined out of phase in a properly biased stage to cancel noise.

A DIODE-BIASED NOISE-REJECTING CIRCUIT

In the circuit shown in Fig. 9 a negative-going composite television signal is taken from across the diode load resistor R1. This signal is applied to the grid of the sync amplifier, which is the second section of tube V1 through an isolation network consisting of L1 and R2.

The composite signal is direct-coupled to the grid of the sync amplifier to prevent a shift in the blanking and sync tip levels with changes in average brightness. Since the sync pulses swing negative, a strong signal might drive the amplifier grid beyond cut-off during the sync pulse interval. To avoid this clipping of the sync pulse, the bias voltage for the sync amplifier is applied through a bleeder network consisting of resistors R1 to R7. The voltage divisions produced by the bleeder network are controlled by the first section of V1 to accommodate wide ranges of input signal level.

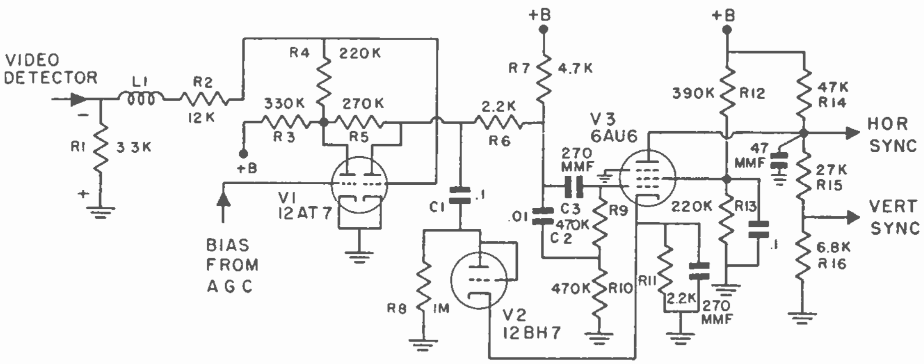

FIG. 9. A typical sync amplifier-sync separator circuit in which a diode is used for both noise reduction and noise cancellation.

The control tube is used in conjunction with the bleeder network to prevent strong signals from biasing the sync amplifier (second section of V1) close to or beyond cut-off. With negative-going sync pulses, a voltage having the polarity shown is developed across R1. Since the amplifier is direct-coupled to the video detector output, this voltage would be applied to the grid of the sync amplifier unless we took steps to prevent it. When the received signal is weak, the bias on the tube would not be high enough to cause any trouble. However, when a strong signal is received, the bias might be so high that the sync amplifier would be operating at or near cut-off. When the negative-going sync pulse reached the grid of the tube, it would drive it even further negative—it might drive it beyond cut-off. If this happened, the sync pulse would be clipped and would not appear in the output. Therefore, to prevent this, we use the first section of V1 as a control tube.

A negative bias from the agc line is applied to the grid of the first section of V1. When a strong signal is received, the bias applied to the control tube will be high and the tube will be driven to or near cut-off. When the control tube is not conducting or is conducting just a small amount of current, it permits the bleeder network to apply a positive potential to the grid of the sync amplifier (second section) to match the higher dc component of negative voltage developed across resistor R1 by a strong signal. This action makes it possible to have the proper bias on the amplifier grid to prevent clipping of the negative-going sync pulse. For a weak signal, the agc bias is less negative, and the sync control tube conducts a higher current. As a result, the voltage divider action is such that a less positive potential is applied to the grid to accommodate the less negative voltage drop across resistor R1. The control section of the sync stage, therefore, acts as an adjustable voltage divider that permits application of proper bias to the sync amplifier with respect to the level of the received signal.

A positive-going composite signal is developed across the sync amplifier load resistors R6 and R7. It is applied through capacitor C1 to a noise clipper stage, V2, and through a resistor-capacitor network to the grid of the sync separator tube, V3. The noise suppressor circuit acts as a diode clipper and removes noise impulses riding the top of the sync pulses. It also clips off any noise impulses that occur between sync tips and rise above the amplitude of the sync tips.

The arriving sync pulses cause the diode to conduct and charge capacitor C1 to peak value. The long time constant of capacitor C1 and resistor R8 prevents the capacitor from discharging between sync pulses when the diode is in a non-conducting state. Each sync pulse causes the diode to conduct to recharge capacitor C1. However, any pulses that exceed the level of the sync pulse either during or between sync pulses will cause the diode to conduct. This will clip the noise pulses to the level established by the sync pulses. Noise pulses therefore are clipped off prior to application of the composite signal to the grid of the sync separator.

To make the noise reduction action still more effective, a noise cancellation also exists. When a strong noise pulse arrives and causes the diode to conduct heavily, the diode current also develops this same pulse across resistor R11. This resistor, in addition to being the diode cathode resistor, also serves as the cathode resistor for the sync separator stage. Thus any positive noise pulse present in the composite signal and applied *to the grid* of the sync separator is further cancelled by the application of a similar positive pulse *to the cathode* of the same tube. Consequently, in our noise reduction circuit we not only have noise clipping but noise cancellation as well, to make the sync circuits more immune to arriving noise pulses.

A pentode sync separator is used in the circuit shown. It operates at low screen and plate voltage to permit early cut-off and effective removal of video information below the blanking level. The voltage divider arrangement consisting of resistors R12 through R16 determines the plate and screen-grid voltages and holds them constant at their low values despite the changes in tube current with changes in arriving signal levels at the grid of the separator. Thus the cut-off bias and the saturation level of the tube remain at fixed voltage levels. The clipping and amplitude of the sync pulse output remains uniform for variations in applied signal strength.

The positive-going composite signal is applied to the grid of the separator through a voltage divider consisting of capacitors C2 and C3 plus resistors R9 and R10. The purpose of the divider is to establish a fast enough time constant to permit the sync pulse tips to determine the average bias. At the same time, the time constant must be long enough to prevent differentiation of the vertical blanking pulse and consequent reduction in output level of the vertical synchronizing information. Thus the grid circuit network has almost a dual time constant.

When the tube draws grid current, the cathode-to-grid resistance is low. The time constant of C3 and the cathode-to-grid resistance of the tube is therefore low, and C3 can be charged rapidly by the sync pulses. The time constant of this same capacitor and the two resistors is sufficiently long so the charge might be held between arriving sync pulses. Insofar as the vertical blanking pulse is concerned, the input time constant would be too short if it were not for the presence of the large capacitor C2. The long time constant of C2 and resistor R10 prevents the drop-off of the vertical blanking level, which could result in a fall-off in the amplitude of the vertical sync pulses. Resistor R9 effectively isolates the two capacitors so that the large capacitor does not reduce the fast time-constant charge of the small capacitor, and the small capacitor cannot lower the time constant of the C2-R10 combination when the vertical blanking pulse is arriving. This divider input circuit, because it maintains the vertical synchronizing information at the proper level with respect to the horizontal sync, also makes the receiver more stable and less subject to noise interference during a reduced amplitude vertical sync period.

Two outputs are derived from the plate circuit of the sync separator, one to supply negative synchronizing information to the horizontal synchronizing system, and the other to supply it to the vertical synchronizing systems.

A NOISE-REDUCING SYNC SYSTEM

Another sync separation and noise-reducing system is shown schematically in Fig. 10. In this system, the composite signal is taken from two points in the video amplifier and applied to a 6BE6 sync separator and noise cancelling circuit. The actual sync separator segment uses the signal grid or second control grid of the tube. A positive composite signal from the video amplifier is applied to this grid. This signal drives the grid positive and grid current flows, charging capacitor C1 beyond cut-off. The tube then amplifies only the sync pulse portion of the composite video signal. Thus, sync separation occurs without the application of any signal to the first control grid of the tube.

it has an opportunity to reduce the amplitude of the synchronizing information or trigger the sawtooth generating circuits erroneously. Noise cancellation in the circuit of Fig. 10 is accomplished by applying a second but negative composite signal to the first grid of the separator. Except for polarity and amplitude, the two composite signals are identical. The signal applied to the second grid, however, has a greater amplitude because

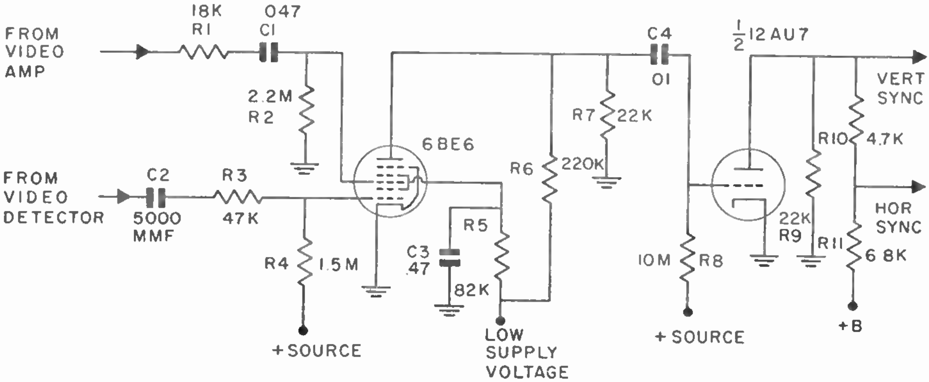

FIG. 10. Sync separator and noise reduction circuits.

However, a disadvantage of a basic sync separator system is that sharp bursts of noise will place a high charge on capacitor C1. Therefore, with strong noise, the noise pulses themselves will appear in the output of the separator. In addition, the amplitude of the desired synchronization information will be reduced, because of the high bias placed on the separator tube. In fact, with very high amplitude noise pulses, the average simple separator could be cut off, which would prevent the arrival of the sync pulses at the sawtooth generating circuit for an extended time, and result in loss of synchronization.

To eliminate this difficulty, every precaution is taken in modern design to lower the influence of noise, before it is removed in a later section of the video amplifier. The stronger signal has the greater effect on plate current flow, and therefore a negative composite sync signal is developed in the plate circuit of the separator.

The first grid is biased so that when any applied signal swings more negative than the sync tip, the separator tube is cut off. Whenever a noise pulse that exceeds the amplitude of the sync pulse arrives, the separator tube is cut off. It is impossible for the same noise pulse arriving at the second grid to draw current and charge capacitor C1. This circuit is called a *gated sync separator.*

The action of the noise cancelling circuit is shown in the waveform drawings of Fig. 11. Notice in particular that the noise pulses are not just clipped, but are completely removed from the mixed synchronizing information that appears in the output of the separator, as a result of the complete cut-off of the separator during the presence of the noise pulse. Thus if a noise impulse happens to occur immediately on top of a horizontal sync pulse, both the noise impulse and the sync pulse are removed. This does not matter in the modern television receiver, because the horizontal synchronization depends upon the average frequency of the arriving sync pulses and not on the presence of each individual sync pulse.

earlier because of the much weaker composite signal applied to this grid. In a strong signal area, if cut-off occurs too soon, the actual synchronizing information would be clipped or "gated" off.

The negative sync signal from the separator output is applied to the grid of the sync amplifier. Here its amplitude is increased and it is inverted for proper application to the synchronizing circuits of the sawtooth generators. Note that the sync amplifier also functions as a clipper and helps to level the sync tip and base line of the composite sync signal. The grid is returned to a positive grid

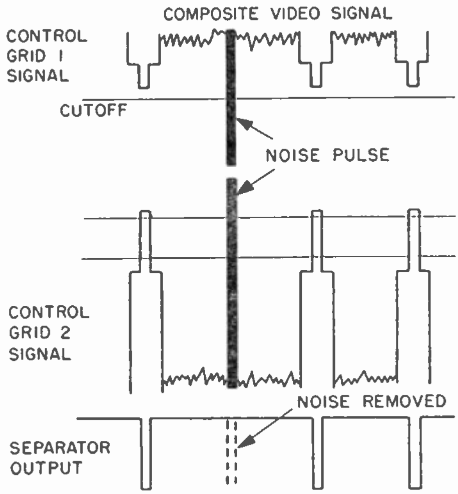

FIG. 11. Two video signals 180° out of phase are fed to the sync separator to produce effective noise cancellation.

In some receivers the bias voltage applied to the bottom of the grid resistor R4 is made adjustable so the actual cut-off level can be set with respect to the average signal strength in a given area. It can be adjusted for strong signal or weak signal reception. In a weak signal area, it would be advisable to have the cut-off occur

source through a large grid resistor, and therefore the tube itself is biased near zero voltage. As a result, the base line of the negative sync signal is held flat by limiting action and any instantaneous positive sweep is leveled by grid conduction and early saturation (obtained with the low operating plate voltage). Likewise, the low plate voltage permits an early cut-off and helps to maintain the flatness of the negative-swinging sync tips as well.

It is also possible to obtain noise cancellation by separate amplification and inversion of the noise signal prior to reinsertion as a cancellation component. A circuit of this type is shown in Fig. 12.

the composite signal that is being transferred through isolating resistor R2 and the capacitor-resistor network to the grid of the triode sync separator.

The first section of the noise tube V1 is referred to as a "gated leveler." It prevents the noise inverter section from conducting whenever the horizontal sync pulses arrive at the in-

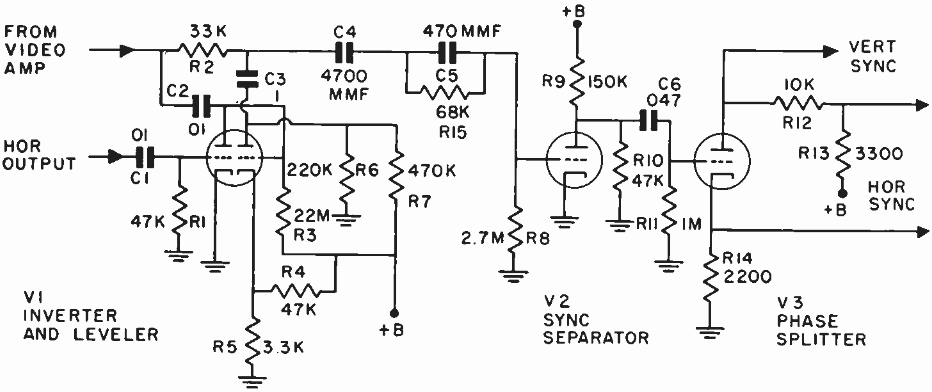

FIG. 12. A noise-reducing sync circuit in which the noise pulse is amplified, inverted, and reinserted into the composite video signal to cancel the noise pulse.

The composite video signal from the video amplifier is applied to the grid of the inverter stage through capacitor C2. The inverter is biased to cut-off because of the very low value of plate voltage and the high cathode bias obtained through the supply voltage bleeder network consisting of resistors R4 and R5. However, if the positive composite signal applied to the grid of this inverter stage has a noise component that exceeds the sync tip, the tube will conduct and produce a negative amplified noise pulse across its plate resistor R7. This negative noise pulse is reinserted into the composite signal through coupling capacitor C3. Thus, it cancels the similar but opposite polarity noise component present in

verter grid. This is accomplished by the application of a horizontal pulse derived from the horizontal output stage to its grid. This gate pulse from the horizontal output tube arrives at the same time as the incoming sync pulse. Thus the gated leveler will conduct and bias the noise inverter tube so far negative that it cannot conduct during the horizontal sync pulse interval. Consequently, the gated leveler helps to establish the bias for the noise inverter during the sync pulse interval and prevents it from clipping out the synchronizing information.

The composite video signal is applied through the filter network consisting of capacitors C4 and C5 and resistor R15 to the grid of the separator. As mentioned previously, the filter network maintains the horizontal and vertical synchronizing information at the proper relative level and therefore improves the noise immunity of the synchronizing system. The negative composite sync signal at the output of the triode separator is applied to still another sync amplifier and phase splitter. This stage develops a vertical synchronizing pulse of the proper polarity for application to the integrating network. It also develops two horizontal synchronizing components of opposite polarity, for application to a phase detector type of frequency control circuit.

Separate horizontal and vertical synchronization channels can also be used to permit optimum design of each channel with respect to the frequency and shape of the sync pulse component it is to emphasize. At the same time, the use of the double channel permits better isolation between the horizontal and vertical synchronizing components, which can interact and cause interlace disturbances. In this system, the signals may be divided into two separate channels following the take-off point in the video amplifier. There will often be two separate sync amplifiers and two separate sync separators.

Separating the Horizontal and Vertical Sync Pulses

The final step in the preparation of the sync information is inter-sync segregation. The segregation of the horizontal from the vertical information is accomplished with resistor-capacitor networks, referred to as differentiators and integrators. The process of segregation involves the utilization of specific segments of the received pulses. The leading edges of the pulses are used for synchronization of the horizontal deflection waveform, and the longer duration interval of the vertical synchronizing pulses is used for controlling generation of the vertical deflection waveform.

lose control of the horizontal synchronization, because, as mentioned in an earlier lesson, there are a great many lines that occur during the lengthy vertical retrace period.

The six vertical sync pulses are of long duration and short spacing. At the television receiver they are blended together to form a rising waveform that will dominate all the horizontal information and control the vertical sweep generator. At the beginning and end of the six vertical sync pulses are two groups of six shorter duration equalizing pulses that are used to maintain proper vertical synchroniza-

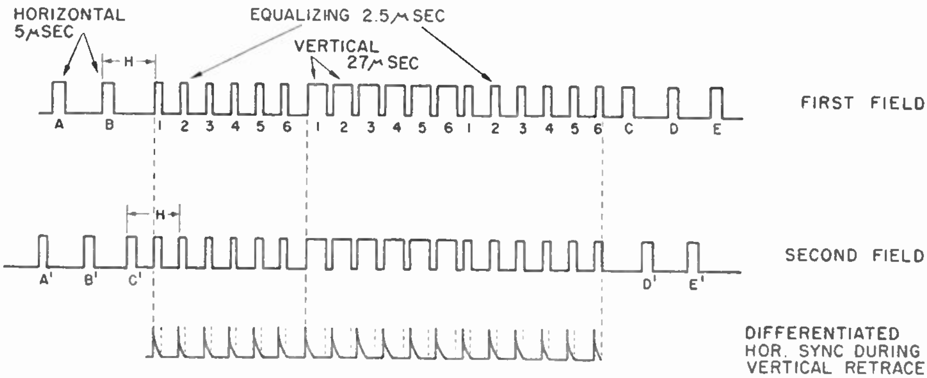

FIG. 13. Horizontal synchronization during vertical retrace.

tion and interlace. These leading and trailing equalizing pulses assist the vertical sync group in firing the vertical sawtooth generator precisely, so there will be true interlace of the scanning lines.

The composite sync signal shown in Fig. 13 contains three basic pulses—horizontal, equalizing, and vertical. The horizontal synchronizing information is contained in the leading edges of all the pulses. It is contained in the leading edges of the equalizing and vertical sync pulses as well as the leading edges of the horizontal sync pulses. Even during the vertical retrace period, it is not advisable to

HORIZONTAL SYNCHRONIZATION

The horizontal deflection generator is synchronized by the leading edges of all three sets of pulses, the horizontal sync pulses, the equalizing pulses, and the vertical sync pulses. As we studied earlier, the leading edges of a pulse can be emphasized with the use of a differentiating circuit. When the pulses are applied to a differentiating circuit having a short time constant (small capacitor and low value resistor), the leading edges of all pulses are emphasized and developed across the differentiating resistor. In the horizontal sync pulses in Fig. 14, the leading edge develops a sharp positive spike, and the trailing edge a sharp negative spike. However, the negative spike is not utilized and is clipped off. The positive portion is applied as synchronization to the horizontal deflection generator. During the vertical retrace interval, the leading edges of the vertical synchronizing pulses and of the equalizing pulses are also differentiated and used

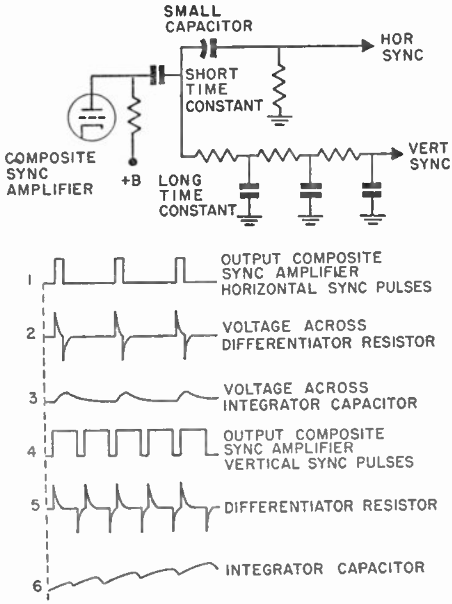

FIG. 14. Basic inter-sync separator systems.

to maintain horizontal synchronization as shown in waveform 5 of Fig. 14.

It is important to remember that horizontal synchronization is maintained by the leading edges of all received sync pulses. During the vertical retrace interval, the leading edges arrive at twice the frequency of the horizontal sync pulses (double-line rate). This double-line rate is required in an interlaced system, because the vertical interval begins one line away from the last horizontal sync pulse at the end of one field but only half a line away from the last horizontal sync pulse at the end of the second field, as shown in Fig. 13. Notice in the first waveform of Fig. 13 that the last horizontal sync pulse B is exactly one line away from the first equalizing pulse, equalizing pulse 3 is one line from equalizing pulse 1, and equalizing pulse 5 is one line from equalizing pulse 3. Thus, at the end of the first field, the odd numbered equalizing and vertical sync pulses maintain synchronization of the horizontal circuits.

The second field waveform shows the first equalizing pulse only ½ line away from the last horizontal pulse C, and the *second* equalizing pulse exactly one line away from the last horizontal sync pulse. Consequently, at the end of the second field, the horizontal is synchronized by the leading edges of the even numbered equalizing and vertical sync pulses.

The one-line separation between the last horizontal sync pulse and the first equalizing pulse in one field, and the half-line separation between the last horizontal sync pulse and the first equalizing pulse in the next field results from the use of interlaced scannings for which there are 262½ lines transmitted for each field. Thus, to maintain true synchronization of the horizontal circuits during the vertical retrace periods, it is necessary that these equalizing and vertical sync pulses be transmitted at double-line rate.

Horizontal control, in fact, is the basic reason for slotting the vertical sync pulse group. If it were not for the necessity of maintaining horizontal synchronization, it would be possible to transmit one long continuous pulse to establish vertical synchronization.

In summary, the differentiating circuit emphasizes the leading edges of all received sync pulses. At the same time, the differentiator reduces the long duration of the vertical sync information and prevents it from influencing horizontal synchronization.

of the integrator prevents any appreciable discharge of the integrating capacitors. This means the integrator charges in steps, rising to an appreciable level during the interval of the vertical sync pulses. At a prescribed voltage level, the integrator charge has risen to a point at which it will trigger the vertical oscillator, initiating the vertical retrace as shown in Fig. 15.

The horizontal as well as the equalizing sync pulses are also present at the input of the integrator. However, these pulses are of such short duration and long spacing that they place only a very small charge on the integrator, as shown in waveform 3 of Fig. 14. Because of the long interval between arriving horizontal sync pulses, the integrator is discharged for each line. Thus the horizontal sync pulses and the equalizing pulses do not build up

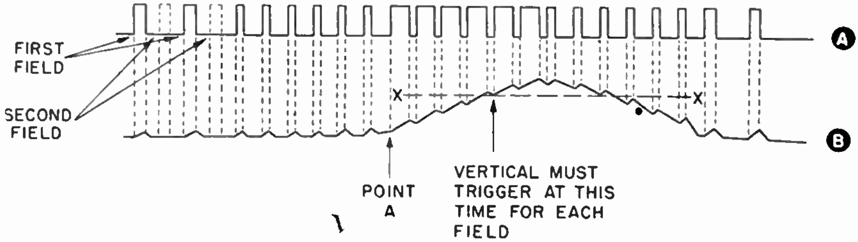

FIG. 15. Vertical synchronization.

VERTICAL SYNCHRONIZATION

The vertical deflection circuits are synchronized by the group of six vertical sync pulses that act as a single long continuous pulse of almost 200 microseconds to trigger the vertical oscillator. When the vertical sync pulses shown in Fig. 14 arrive at the integrating circuit, they charge the integrating capacitors slowly because of the long time constant. Between charges the very long time constant

an increasing charge on the integrator and therefore cannot trigger the vertical oscillator.

By proper choice of time constants and arrangements of resistor-capacitor networks, it is possible to segregate the horizontal and vertical components of synchronization—the horizontal information is contained in the leading edges of the combined sync pulses, and the vertical synchronization is contained in the long duration vertical sync period.

INTERLACE TIMING

Although interlace may seem difficult to understand, it is basically simple and automatic. At times, so much emphasis is placed on the equalizing pulses that the technician assumes that they create the interlace. Actually, the interlace is automatic, because of the ratio between line frequency and field frequency. The equalizing pulses aid in maintaining the proper interlace at the receiver.

Fig. 16 demonstrates how easily interlace is accomplished. Let us assume that we have pulse repetition rates at which there are five of the bottom pulses for each two of the top pulses. In this imaginary system there are two vertical pulses per second and five horizontal pulses. The first vertical pulse will occur between the second and third horizontal pulses, and the second vertical pulse will coincide with the fifth horizontal pulse. The third vertical pulse will occur midway between the 7th and 8th horizontal pulses. In other words, we have a television system that contains 2½ lines per field. For example, when the first vertical pulse arrives, the scanning line will be at the midpoint between the second and third horizontal pulses, and when the second vertical pulse arrives, the scanning beam will be at the end of a horizontal line.

In our commercial television system, the very same relationship is attained by using 262½ lines per field instead of 2½ as in the example. The relationship between pulses is identical except for the faster rate of pulse transmission. Consequently, with a field rate of 60, and a line rate of 15,750, there are 262½ lines per field and interlace is automatic.

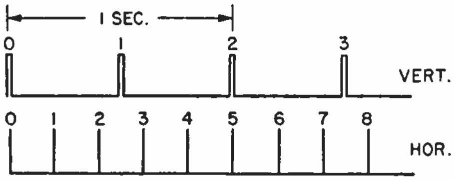

FIG. 16. Interlace is automatic.

At the receiver the problem is not to establish interlace, because that has already been done by the choice of line and field rates, but to prevent line pulses and noises from upsetting the interlace relationship. The vertical oscillator must be triggered at exactly the same time for each television field. Thus, every precaution must be taken to prevent the horizontal sync pulses, noise impulses, or any other receiver disturbances from causing faulty synchronization of the vertical oscillator.

There is one thing that could upset the interlace. At the end of one field, the start of the vertical blanking interval is *one line* away from the last horizontal pulse, but at the end of the succeeding field, it is only *one-half line* away from the last horizontal pulse. Consequently, a few lines prior to the firing time of the vertical oscillator, there is a different charge on the integrating capacitor (from the last horizontal pulse) depending on whether it is the end of the first field or the end of the second field. It is the purpose of the six equalizing pulses (of short duration and long spacing) to discharge the integrating capacitor to a fixed voltage level regardless of the charge at the start of the vertical retrace interval, so that the vertical oscillator will be triggered precisely at the same instant for each field. The trailing set of equalizing pulses discharges the integrating circuit to the same voltage level at the conclusion of the vertical sync period.

Therefore no residual charge on the integrating capacitor is carried over from one field to the next.

As you have learned, a single resistor and capacitor can function as an integrating circuit. However, in actual practice, groups of two to four resistors and capacitors are used to further emphasize the six vertical sync pulses and reduce the charges contributed by horizontal synchronizing information or noise impulses. This more effective filtering action of an elaborate integrating network assures a more stable and rigid interlace and minimizes interference from other synchronizing pulses or from arriving noise impulses.

TYPICAL CIRCUITS

The inter-sync separator can be connected to supply either balanced or unbalanced horizontal sync output. When horizontal sync pulses of equal amplitude but opposite polarity are required, both plate and cathode outputs from a so-called phase splitter can be used to form the dual horizontal pulses required, as shown in Fig. 17.

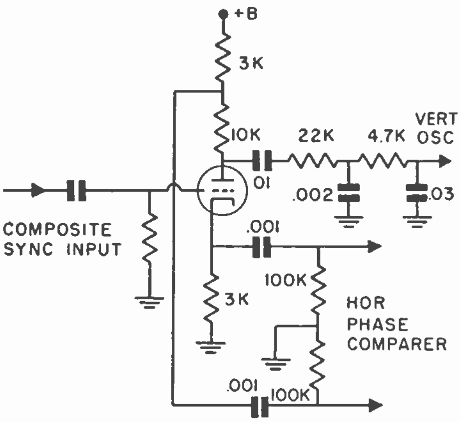

FIG. 17. Equal sync pulses of opposite polarity can be obtained from a sync amplifier for use with a horizontal phase detector.

With the negative composite sync applied to the grid of the amplifier, a negative pulse is removed from across the cathode resistor and applied to a differentiator. A positive pulse is removed from across a resistor of similar value inserted in the plate circuit, and applied to another differentiating circuit. The vertical information is removed at the plate of the phase-splitter tube and applied to the long-time-constant integrating circuit.

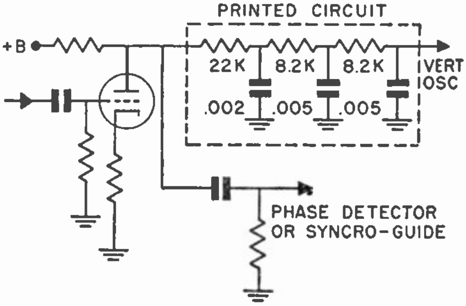

FIG. 18. A single-ended sync amplifier circuit.

A circuit that provides sync pulses of only one polarity, as is required for certain types of phase detectors or syncro-guide horizontal oscillators, is shown in Fig. 18. Often the integrator network is in the form of a printed circuit consisting of three resistors and three capacitors forming a triple integrator network in a unit no larger than a single conventional paper capacitor. Of course, an integrator made up of separate resistors and capacitors could be used just as well.

Using the Oscilloscope in Sync Circuits

The oscilloscope is the most useful service instrument for sync circuits. It can be used both for adjustment and for trouble-shooting. It permits you to trace the various sync signals through the sync circuits, and, when calibrated properly, can be used as a signal voltmeter to measure the amplitude of the pulses. In the instruction manuals for many television receivers, the manufacturers show the waveforms to be found in the sync and sweep circuits and often give the normal peak-to-peak amplitude of the various waveforms.

It is very important for effectively using an oscilloscope to understand the form in which the signal information should appear. For example, the waveforms in various sections of the sync system were illustrated in Figs. 3, 13, 14, and 15. However, on an oscilloscope, the waveforms do not always appear exactly as anticipated, because of the limitations of the average oscilloscope.

When an oscilloscope is used to observe waveforms at a point in the circuit where both the horizontal and vertical pulses are present, the waveforms are observed at two different oscilloscope sweep frequencies. Usually you should adjust the scope to see 2 or 3 complete lines or fields rather than only one. If you try to view only one, part of the pattern may be lost.

To observe two fields of the television signal, set the oscilloscope to half the field frequency (30 cycles). To observe two lines, set the oscilloscope to half the line frequency (7875 cycles).

When the oscilloscope is connected to the grid of the first synchronizing stage, the composite video, blanking, and sync waveform can be observed. With the oscilloscope frequency set on half the line rate, horizontal sync, horizontal blanking, and video information can be observed as in Fig. 19A. If the oscilloscope sweep frequency is then adjusted to 30 cycles, two fields of video information are shown as in Fig. 19B. Notice in particular that not only is the vertical blanking and sync interval present, but also the entire group of line intervals (262½) that occur between vertical blanking intervals appears as the illuminated hazy area between the vertical blanking intervals.

Thus, you can expect to find not only the vertical information when observing the composite signal at field frequency, but also the signal information between vertical intervals. The horizontal pulses, of course, do not appear distinct in this representation because so many of them exist (262½) between vertical intervals, that they blend together. Likewise the equalizing pulses and vertical sync pulses do not appear as separate pulses because they represent such a small time segment of the complete vertical period that they blend together.

Horizontal blanking and sync pulses can be observed more distinctly because they form an appreciable percentage of the total line period. Thus with the oscilloscope adjusted to half the line frequency, the horizontal sync and blanking pulse stands out clearly as in Fig. 19A.

If the frequency response of the oscilloscope is limited, the pattern obtained will not be exactly like Fig. 19A. If the high-frequency response is poor, the pulse will be somewhat rounded. You must therefore make allowances for distortion introduced by the oscilloscope.

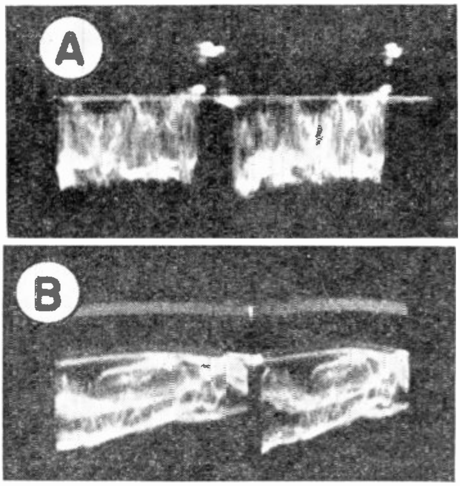

FIG. 19. A, horizontal intervals at sync take-off; B, vertical intervals at sync take-off.

With the oscilloscope adjusted to half the line frequency and connected to the sync separator output, separated horizontal sync pulses appear distinctly as in Fig. 20A. When the oscilloscope is adjusted to one-half the field rate, a vertical pulse, shown in Fig. 20B, appears. Again the hazy information in the background is formed by the great many individual horizontal pulses that occur between vertical sync pulses. Likewise the vertical sync interval is such a small portion of the total field time that the actual equalizing and slotted vertical sync pulses do not appear as such on the oscilloscope screen.

When the oscilloscope is connected to the output of the integrating circuit, the resultant waveform is not always a presentation of the vertical sync pulse. The vertical sync pulse at this point is of very low amplitude compared to the actual grid waveform of a vertical blocking oscillator. To observe the vertical sync pulse, you must remove the vertical oscillator tube or in some other way make the vertical oscillator inoperative. The waveform obtained at the input of a vertical blocking oscillator, with the oscillator operating, is shown in Fig. 21A. The waveform obtained with the oscillator inoperative is shown in Fig. 21B.

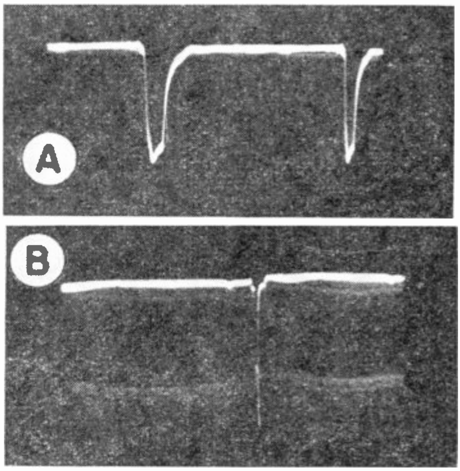

FIG. 20. A, horizontal sync at sync separator output; B, vertical sync at sync separator output.

To observe the horizontal sync pulse at the output of the differentiator circuit, adjust the sweep to one-half the line frequency. Again the actual horizontal synchronizing pulse at this point can be observed only if the horizontal oscillator itself is made inoperative, because the horizontal oscillator waveform is much greater in amplitude than the very small pulse that synchronizes it. The waveform obtained with the oscillator operating is shown in Fig. 22A and with the oscillator inoperative in Fig. 22B.

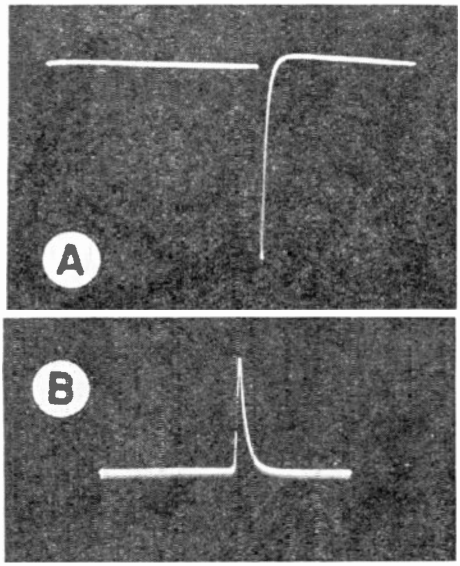

FIG. 21. A, integrator, vertical oscillator in operation; B, integrator, vertical oscillator inoperative.

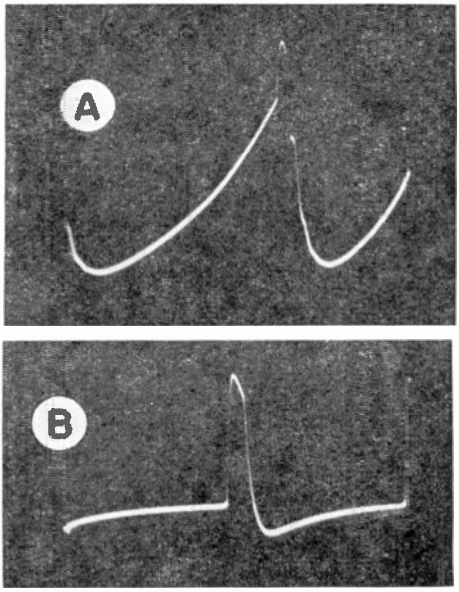

FIG. 22. A, horizontal sync, horizontal oscillator in operation; B, horizontal sync, horizontal oscillator inoperative.

SUMMARY

The ability to interpret the information that appears on the oscilloscope screen in terms of the pulses that exist in the circuit can help you to understand and use your oscilloscope better. You must remember that your oscilloscope may have some tendency to distort the waveform, particularly if the scope has only a limited frequency response. Nonetheless the information that your oscilloscope can give you should be helpful in locating defects in the sync section or for analyzing the performance of the sync or sweep stages of a TV receiver.

Synchronizing Sweep Generators

We have already studied sync take-off circuits, sync separation, sync segregation, and the shaping of the horizontal and vertical sync pulses for application to the oscillators to be synchronized. The next step is to find out just how the sync pulses synchronize the deflection generator circuits.

In the vertical sweep circuits, the vertical sync pulses lock in the vertical sweep generator (blocking tube oscillator or multivibrator) directly with each arriving vertical sync pulse by initiating the retrace period of the vertical oscillator. Horizontal synchronization in most television receivers operates on a so-called "flywheel principle" in which the average frequency of the arriving horizontal sync pulses determines and synchronizes the horizontal sweep generating circuits.

In practically all television receivers, the deflection oscillators are free-running and operate continuously despite the presence or absence of sync pulses. A typical blocking oscillator used as a vertical sawtooth generator must have a free-running or non-synchronized frequency *lower* than the frequency at which it is locked in by the arriving sync pulses.

It is important to realize that a sweep-generating circuit can be synchronized only if the free-running frequency is brought near to the frequency of the sync pulses. The receiver has horizontal and vertical hold or frequency controls to do this. At this point the sync pulses establish control of the oscillators and lock in the scanning cycle rigidly. Let us now consider this synchronizing action.

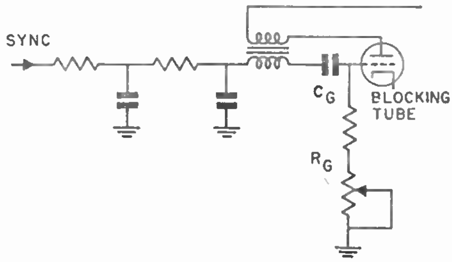

FIG. 23. A typical blocking oscillator.

VERTICAL SYNC SYSTEMS

You have already studied blocking oscillators and will recognize the circuit shown in Fig. 23 as a blocking oscillator. It is typical of the circuits used as the vertical oscillator in TV receivers. The waveform of Fig. 24A is typical of the grid signal (the charge and discharge cycle of the grid capacitor through the grid resistor). In synchronizing the blocking tube, the vertical sync pulse arrives just before the instant at which the normal free-running grid waveform reaches the conduction point of its cycle as shown in Fig. 24B. Since this time of conduction could vary when the oscillator is free-running, the arrival of the sync pulse just before this time always triggers the oscillator at precisely the same time spacing as the arriving sync pulses. Consequently, the sync pulse arrives at the grid and immediately drives the tube into conduction. This initiates the feedback cycle that begins the retrace period of the oscillator. This occurs for each arriving pulse so that the oscillator is locked in at the pulse frequency as shown in Fig. 24C.

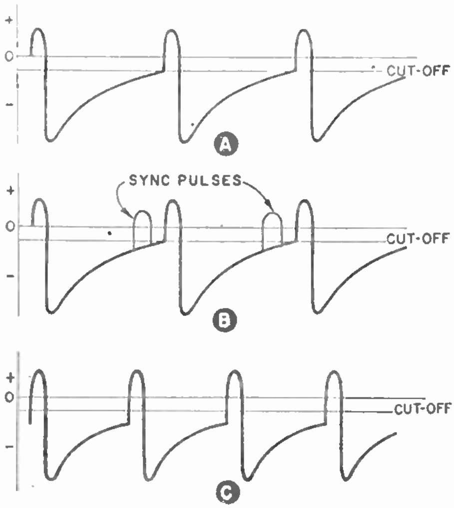

FIG. 24. A, blocking oscillator grid curve; B, curve when sync pulses appear; C, how the sync pulses drive the grid into the region of plate-current flow.

This very precise timing depends on the arrival time of the vertical sync pulses. If some other disturbance such as noise impulses or horizontal synchronizing components that stray into the vertical circuits arrive just ahead of the vertical sync pulses, they may cause erroneous synchronization of the vertical oscillator. This will create a momentary or continuous roll of the picture. Such a possibility emphasizes the need for the integrator circuit and the precautions that are taken in the sync circuits to minimize or cancel noise components.

A multivibrator, Fig. 25, can be synchronized in the same way with the application of a positive pulse to the section marked V2. At the instant the sync pulse arrives, V2 is driven into conduction and initiates the retrace period. A multivibrator can also be synchronized by applying a negative-going pulse to the grid of V1. The negative pulse drives V1 to

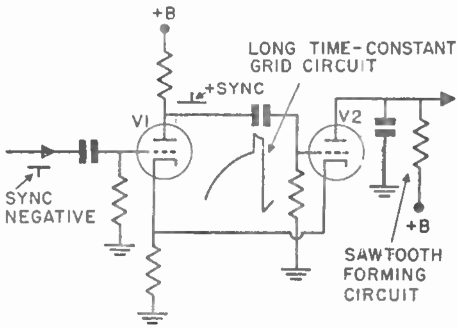

FIG. 25. Synchronization of multivibrator.

cut-off and a strong positive pulse will be developed in the plate circuit of this stage. This pulse is applied to the grid of V2 and causes this stage to conduct and initiate the retrace.

HORIZONTAL SYNC SYSTEMS

When a multivibrator is used to generate the horizontal sweep, the frequency of the oscillator is generally controlled by the average frequency of the horizontal sync pulses. Therefore, instead of being fed directly to the horizontal oscillator, the sync pulses are fed to a separate stage where an average dc voltage is developed and used to control the oscillator frequency.

In this type of circuit, the sync pulse does not arrive at the grid of the multivibrator. Likewise any noises that might arrive along with the sync pulses cannot trigger the multivibrator erroneously. The sync pulses place a dc charge on the grid circuit of the multivibrator that depends on their arrival time. As the average frequency of the sync pulses changes in relation to the oscillator frequency, the charge changes also, and causes the horizontal oscillator frequency to follow the frequency of the horizontal sync pulses.

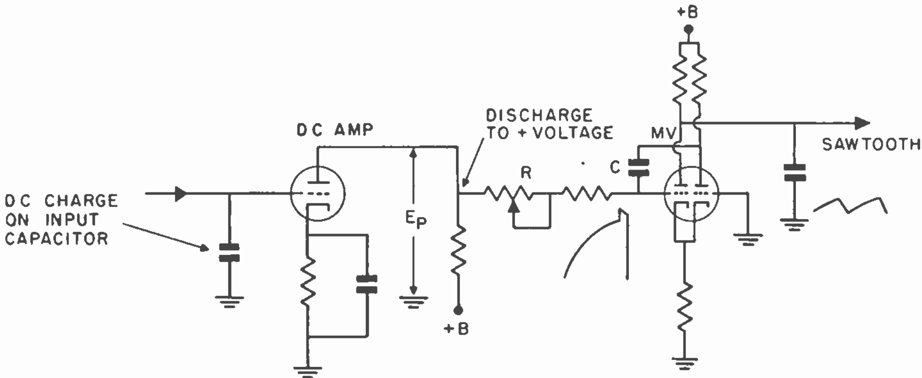

FIG. 26. A typical multivibrator and control tube used to control the multivibrator frequency.

A circuit of this type is shown in Fig. 26. The waveforms in Fig. 27 show how the dc potential controls the frequency of the oscillator. In the multivibrator circuit, the grid is returned to a positive supply potential point. The potential of this point influences the frequency of the multivibrator because it determines the voltage range through which the grid capacitor discharges. After the grid capacitor C has been charged negatively to a value of *minus* EC it attempts to discharge to zero and on to some *plus* value. The capacitor charge never reverses during this discharge cycle, because as soon as cut-off voltage is reached, the first section of the multivibrator starts conducting and a new cycle is started.

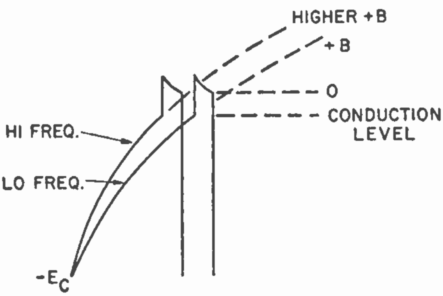

FIG. 27. The waveform on the grid of the first stage of the multivibrator.

The rate at which the capacitor discharges or the time required to reach cut-off voltage depends on the potential toward which it attempts to discharge, as shown in Fig. 27. You can see that the discharge slope is steeper when the capacitor discharges toward the higher supply value, so the cut-off point is reached more rapidly, and the frequency increases.

Since the plate voltage on the dc amplifier controls the discharge time and is in turn controlled by the charge on the input capacitor, the charge placed there by the sync pulses regulates the frequency of the horizontal oscillator. This permits a horizontal deflection circuit far less affected by noise impulses than a directly synchronized sweep generator.

It is also possible to control the frequency of a multivibrator with a dc bias voltage applied to the grid of one section of the multivibrator as in Fig. 28. The bias is applied to V1, and V2 forms the wave shape needed to drive the horizontal output tube.

The frequency is controlled by changing the voltage toward which C2 must discharge. This is the voltage at the plate of V1. Increasing this voltage increases the frequency;

decreasing it decreases the frequency.

This voltage at the plate of V1 depends upon the drop across RP. When the drop across RP is high, the voltage at the plate of V1 is low.

The drop across RP depends upon the grid bias. A low bias increases the current through V1 and RP. This increases the voltage drop across RP, and reduces the voltage at the plate. Increasing the bias reduces the current through V1 and RP. This reduces the voltage drop across RP and raises the voltage at the plate of V1.

Since the frequency depends upon the voltage at the plate of V1, reducing the bias reduces the frequency; increasing it increases the frequency.

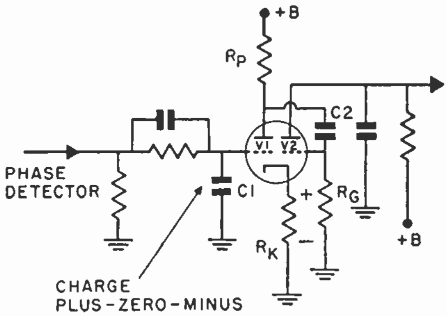

FIG. 28. The frequency of a multivibrator can be controlled by varying the dc bias applied to one section.

HORIZONTAL AFC SYSTEMS

It is possible to synchronize the horizontal sweep oscillator by direct application of the sync pulse as discussed previously. However, the presence of noise impulses along with the sync pulses can cause faulty synchronization. For example, a sharp noise pulse just ahead of a horizontal sync pulse could trigger the retrace period too early and displace the succeeding line of video information. Likewise, groups of noise pulses could cause improper synchronization over a number of lines and cause line displacements. This is called horizontal tearing. Nevertheless, direct synchronization of the horizontal sawtooth oscillator was used in some early TV receivers.

In the modern receiver, the horizontal sync pulses still maintain synchronization of the horizontal sweep, but they do so by indirect means. In the so-called horizontal automatic frequency control circuit, the average frequency of the arriving sync pulses over a number of lines is used to establish synchronization of the horizontal oscillator, thus preventing triggering by noise pulses.

In a horizontal afc system, shown in block diagram form in Fig. 29, there are three basic circuits—the comparison circuit, the oscillator circuit, and the deflection output circuit. The sweep generators and deflection output circuits were discussed in a previous lesson. In this lesson we will discuss the process of synchronizing the horizontal oscillator.

The locally generated signal is fed back to the comparison circuit from the horizontal output stage. In the comparison circuit, the frequency and phase of this signal are compared with the frequency and phase of the sync pulses to produce a dc voltage that depends on their frequency and phase relationships. This dc voltage in turn regulates the frequency of the horizontal oscillator. Consequently, the horizontal oscillator is maintained on proper frequency by a dc voltage instead of by the sync pulses. When the incoming sync pulses and the locally generated signal are in phase, there is no voltage developed by the comparison stage. If the two signals deviate in phase, a voltage is developed that brings the oscillator back in phase with the sync pulses.

tor signals. This pulse establishes a dc voltage to control the sweep oscillator frequency.

PHASE DETECTOR

A phase detector afc system compares horizontal sync pulses of equal amplitude but opposite polarity with the locally generated sawtooth wave that is fed back from the horizontal output circuits. A typical circuit is shown in Fig. 30.

The feedback voltage is initially in the form of a pulse from the horizontal output circuit, but is integrated into

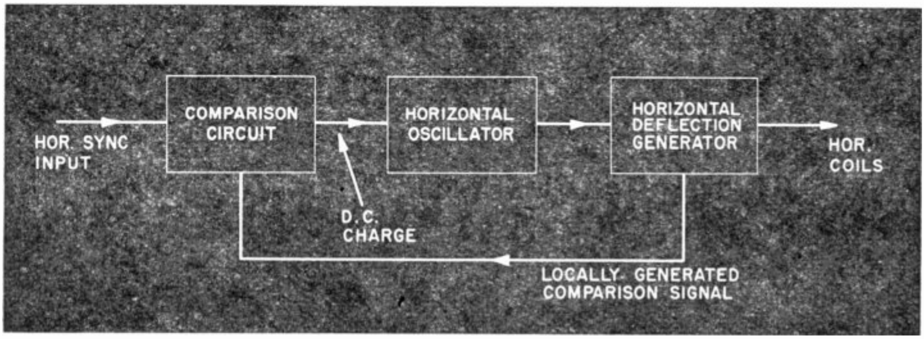

FIG. 29. Block diagram of horizontal afc system.

There are three basic methods of comparison as follows:

1. *A phase detector system* that compares the incoming sync signal with the locally generated signal and produces a dc voltage that is used to control the frequency of a blocking tube or multivibrator sweep generator.

2. *A phase discriminator system* that produces a dc charge that biases a reactance tube. The reactance tube regulates the frequency of a sine-wave-sweep oscillator.

3. *A pulse width system* that develops a pulse, the duration of which depends on the phase relationship between the sync and the sweep oscilla-

a sawtooth wave by the network consisting of resistor R1 and capacitor C3. Capacitor C6 acts as a blocking capacitor, and resistor R2 aids in shaping the sawtooth and provides a dc return path for the phase detector diodes. The operation of the phase detector circuit can best be understood by first considering the circuit when just one of the basic signals is applied.

With the application of a positive sync pulse to the top diode and a negative sync pulse of equal amplitude to the lower diode, both diodes conduct. The diode currents flow in opposite directions through resistor R5 in the output circuit. The positive pulse applied to the plate of diode D1 will cause diode current to flow from the plate of D1 through resistors R3 and R5 to ground, through R2, and back to the cathode of D1. The negative pulse applied at the same time to the cathode of D2 will cause current to flow from the plate of D2 through resistor R2 to ground, through R5, R4, and back to the cathode of D2. If the diode circuits are balanced, and the applied sync pulses are of equal amplitude, equal currents flow through resistor R5 in opposite directions and there is a zero voltage drop across the resistor and a zero charge on capacitor C5. The diode currents, however, do charge capacitors C1 and C2 with the polarities indicated to prevent the diodes from conducting between pulses. Thus the diodes are keyed into conduction only during the time interval of the arriving sync pulses.

or zero axis), D2 conducts. Since the two diodes again conduct equally, but in opposite directions, the net output across R5 is again zero.

The phase detector circuit functions only when both signals are applied simultaneously. If the sync pulses and the feedback sawtooth wave are exactly in phase, the sync pulses coincide with the center of the retrace portion of the sawtooth wave. Under this condition, as shown in A of Fig. 31 (assuming 5-volt pulses and a 5-volt peak-to-peak sawtooth), the pulses arrive when the sawtooth wave is going through zero. Thus at the instant the diodes are triggered into conduction by the arriving sync pulses, there is a 5-volt difference of potential across the top diode and a 5-volt difference across the bottom diode. These equal potentials draw

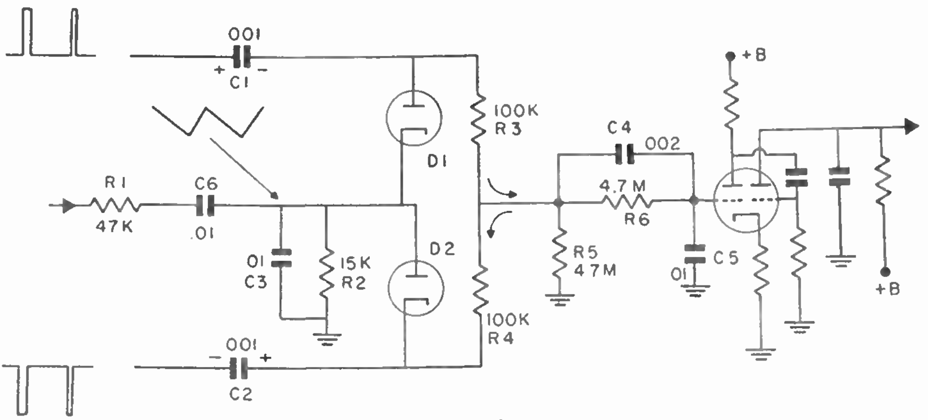

FIG. 30. A typical phase detector afc system.

If the sawtooth wave alone were applied to the phase detector, the output would again be zero and the charge on capacitor C5 zero. As the sawtooth falls below zero, it applies a negative voltage to the cathode of D1, and the diode conducts. On the positive portion of the sawtooth cycle (positive with respect to its central

equal currents of opposite direction through resistor R5, and the charge on the capacitor C5 remains at zero.

If there is a change in circuit conditions that causes the frequency of the oscillator to increase, the sync pulses will move up on the sawtooth as shown in Fig. 31B. Now the sync pulses occur when the sawtooth is positive. This makes the cathode of D1 and the plate of D2 positive. If under these conditions the cathode of D1 is 2 volts positive, as indicated, and the plate 5 volts positive, the net difference of potential across D1 is only 3 volts. At this very same instant the same positive 2 volts contributed by the sawtooth is also present on the plate of D2 along with a 5-volt negative pulse applied to its cathode, producing a net difference of potential across D2 of 7 volts. Consequently, D2 will conduct a greater current through the output resistor R5 than D1.

The polarity of the voltage across R5 will therefore be determined by the current through D2, so the junction of R3, R4, R5, and R6 will be positive with respect to ground, placing a positive charge on capacitor C5. This positive charge on the grid of the horizontal multivibrator causes the frequency to decrease to that of the sync pulses, restoring the in-phase condition between the deflection waveform and the sync pulses.

If the oscillator frequency decreases, the sawtooth wave will be negative with respect to its zero axis when the sync pulses arrive as indicated in Fig. 31C. Under these conditions the difference of potential across D1 will exceed that across D2 and the current through D1 will be greater than the current through D2. The unbalanced currents will develop a voltage across R5. The net voltage drop across resistor R5 and the charge on capacitor C5 will be negative with respect to ground and will increase the frequency of the multivibrator the proper amount.

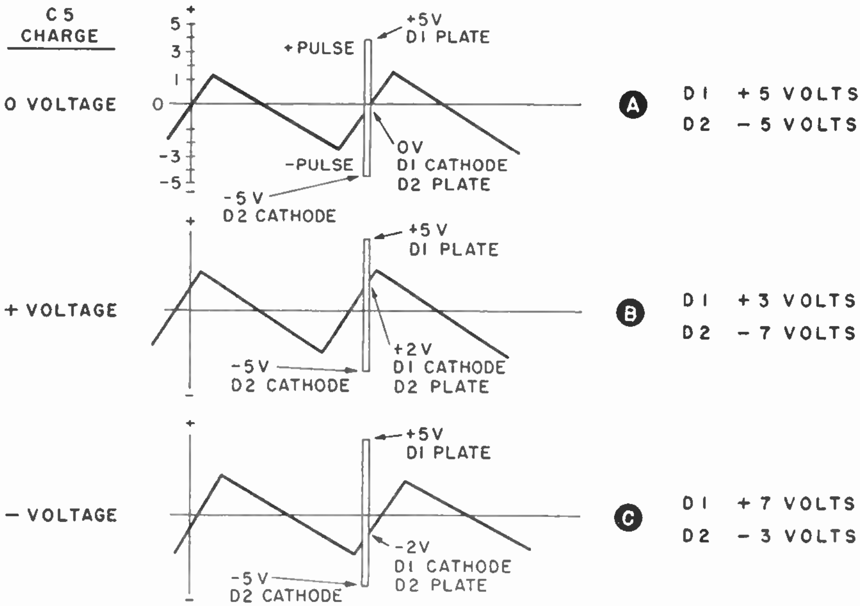

FIG. 31. A, the phase relationship between the sync pulses and the sawtooth signal applied to the phase detector when the oscillator is operating at the correct frequency. B, the oscillator frequency is high. C, the oscillator frequency is low.

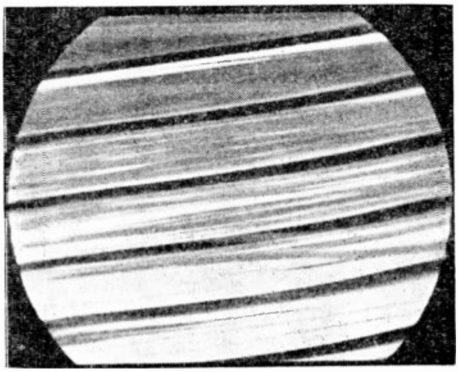

FIG. 32. Diagonal bars obtained just prior to synchronization when the horizontal hold control is rotated.

A long-time-constant network consisting of resistors R5 and R6 and capacitors C4 and C5 is used at the output of the phase detector for a number of reasons. For example, the time constant must be made long enough so the instantaneous current changes through resistor R5 do not cause the charge on capacitor C5 to vary quickly. In fact, the charge on capacitor C5 is the average of the instantaneous changes across resistor R5 for a number of lines. Thus, rapid instantaneous changes of multivibrator frequency, which would make the system more susceptible to noise, do not occur. Likewise sharp noise pulses do not influence the multivibrator frequency, because they cannot change the charge on C5 because of the long time constant of R5, R6, C4, and C5. In fact, the capacitor-divider arrangement of C4 and C5 further de-emphasizes noise pulses because it acts as a voltage divider, and most of the voltage appears across C4. This divider action does not hamper the normal functioning of capacitor C5 because C5 accumulates its dc charge over the necessarily longer time interval by charging through resistor R6.

The time constant of this network, though long, is made short enough to follow the normal variations in the frequency of the sync pulses or drift in the frequency of the horizontal multivibrator. Otherwise there would be annoying line displacements and ragged raster edges, because the horizontal oscillator could not follow sync changes quickly enough.

One of the advantages of the phase detector circuit, as compared to other types of horizontal afc circuits, is that no adjustment of the detector is necessary. The only adjustment is setting the horizontal multivibrator frequency properly, as mentioned in the preceding lesson, by setting the horizontal stabilizing circuit and the horizontal hold control, if one is used, so that the arrival of the sync pulses matches the center of the retrace period of the feedback sawtooth. This adjustment ensures that the sync pulses occur during the retrace interval of the deflection waveform and that proper synchronization occurs when the customer-adjusted horizontal hold control is set at the approximate center of its range.

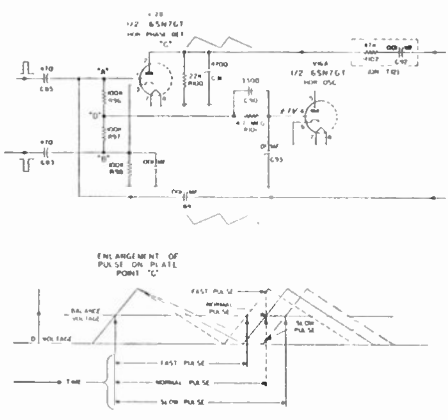

FIG. 33. A triode phase detector.

In most receivers using a phase detector afc, the horizontal controls are properly adjusted if the horizontal goes out of synchronization at each end of the adjustment range of the horizontal hold control. When the synchronization point is approached, diagonal bars such as shown in Fig. 32 will appear, just before the synchronization point is reached. There will be the same number of these bars at both ends of the range of the hold control, but they will slope the opposite way at the two ends.

A Triode Phase Detector. A modified phase detector using a triode is shown in Fig. 33. It compares synchronizing pulses fed to the grid and cathode of the tube with a sawtooth wave fed to the plate of the tube from the output of the deflection circuit. The dc voltage developed by the phase detector is used to control the multivibrator used as the horizontal oscillator.

A positive-going sync pulse is applied to the grid of the triode phase detector, and a negative-going pulse to the cathode. The sync pulses alone will cause grid current. Point A will therefore be negative with respect to point B and the cathode. The exact voltage between the grid and the cathode will depend upon the amplitude of the sync pulses. Very little plate current will be drawn when the pulses alone are applied to the tube, so that insofar as the action of the pulses is concerned, the cathode will be essentially at ground potential.

The sawtooth applied to the plate of the tube will cause plate current to flow. When plate current flows, a voltage will be developed across R98, making the cathode positive with respect to ground. The amplitude of the sawtooth voltage applied to the plate of the tube is controlled by the design of the circuit components, so that the voltage at point D will normally be zero.

As an example of how this is accomplished, let's suppose that with the sync pulses alone applied to the grid and cathode of the tube, point A is —4 volts with respect to ground.

With —4 volts at point A, the amplitude of the sawtooth signal applied to the plate of the tube is adjusted until the cathode current drawn through R98 develops a voltage drop of 4 volts across this resistor. This will place point B 4 volts positive with respect to ground. If A is —4 volts and B +4 volts, then the point mid-way between the two, which is point D, will be at zero potential.

An enlargement of the pulse on the plate is shown below the schematic diagram in Fig. 33. If the sync pulses occur when the sawtooth voltage reaches the line marked "balance voltage," the resultant voltage at point D will be zero. However, if the oscillator frequency should change so that the frequency increases, the sawtooth pulse will reach the balance voltage before the sync pulse arrives. By the time the sync pulse arrives, the sawtooth will be positive enough to cause the plate current to increase to a high enough value to develop sufficient positive voltage at point B to make point D positive. This positive voltage is applied to the grid of the multivibrator and will slow down the multivibrator.

If the multivibrator frequency should decrease, the sawtooth wave fed to the plate will barely rise above zero voltage when the sync pulse arrives, and as a result there will be little or no plate current flowing during the sync-pulse interval. This means that point A will be negative with respect to ground, and point B will be essentially at ground potential. Point D will therefore be negative, and the negative voltage applied to the grid of the multivibrator will speed up the multivibrator.

As long as the sawtooth signal is fed to the plate of the tube in the proper phase relationship with the sync pulses, the output voltage at point D will be zero. However, once the two signals get out of phase, a voltage will be developed at point D which will correct the error by changing the multivibrator frequency.

such a high positive value that it would be impossible for the sync pulses to overcome this voltage and get the oscillator back into sync.

PULSE-WIDTH AFC

The pulse width, or "syncro-guide" circuit, as mentioned in the sweep circuit lesson, consists of a blocking oscillator and a control tube as shown in Fig. 34. The blocking tube oscillator uses an auto-transformer arrangement to obtain feedback between plate and grid circuits. The oscillator tube is biased near cut-off by the charge on capacitor C3.

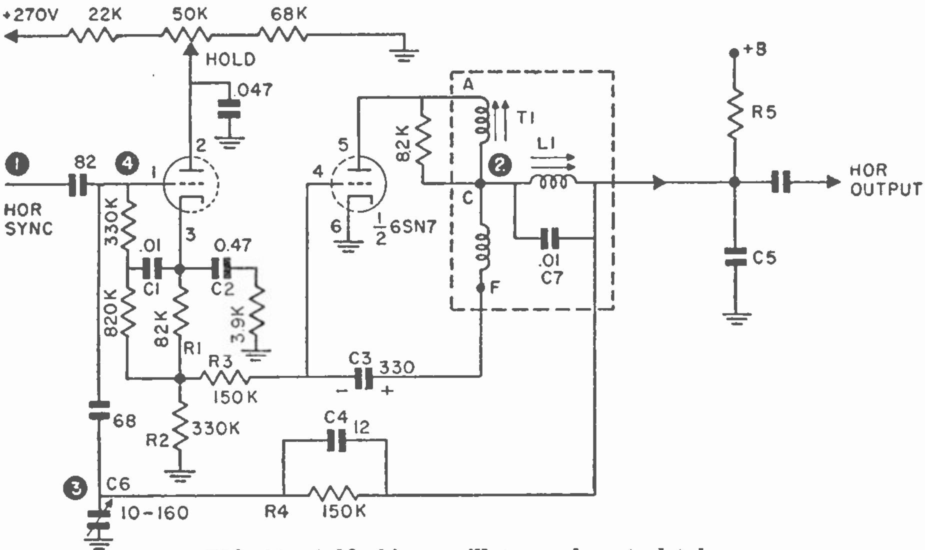

FIG. 34. A blocking oscillator and control tube.

A sawtooth having the opposite polarity to that of the sawtooth signal applied to the plate is fed to the grid of the phase detector. The sole purpose of feeding the signal to the grid is to keep the phase detector balanced when there are no sync pulses present, such as when you tune to an unused channel. If this pulse were not applied to the grid, point D would rise to

The frequency of the blocking tube oscillator is regulated by the dc charge placed on capacitor C2 by the control tube. Resistors R1 and R2 act as a voltage divider across this capacitor, supplying the proper dc voltage level through resistor R3 to the grid of the blocking tube. The charge placed on capacitor C2 is governed by two things—the setting of a horizontal hold control in the plate circuit of the control tube, and the duration of the pulse applied to the grid of this tube.

The hold control determines the plate voltage of the control tube and the amount of dc current drawn by the tube and, therefore, the dc charge placed on capacitor C2. The charge on capacitor C2 is also affected by the duration of the pulse applied to the grid of the control tube. The duration of this pulse, in turn, is determined by the frequency and phase relationship between the incoming horizontal sync pulses and the locally generated signal (fed back from the horizontal sawtooth generating circuits by way of capacitor C4 and resistor R4).

The oscillator control tube is biased so that plate current flows only during the positive peak of the signal applied to the grid. This peak occurs when the sync pulse arrives, so the sync pulse actually determines the charge placed on capacitor C2. The charge placed on the capacitor C2 is determined by the length of time the control tube conducts. This, in turn, depends on the phase relationship between the sync pulse and the feedback signal supplied to the grid.

The signal applied to the grid of the control tube is made up of the incoming sync pulse, the sawtooth wave developed at the output circuit of the oscillator (sawtooth-forming circuit consists of resistor R5 and capacitor C5), and a sine-wave component contributed by the output resonant circuit of the transformer (winding L1 and capacitor C7). The sawtooth component is shaped by resistor R4 and capacitor C6, to form a partial parabolic wave that emphasizes the retrace portion of the generated sawtooth. The sine-wave component is added in

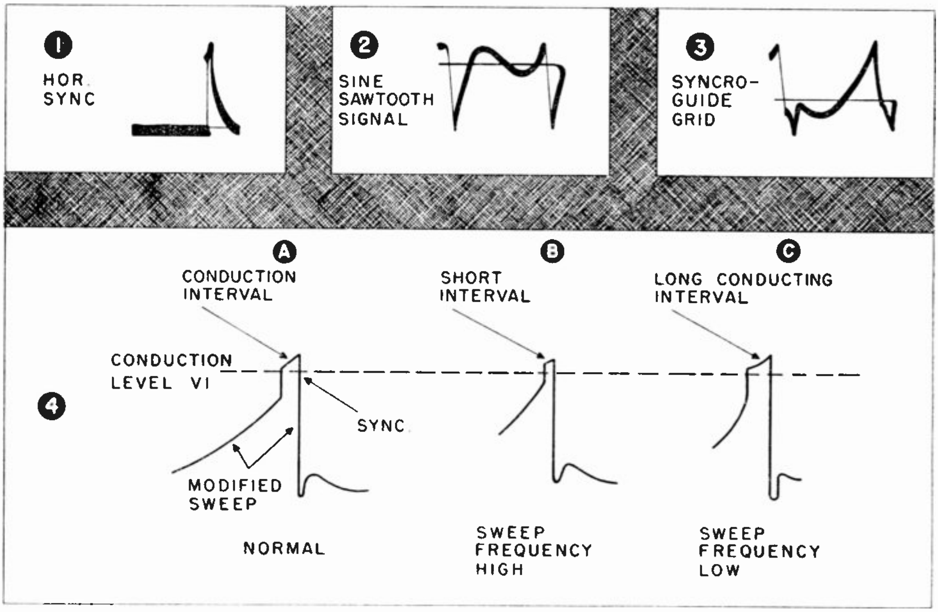

FIG. 35. Waveforms found in the pulse width circuit. The numbers on the diagram in Fig. 34 correspond to the numbers on the waveforms.

proper phase by the tuned circuit, to further emphasize the retrace portion of the feedback signal. The waveform at the syncro-guide grid is made up of the incoming sync waveform and the fed-back modified signal, shown in 1 and 3 of Fig. 35. The addition of waveforms 1 and 3 produces the resultant syncro-guide input signals shown in 4 of Fig. 35.

The length of time the control tube conducts determines the amplitude of the charge placed on the cathode capacitor C2. The time the tube conducts depends upon the position of the sync pulse with respect to the modified waveform (in other words, the phase relationship between modified waveform and incoming sync).

which now appears slightly displaced to the left of its original position. Thus, the tube does not conduct for as long an interval, and the charge on the cathode capacitor drops; the blocking tube grid-voltage decreases, and the frequency decreases to the same frequency as the sync pulses.

In the waveform shown in 4C of Fig. 35, the horizontal frequency is low. The sync pulse therefore arrives too soon, drives the grid into the plate current region, and remains above cut-off for a longer interval because the drop off of the modified waveform is displaced to the right of its in-phase position. This increases the cathode charge, the blocking-tube grid voltage rises and causes a compensating increase in the horizontal frequency to match the incoming sync pulses once again.

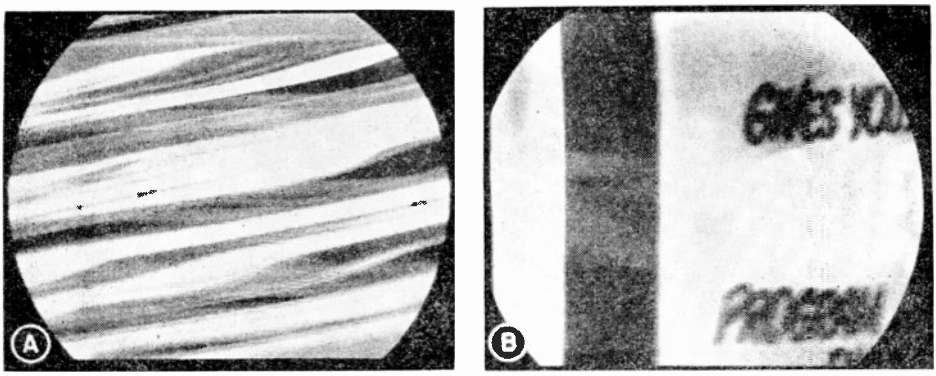

FIG. 36. The diagonal bars obtained just before the oscillator locks in are shown in A, and the blanking bar that may appear on the left as the hold control is rotated fully clockwise is shown in B.

In waveform 4A of Fig. 35, the sync pulse is above cut-off the proper length of time to charge the cathode capacitor to the proper voltage, to hold the blocking tube on correct frequency. In waveform 4B, the horizontal frequency is too high. The sync pulse therefore arrives somewhat later than in 4A, and a part of the pulse is dropped below cut-off by the sharp decline of the modified waveform

This method of frequency control, referred to as a pulse-width system, controls the frequency by the length of the pulse duration. Again the blocking tube frequency is controlled by a dc voltage determined by the horizontal sync pulses. It is not triggered directly by the sync pulses and is therefore not subject to erroneous synchronization by noise pulses.

The noise immunity and stability of this type of sync control system depends upon proper adjustment of the control-tube and oscillator controls. To check the adjustments, tune in a local television station and then rotate the horizontal hold control fully counter-clockwise. In this position the picture should remain in synchronization, but if the channel selector is turned off the channel and immediately back on, the picture should be out of sync. Now rotate the hold control clockwise, and notice that the number of diagonal bars that appear on the screen will be gradually reduced. At the instant only two or three bars appear, as in Fig. 36A, the picture should pull into sync immediately. This location of pull-in should be about 90 degrees from the extreme counter-clockwise position. Rotating the hold control an additional 90 degrees should not cause the picture to fall out of synchronization. As the control is turned to its extreme clockwise position, a blanking bar may be pulled into the picture as shown in Fig. 36B. On some receivers the bar does not quite pull in.

If the noise immunity and oscillator stability are not satisfactory, the syncro-guide circuit must be adjusted in accordance with a recommended procedure. The adjustment is best made by attaching an oscilloscope at point C (Fig. 34) to observe the pattern on the oscilloscope screen as the various adjustments are made. These adjustments are important and the technician should follow the manufacturer's recommended procedures very carefully to obtain the most efficient syncro-guide operation.

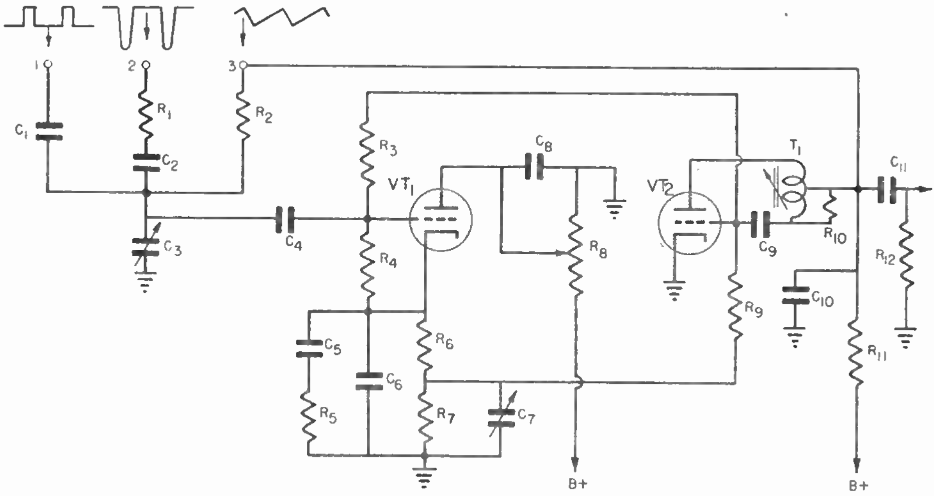

FIG. 37. Schematic of a pulse-width circuit.

The four controls that must be adjusted are the two slugs in the oscillator transformer T1, the hold control, and the capacitor C6. The hold control and C6 primarily affect the frequency, and the transformer adjustments affect the oscillator phase and the phase of the signal fed back to the grid of the control tube.

An earlier syncro-guide system, which is shown in Fig. 37, uses the same basic principles, but has a slightly different means of forming the grid waveform of the control tube. The modified input waveform is obtained by the addition of a fed-back sawtooth wave and a sharp pulse derived from the deflection output circuit. The sawtooth is fed in at terminal 3, and the sharp pulse at terminal 2. The addition of these two signal components forms a modified wave like that shown in 3 of Fig. 35 at the grid of the control tube. To this is added the incoming sync pulses to form the usual syncro-guide grid waveforms as shown in 4 of Fig. 35.

tem, a sine-wave oscillator is used to form a line-rate sine wave. This sine wave is used to control the generation of a sawtooth as well as to serve as excitation for a phase discriminator circuit. In the phase discriminator circuit, the sine wave is compared with the sync pulse. Once again, a difference in phase develops a dc output that is applied to a reactance tube. The reactance tube, in turn, is connected into the resonant circuit of the sine-wave oscillator and in part determines its frequency of oscillation. The schematic of this circuit is shown in Fig. 38.

An electron-coupled Hartley oscillator generates the line-rate sine wave.

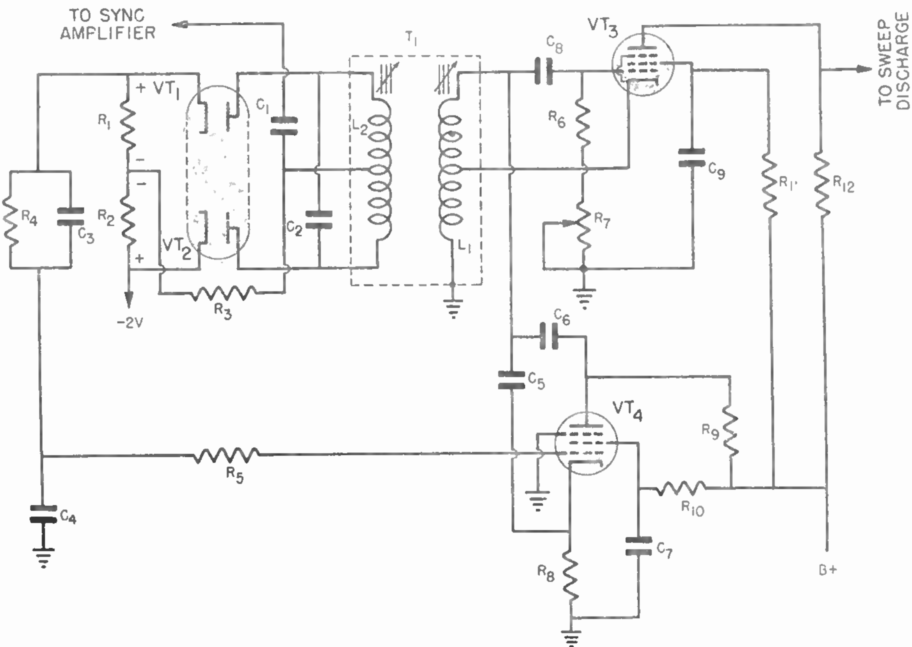

FIG. 38. Syncro-lock horizontal afc circuit.

SYNCRO-LOCK SYSTEM

In many of the earlier receivers and in some few of the newer ones, a system of horizontal control referred to as "syncro-lock" is used. In this sys-

The oscillator frequency is determined by its resonant circuit (of which the reactance tube is a part) and the time constant of C8, R6, and R7. The variable resistor R7, which can vary the oscillator frequency, can be used as the hold control. The plate output is used to trigger a conventional discharge tube that forms the horizontal sawtooth wave.

The frequency of an oscillator, you remember, can be controlled by a dc bias on the grid of a reactance tube. Thus, the frequency of the sine wave oscillator VT3 is controlled over a limited range by the charge on capacitor C4 which is in the grid circuit of the reactance tube VT4. The charge on C4, which is developed by the phase discriminator, changes as the phase relationship between the sine waves, that are fed into the phase discriminator circuit, and the sync-pulses change.

The syncro-lock circuit is extremely stable and provides excellent oscillator stability even in areas where the signal is weak and the noise level high. However, this system has been abandoned because of the number of tubes required.

COLOR SYNCHRONIZATION SYSTEM

In a color receiver, in addition to the conventional horizontal and vertical synchronizing circuits, a special color synchronizing circuit is used to make certain that the chrominance (color) information is superimposed properly on the luminance (brightness) information. This superimposition must occur at the proper time and in synchronism with the chrominance information from the station. For example, the synchronizing system makes certain that the red hue of a red rose on a bush falls exactly on the rose and is not displaced so that the red hue falls on the leaves of the rose bush.

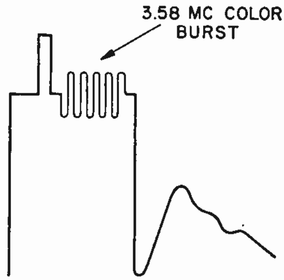

FIG. 39. The 3.58-mc color burst is placed on the back-porch of the horizontal blanking pulse.

The composite color television signal, accepted as standard by the Federal Communications Commission, differs from the standard monochrome signal, by the addition of a color synchronizing burst that rides on the back-porch of the horizontal blanking pulse as illustrated in Fig. 39. The burst signal occurs at the chrominance sub-carrier frequency of 3.58 megacycles (the chrominance sub-carrier is a signal that is modulated by the color hue and saturation information in the color television system). This small sample of the basic sub-carrier frequency, that is added to the blanking pulse, must synchronize the receiver circuits that release the chrominance information in proper sequence for perfect superimposition of the color information on the monochrome picture detail.

The sub-carrier burst consists of about 8 cycles of the basic sub-carrier frequency, which is applied to a comparison circuit in the receiver. Here it is compared with the locally generated sub-carrier frequency that is actually releasing the color information continuously. Thus the few cycles in the color burst must synchronize the local sub-carrier generator. This stage is generating and inserting the sub-carrier into the received chrominance information, so that the chrominance data can be released properly.

The composite video signal from one of the video amplifiers in the color receiver is first applied to a burst amplifier. A negative horizontal gate pulse from the horizontal deflection circuit is also applied to the burst amplifier as shown in Fig. 40. The gate pulse, which is applied to the cathode, permits the burst amplifier to conduct only during the back-porch of the horizontal retrace interval. Thus synchronizing, video, and noise impulses, which arrive between the sub-carrier bursts, are prevented from appearing in the plate circuit of the burst amplifier.

burst signal is then coupled to the resonant circuit in the input of the phase detector. Thus bursts of pulses of equal amplitude but opposite polarity are applied to the two diodes. A comparison sine wave is applied to the other side of the phase detector much as the sawtooth wave in the previously discussed horizontal afc systems. If the locally generated sine wave and the burst pulses have the correct phase relationship, the sine wave will be going through zero when the peak of the burst pulse is applied to the phase detector. (There is a 90-degree phase displacement between the two signals.) Under these conditions, there will be zero output from the phase detector. However, if there

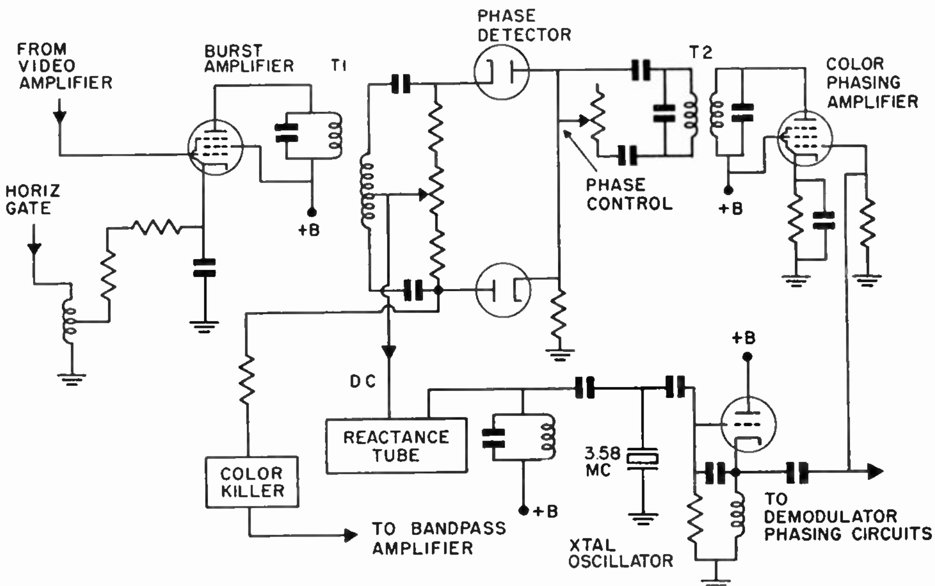

FIG. 40. Simplified circuit of a color synchronization system.

A resonant circuit in the plate circuit of the burst amplifier is tuned to the 3.58-megacycle sub-carrier frequency to emphasize this component and reject all others. The amplified

is a phase displacement between the locally inserted sine wave and the burst pulse of other than 90 degrees, a positive or a negative dc voltage, depending on the direction of the phase and frequency change, is developed at the output of the phase detector. This dc voltage is supplied as bias to the reactance tube, shown as a block in Fig. 40.

The reactance tube is connected across a crystal-controlled oscillating circuit, which generates the sub-carrier sine wave that is applied to the chrominance or color demodulator circuits. A portion of this same crystal-controlled sine wave is also applied, through the color-phasing amplifier and phase-shift transformer T2, to the phase detector. This is the locally generated component that is compared with the incoming burst frequency. Consequently, the incoming sub-carrier burst synchronizes the crystal-controlled sub-carrier generator of the receiver, so the phase of this locally generated sub-carrier is proper for correct demodulation of the color information.

When a color receiver is to reproduce a monochrome (black and white) picture, there is the possibility of disturbing signals from the color channels of the receiver. To prevent this, a color-killer circuit is used in the color synchronization system. It is operated by the dc component developed by the phase detector. It cuts off the bandpass amplifier, which is the door into the chrominance channel, and prevents operation of the chrominance channels during the reception of a monochrome picture.

Location of Sync Defects

The location of defects in the sync circuits can be best accomplished in an orderly step-by-step manner. The following procedure can be used satisfactorily with most receivers.

1. Observe Picture on Screen. Analyze disturbance and try to determine which section of receiver is most probably defective. The photographs of Fig. 2 show most common disturbances in sync circuits. By identifying the type of trouble you have, you can usually isolate the trouble to a small section of the sync system.

2. Check Tubes. Check tubes in sync stage, vertical oscillator, and horizontal oscillator (still the most common source of trouble) by substitution while observing the picture.

3. Apply Oscilloscope. Use oscilloscope to narrow down defect to a particular stage of the sync system. Use scope to make certain that proper composite signal is being applied to

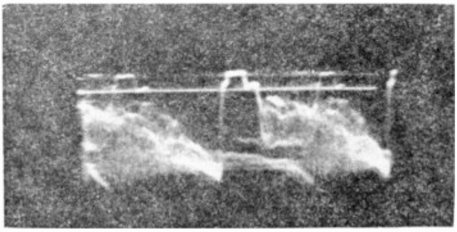

FIG. 41. Waveform shows sync clipping in video amplifier. It causes unstable synchronization because of reduced level of sync (narrow voltage range between sync tip and blanking level.)

sync input (refer to the photos of Fig. 19). On occasion sync is clipped by failure in the video amplifier or agc before it reaches the sync-circuit input, as shown in Fig. 41.

4. Use Oscilloscope and VTVM. Use scope and VTVM to locate defective component. It is helpful to be able to measure the peak waveform voltage as well as dc voltages in the sync circuits.

To isolate a defect, the oscilloscope can be attached for observation at four key check points (again refer to the photos of Fig. 19) in the sync circuits:

(*a*) *Sync Input.* A scope attached at the sync input indicates immediately if the defect is in the sync circuits or in a preceding stage. A means of measuring peak amplitude is often helpful, as the measurement can be compared with what the manufacturer considers normal at this point.

(*b*) *Sync Separator-Amplifier Output.* A scope test here permits you to check the separation action and the build-up of sync prior to segregation.

(*c*) *Vertical Integrator and Oscillator.* A scope observation at this point permits you to check if the vertical sync pulse is present and ready to synchronize the vertical oscillator (vertical oscillator tube must be inoperative for this check). Likewise, with oscillator tube in operation, check to see how the oscillator waveforms compare with those recommended by manufacturer.

(*d*) *Horizontal Sync Input and Oscillator.* Here the scope permits you to check for the presence of the horizontal sync pulse at the point of synchronization (horizontal oscillator tube inoperative). Likewise with tube in operation check to see how oscillator waveforms compare with those recommended by the manufacturer.

OSCILLOSCOPE VOLTAGE CALIBRATION

It is easy to check the amplitude of various sync circuit waveforms to see if they comply with the levels indicated as normal by the manufacturer. Some oscilloscopes have built-in voltage calibrators, and external voltage calibrators are available to calibrate any oscilloscope. Since the voltage calibrator is a rather simple device, one can be constructed using a few simple components.

The peak voltage of an oscilloscope waveform can be measured by using a substitution principle. For example, the desired waveform can be presented on the scope screen and the scope vertical gain control adjusted until the vertical height of the pattern covers a prescribed number of divisions (let us say four divisions). After the gain control and/or attenuator have been adjusted so the pattern is the desired height, these controls *should not be adjusted again.* Next the waveform is removed and a 60-cycle sine wave is applied to the vertical input of the scope. Now the *amplitude control on the calibrator* is adjusted (remember not to adjust or change the setting of the vertical gain control on the scope) until the sine wave occupies exactly the same number of divisions (four in our assumed example). The rms value of the 60-cycle sine wave is now measured on an accurate meter. This reading indicates the rms voltage that had to be applied to the scope input to obtain the same deflection on the scope screen as the waveform to be measured. To convert this reading to the peak-to-peak voltage, multiply the meter reading by 2.82 (peak-to-peak voltage equals 1.4 x 2 x rms).

A simple voltage calibrator can be constructed from a 6.3-volt filament transformer, an accurate 0-10 volt 60-cycle meter, a potentiometer, and a few resistors as illustrated in Fig. 42. The voltage across the output can be adjusted with the potentiometer. The meter reading indicates rms volts applied to the oscilloscope input. An additional resistor divider at the output can be used to divide the output voltage by a factor of 10 to obtain very low sine-wave components for measuring weaker signal amplitudes.

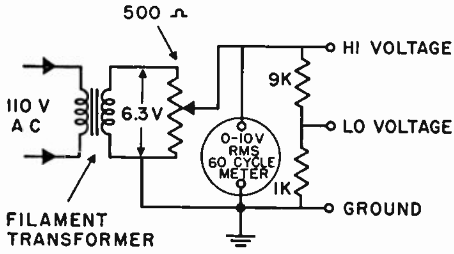

FIG. 42. Diagram of a voltage calibrator for use with an oscilloscope.

To summarize the operation of the calibrator in measuring pulse amplitudes, follow this step-by-step procedure:

1. Apply pulse to be measured to the oscilloscope input. Adjust the vertical attenuator and vertical gain control of the oscilloscope until the pattern occupies a prescribed number of vertical divisions on the scope screen. Do not again adjust these controls until the measurement has been completed.

2. Apply the calibrating sine wave to the same vertical input of the oscilloscope. Adjust the calibrator potentiometer until the sine wave occupies the same number of scope divisions.

3. Multiply the rms meter reading on the meter by a factor of 2.82 to obtain the peak pulse voltage.

Lesson Questions

Be sure to number your Answer Sheet 56B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. If a defect in the sync separator prevents the sync pulses from reaching the horizontal and vertical sweep oscillators, will the oscillators continue to oscillate?

2. If, in a TV receiver, you find that you can sync the vertical sweep oscillator but not the horizontal, where would you look for trouble, in the sync separator or in a sync amplifier used to amplify only the horizontal sync pulses?

3. Why are isolating circuits needed at sync take-off points?

4. What is the purpose of the sync separator stage?

5. What two techniques are used to make synchronization less subject to noise interference?

6. How do we cause a tube to cut off at a low negative bias?

7. What is the function of the integrator?

8. What is the disadvantage of applying the sync pulse directly to the horizontal oscillator to obtain synchronization?

9. Why are horizontal afc systems not subject to noise triggering?

10. If in servicing a TV set with an oscilloscope, you found the sync pulses clipped at the input to the sync separator, where would you look for trouble, in the sync separator or in the video circuits?

TO BE INDEPENDENT, PRACTICE ECONOMY

To become truly independent, the practice of *simple economy* is necessary. And *economy* requires neither superior courage nor great virtue. It requires only ordinary energy and consistent attention. Essentially, *economy* is the spirit of orderliness applied to the administration of your own *personal affairs*. It means management, regularity, prudence, and the avoidance of waste.

Economy also requires the power to resist present gratification of your wants, in order to secure future benefits. And even wild animals practice this *economy* when they store food for the winter!

Yes—the practice of *economy* is necessary unless and until you figure out some fool-proof way to make money faster than you can spend it! I'll admit that a few men have been able to do this—but until you can discover this golden secret, your best road to independence will be the day in and day out practice of *reasonable economy*.

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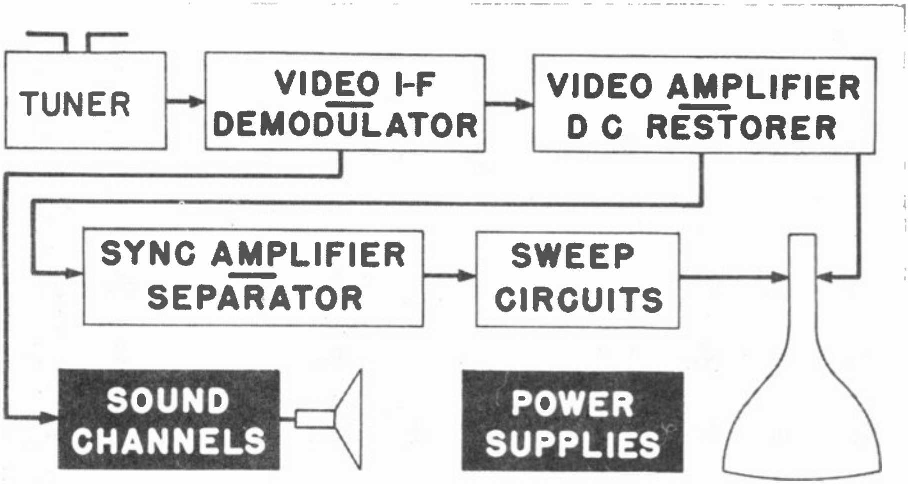


YOU HAVE now studied all of the sections of the television receiver that are directly responsible for the reproduction of a picture. This lesson covers some of the auxiliary circuits. These are absolutely essential to the complete television set, but are not directly involved in reproducing the television picture.

All of the circuits covered in this lesson have been touched upon in your previous lessons. You cannot study any television circuit without recognizing the existence of power supplies. In your lesson on i-f amplifiers and video amplifiers some of the methods of sound take-off were discussed, and you learned that a sound signal exists throughout the television system up to the video amplifier.

You will recall from your study of tuners and i-f sections that an agc (automatic gain control) voltage is invariably fed back to some of the i-f amplifiers and also is usually fed back to the tuner. Thus, none of the circuits studied in this lesson will be entirely new to you, but you will learn more of the details of their operation.

POWER SUPPLIES

The block diagram in Fig. 1 illustrates the general pattern of the most frequently used power-supply system in modern television receivers. Other systems have been used and will be found in some receivers still in use,

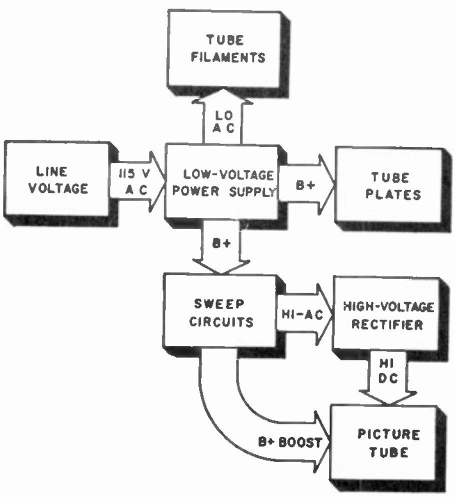


FIG. 1. A block diagram of the most frequently used TV power-supply system.

but in general this is the system that you will encounter most often in TV receiver servicing. Of course, all of the systems in use today will be studied in more detail later in this lesson.

The top four blocks in the diagram in Fig. 1 represent an ordinary power supply much like the ones that you are familiar with from radio servicing. A 115-volt ac line voltage is fed into a low-voltage power supply, which in turn supplies low-voltage ac to the tube filaments (usually 6 or 12 volts), and a dc voltage usually between 200 and 300 volts to the plate circuits of the various tubes in the receiver. However, from your previous studies of television circuits, you know that these voltages are not enough to supply the complete television receiver. The television picture tube demands voltages that are beyond the ability of the ordinary radio receiver power supply to produce. Therefore, we have additional power supply sections, which are represented by the bottom three blocks.

You will recall from your lesson on sweep circuits that, in addition to supplying the necessary sawtooth current to the deflection yoke, the horizontal sweep circuits are actually a part of a high-voltage power supply system. Pulses of very high voltage are supplied by the sweep circuits to a high voltage rectifier, which in turn supplies an extremely high dc voltage to the picture tube. You will also recall that the rectifier action of the damper tube in the horizontal sweep circuits supplies a "B+ boost" voltage. It adds about 50% to the normal 200- to 300-volt B+ supply. This B+ boost voltage, usually about 450 volts, is sometimes used to supply the first anode of the picture tube and often the plates of some of the other tubes, such as the horizontal deflection amplifier.

From this brief study of the power supply system, shown in Fig. 1, we can summarize the various voltages that the television power supply must furnish. It must supply a low voltage for the tube filaments, a normal B+ voltage of 200 to 300 volts for most of the tube plates, a "B+ boost" voltage somewhere between 450 and 500 volts for the picture tube first anode and possibly the plates of some other tubes, and an extremely high dc acceleration voltage (about 20,000 volts in some cases) for the picture tube. The various methods used to supply these voltages by the different power supply systems will be studied in detail.

SOUND SYSTEMS

The sound system of a TV receiver actually begins at the antenna, because the sound is received in the form of a frequency-modulated carrier at the same antenna that receives the video signals, and it accompanies the video signal through some of the stages of the TV receiver. From your study of previous lessons, you should be familiar with the manner in which the sound signals are transported through the stages of the receiver common to both sound and video signals. You also know, from your previous studies, that there are two different methods used to separate sound from video signals, the separate channel system and the intercarrier system.

The block diagram in Fig. 2 illustrates the general plan of an inter-carrier sound system. This is the most frequently used system in modern television receivers, but there are still many receivers having separate sound channels.

In the block diagram, sound and video radio-frequency signals are received at the antenna and delivered to the tuner. The tuner converts the signals into i-f signals, and delivers them to the video i-f amplifiers for further amplification. The sound and video signals from the i-f amplifiers are delivered to the video detector. In the video detector, the sound and video signals beat together, producing a 4.5-megacycle sound i-f signal. This signal is further amplified in the sound i-f amplifier and fed to a sound detector, which is usually a ratio detector. From the sound detector, audio signals are sent to a conventional audio amplifier where they are further amplified and then used to drive the speaker.

In your previous studies you have been concerned with the video signal, and with the sound only insofar as separating it from the video signal and keeping it from interfering with picture reproduction are concerned. In this lesson we will be concerned with the preservation and reproduction of the sound. You have already studied tuners, video i-f amplifiers, and video detectors; this lesson will deal with sound i-f amplifiers, sound detectors, and audio amplifiers.

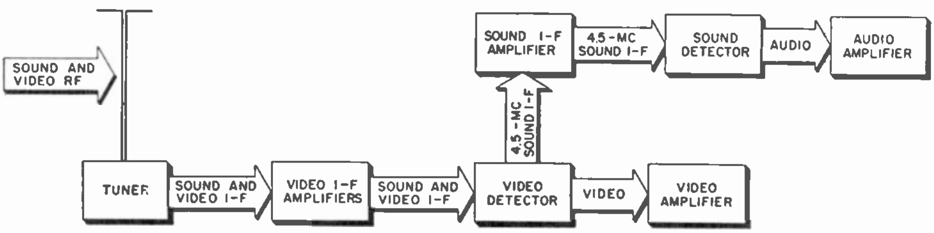


FIG. 2. A block diagram of a commonly used sound system.

AUTOMATIC GAIN CONTROL

The primary purpose of automatic gain control in television receivers is exactly the same as that for automatic volume control in broadcast receivers. (In fact, avc should be called agc.) That is, the automatic gain control serves to change the bias on certain tubes in the receiver to compensate for variations in the strength of the carrier signal being received. However, the nature of the television signal is somewhat more complex than the ordinary broadcast signal. Therefore, you will find that the gain control systems used in television receivers are generally more complex than those used in broadcast receivers.

The general plan of an automatic gain control system is shown in the block diagram in Fig. 3. Here the composite video signal is received at the tuner, its i-f output signal is amplified in the video amplifiers, and a detected composite video signal is available at the detector. The agc

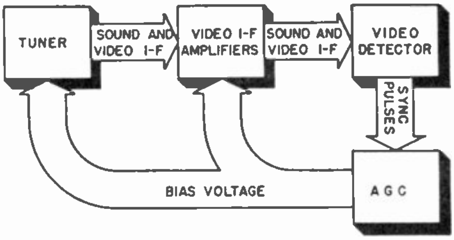


FIG. 3. The general plan of automatic gain control systems.

system may receive the composite video signal. However, since the strength of the bias voltage produced by the agc system is usually dependent upon the sync pulses only, the sync pulses are indicated as being received by the agc system.

The reason that the agc system must operate from the sync pulses is that the agc bias voltage fed back to the tuner and the i-f amplifiers must be proportional to the strength of the carrier signal, and therefore must be derived from a signal that is always in direct proportion to the carrier strength. The sync pulses are the only portion of the composite video signal that meets this requirement. They will always be in direct proportion to the strength of the carrier, but the picture portion of the video signal will vary according to the requirements of the picture being reproduced.

The agc system utilizes the sync pulses to produce a bias voltage that may be fed back to the video i-f amplifiers and/or the rf tuner. When there is an increase in carrier strength, the negative bias on those stages fed by the agc system will increase in proportion and thus maintain a fairly constant reference amplitude for those signals fed into the video detector. The various methods of accomplishing agc are discussed in detail later in this lesson.

From the foregoing descriptions of television power supplies, sound systems, and automatic gain control you can see that most of this lesson will be in the nature of review. If you have difficulty thoroughly understanding any of the concepts presented in this lesson, you may find a brief review of previous lessons on radio power supplies, automatic gain controls, and your more recent lessons on the various sections of the television receiver helpful.

Low-Voltage Power Supplies

The purpose of the low-voltage power supply is to supply a low, usually ac, voltage to the tube filaments in the television receiver and to supply the B+voltage for most of the tubes in the set. These two are the basic requirements for almost all pieces of equipment using vacuum tubes. Therefore, you will not find anything in television low-voltage power supplies that is radically different from power supplies that you have already studied.

Just as in ordinary radio receivers, there are two main types of low-voltage power supplies: the transformer type and the transformerless type. Both of these are very similar to their radio receiver counterparts, but you will find that the larger number of tubes used in the television set makes some increased demands on the low-voltage supply that requires the use of larger components and sometimes unconventional circuits.

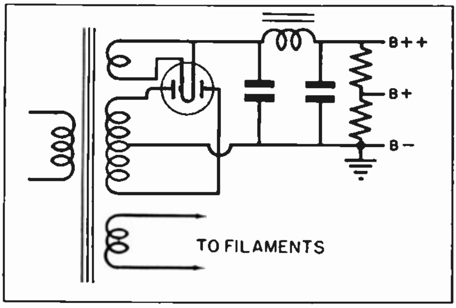


FIG. 4. Basic full-wave rectifier circuit.

TRANSFORMER TYPE

The basic full-wave rectifier circuit shown in Fig. 4 will refresh your memory of conventional transformer-type power supplies. The main difference between this basic power supply and those used in television receivers is that in the television receiver there is apt to be more of everything. The large number of tubes in the television receiver requires a heavy duty rectifier or two rectifiers connected in parallel to supply sufficient plate current. Because of the high current range and the necessity for good decoupling in the television receiver, more filter capacitors of higher capacity will be used. The many different tubes in the television set require a number of different plate-supply voltages. Therefore, there will be more taps on the voltage divider across the output of the power supply. Because of the large number of filaments to be supplied, sometimes filament windings of two different current ratings are used. There are usually two filament windings in addition to the 5-volt winding which supplies the rectifier filament.

A typical low-voltage power supply is shown in Fig. 5. Note that one plate of each rectifier tube is connected in parallel with the corresponding plate of the other tube. The same current-carrying capacity could be achieved by connecting the two plates of each tube together and using each tube as a half-wave rectifier in a full-wave circuit; but in that case, if one tube failed, we would get half-wave rectification and greatly reduced voltage output. With the arrangement shown, if one tube fails, the other tube is somewhat overloaded, but operation is not greatly impaired until both tubes fail.

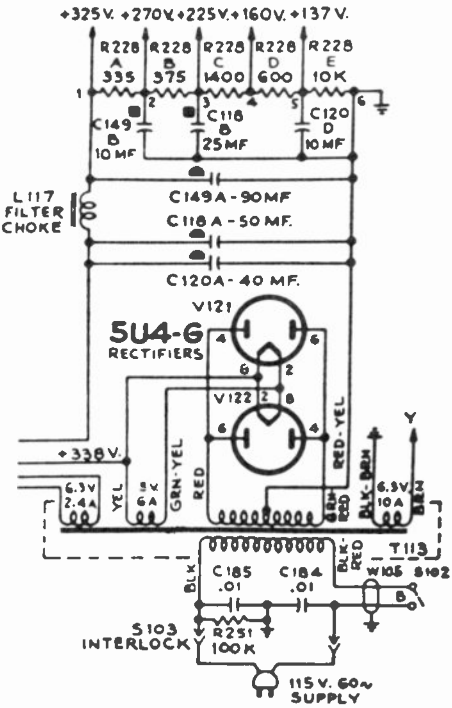


FIG. 5. Typical transformer-type low-voltage power supply.

In addition to the 90-mfd of input and output capacity in the filter network, there are relatively high capacities shunting the various resistors in the voltage divider. These provide additional filtering action.

Some television receivers have low-voltage power supplies that produce negative as well as positive voltages. A simplified circuit of such a power supply is shown in Fig. 6. Note that the over-all voltage output of this supply is about the same as the one shown in Fig. 5, but its maximum voltage to ground is 215 volts. This enables the manufacturer to make some saving on components such as bypass and decoupling capacitors, that must be connected from B+ to ground, because their working voltage need not be as high as it would be if the negative side of the power supply output were connected to ground, making the positive side 335 volts. However, the full 335 volts may be utilized where necessary.

Remember that the voltage applied between any two elements of a stage is equal to the voltage difference between the elements. Fig. 7 shows how a vacuum tube may operate with all of the dc voltages to its various elements negative with respect to ground. It is not uncommon to find an arrangement of this sort in TV circuits, particularly when used with dc-coupled video amplifiers. If the stage shown in Fig. 7 required a plate potential of 335 volts, it would be possible to obtain this from a power supply of the type illustrated in Fig. 6. With the —120-volt tap attached to the cathode, and the +215-volt tap attached to the plate, there would be a difference of potential between cathode and plate of 335 volts, utilizing the complete voltage output of the power supply shown in Fig. 6.

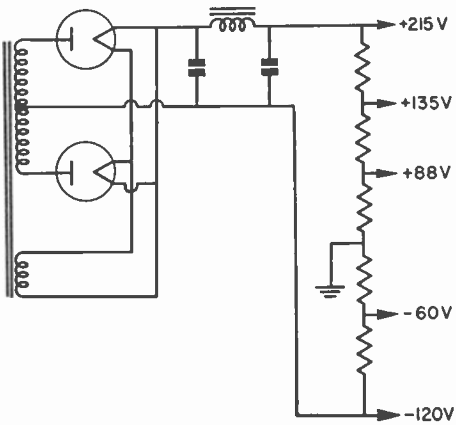


FIG. 6. Simplified circuit of a low-voltage power supply producing both positive and negative voltages.

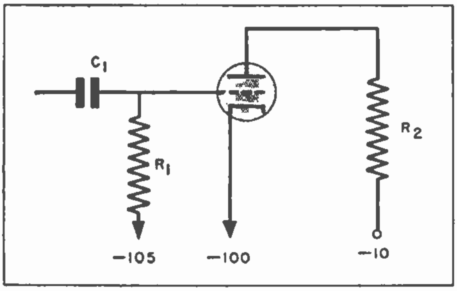


FIG. 7. This tube will conduct with negative voltages applied to all of its elements, because the plate is positive with respect to the cathode and the grid is only 5 volts negative with respect to the cathode.

From the foregoing description of the transformer type of low-voltage power supply it is obvious that there is very little difference between it and the conventional power supplies used in other electronic equipment. It is simply a full-wave rectifier type of power supply which takes into consideration the increased requirements of a large number of vacuum tubes.

TRANSFORMERLESS TYPE

The transformerless low-voltage power supply for television receivers is similar to its radio counterpart in principle only. In actual practice, it is considerably different from the average ac-dc receiver power supply. You will recall that the transformerless radio receiver usually has a very simple filament string, the tube filaments all connected in series across the 115-volt line. The large number of tubes used in a television set prevented such a simple arrangement when the transformerless power supply for television was first conceived. However, a special series of tubes has been developed for television, the filaments of which may be connected in a simple series string. The plate voltage requirement of the television circuits exceeds the voltage available from the simple half-wave rectifier circuit generally used in ac-dc radios. Therefore, some form of voltage multiplier that does not require a transformer must be used for the plate supply circuit of the transformerless power supply. We will discuss this later in this lesson.

Filament Supply. A typical filament supply circuit for TV sets using conventional tubes is shown in Fig. 8. Here, five tubes in series with R1 form one string, and eight tubes plus R2 form another. These two series strings both pass current through tubes VT1 and VT2. Tube VT1 has a current rating twice that of any tube in the series strings so that it can carry both currents. Tube VT2 does not have as high a rating, so it is shunted by resistor R3, which carries the extra current.

The resistors R1 and R2 reduce the supply voltage to the amount required by each series string. They also usually have a ballast action to protect the tubes when the set is first turned on. The tube filaments have low resistance when cold, so a high current could flow through them until they warmed up, if these resistors were not used, and the lives of the tubes would be shortened. To prevent this, the series resistors used are usually

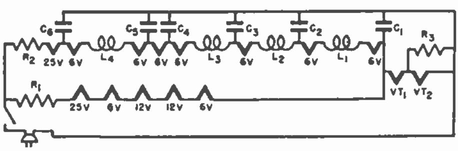


FIG. 8. A series-parallel filament circuit typical of circuits used before the development of special tube types for series connection.

either ballast tubes or special "Globar" resistors made so that their resistances decrease as they get warm. The cold resistance of these resistors is high enough to limit the starting current to a safe value; then, as the tubes warm up, the resistance of the ballast resistors decreases enough to permit the filaments to get the proper currents. If they burn out, it is important to replace them with exact duplicates.

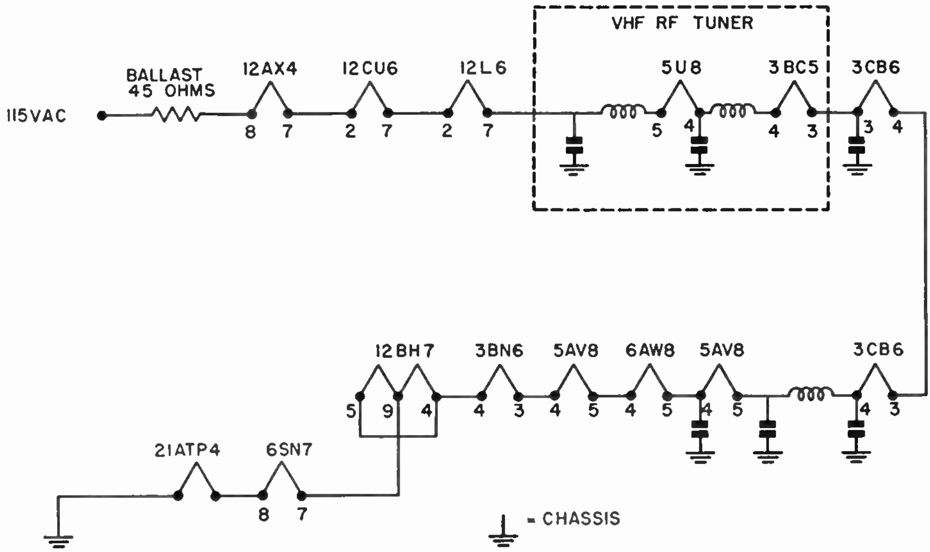


FIG. 9. Series filament string using tubes designed specifically for this type of operation.

The by-pass capacitors and rf choke coils shown act as filters on the rf and i-f tube filaments to prevent stray coupling between stages along the filament leads.

A simpler filament circuit is shown in Fig. 9. This circuit utilizes the special tube types with filaments designed specifically for series operation. Note that many of the tubes in this series string are familiar conventional tubes, but there are also a number of tubes having 3-volt or 5-volt filaments. These are the types which allow series connection of all tube filaments. The filaments of these special tubes are designed for a current of 600 ma. Except for their filament ratings, these tubes are the same as the equivalent 6-volt tubes. That is, the 3CB6 is the same as a 6CB6, and a 3BC5 is the same as a 6BC5, etc. Also note that the choke coils and capacitors are still necessary in the rf and i-f tube filament circuits to prevent stray coupling between these stages, and a low-resistance ballast resistor is still required in series with the filaments.

Plate Supply. The obvious solution to supplying a voltage somewhere between 200 and 300 volts to the plates of the various tubes in a television set is the use of a voltage-

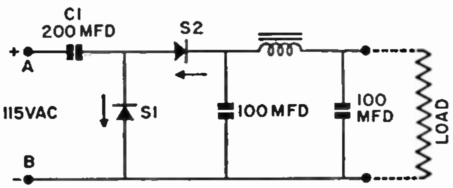


FIG. 10. A voltage-doubler circuit similar to circuits used in many TV sets.

doubler circuit. To refresh your memory on the operation of these circuits, a simple voltage doubler much like those used in TV sets is shown in Fig. 10. Instead of the more familiar vacuum tube rectifiers, the circuit uses selenium rectifiers. These consist of washers coated with selenium, which has the property of conducting far better in one direction than in the other. Although not perfect rectifiers, they are satisfactory and have several advantages over the conventional vacuum tube rectifier. They are small and do not take the space required for vacuum tubes of equivalent rating, and even more important in their application to low-voltage TV power supplies, they require no filament voltage or current.

The operation of the circuit shown in Fig. 10 can best be understood by studying Fig. 11. As shown here, an ordinary sine wave voltage, with a peak amplitude E on each side of O, is applied across terminals A and B of the voltage doubler. When the input voltage makes terminal B positive with respect to terminal A, S1 will conduct in the direction indicated by the arrow beside it. Thus, electrons will be drawn away from the right-hand plate of condenser C1, making that side of the condenser positive. By the same token, electrons will collect on the left-hand plate of C1, making it negative. Because S1 will not conduct in the opposite direction, after a few cycles of input voltage have been applied, C1 will be charged to the peak value of the sine wave voltage with the polarity indicated. Thus across rectifier S1 there are two voltages—the dc voltage equal to the peak value of the input sine wave, E, and the input sine wave voltage. When these two voltages are combined, the over-all effect is to raise the reference level of the sine wave voltage from O to E so that the peak positive value of the sine wave is 2E, just twice the peak positive value of the input voltage.

The second half of the voltage doubler should be very familiar to you. It is nothing more than the simple half-wave rectifier circuit that you have encountered many times in ac-dc radio receivers. It consists of S2 and a conventional filter network. The function of this section of the voltage doubler is simply to rectify and smooth out the ac voltage that appears across S1, producing a dc output that approaches 2E as its peak value.

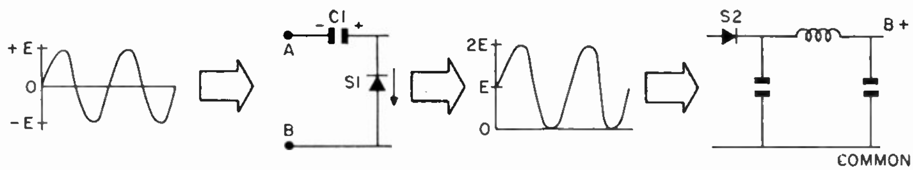


FIG. 11. Half-wave voltage doubler action.

The voltage doubler just described is a half-wave or cascade type of voltage doubler. It is the most widely used type in modern transformerless low-voltage power supplies, and is the basis of many more complicated systems that have been used in television receivers.

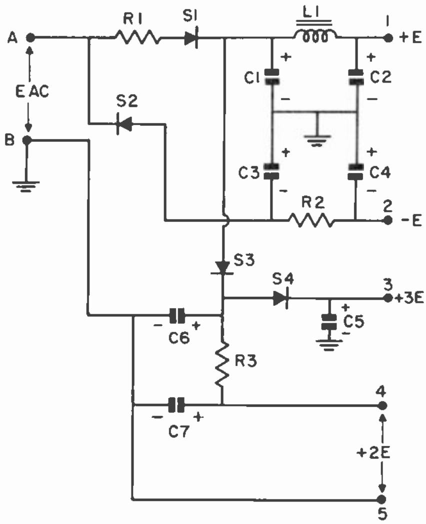


FIG. 12. An elaborate voltage multiplier typical of some that have been used in TV receivers.

With additions to and variations of the basic voltage doubler circuit, it is possible to develop voltage multipliers with outputs three or four times the value of the ac input voltage. Such systems have been used in television receivers, and it is possible that you have encountered them. One such system that makes it possible to get voltages up to four times the value of the input is shown in Fig. 12.

It is possible to get four different B+ voltages from this circuit in approximate multiples of the power line voltages. Each of these different voltages can be fed independently to circuits requiring it.

S1 is simply a half-wave rectifier that provides a voltage of positive polarity at terminal 1 that is approximately equal to the line voltage, E. S2 is also a half-wave rectifier with polarity reversed so that it supplies a dc voltage of negative polarity with respect to ground at terminal 2, that is equal to the line voltage.

S1 and S3, along with C6, C7, and R3, form a voltage-doubler circuit that supplies a voltage equal to twice the line voltage across terminals 4 and 5. The dc voltage that appears across C6 is equal to twice the line voltage and is combined with the line voltage in another voltage-doubler action and rectified through S4 so that a voltage equal to three times the line voltage appears between terminal 3 and ground. Thus, there is available at the output of this power supply a voltage equal to one, two, three, or four times the value of the ac input voltage. There is a voltage of —1E between terminal 2 and ground, a voltage of 2E between terminals 4 and 5, a voltage of 3E between terminal 3 and ground, and a voltage of 4E between terminals 2 and 3.

Such elaborate power supplies as that shown in Fig. 12 are rarely used in modern television sets, but it is well to be familiar with the concept of voltage multipliers in the event that you should find them used in some older sets. Some other voltage multiplier circuits will be studied later in this lesson in the section on high-voltage power supplies.

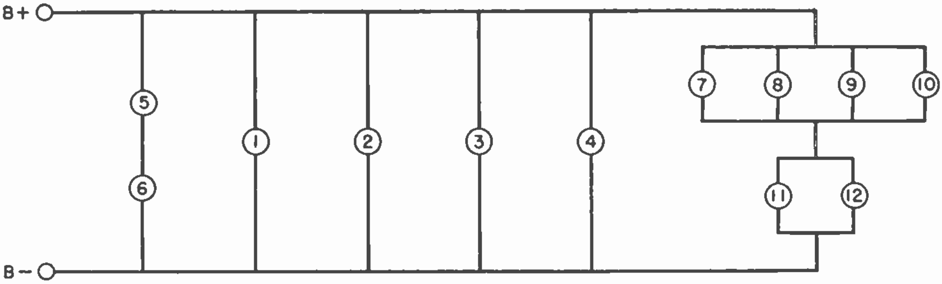


FIG. 13. A B+ voltage-distribution system used with a transformerless supply.

B-Supply Distribution. Since the current available from any voltage multiplier circuit is rather limited, it is common practice not to use a bleeder with transformerless supplies but to arrange the tube circuits insofar as possible to use the full output of the B supply. If some stages are to operate at lower voltages, the stages may be connected so as to divide the voltage between them, as shown in Fig. 13. Here, the stages numbered 1, 2, 3, and 4 are connected directly across the full B supply. Stages 5 and 6, however, are in series across the supply. This arrangement is permissible if the two stages are to operate from half the total supply and draw identical currents.

In the rest of the circuits, stages 7, 8, 9, and 10 are in parallel, and their currents flow through stages 11 and 12. In this case the plate current sum of the first four must equal that of the latter to give the proper voltage division.

Fig. 14 shows how two tubes may be connected in series across the power supply. In this case the dc path, starting from B—, goes to the cathode of VT1, then through this tube and its load resistor R2 to the cathode bias resistor R4 of VT2. From here, the path is through tube VT2 and its load resistor R5 back to B+.

B+ Boost. When a simple voltage doubler such as that shown in Fig. 10 is used, it is hardly possible to get more than 250 to 275 volts at the output of the doubler. As you already know, in modern television sets, voltages close to 400 volts or more are required for the picture tube first anode and sometimes other tubes in the set. These voltages could be obtained, and have been in some older sets, with an elaborate voltage multiplier of the type shown in Fig. 12. However, in modern TV sets, a simpler and more economical system is used.

You will recall from your lesson on sweep systems that it is possible to obtain an additional high voltage from the action of the damper tube in the horizontal sweep system. Fig. 15 shows the manner in which a voltage

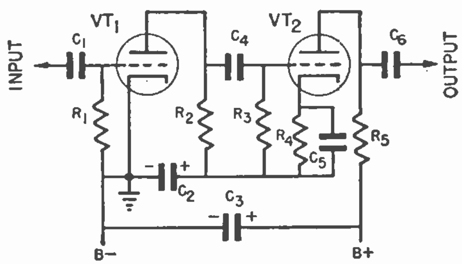


FIG. 14. How two tubes may be connected in series across the B supply.

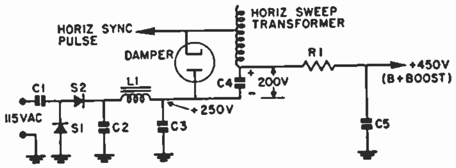


FIG. 15. B+ boost is obtained by utilizing voltage developed by current flow through the damper tube.

developed by the current flowing through the damper tube is added to the B+ voltage supplied by a simple voltage doubler circuit. C1, C2, and C3, S1 and S2, and L1 form a voltage doubler circuit and filter combination that produces 250 volts dc across C3. This dc potential appears at the plate of the damper tube. The damper tube is conducting about 50% of the time the horizontal sweep circuit is in operation; in effect, its operation is much like that of a half-wave rectifier, and a dc potential (in this case about 200 volts) is developed across C4. Since C4 and C3 are in series, the voltages across them are additive when in the proper polarity. Thus a net boosted B+ voltage of 450 volts appears across C5.

This simple system of increasing the B+ voltage is used in transformer-type power supplies as well as in the transformerless type. Its economy in either case is obvious. When a flyback horizontal sweep system is used, as in most modern receivers, a damper tube is essential anyway, so the extra B+ is obtained at very little extra cost. Thus, complicated voltage multiplier systems are avoided; or in the case of transformer type supplies, the size of the transformer itself can be considerably reduced.

High-Voltage Power Supplies

The development of high-voltage power supplies in TV receivers is tied directly to the development of larger picture tubes. In the first commercial television sets the picture tubes were so small that it was possible to obtain their acceleration voltage from a conventional transformer type 60-cycle power supply. As larger picture tubes were developed, requiring higher acceleration voltages, it became impractical to supply this voltage in the conventional manner because of the danger of this type of supply and because of its high cost.

There are television sets still in use today that use 60-cycle, rf, and pulse type high-voltage power supplies, but the modern television receiver uses some type of flyback high-voltage supply which utilizes pulses developed across the horizontal output transformer to generate the necessary high voltage.

EARLIER TYPES

Until it became necessary to supply more than 5000 or 6000 volts to the picture tube for acceleration, conventional transformer-type power supplies could be used for high voltage. Such a 60-cycle supply is shown in Fig. 16 This half-wave rectifier circuit supplies 6000 volts between the filament of the rectifier tube and ground. The half-wave supply is used because a full-wave power supply would require a transformer secondary with twice as many turns as that shown in Fig. 16.

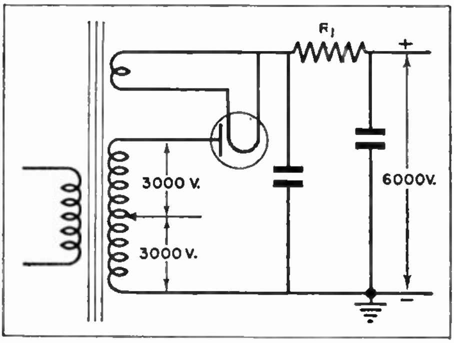


FIG. 16. Half-wave transformer-type high-voltage power supply.

Note that the filter system used with this power supply uses a resistor instead of a choke coil. Since very little current is demanded of the power supply, this resistance can be fairly high without impairing the operation of the picture tube and at the same time serve as a safety feature. As long as this resistance is of sufficiently high value, even a small amount of current drawn from the circuit will cause the major portion of the voltage drop to be across the filter resistance rather than across the load which draws the current. Therefore, if the serviceman accidentally touches the high-voltage lead, the voltage will be so divided that the greater drop is across the filter resistor and the voltage applied to his body may not be fatal. However, bear in mind that the effects of electric shock vary with individuals. A voltage that is not harmful to one may be fatal to another. Therefore, EXERCISE EXTREME CAUTION WHEN WORKING NEAR ENERGIZED HIGH-VOLTAGE SUPPLIES. Even when

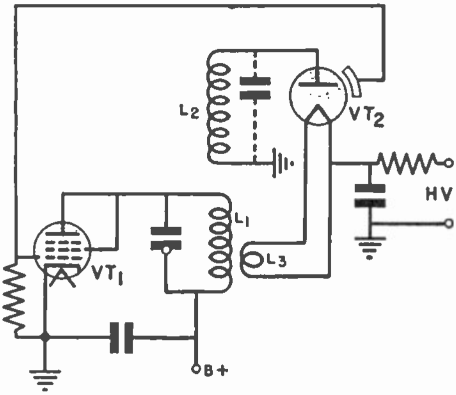


FIG. 17. A typical rf high-voltage power supply.

the high-voltage supply is not energized, ground all capacitors in the circuit to make sure that they are discharged before touching any part of the circuit.

RF Power Supply. Since the amount of current needed from the high-voltage power supply is very nearly negligible—a few microamperes—it has been possible to develop high-voltage power supplies that are much less cumbersome and expensive than the conventional 60-cycle type. One of these is the rf power supply.

By using an rf oscillator to supply a voltage with a frequency of somewhere between 50 and 300 kc, and then stepping up this rf voltage and rectifying it, it is possible to obtain a high dc voltage with much lighter and less expensive coils than are necessary in a 60-cycle transformer. The schematic diagram of a high-voltage power supply operating on this principle is shown in Fig. 17. VT1 is the rf oscillator tube. It is usually a receiver type power output tube. The power requirements of the supply are usually less than 1 watt. The coil L1 and the capacitor connected across it form a parallel resonant circuit in the plate circuit of this tube. Oscillator feedback is obtained from a pickup coil or plate, which may consist of a coil of wire or a sheet of tin foil wrapped around the rectifier tube VT2. This method of feedback makes coil L2 the frequency-controlling winding so that the resonant circuits in the oscillator and in the rectifier tubes are locked together, and loss of high voltage output due to frequency drift in the oscillator is kept at a minimum.

The rectifier tube, VT2, has a very low filament power drain so that it may also be supplied by the energy developed in the rf oscillator. Coil L3 picks up the necessary energy from the oscillator circuit to supply the filament of the rectifier. The rf ripple in the output of the rectifier requires a much lower value of capacity for filtering than does a 60-cycle supply, therefore there is less danger of serious shock from the discharge of filter capacitors in this supply.

The rf voltage supply we have just described has two basic faults. One is that it can produce interference. In an ordinary radio, a frequency of 150 kc or so would be ignored. In a television set, however, this signal will produce a visible interference with the picture if it gets into the video system. (Remember that the video amplifier is capable of passing frequencies from 10 cycles to 4 megacycles, so the rf oscillator frequency is well within this range.) Careful shielding and filtering of the supply leads is necessary to keep this interference at a minimum. (In addition, the shielding serves as a safety device by preventing accidental contact with the high-voltage circuits, which could cause shocks or rf burns, but this is merely incidental to its primary job of eliminating interference.)

Another fault is that the high-voltage supply is independent of the sweep circuits. If the sweep system fails and the high-voltage supply remains on,

The pulse supply shown in Fig. 18 contains a blocking oscillator, an amplifier, and a rectifier. The blocking oscillator produces pulses, just as a similar type does in sweep circuits. These pulses are amplified, then stepped up by transformer T1. Since the blocking-oscillator half-wave pulses have a frequency of about 150 kc, T1 is an rf transformer.

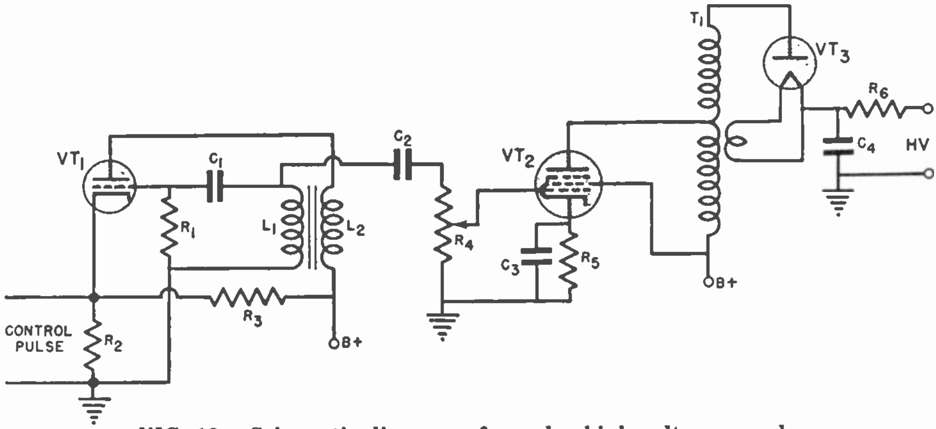


FIG. 18. Schematic diagram of a pulse high-voltage supply.

the electron beam will be concentrated in a single spot on the face of the picture tube. This concentrated beam will burn the fluorescent screen away, thus ruining the tube. (This is also a disadvantage of the 60-cycle supply.

Pulse Type. A high-voltage power supply that overcomes most of the disadvantages of the 60-cycle and rf supplies is the pulse type. Here a blocking oscillator, triggered by the output of the horizontal sweep circuits, is used in place of the rf oscillator. Although this particular type of power supply uses more parts than the rf supply, its advantages in operation outweigh the additional cost of parts.

The oscillator cannot operate until a control pulse is received and is applied across R2 in such a way that the polarity of the control pulse opposes that of the dc drop across this resistor.

This trigger pulse for firing the blocking oscillator is obtained from the output of the horizontal sweep amplifier and occurs only during the retrace portion of the horizontal sweep. Thus, the oscillator VT1 is unblocked only during the horizontal retrace. As soon as it is unblocked, it generates a pulse. This pulse is completed before the horizontal retrace ends; then the oscillator is blocked again by the action of R2 and R3 until the next sweep retrace.

The pulses produced by the oscillator are amplified by VT2, rectified by VT3, and stored in the input filter capacitor. Because very little current is needed, it is possible for a low-capacity capacitor to hold this charge reasonably well during the long time interval from pulse to pulse.

Since this power supply cannot operate at all unless a trigger pulse comes from the horizontal sweep, the high voltage will be removed from the picture tube at once if anything happens to block the operation of the sweep. Furthermore, the oscillator is allowed to operate only during the time of the sweep retrace. Since the face of the picture tube is kept blank during that interval by the pedestal and the sync pulse, any interference that might be produced by the oscillator will be invisible. Therefore, this circuit eliminates both the objections we found to the rf supply.

Another respect in which this pulse supply is better than the rf supply is that its output is not dependent upon resonance and therefore is not subject to variations caused by frequency drifts. The step-up transformer T1 depends upon its turns ratio, not on resonance, for the voltage step-up. The output is controlled by the variable resistor R4, the setting of which determines the amount of signal fed to the grid of the pulse amplifier.

Of course, more parts are used in this supply than in an rf type, but its advantages make its use worth while in spite of its greater cost.

THE FLYBACK SUPPLY

All of the previously described high-voltage power supplies are adaptable to television sets using

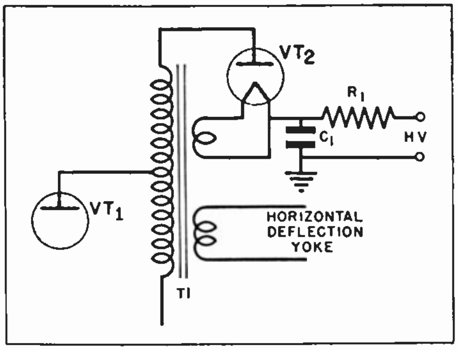


FIG. 19. Schematic diagram of a flyback high-voltage supply.

either electrostatic or electromagnetic deflection in their picture tubes. However, the modern television receiver almost invariably utilizes electromagnetic deflection. Consequently almost all modern receivers use some form of flyback power supply which economically overcomes all of the disadvantages of the power supplies previously mentioned.

You have already been introduced to the flyback power supply in your study of sweep circuits. Therefore, much of the material here will be a review. However, here we will study only those sections of the horizontal sweep system pertinent to the study of producing the high acceleration voltage required by picture tubes.

Fig. 19 is a schematic diagram of a flyback high-voltage supply. VT1 is the horizontal output tube, the output of which is connected to the primary of T1. T1 acts as a combination horizontal output transformer and high-voltage transformer. The two secondaries of T1 are the winding for the high-voltage rectifier filament supply, and the winding that supplies a sawtooth current to the horizontal deflection yoke. However, you will recall that when considering this transformer as a high voltage supply transformer, the secondary acts as the primary and vice versa. The high voltage is not derived from the output of VT1, but from pulses which originate in the horizontal deflections coils due to the rapid collapse of deflection coil current.

From your study of sweep circuits you will recall that when the horizontal deflection coil current collapses, oscillation is set up, one half-cycle of which is utilized in supplying the high voltage and in shaping the sawtooth current waveform. Thus, positive voltage pulses appear across the transformer winding that is connected to the horizontal deflection yoke. These pulses are fairly high voltage, usually somewhere between 2000 and 3000 volts. The winding to which the plate of the high-voltage rectifier, VT2, is connected has four or five times as many turns as the one that is connected to the deflection yoke. Therefore, the voltages across it are sometimes as high as 20,000 volts. These high-voltage pulses are rectified by VT2, and the value of C1 is such that it does not discharge appreciably between pulses. The pulses are at the frequency of the line repetition rate, slightly over 15 kc.

This is a very economical type of high-voltage supply, because it utilizes parts that are essential for the sweep circuits so that no special oscillators are necessary. The power supply is created simply by adding a few more turns to the primary of the horizontal output transformer and a high-voltage rectifier with a filament winding on the transformer. The only completely new parts added are the rectifier tube and filter system. Besides being very inexpensive, this power supply has the advantage of operating only during retrace time when the screen is dark. If anything happens to the horizontal sweep oscillator circuit that makes the sweep fail, the high-voltage pulse will not be generated, and, therefore, there will be no high voltage applied to the picture tube. If high voltage were applied while the sweep was inoperative, the stationary electron beam would burn the face of the picture tube.

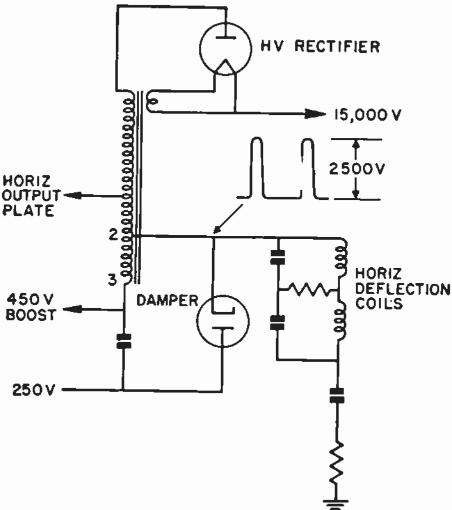


FIG. 20. High-voltage power supply with auto-transformer type of horizontal output.

The flyback power supply shown in Fig. 20 is more commonly found in modern receivers. The principal difference between this and the one shown in Fig. 19 is that an auto-transformer is used instead of a conventional transformer with primary and secondary windings. However, the principle of operation is the same if you consider the single winding in the auto-transformer between points 1 and 3 as the primary winding, and the segment between points 2 and 3 as the secondary winding. Of course, for power supply purposes we would actually consider the segment that is between 2 and 3 as the primary and the segment between 1 and 3 as the secondary. Voltage pulses of about 2500 volts appear across the segment of the winding between points 2 and 3. Through transformer action, this voltage is stepped up across the full winding from points 1 to 3 to a value of about 15,000 volts.

These high-voltage pulses are then rectified by the high-voltage rectifier and appear at the picture tube as a dc potential. You will note in the output of the rectifier tube that there is no conventional filter. The filter, in this case, consists of the capacity between the inside and the outside coatings on the picture tube. The high voltage is connected to the inside coating, which acts as an acceleration anode, and the outside coating is grounded. The capacity thus formed with the glass of the tube as a dielectric serves as the filter for this high-voltage power supply.

The power supply just described is the one that you will most frequently encounter in TV service work. In servicing older TV receivers you might encounter 60-cycle, rf, or pulse type supplies, all of which have been described. In addition to these you may find, in some special applications, power supplies that produce extra-high voltages. Therefore, some explanation of these will be given here.

EXTRA-HIGH VOLTAGES

Extra-high voltages for special applications are obtained by using voltage multiplier circuits in conjunction with pulse or flyback type high-voltage supplies. These are very similar to some of the voltage multiplier circuits that you studied in the section on low-voltage power supplies. You will note that the high voltage multipliers invariably use vacuum tubes rather than selenium rectifiers because selenium rectifiers would not withstand the high voltages across them.

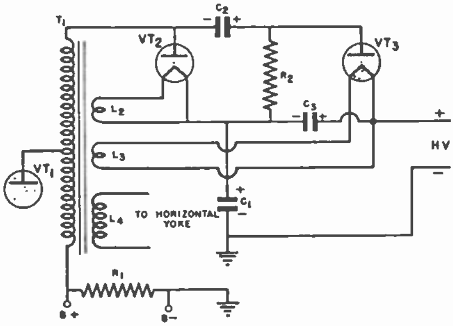


FIG. 21. A voltage doubler used with a flyback high-voltage supply.

The most popular form of voltage-multiplying circuit is shown in Fig. 21. Transformer T1 is the output transformer for either the flyback or pulse circuit and supplies pulses for the high-voltage supply. The resistance, R1, is the low-voltage bleeder; it serves only to complete the circuit from C1 to T1 insofar as the high-voltage supply is concerned. Here is how the circuit works:

On the first pulse, rectifier VT2 charges capacitor C1 to the full output voltage rating of T1. When the pulse cuts off, there is a relatively long period (during the horizontal trace time) in which there is no voltage pulse. C1 is always connected across C2 through paths consisting of R2 on one side and R1-T1 on the other. During the time that VT2 is off, C1 discharges somewhat, charging C2 with the polarity shown. (After several cycles of operation, the voltage across C2 becomes practically equal to that across C1.)

Now, on the next forward pulse, when the upper end of transformer T1 is positive, VT2 again conducts to recharge C1. At the same time, voltage is applied to VT3. The voltage applied is the sum of the pulse voltage across T1, plus the voltage across C2, and minus the voltage across C1. Since the voltages across C1 and C2 are equal and opposite, the voltage developed across T1 is what is applied to VT3. This tube then conducts, allowing the full T1 voltage to be applied to C3. As a result, C3 is charged to the same voltage as C1.

The high-voltage output is the voltage across C1 and C3 in series. Hence, each capacitor supplies half the voltage. If the output is, let us say, 20,000 volts, the voltage across C1 is 10,000 volts, and the voltage across C3 is likewise 10,000 volts. Hence, neither of these capacitors has to have an extremely high voltage rating, which means they can be relatively inexpensive. That is an important feature of this circuit; in some other voltage-doubling circuits at least one capacitor has to be able to withstand a higher voltage.

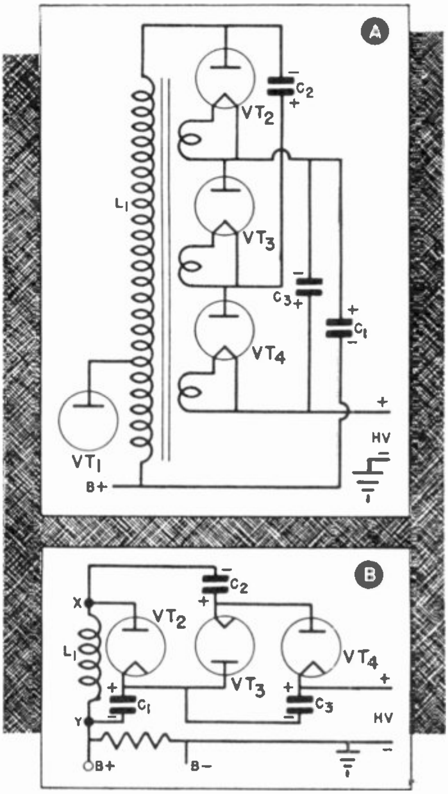


FIG. 23. The action of the voltage-tripler circuit (part A) is shown in part B.

This feature is even more important if the voltage must go up to 30,000 volts or more. A voltage tripler, using the same basic circuit (Fig. 22), is used to produce such voltages. In the circuit in Fig. 22, conduction of VT1 initially charges C1. Then, while VT1 is off, C1 charges C2. On the next pulse of the input voltage, VT2 conducts, charging C3; on the next, C3 charges C4; and on the next, VT3 conducts, charging C5. All five capacitors in the circuit then have the

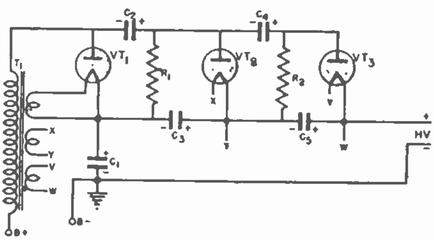


FIG. 22. A voltage-tripler circuit.

same voltage across them. The high-voltage output is the sum of the voltages across C1, C3, and C5.

Another form of voltage tripler is shown in Fig. 23A. This circuit uses fewer parts than the one in Fig. 22, but two of the capacitors must have twice the voltage rating needed in the other circuit. This supply is unusual in that it is driven by a sine-wave voltage instead of by pulses.

The voltage-multiplying action is shown in Fig. 23B. When the polarity of the voltage across L1 makes the upper end (X) of L1 positive, current will flow through the rectifier tube VT2 and thus charge capacitor C1 to a voltage equal to that across the coil. When the polarity reverses, the voltage across L1 plus that across C1 is applied to VT3, causing VT3 to pass current. When VT3 conducts, C2 is charged; since the applied voltage is equal to the sum of the voltage across C1 and L1, C2 is charged to twice the voltage across L1 and must be rated accordingly. On the next half cycle C3 is charged by the voltage across C2 to a value that is twice the source voltage. The output is the sum of the voltages across C1 and C3, three times the source voltage.

Sound Systems

Almost all the material contained in this section is a review. In your study of video sections of the TV receiver, you became familiar with the various methods of sound take-off and the intercarrier i-f system. In earlier studies of FM broadcast receivers you became familiar with FM i-f amplifiers and detectors. Audio amplification is an old story to you. All of these things will be reviewed in this section and, perhaps in some cases, embellished with some facts that you have not learned before.

In previous lessons we have traced the video signal from the antenna to the picture tube, and we learned that, through a large part of its route, the video signal is accompanied by the sound signal. Our principal concern with the sound signal at the time was to see that it did not produce interference in the picture. Here we are concerned with finding out how the sound signal proceeds through the various stages of the television receiver and is faithfully reproduced at the speaker.

THE TUNER

The response of the tuner is generally broad enough so that it treats both sound and video signals impartially, and nothing really unique happens to the sound signal in this section of the receiver. However, since the frequency relationship between the sound and video carriers is reversed, a brief review of what happens in the tuner is worthwhile.

Fig. 24 is a graphic illustration of what happens to the television signal in the tuner. You will recall that the television transmitter sends out an AM video signal along with an FM sound signal. The sound carrier is

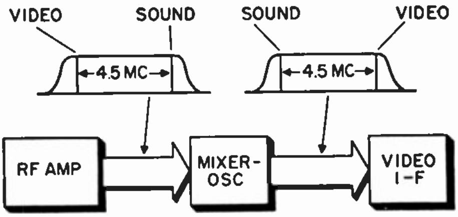


FIG. 24. When the television signal is converted in the mixer-oscillator section, the relative positions of the sound and video carriers are reversed.

always 4.5 mc above the video signal carrier. The response of the rf amplifier is sufficiently broad to amplify both of these signals. The amplified video and sound signals are delivered from the rf amplifier to the mixer-oscillator section of the tuner. In the mixer-oscillator section, the sound and video signals from the rf amplifier are beat against a signal produced by the oscillator, the frequency of which is higher than either the sound or video carrier. The output of the mixer-oscillator section is the difference between the sound and video signals from the rf amplifier and the oscillator signal against which they are beat. Since the sound carrier output of the rf amplifier is 4.5 mc higher than the video carrier output, there will be less difference between the sound carrier and the oscillator signal than there will be between the video carrier and the oscillator signal. For this reason, in the output of the mixer-oscillator section, *the sound carrier will be 4.5 mc lower in frequency than the video carrier* instead of 4.5 mc higher as it was in the transmitted signal. This is the most important fact to remember about the action of the tuner on the sound signal. To fix this fact firmly in mind, let us go through an example with actual frequencies as they would be treated in a typical receiver.

Let us say that a modern television receiver is tuned to channel 2. You will recall that channel 2 covers a 6-mc band from 54 to 60 mc. This complete band will be amplified by the rf amplifier. The picture carrier frequency within this band is 55.25 mc and the sound carrier is 59.75 mc. In most modern receivers the local oscillator frequency will be 101 mc. In the mixer section of the receiver, the picture carrier 55.25 mc is beat against the 101-mc local oscillator signal producing an i-f picture carrier, the frequency of which is 45.75 mc. The 59.75-mc sound carrier will also be beat against the 101-mc oscillator signal, producing an i-f sound carrier frequency of 41.25 mc. Thus, at the output of the mixer section of the tuner, we have a sound carrier which is 4.5 mc lower in frequency than the picture carrier.

In older television sets you are apt to find i-f frequencies that are much lower. For example, 21.25 mc once was a very common sound i-f carrier frequency.

From the mixer stage of the tuner the sound signal will go through some form of i-f stage. If a separate sound channel system, such as that used in older television receivers, is used, the sound signal may go directly from the mixer to a sound i-f system or it may go through one or more video i-f stages before it is fed to the sound channel. In an intercarrier sound system, which is used in most modern receivers, the sound will accompany the picture signals through the video i-f stages.

I-F SYSTEMS

Except for the tuner, early television receivers were actually two receivers; one for the picture signal and the other for the sound. In these receivers the sound signal was picked right off the output of the tuner and amplified through three or four sound i-f stages; then it was detected, amplified in an audio amplifier, and delivered to the speaker. Through experience it was found possible to utilize some of the video i-f stages to replace sound i-f stages. That is, allow both video and sound signal to be amplified in one or two video i-f stages and then take off the sound signal. This cut down on the number of sound i-f stages required. The further back along the video i-f section the sound is taken off, the less amplification is required in the sound i-f section. Any system in which the sound is taken off ahead of the video detector is known as a "separate-channel" sound system.

The most popular system in modern receivers is called the "intercarrier" system. Here the sound signals accompany the video signals through the video detector. In the video detector a beat frequency of 4.5 mc is produced by beating the sound carrier against the video carrier. This frequency becomes the sound i-f, which is taken off either immediately after the video detector or after the video amplifier. When this system is used, it is necessary to have only one sound i-f stage. This economy explains the popularity of this system with set manufacturers. Fig. 25 shows a block diagram of a separate channel system (A) and an intercarrier sound system (B).

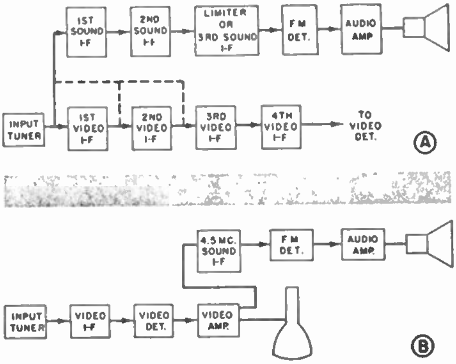


FIG. 25. Separate-channel (A) and intercarrier (B) sound i-f systems.

Separate Channel System. As we have already said, where separate-channel sound is used, the sound i-f signal is extracted from the video signal path either immediately following the converter stage or after one of the i-f stages. There are two problems involved in sound take-off. The first, of course, is to deliver the sound signal to the sound i-f stage. The second is to eliminate as much as possible of the sound signal from succeeding video i-f stages. This second problem, however, is not too great at the point of sound take-off because traps may be inserted in succeeding video i-f stages and video amplifiers. The sound signal is usually removed from the video signal path by means of a trap circuit tuned to the sound i-f frequency. The signal developed across this trap is the source for the sound i-f signal.

Fig. 26 is a schematic diagram of a typical separate-channel sound i-f system. Here the sound accompanies the video signal through the first two video i-f amplifier stages. It is removed by means of a trap at the output of the second video i-f. When the sound take-off trap is properly

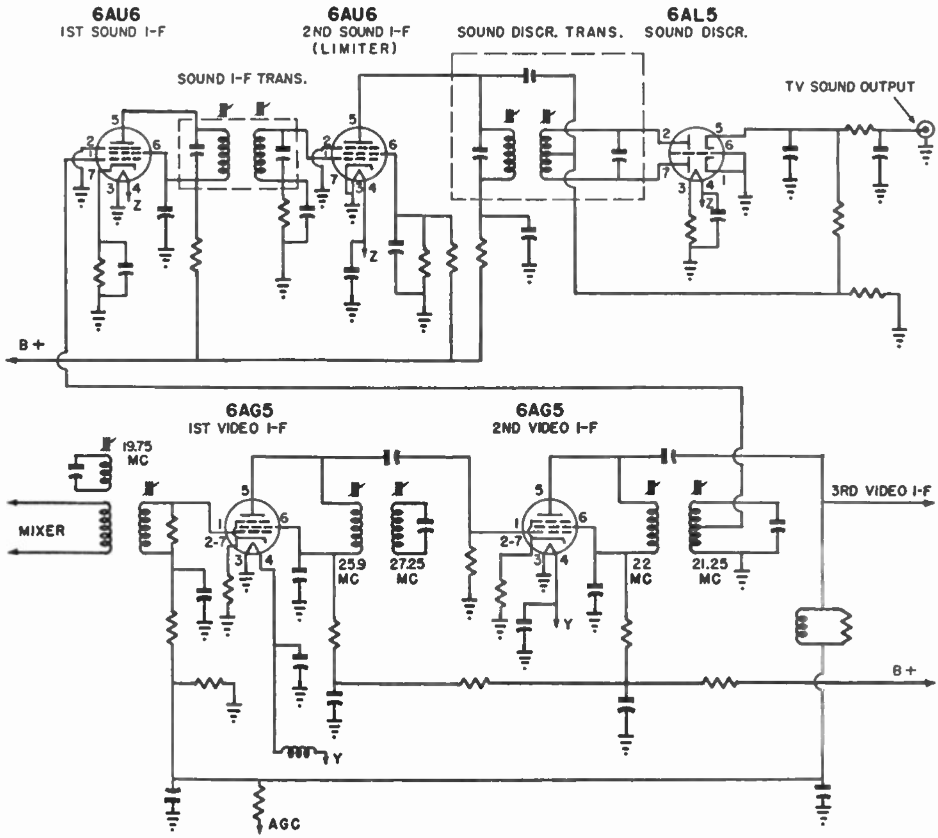


FIG. 26. **Sound i-f system of a receiver using a separate-channel sound i-f.**

resonated, a maximum sound signal is fed to the sound i-f stage, and a minimum sound signal is passed on to the succeeding video i-f stage. Note that the sound i-f frequency in this receiver is 21.25 mc. From the sound take-off point, the rest of the sound system is almost identical to that found in FM broadcast receivers. The sound i-f response is about 300 kc. In this particular circuit there is one i-f stage, which is followed by a second i-f stage which also acts as a limiter.

Intercarrier I-F System. In the intercarrier system the two carriers pass through the video i-f amplifier together. When both are applied to the video detector, a beat of 4.5 mc occurs between the two carriers. This difference frequency is frequency-modulated by the sound signal and somewhat amplitude-modulated by portions of the video signal. This new 4.5-mc carrier then passes through one or more stages of the video amplifier. At some point it is trapped out of the video path and applied to the 4.5-mc sound i-f section. The sound i-f is tuned to 4.5 mc regardless of the video i-f carrier frequencies. This 4.5-mc signal with its complex modulation is amplified by the sound i-f and then fed to either a limiter or a ratio detector. Here any amplitude modulation is wiped out, with the result that only the frequency modulation produces an audio signal. (Of course, if any stage in the chain handling the 4.5-mc signal is overloaded by this or any other signal, cross-modulation products will be set up, with the result that some of the video modulation may cause a hum from the loudspeaker.)

Intercarrier Beat. The FM detector is supposed to remove all amplitude variations from the i-f beat signal produced in the intercarrier system. To make it easier for the detector to do so, the amplitude modulation in the beat signal is kept as small as possible. This is done by taking advantage of two facts:

1. When two signals are allowed to beat together, and one signal is very much weaker than the other, the amplitude of the beat signal is approximately equal to the amplitude of the weaker signal and practically independent of the amplitude of the strong signal.

2. If either of two beating signals is frequency-modulated, the complete frequency modulation appears in the beat signal.

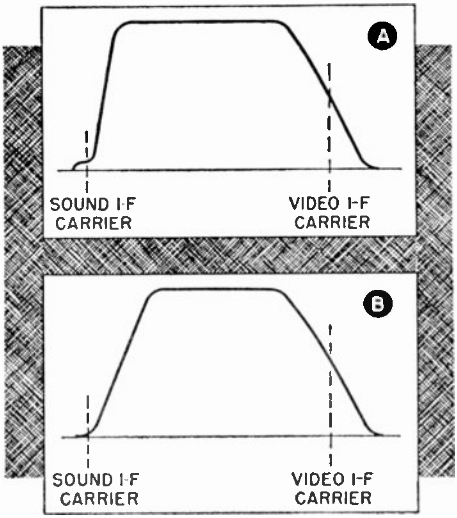


FIG. 27. The ideal video i-f response of an intercarrier set is shown in part A. The response shown in part B is often used in practice.

These characteristics of beat signals are made use of in the intercarrier system by reducing the strength of the sound i-f carrier so that it is far weaker than the video i-f carrier when the two signals are applied to the video demodulator. As a result, the amplitude of the 4.5-mc beat signal, which is frequency-modulated by the sound, depends upon the amplitude of the sound i-f signal.

The sound i-f carrier can be reduced to the desired strength (about 5% or 10% of the video i-f carrier strength) in an intercarrier set by using video i-f stages having the response shown in Fig. 27A. Notice that this response has a small flat plateau around the sound i-f carrier frequency; as a result, there is little possibility of slope detection of this carrier and consequently little chance of cross modulation. The shape and amplitude of the response at this frequency are determined by the alignment of the i-f amplifier and by the judicious use of traps. These traps are not tuned directly to the sound carrier; instead, they are tuned near and to either side of it to produce the desired response.

Because of the difficulty of securing the response shown in Fig. 27A, the one pictured in Fig. 27B is often used in intercarrier sets. There is no plateau at the sound-carrier frequency in this latter; instead, the response is merely made low at this frequency. Cross modulation can

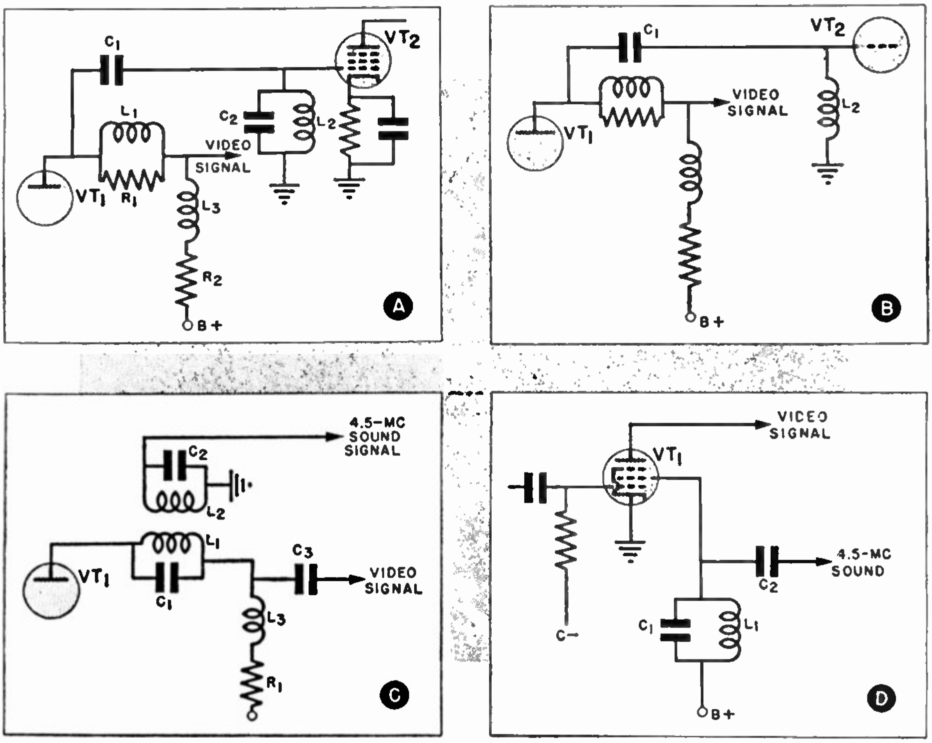


FIG. 28. **Various kinds of sound take-off circuits used in intercarrier sets.**

therefore occur in a set in which this arrangement is used.

Since the sound i-f carrier is held at a fairly low value in passing through the i-f section in the intercarrier system, most of the amplification it is to get must be received in some later section. Usually the video amplifier is used to furnish the desired gain so that it will not be necessary to add a stage to the 4.5-mc amplifier.

Sound Take-Off. When the intercarrier system is used for the sound, the 4.5-mc beat can be taken right from the output of the video detector, but since it is necessary to increase the strength of the signal, it is often taken from the output of the video amplifier. Trap circuits are commonly used as sound take-offs.

Various forms of trap take-offs are shown in Fig. 28. In the simplest (Fig. 28A), a parallel resonant circuit L2-C2, tuned to the 4.5-mc carrier, is placed in the grid circuit of the sound channel amplifier VT2 and is fed through coupling capacitor C1 from the plate of the video amplifier VT1.

A disadvantage of this arrangement is that it does not reduce the amount of the 4.5-mc carrier in the video signal. The circuit shown in Fig. 28B is more satisfactory in this respect. Here, the coupling capacitor C1 resonates with coil L2 to form a series resonant circuit at 4.5 mc. At resonance, this circuit offers a minimum load for the video amplifier VT1, so the output of VT1 at the 4.5-mc carrier frequency is minimized. On the other hand, since this is a series resonant circuit, whatever 4.5-mc signal does appear across it will produce a maximum voltage across L2 for application to the sound amplifier.

The arrangement shown in Fig. 28C also minimizes the amount of the beat signal in the picture signal. Here, a parallel resonant circuit tuned to 4.5 mc is connected in series with the load circuit of VT1. Most of the 4.5-mc beat signal in the output of VT1 is developed across this circuit, so very little is passed on through C3 with the video signal. The sound carrier is fed to the sound amplifier from the resonant circuit L2-C2, which is tuned to 4.5 mc and inductively coupled to L1-C1.

In the arrangement shown in Fig. 28D, the take-off circuit is in the screen-grid circuit of one of the video amplifier stages. It is possible to take the sound from here because any signal in the plate circuit also exists in the screen circuit. (Ordinarily, of course, we get rid of the signals in the latter circuit by by-passing the screen grid.) With this arrangement, there is a minimum of interaction between the sound and video circuits.

When the take-off systems shown in Figs. 28A and 28D are used, grain traps that are tuned to 4.5 mc are needed in the stages following the sound take-off points to reduce the effects on the picture of this 4.5-mc beat signal.

As we mentioned earlier, the 4.5-mc sound amplifier in the intercarrier system usually consists of only a single stage (tuned to 4.5 mc but otherwise like a conventional sound i-f stage). It is usually followed by a ratio detector; if not, the single stage is adjusted to act as a limiter, and a discriminator is used.

An advantage of the intercarrier system is that it is far less subject to difficulty because of oscillator drift than the standard system. In the dual-channel system, any considerable drift in the oscillator frequency may shift the sound i-f outside the pass band of the sound i-f section, distorting the sound or wiping it out altogether. If this occurs, it will be necessary to re-tune the oscillator, which is done either by adjusting the fine tuning control or by realigning the receiver.

In the intercarrier system, the 4.5-mc sound i-f is not produced by the local oscillator. The only thing that an oscillator shift can do is change the relative levels of the sound and video i-f carriers to such an extent that the sound signal may have an undesired amount of video signal in it; or, if the shift is very large, the sound beat signal may become somewhat weakened. In general, however, the oscillator can drift far more in an intercarrier system than it can in the dual-channel system before the sound signal is upset to any great extent. This advantage, along with its obvious economy, has made the intercarrier system almost standard in modern receivers.

SOUND DETECTORS

The two principal types of sound detectors that you are apt to find in TV receivers are the limiter-discriminator combination and the ratio detector. You will most likely find the limiter and discriminator in older sets. The modern TV receiver almost invariably uses the more economical ratio detector. Although you have already studied both of these systems in previous lessons, a brief review is given here.

Limiter-Discriminator. A typical limiter-discriminator circuit is shown in Fig. 29. Here, the limiter stage, VT1, is much like any other i-f amplifier stage except that the bleeder resistor R5, and the series resistor R6 make the screen grid and plate voltage on this stage very low—only about 48 volts. These low operating voltages make the upper knee of the characteristic response of this stage very low and sharp.

The grid circuit contains the grid leak and capacitor combination R4-C9. Capacitor C9 tends to keep charged to the average voltage of the peaks of the input signal, thus maintaining a steady bias on the tube that will keep its output constant even if the input signal undergoes sudden momentary changes in amplitude. This capacitor therefore minimizes the effect of noise when the signal is weak.

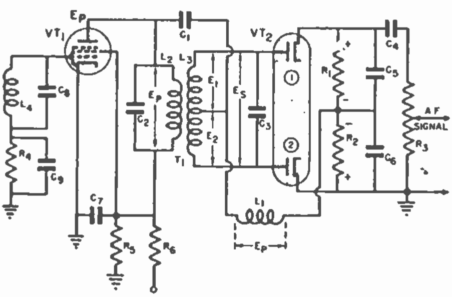


FIG. 29. Schematic diagram of a typical FM limiter-discriminator section.

When the signal is strong, the low voltages applied to the screen and plate effectively wipe out amplitude changes in the input signal. Because these voltages are so low, the output of the stage will not go above a certain limit no matter how strong the input signal becomes. Thus, if the strength of the FM signal is great enough to drive the stage to its full output, any increases in signal strength caused by noise accompanying the FM signal will not affect the output. In other words, the noise will be wiped out by the limiter stage. (In an intercarrier system, this limiting action will also tend to wipe out any portions of the video signal that may accompany the sound carrier.)

The transformer T1 transfers the signal from the limiter VT1 to the discriminator circuit, in which tube VT2 is used. The primary circuit L2-C2 is tuned to the incoming signal. This signal is transferred to the tuned secondary circuit L3-C3 and is also fed through C1 so that it appears across L1.

The voltage induced in L3 produces the voltages E1 and E2 across the two sections of this coil. These voltages are always equal in magnitude and 180° out of phase with each other.

The voltage applied to diode 1 of VT2 consists of E1 plus the signal Ep that exists across L1. (The path from L1 to the cathode of this diode is through the by-pass capacitor C5, which is virtually a short at the frequencies involved.) Similarly, the voltage applied to diode 2 of VT2 consists of E2 plus Ep, the path being completed through by-pass capacitor C6. Therefore, at resonance and with no modulation, equal voltages are applied to the diodes; as a result, equal and opposite currents flow through the resistors R1 and R2. The voltage between the two cathodes of VT2 is zero under such conditions.

Off resonance (that is, at frequencies other than the resting or no-modulation frequency), however, the shift in phase relationships causes the voltages applied to the two diodes to be unequal. When the applied signal swings below the resting frequency, the voltage applied to diode 1 of VT2 becomes greater than that applied to diode 2; consequently, a greater current flows through R1 than flows through R2. As a result, the voltage drops across the two resistors become unequal, and a net voltage appears across them that has the same polarity as the drop across R1. Conversely, when the applied signal swings above the resting frequency, a net voltage appears across R1 and R2 that has the polarity of the drop across R2.

Thus, swings of the applied signal above and below the resting frequency produce an ac voltage across R1-R2. This voltage feeds through C4 to appear as the output voltage across R3. At each instant the value of this output voltage is proportional to the deviation of the incoming signal frequency from the resting frequency. Thus, it is an audio signal voltage that corresponds to the one used to modulate the FM transmitter.

The Ratio Detector. The use of a ratio detector eliminates the need for the limiter stage. Therefore, since it cuts manufacturing costs, it is natural that it has become almost universally used in modern TV receivers. A schematic diagram of a typical ratio detector circuit is shown at Fig. 30.

At first glance, this circuit is very similar to that of the discriminator you have just studied. However, there are two important differences—one of the diode tubes is reversed, and a charge storage capacitor C4 has been added to the circuit.

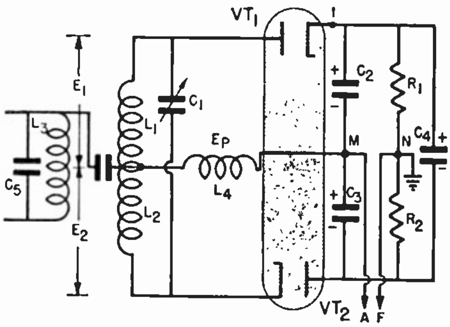


FIG. 30. A typical FM ratio detector.

At the resting frequency, the voltage Ep adds to E1 and to E2 to make both diodes conduct equally, just as in the discriminator. Because of the way they are connected, both diodes conduct at the same time, charging the equal capacitors C2 and C3 with the polarities shown. At the same time, capacitor C4 is charged to a voltage that is equal to the *sum* of the voltages across C2 and C3.

The capacity of C4 is such that the voltage across it cannot change very fast. As a result, the sum of the voltage across C2 and C3 will remain relatively constant unless the average strength of the received signal changes.

Now let us suppose that the incoming signal varies in frequency. When it shifts in one direction, one diode will conduct more than the other, so that the instantaneous voltages across

C2 and C3 will no longer be equal. However, their sum will remain that of the charge across C4—because the voltage across C4 cannot change readily. Let us assume that diode VT1 momentarily conducts more current so that the voltage across C2 goes up, and the voltage across C3 drops, but the voltage across C4 remains the same. There will now be a voltage difference between points M and N, because the voltage between point 1 and point M has changed, while that between point 1 and point N has not.

When the incoming frequency swings in the other direction, the opposite action will occur—the voltage across C3 will become greater and that across C2 will become less. As a result, a voltage difference of opposite polarity will be produced between points M and N.

The voltage difference between points M and N will therefore be an ac signal whose amplitude depends on the amount the incoming signal deviates from the resting frequency and whose frequency depends on the rate at which the deviation occurs. In other words, it will be a reconstruction of the audio signal that was originally used to modulate the FM carrier.

This circuit will not respond to amplitude variations in the input signal, because such changes will merely make both diodes conduct either more or less without making them conduct unevenly. As we have seen, the diodes must conduct different amounts of current to make any voltage difference appear between points M and N, and this difference in their conduction can be produced only by a change in the frequency of the applied signal. Therefore, any amplitude variations caused by noise or a video signal accompanying the FM signal will not appear in the output of the circuit.

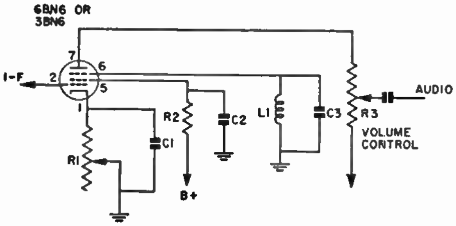


FIG. 31. Schematic diagram of a gated-beam FM detector.

Gated-Beam Detector. The gated-beam detector also operates as both limiter and detector. Its principle of operation is somewhat different from that of the discriminator or the ratio detector, and it utilizes a tube of special construction. The schematic diagram for a typical gated-beam detector circuit is shown in Fig. 31.

The limiting action of the gated-beam tube is caused by the sharp cut-off and saturation characteristics of the grid voltage-plate current curve as shown in Fig. 32. From this curve you can see that if the tube is biased at the mid-point of the curve, slightly over —4 volts, it takes a positive grid swing of only slightly over 1 volt to reach saturation and a negative swing of about a volt and a half to reach the cut-off point. Thus, when a normal i-f signal is applied to the grid, the positive half of the i-f cycle will drive the tube to saturation, and the negative half cycle will drive the tube to cut-off, so that any amplitude variations in the signal are effectively eliminated, and a limited square-wave voltage is produced between the grid attached to pin 2 (signal grid) and

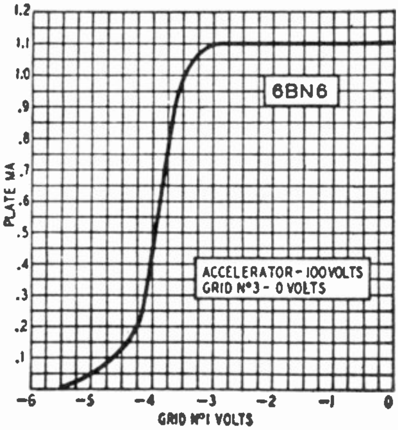


FIG. 32. Grid voltage-plate current curve of a gated-beam tube.

the grid attached to pin 6 (quadrature grid).

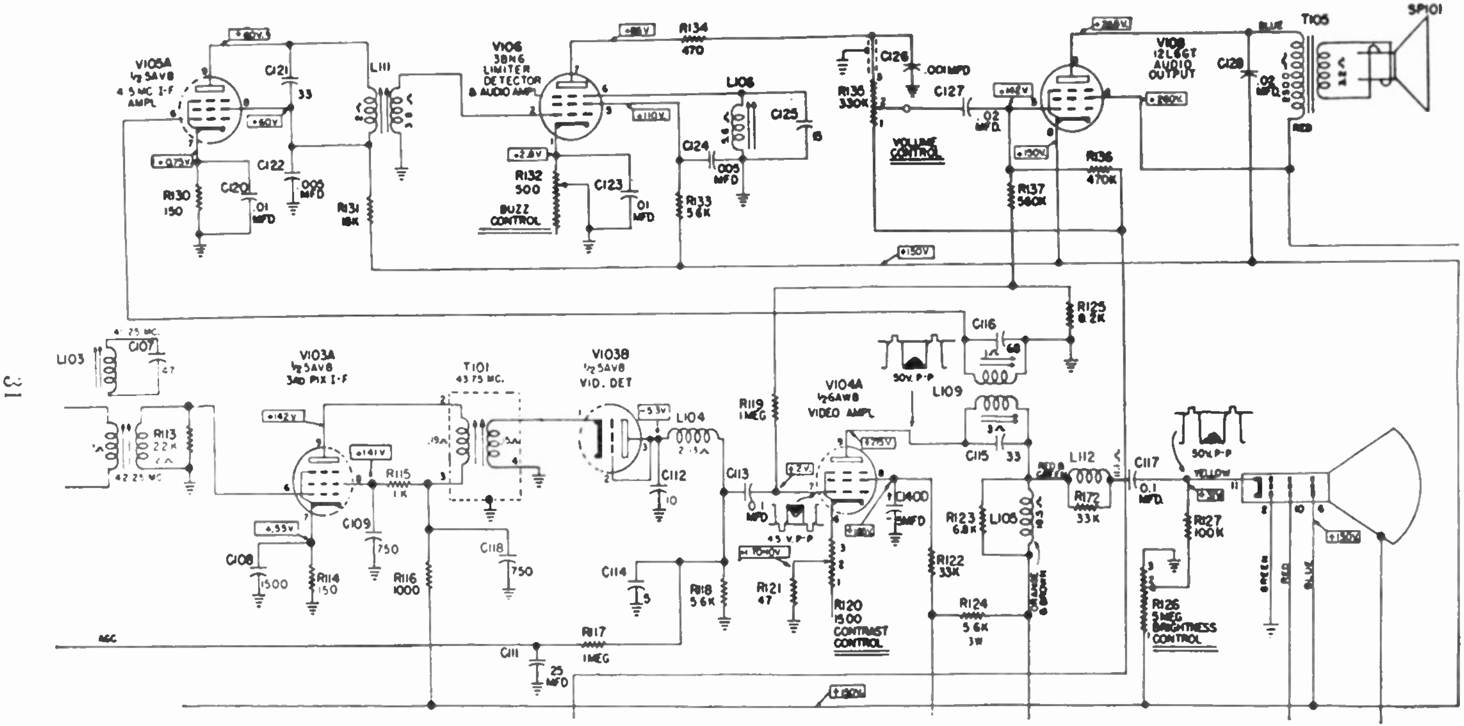
To understand the detector action of this tube, some explanation of the function of the various grids it contains is necessary. The construction of the tube is such that a beam of electrons is formed at the cathode and attempts to travel from cathode to plate. The grid attached to pin 5 is known as the accelerator, and its function is to speed the beam on its way. The other two grids may be referred to as gates. In order for the electron stream to flow from cathode to plate, both gates must be open. That is, they must have a potential on them that will allow the electron stream to pass. When the tube is acting as both limiter and detector, the first gate is cutting off the peaks of the incoming signal, thus performing the limiting function. The accelerator grid has a positive potential applied and its physical shape is such that it helps form the electron beam at the same time that it accelerates it on its trip toward the plate. The second gate (pin 6) is connected to a resonant circuit consisting of L1 and C3. This parallel resonant circuit is resonant at the center frequency of the incoming i-f signal. This circuit will oscillate, because of the space charge within the tube at its resonant frequency, but its oscillations will lag behind those of the incoming signal by 90°. Thus, both gates are open together for only a fraction of a complete cycle.

When the incoming i-f signal deviates from the center frequency, the phase relationship between the two signals is changed, and consequently the length of time that both gates are open is changed. If the frequency of the incoming signal increases, the two gates are open together for a shorter time, allowing less average plate current to flow. If the incoming frequency decreases, the two gates are opened together for a longer time, allowing more average plate current to flow. Thus, the plate current of the tube varies in amplitude with the frequency of the incoming i-f signal, producing an audio signal.

In addition to performing the limiting and detector functions, the gated-beam tube also will supply enough audio amplification to drive a power amplifier tube, so that one stage of audio amplification may be eliminated. Thus, after the gated-beam tube, there is need for only the power amplifier to drive the speaker, which completes the audio system. Where other types of sound detectors are used, it is usually necessary to have two stages of audio amplification.

AUDIO AMPLIFIERS

The audio amplifier section of the



Courtesy Crosley

FIG. 33. Sound system of a modern TV receiver.

TV receiver usually consists of two stages. The detector is usually followed by a voltage amplifier. The output of this drives a power amplifier, which drives the speaker.

As was mentioned before, sometimes only one stage of audio amplification is used, particularly if a gated-beam tube is used as a detector. In general, the circuits are quite conventional and no detailed analysis of them need be made here.

The schematic diagram in Fig. 33 shows the i-f, detector, and audio stages of the sound system used in a modern television receiver. This circuit illustrates how modern circuitry makes possible the economy that enables the manufacturer to produce a low-cost television set. An intercarrier i-f system is used, and the sound is taken off at the output of the video amplifier. Thus, only one sound i-f amplifier is necessary. A single gated-beam detector acts as limiter, detector, and audio amplifier, making one tube do the work of three. Following the gated-beam tube, there is only a single audio stage, which drives the speaker. Thus, this circuit represents a saving of at least two stages over older circuits using separate-channel sound systems and more conventional detectors.

Automatic Gain Control

The need for and operation of automatic gain control (agc) can best be understood by referring to the block diagram in Fig. 34. This figure outlines the gain control system of a modern TV receiver. The two manual controls allow the operator to adjust contrast and volume to whatever levels he finds most pleasing to the eye and ear. Although the contrast control is pictured in Fig. 34 as being at the input of the picture tube, it may actually be in any one of several locations. In modern sets, it is most frequently found in the cathode circuit of one of the video amplifier

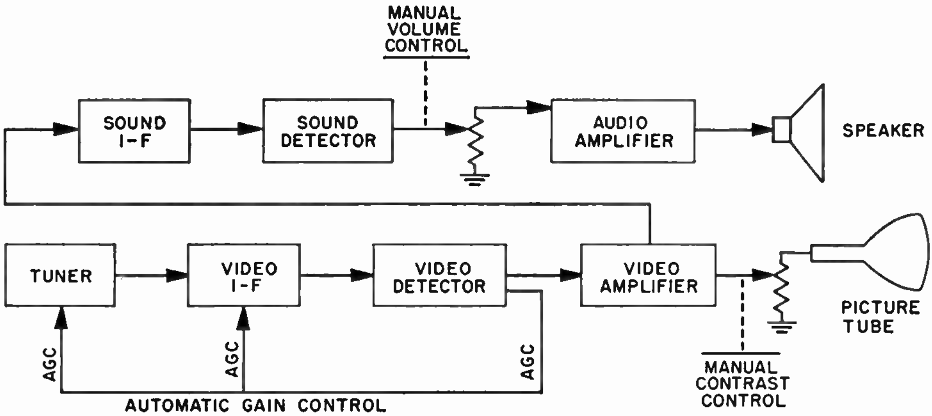


FIG. 34. The modern TV receiver incorporates separate manual controls for contrast and volume, plus automatic gain control for both.

stages. In any event, it will usually be located some place beyond the point of sound take-off so that the contrast control will vary the amplitude of the video signal without affecting the audio volume at the speaker.

At first glance, one might be inclined to think that the two manual controls for the gain of the video and audio amplifiers would be sufficient. This would be true if a carrier signal of constant amplitude were received on all stations on the television receiver. However, for various reasons, we cannot depend on this. Different stations transmit at different power levels and are at different distances from the receiver; therefore, the strength of the received signal will vary from one channel to the next. Physical disturbances of the receiver antenna, such as high winds, may cause variations in signal strength very much like fading. There are other varying physical conditions that may cause variations in signal propagation, such as airplanes flying near the receiver, which may cause signal strength variations. Because of these and other uncontrollable variables, it is essential to have some form of automatic gain control that will allow the set owner to receive his picture and sound with a fairly high degree of consistency at the levels at which he has set the volume and contrast. Therefore, an agc signal in the form of negative bias is fed to stages in the receiver through which both sound and picture signals pass. This negative feedback is controlled by the amplitude of the received carrier signal so that when a signal of high amplitude is received, the negative bias on the rf section and the video i-f section is made more negative, reducing the over-all gain.

In order to maintain a good signal-to-noise ratio, the negative bias fed to the rf section must not become effective until very strong signals are received. The agc bias applied to the i-f stages (it is usually only applied to the first two i-f stages) is effective for normal signals, and therefore compensates for smaller variations in signal strength. The curve shown in Fig. 35 shows the ideal relationship between i-f and rf agc response. The horizontal axis in this diagram represents the received signal strength increasing from left to right and the vertical axis represents applied bias.

In older TV receivers you may find that the block diagram of the gain control system would be somewhat different from that shown in Fig. 34. Frequently, the manual contrast control also controlled the agc voltage to a certain extent. However, the independent manual controls as shown in Fig. 34 have been found to be more satisfactory.

BASIC AGC

An agc system must operate from some component of the signal that is proportional to the strength of the carrier, since it is the carrier's strength

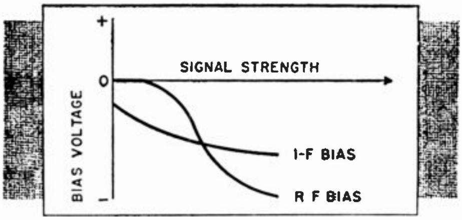


FIG. 35. An ideal relationship between agc bias voltages applied to i-f and rf stages.

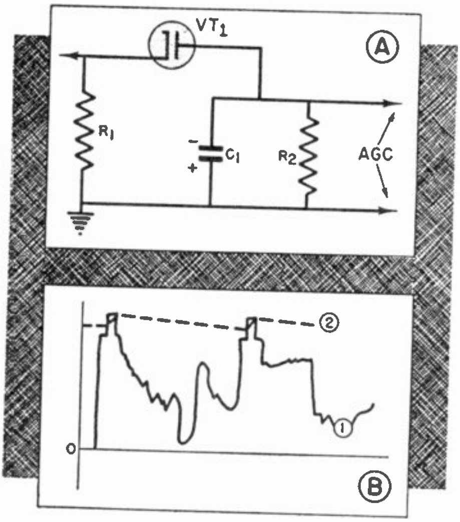


FIG. 36. A simple agc system.

at any moment that determines what the gain of the set should be at that moment. The only part of a TV signal that meets this specification is the height of the sync pulses. These extend upward from the no-signal or black level pedestal by a fixed percentage of the carrier strength. (This percentage may be different for different transmitters, but is always the same for one transmitter.) If the carrier strength changes, the amplitudes of the peaks of these sync pulses from the black level and from the zero level will change proportionately.

Of course, the sync pulses exist during only a small fraction of the whole TV signal. If the pulses are to furnish a control voltage, therefore, we must find some way to make their effect last from at least one pulse to the next. This is most easily done by using the pulses to charge a capacitor in an R-C network.

A simple agc circuit that uses the peaks of the sync pulses is shown in Fig. 36A. This consists of a diode rectifier with a time constant filter C1-R2. When a TV signal like that shown by curve 1 in Fig. 36B is applied to R1, VT1 conducts whenever the signal exceeds the charge stored in C1. Since the diode then has low resistance, C1 charges rapidly up to the peak voltage of the sync pulses during the time that VT1 conducts.

When the signal swings below the peak level, C1 must then discharge through R2. This discharge is slow, since R2 has a high resistance—so slow that C1 discharges very little during the period of one line. At the end of this line, another sync pulse recharges C1 at once to the full peak voltage. Therefore, the voltage across C1 follows curve 2 in Fig. 36B and, as you can see, remains nearly at the peak value at all times.

We can use the voltage across C1 as an agc voltage by applying it to the video i-f stages as a bias. When we do so, the bias on these stages will be proportional to the strength of the carrier; it will increase on strong signals and decrease on weak ones, thereby varying the gain so that the signal applied to the video detector will be very nearly constant.

Selecting the proper time constant for the R2-C1 circuit in Fig. 36A is somewhat of a problem. There are reasons for making it short and others for making it long. If we make it short (that is, use a value of R2 that will permit C1 to discharge fairly rapidly), the circuit will be able to follow more rapid fluctuations in the signal and will offer more freedom from noise interference than it will if we make the time constant long. On the other hand, a short time constant may make the set lose vertical sync. Let us see why these effects can occur.

First, suppose a sharp noise pulse that is higher than the peak of the sync pulse is received. The gain of the set will automatically and suddenly be reduced by the agc circuit. If the time constant is long, C1 will hold its high charge for several lines, during which time the gain of the set will be reduced. Therefore, the use of an agc circuit having a long time constant means that there will be "holes" (large blacked-out areas) in the picture when noise is present, whereas the picture on a set with a manual contrast control would show nothing more than nearly unnoticeable short black streaks under the same conditions.

Suppose, on the other hand, that we make the time constant quite short. Capacitor C1 will then discharge considerably in between the horizontal sync pulses, so the average agc voltage (the voltage across C1) will be relatively low. When a vertical sync pulse (which is much broader than a horizontal pulse) is received, however, C1 will be charged for a much longer time than it is during the horizontal pulses; consequently, the average voltage across C1 will increase during the vertical pulse. This means that the gain of the set will be reduced during the vertical pulse, an effect that may make the set lose vertical sync.

Since synchronization is extremely important, a simple agc system like this is usually made slow-acting (given a long time constant). Such a system will compensate for signal changes like those produced by switching stations, but cannot take care of rapid fluctuations, and of course is poor when noise is present.

The dc voltage that is obtained as a result of the agc action is usually applied as a bias to the i-f amplifier stages, appropriate R-C decoupling networks being used to prevent coupling between the stages. The signal may also be applied to the rf stage ahead of the converter, in which case some arrangement is generally used so that the bias applied to the rf stage will be unaffected on weak signals but will increase rapidly on strong signals.

There is usually some control in the agc network to set the threshold beyond which it operates. In older sets this may be the contrast control for the set, but in later models it is usually a separate control mounted at the rear of the set.

Because it is the most economical, the basic agc system with slight modifications is used in many modern low cost TV sets. However, the limitations of the basic agc system are overcome in many sets by using a slightly more complex system known as a keyed agc system.

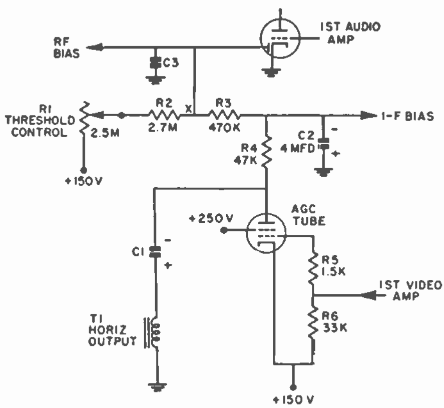


FIG. 37. A typical keyed agc system.

KEYED AGC

Most keyed agc systems used in modern receivers make use of a source of agc bias voltage which operates on the horizontal sync pulses only, and is unaffected by any noise or other variations that occur between the horizontal sync pulses. A typical keyed agc system is shown in Fig. 37.

The cathode of the agc tube has a 150-volt positive potential supplied to it. The positive 150-volt bias is also applied to the grid through R6 and R5. The plate is almost at zero potential. There may be a small positive voltage due to the drop across the diode in the first audio amplifier.

Obviously, with these potentials, no plate current will flow under static conditions. However, when a signal is being received, these static conditions are altered. A positive-going composite signal from the plate circuit of the first video amplifier is applied to the grid through R5. This is the signal that controls the agc voltage. The plate is connected to a winding on the horizontal output transformer through a capacitor, C1, so that during every horizontal retrace period, a positive voltage pulse is applied to the plate. This positive pulse is sufficient to cause the tube to conduct, if the positive-going sync pulse applied to the grid is of sufficient amplitude. The plate current flowing through the tube is controlled by the amplitude of the positive horizontal sync pulse that appears on the grid simultaneously with the positive pulse applied to the plate.

When the agc tube conducts, electrons flow from cathode to plate, charging capacitor C1 with the polarity shown. C1 is of relatively low value so that it has time to discharge between positive voltage pulses. However, the R-C filter, consisting of R4 and C2, filters the pulsating voltage across C1 so that a constant dc potential appears across C2. The amplitude of this voltage will depend on the amplitude of the video signal applied to the grid of the agc tube.

R1, R2, and R3 form a series resistance combination through which agc current flows from the negative side of C2 to ±150V. The setting of R1 determines the current that will flow through R3 and R2 for a given charge on C2, and hence the agc voltage developed. The diode is connected between the junction of R2 and R3 and ground to avoid the possibility of applying a positive bias to the rf tube.

The keyed agc circuit described is typical, but there are a number of different variations which may be encountered. The threshold control may be in the grid circuit of the agc tube; the grid signal source may be an agc detector at the output of the last i-f stage; the source of positive pulses applied to the plate of the agc tube may differ. This is sometimes simply taken off the primary winding of the horizontal output transformer, through a capacitor and dropping resistor, instead of having a separate winding on this transformer. These are just a few of the variations; however, the same principles will apply to almost any agc circuit that you may encounter. If you have gained a thorough understanding of the basic agc circuit and the keyed agc circuit described here, you will have very little difficulty understanding any agc system.

Lesson Questions

Be sure to number your Answer Sheet 57B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next Lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. List the two voltages that the TV low-voltage power supply must furnish.

2. What type of sound detector is usually used in a TV receiver with an intercarrier sound system?

3. From what portion of the television signal is the agc bias voltage usually derived?

4. In a TV set that has no low-voltage power transformer, what type of B+ supply is usually used? Filament supply?

5. Would you expect to find a bleeder resistor in a TV receiver with a transformerless power supply?

6. How does having the high-voltage power supply controlled by the sweep system protect the picture tube?

7. Where is the sound take-off point in (a) a separate-channel sound system and (b) an intercarrier system?

8. What three functions may be performed by a gated-beam tube in a TV sound system.

9. What would be the effect on the television picture if the time constant of C1-R2 in Fig. 36A were too short?

10. Why is the keyed agc system rarely affected by sharp noise pulses?

GOOD RESOLUTIONS

When you make a good resolution, put it into effect *at once.* To postpone it is deadly. Anything that can be done next month or next year can be done NOW—or at least a start can be made toward it.

Millions of people dream about doing fine, worthwhile things. But only a *few hundred* people ever get around to actually doing these things.

The *few hundred* may not be as smart as the others—may not be as talented, as capable, or as well educated. But they ACT and achieve concrete results—while the plans and good resolutions *of the millions* fade out into airy nothings.

Remember this when you make plans—when you make good resolutions. Put your plans and resolutions into effect *at once.* Get started!

J. E. Smith

HOW TO USE TV TEST EQUIPMENT

REFERENCE TEXT 57BX

RADIO—TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL

NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE

In this section, you learn how this important piece of test equipment functions and the design requirements necessary to make it useful in radio and television servicing work.

This section is designed to show you the many uses of an oscilloscope in television servicing. We go through the major sections of a television receiver and point out how the oscilloscope is used in wave-form observation and trouble-shooting.

These test instruments are needed in practically all television alignment work. Therefore, in this section you learn their characteristics and how to use them in the most efficient manner.

Here you study other types of test equipment used in radio and television service work.

All the pieces of test equipment discussed in this reference text are used to check through a color television receiver. You learn where each instrument can be connected to obtain the best results, and the precautions to observe in the various sections of the receiver.

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HOW TO USE TV TEST EQUIPMENT

IT IS very hard to do thorough and efficient radio or TV service work without the aid of good test equipment. Of course, you may be able to find burned out tubes and other surface defects, but some type of test instrument is necessary in measuring voltages, observing signal waveforms, making precise adjustments, and locating obscure troubles in electronic circuits.

When selecting a piece of equipment, especially an oscilloscope, you will be faced with the problem of finding one that will fill your needs and still be reasonably priced. In this reference text, we will give you an idea of the features that the various types of test instruments should have to be the most useful.

Even the best designed pieces of equipment have their limits. We will point these out and describe means of overcoming them. For example, a scope cannot be used to observe waveforms in all electronic circuits without the aid of suitable probes. For instance, a low-capacity probe must be used when the response of a video amplifier is being checked; otherwise, the input capacity of the scope will reduce the high-frequency response of the amplifier.

Regardless of the efficiency of the test equipment, it will be of no benefit if it remains unused. Therefore, we will briefly describe the uses for the various pieces of equipment and point out the methods of connecting them for the best results. The first time that you use a new piece of rather complex test equipment, progress will be slow and awkward; the more you use this piece of equipment, the sooner it will return dividends in improved and faster work.

The Operation And Characteristics Of An Oscilloscope

The oscilloscope is one of the most useful instruments in radio-TV servicing. You can use a scope as a signal tracer to follow the signals through a TV receiver to find where the signals may be lost or distorted. To use a scope effectively, however, you must know how it works and how its features influence its performance.

Basically, an oscilloscope uses a tube, in which a concentrated stream of electrons "paints" a picture of a repeating waveform on a fluorescent screen by continuously superimposing cycles of this waveform, one over the other. The tube, as shown in Fig. 1, is similar to the picture tube used in TV sets, except it uses electrostatic instead of electromagnetic deflection. It contains an electron gun to form the electron beam, and a deflection system, consisting of vertical and horizontal deflection plates, to move the beam to any place on the screen. The circuits in the scope generate and control the various signals and voltages that must be applied to the tube. As in a TV set, both ac and dc voltages must be applied to the electrodes.

There are four controls that vary the dc voltages applied to the scope. There are two centering controls. By adjusting these, you can move the beam and pattern that you are observing to a position on the screen where it is easy to see. Two other controls are the brightness and focus controls. The brightness or intensity control regulates the number of electrons in the beam, and, therefore, the brightness of the trace. The focus control regulates the concentration of the beam electrons so that they arrive as a small diameter in-focus beam at the screen.

AC DEFLECTION SIGNALS

The electron beam is used to paint a picture of a waveform on the face of the tube. This is done by applying the waveform to be viewed, to the vertical deflection plates, and a sawtooth signal to the horizontal deflection plates.

The sawtooth signal causes the beam to move from the left side of the cathode ray tube across the face of the tube to the right side of the tube at a constant speed. When the beam reaches the right side of the tube it is rapidly returned to the start of the line at the left side of the tube. This is done over and over, thus superimposing the pattern each time it goes across the tube.

The length of the line traced across the face of the tube can be controlled by means of a horizontal gain control on the oscilloscope, which regulates the amplitude of the sawtooth wave.

In order for a stationary pattern to appear on the screen, the frequency and phase of the sawtooth wave must be synchronized with the wave applied to the vertical plates. Its frequency can be the same as that of the applied

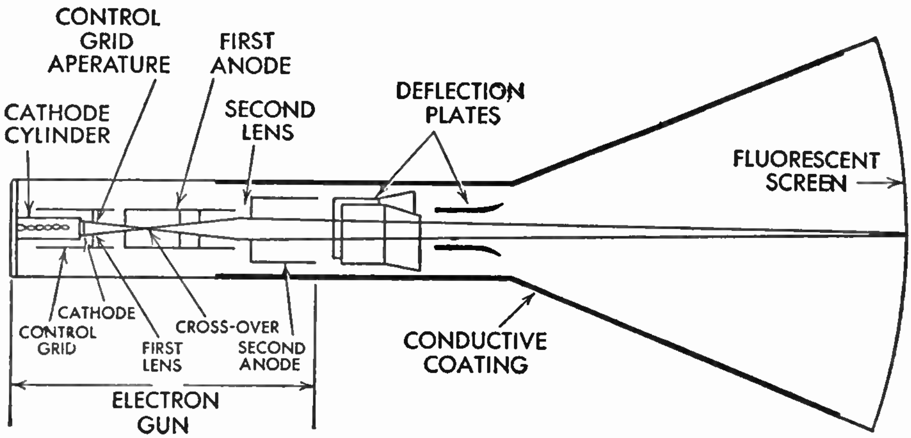


FIG. 1. Plan of oscilloscope tube.

signal, or it can be some sub-multiple of the applied frequency. If it is the same frequency, the beam will move across the screen once for each cycle, and one cycle will appear on the screen; if it is half the frequency of the applied signal, the beam will move across the screen once for each two cycles, and two cycles will appear on the screen. If it is one-third the frequency, three cycles will appear, etc.

This synchronization of the horizontal sawtooth with the signal applied to the vertical plates is accomplished by feeding part of that signal to the horizontal oscillator that generates the sawtooth. This signal is called the "sync" signal. Its amplitude is adjusted by means of a sync control.

The horizontal oscillator usually has two frequency controls; one is a step-type control, which can be adjusted to one of various ranges; the other is a vernier, which can be adjusted to any frequency within the ranges set by the step control.

Synchronizing the sawtooth generated by the horizontal oscillator in this way, by using part of the signal applied to the vertical plates, is called "internal sync."

Sometimes it is desirable to be able to apply a signal from an external source to the horizontal oscillator. This is used in some alignment procedures. The applied signal is then compared with it. This is called "external sync."

Sometimes it is desirable to be able to sync the oscillator with the power line frequency or a harmonic of it. This is called "line sync."

Sometimes we want to apply a signal to the horizontal plates with a shape other than a sawtooth. This can be done by using an external sweep signal from a sweep generator.

REQUIREMENTS OF A SERVICE OSCILLOSCOPE

The performance and the all-round usefulness of the scope in service work depend upon five major electrical characteristics. These characteristics are frequency response, input impedance, sensitivity, sweep circuit features, and sync arrangements. If you know these characteristics and their influences on the reproduced waveforms, you will be able to tell whether any scope you have or are considering buying will meet your requirements. Let us take up each of these.

Frequency Response. The vertical amplifier system of the scope amplifies the waveforms applied to it so that they can be observed on the screen. It must be capable of passing and amplifying a wide band of frequencies. It must be able to pass the many types of waveforms and frequency components found in modern electronic equipment. For example, the color burst sent in transmitting a color TV program has a frequency of 3.58 mc. For this burst to be seen, the high-frequency response of the scope must be above 3.58 megacycles. In fact, it should have a frequency response up to 4.5 or 5 megacycles.

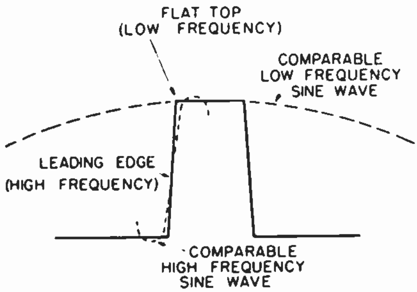


FIG. 2. Comparison between sine waves and time segments of a pulse.

Complex waveforms sometimes contain high-frequency components. If these components are attenuated seriously or shifted in phase with respect to the other frequency components, the waveform becomes distorted as it passes through the vertical amplifier. Therefore, the frequency response of the vertical amplifier determines how faithfully various complex waveforms can be reproduced. If the scope itself distorts the waveform, it cannot be used to find obscure defects.

Let us see how the frequency response of the scope can affect the shape of a square wave. A square wave is a complex waveform that consists of a base or fundamental frequency and an infinite number of odd harmonics. The high-frequency components of the signal determine the speed with which it rises from the base line to the peak amplitude and also the speed with which it will fall back to the base line again at the end of the pulse. For example, the horizontal sync pulse used in commercial TV systems must rise to a prescribed level in one-fourth of a microsecond. This is the length of time it takes a 2-megacycle sine wave to rise from the negative peak to the positive peak, as shown in Fig. 2. A scope must have a frequency response of 2 megacycles to pass the pulse without distortion. If the high-frequency response in the vertical amplifier system is not good, the leading edge of the pulse will not be straight, but will be rounded as shown at the left in Fig. 3. Further loss in high frequencies will destroy the shape entirely.

The shape of the flat top of the pulse is affected by the low-frequency response of the amplifier. The effect of improper low-frequency response is shown in Fig. 3B. The top does not

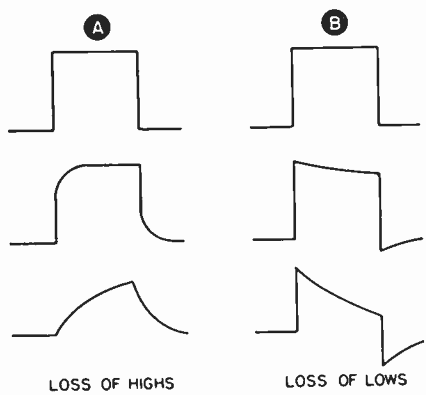


FIG. 3. How the loss of high and low frequency response in the vertical amplifier system of an oscilloscope affects the shape of a square-wave pulse.

remain flat. The poorer the low-frequency response, the more the tilt.

Input Impedance. The input impedance of a scope is an important characteristic because it determines how well the frequency response will be retained, and how much the scope will load any circuit to which it is attached. An oscilloscope is a high-input-impedance device. It presents a high impedance except when it is used in high-impedance circuits or when very high-frequency components are to be reproduced on the screen. The video signal and pulse waveforms contain high-frequency components; impedance of a typical scope is 2 megohms shunted by 20 mmf, its loading effect across a 25,000-ohm load will be quite severe if a high-frequency signal is to be observed. For example, at 320 kc, the loading will reduce the circuit impedance by a factor of approximately 30%. Therefore, there will be a substantial attenuation of the high-frequency components of the 320-kc signal. The waveform would not be faithfully reproduced on the screen; it would be rounded and distorted because of the attenuation of the high-frequency components that make up the signal.

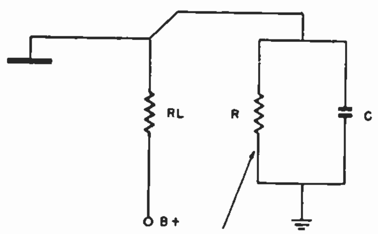


FIG. 4. Oscilloscope loading of a circuit under observation.

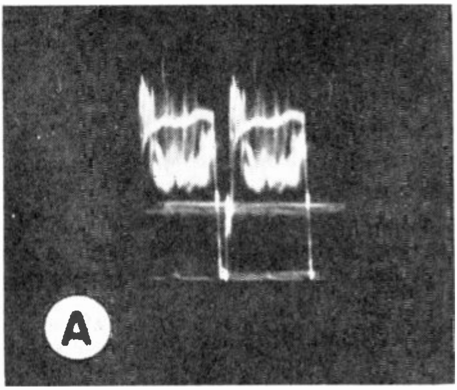
these waveforms must be applied to the scope through the proper type of probe in order to reproduce the high-frequency components faithfully.

The input impedance generally is rated in megohms shunted by micro-microfarads of capacity. The scope connected across any circuit adds this value of resistance and capacity in shunt with that circuit, as shown in Fig. 4. Since the reactance of the capacitive component changes with frequency, the scope will have a more severe loading effect at high frequencies.

The amount of the circuit loading also depends upon the impedance of the circuit across which the scope is attached. If we assume that the input

On the other hand, if the same scope is connected across a 2000-ohm impedance point, it will give a much better reproduction of the high-frequency signals, and the impedance of the circuit will not be seriously reduced. At any frequency below 4 megacycles, both the low- and the high-frequency components of a pulsed waveform will be passed with equal amplification. Therefore, when you are observing waveforms that contain high-frequency components, you will get a truer reproduction of the signals if you connect the scope across a low-impedance circuit.

Although a scope is said to have a specific frequency response, it does not necessarily mean that you can



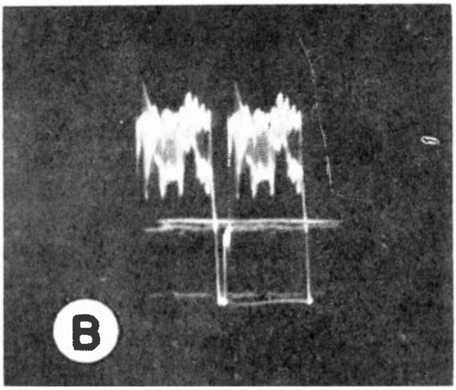


FIG. 5. Use of compensated probe in making high frequency observations. Color subcarrier rides on back porch of horizontal blanking pulse. (A) With probe. (B) Without probe.

pick up a signal of a particular frequency from a circuit and have it faithfully reproduced on the screen. This is particularly true of high-frequency signal components. If the scope has any severe loading effect on the circuit, the signal will be attenuated before it is applied to the vertical amplifier system.

This high-frequency attenuation can be minimized by using a compensated probe and by choosing a point in the circuit where the loading is at a minimum. The compensated probe increases the input impedance of the scope so that there is minimum loading effect on the circuit. With the probe, the input impedance is a known quantity; it does not depend upon the lead length or the ground proximity. Also, the shielded probe lead reduces stray pickup.

The effect of a compensated probe is shown in the color signal waveforms in Fig. 5. In Fig. 5A a compensated probe was used. The amplitude of the color burst signal is normal; but in Fig. 5B a regular uncompensated probe was used, and the signals have been seriously attenuated. Probes will be discussed more fully in a later section.

Sensitivity. The sensitivity of a scope is the minimum signal strength that it needs to produce a usable and undistorted pattern on the screen. If the scope is to be used effectively in checking and making adjustments in weak signal stages of modern TV sets, the vertical amplifier section should be sensitive enough to show the response pattern of a *single* rf stage when a standard service-type sweep generator is used. Also, the scope must have a vertical attenuator system so that high-amplitude signals (up to several hundred volts) can be observed without overloading the vertical amplifier. However, the attenuator system should be well designed to pass both strong and weak signals faithfully.

The sensitivity of a scope is usually rated in rms volts per inch deflection. If the sensitivity is 100 millivolts per inch, a 100-millivolt rms sine wave signal applied to the scope with the vertical gain set at maximum will produce a 1-inch sine wave on the screen. Actually, the oscilloscope is a peak-to-peak voltage indicator because both negative and positive peaks of the waveform are visible. The peak-to-peak voltage of a 100-millivolt sine wave will be $100 \times 1.41 \times 2$, or 282 millivolts. Therefore, a scope can be used not only to observe various types of waveforms, but also to measure them by comparing their amplitudes to the amplitude of a calibrated sine wave. This method will be described later.

Sync and Sweep System Features. The sync and sweep systems of the scope should be versatile and easy to adjust if the instrument is to be used effectively in TV and other electronic service work. The sync system should be efficient enough to provide positive locking of the horizontal oscillator so that the waveshape being viewed will remain stationary on the face of the tube. The horizontal sync system should have provisions for internal and external sync. In addition, 60-cycle sync is helpful in locking in some patterns, and also in comparing the signal frequency with the power-line frequency.

The sawtooth sweep system must be linear to observe waveforms and alignment curves. The sweep frequency range should extend low enough to observe two or three cycles of the lowest frequency repeating waveforms, such as the field rate of a TV signal, and high enough to show the highest frequency waveforms, such as the line intervals of the TV signal.

The horizontal sweep system should be arranged so that the internal sweep circuit can be turned off and an external sweep signal applied to the input of the horizontal amplifier. This arrangement is best in many alignment procedures.

In other alignment procedures, an internal 60-cycle sine wave sweep signal that can be applied to the horizontal circuits is very useful. This eliminates the need for an interconnecting line between the horizontal output of the sweep alignment generator and the horizontal input of the scope. However, provisions must be made for controlling the phase of this sweep when it is used for alignment work.

TYPICAL SERVICE OSCILLOSCOPE

A photograph of a typical service oscilloscope is shown in Fig. 6, and a block diagram of it is shown in Fig. 7. Let us go over it now.

The sensitivity of the instrument is high enough to permit sweep alignment of a single receiver stage (an rf stage, for example) without difficulty. A signal as low as 14 millivolts will produce a usable pattern on the screen. The vertical amplifier will also handle a peak signal of 1000 volts. Thus,

FIG. 6. A typical oscilloscope.

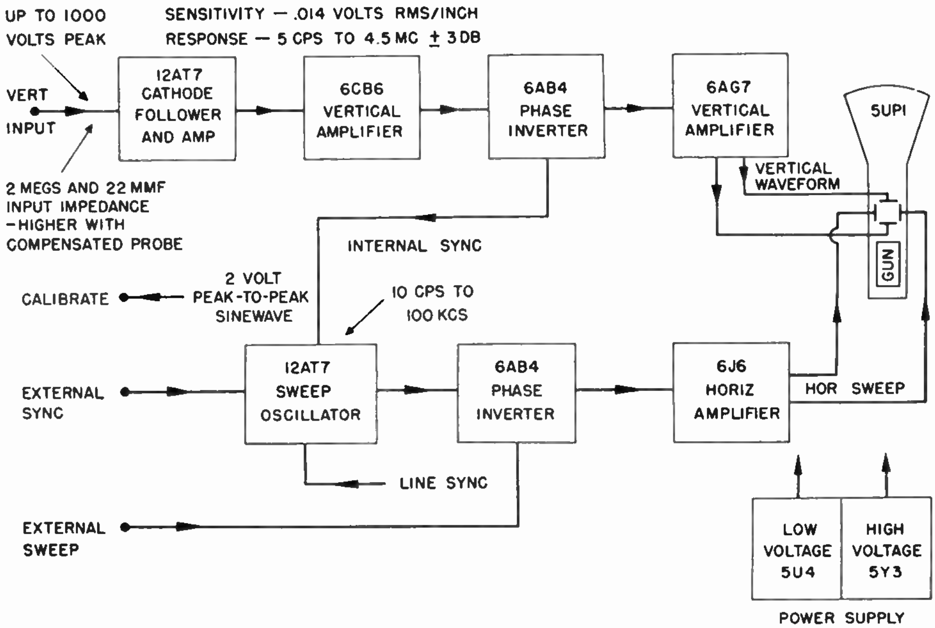


FIG. 7. Block diagram of a typical oscilloscope.

observations can be made of the high-amplitude sweep waveforms.

The vertical amplifier section contains four stages to give the desired high sensitivity and wide-band frequency response. The frequency response is nearly linear from approximately 5 cycles to 4.5 megacycles. With this wide-band response, the scope will faithfully reproduce the sharp leading edges and the long-duration flat-top portions of square-wave signals.

The horizontal sweep oscillator can be synchronized internally, externally, or at the line frequency or harmonics of it. For internal sync, a signal is derived from the vertical pulse inverter and is applied to the horizontal sawtooth oscillator. Provisions are included for using either the positive or the negative half cycle of the signal for sync purposes. The frequency range of the horizontal oscillator extends from 10 cycles to 100 kilocycles, thus making it possible to observe individual cycles of both high- and low-frequency repeating waveforms. It is possible to lock in the horizontal sweep oscillator with sine wave signals as high as 3 megacycles.

The horizontal oscillator can be turned off so that an external horizontal sweep signal can be applied to the input of the horizontal amplifier. Notice that two horizontal stages follow the oscillator to increase the amplitude of the sweep signal applied to the horizontal deflection plates.

On the scope, there are two controls that vary the height of the signal on the screen. One is the vertical attenuator, which is used to keep a strong signal from overloading the scope. The other is the vertical gain control; it is a finer adjustment. These are calibrated so that you can read the peak-to-peak voltage of the signal being viewed when its height is set to one inch.

To do so, you adjust the vertical attenuator and the vertical gain control to give a peak-to-peak deflection of one inch. The screen is ruled so that you can do this easily.

You can then read the voltage from the settings of the two controls. The vertical attenuator has four settings. If it is set at × 1, the voltage can be read directly from the setting of the vertical gain control. If it is at × 10, the reading of the vertical gain control must be multiplied by 10. If it is set at × 100, the reading is multiplied by 100; and if it is set at × 1000, the reading is multiplied by 1000.

The scope has a calibration terminal where a 2-volt peak-to-peak sine wave is available that can be applied to the vertical input of the scope to check the accuracy of the calibration of these two controls. When this known 2-volt signal is applied, and the controls are set so that the vertical attenuator is at × 1 and the vertical gain control is at 2, the pattern should be 1 inch high from peak to peak.

If the calibration is not accurate, it can be adjusted by a control on the scope chassis.

To use the scope in certain circuits and to perform certain operations with the instrument, it is sometimes necessary to use an accessory probe. This may be a direct-connection probe, a low-capacity compensated probe, a demodulator probe, or a resistor-isolated probe. As its name implies, the direct-connection probe is simply a shielded cable with a probe tip on the end. The shield, which is connected to ground, prevents stray pick-up signals from distorting or otherwise interfering with the waveform under observation. The shield, however, causes increased input capacity, which may distort the high-frequency components, so it is more useful at low frequencies.

The resistor-isolated probe, shown in Fig. 8A, inserts a resistor between the circuit under observation and the scope. The resistor functions as an isolating component to prevent the scope from loading the circuit under observation, changing its characteristics, or introducing feedback during alignment. This probe, together with the scope input capacity, serves as a low-pass filter. Thus, high-frequency signal components and harmonics are attenuated so that a clear response curve and marker pattern can be obtained.

When waveforms that contain high-frequency components must be observed, a low-capacity compensated probe is often used to prevent the scope from distorting the waveform. This distortion occurs because the input capacity of the instrument attenuates the high-frequency components more than the low-frequency components.

A diagram of a compensated probe used with the oscilloscope is shown in Fig. 8B. The components are chosen so that they function as a voltage divider and impedance transformer to increase the input impedance of the

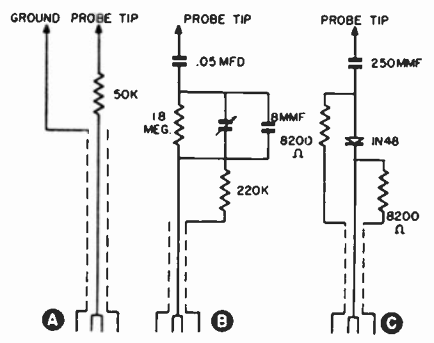


FIG. 8. (A) Resistor-isolated probe. (B) Low-capacity compensated probe. (C) Demodulator or detector probe.

instrument. Thus, by properly choosing the capacity and resistance of the probe with relation to the input impedance of the scope, it is possible to obtain a uniform voltage division over a wide band of frequencies. Both low and high frequencies are accepted with the same sensitivity, and the high-frequency components are faithfully reproduced on the screen.

The resistor and small capacitor in series with the signal path, of course, raise the effective input impedance of the scope. Thus, with the compensated probe, there is less loading on the circuit under observation, equal sensitivity to low- and high-frequency signal components, and more effective shielding between the cable and the external components.

Another useful accessory is the demodulator or detector probe shown in Fig. 8C. It consists of a crystal detector, two resistors, and a capacitor. With this probe, it is possible to demodulate or detect an rf or i-f signal, remove the modulation information, and apply the modulation information to the vertical input terminals of the scope.

The detector probe is especially useful in alignment work and in tracing signals through the rf and video sections of TV receivers. With it, you can observe the modulation at the grid or plate of an i-f amplifier stage. You can even observe the response of a resonant circuit or group of tuned circuits by using suitable sweep alignment equipment and a detector probe with a sensitive scope.

The accessory probes described in this section extend the use of a scope. They permit more critical observation of waveforms without frequency distortion or loading. With them, you can observe the modulation components in rf and i-f sections of receivers. Although the probes are called accessories, they are actually essential parts of the scope if accurate and efficient work is to be done.

How To Use An Oscilloscope

The oscilloscope can be used very effectively as a signal tracer to trace the signal through the TV receiver. By using the signal-tracing technique, you can quickly locate in a receiver you are servicing either a dead stage that the signal will not pass through at all, or a defective stage in which the signal is being distorted. Let us take up each section of the receiver and see how we would do this.

TUNER AND I-F STAGES

To trace the video signal through the tuner and through the video i-f stages, you use a detector probe to demodulate the rf signal. First look for a signal at the output of the tuner. You will not always be able to pick up a signal at this point, because it is usually very weak here. However, if you are close to a strong local station, you may be able to pick up the video signal at this point. When you are looking for a signal at the output of the tuner, turn the vertical sensitivity of the oscilloscope to maximum and adjust the sweep to some submultiple of either the field or the line rate. If you want to look at the field signal, adjust the oscilloscope sweep to about 30 cycles; if you want to look at several lines, adjust the sweep frequency to 7875 cycles per second. If you simply want to use the oscilloscope as a signal tracer to find a dead stage, you can trace either the field or the line signal. However, if there is a defect in the set that is distorting part of the signal, set the oscilloscope sweep frequency to whichever of the two signals is being more noticeably distorted.

If you are unable to pick up a signal at the output of the tuner, move the detector probe to the output of the first video i-f amplifier to see if you can pick up a signal there. In most locations where the strength of the signal from the TV station is reasonably high, you will be able to pick up a signal at the output of the first video i-f amplifier stage. Once you have been able to pick up a signal on the oscilloscope, whether it is at the output of the tuner or at the output of the first video i-f stage, as you go on through the video i-f amplifier, the signal strength should increase. In other words, if you picked up a weak signal at the output of the tuner, the signal should be noticeably stronger at the output of the first video amplifier and still stronger at the output of the second video i-f amplifier.

Continue to trace the video i-f signal on through the video i-f amplifier until you reach the video detector. When you reach the video detector, remove the detector probe; it will no longer be necessary.

If the receiver is completely dead, you can continue to trace the signal through the video amplifier stages using only a direct probe, because it does not matter if the scope upsets the performance of the video amplifier slightly; you are interested in finding the stage that will not pass the signal at all.

On the other hand, if the trouble in the receiver is a defect that is affecting only the high-frequency component of the signal, then you should use a low-capacity probe with the oscilloscope, because the additional capacity that you would introduce by connecting the oscilloscope directly to the video amplifier circuits would distort the wave-

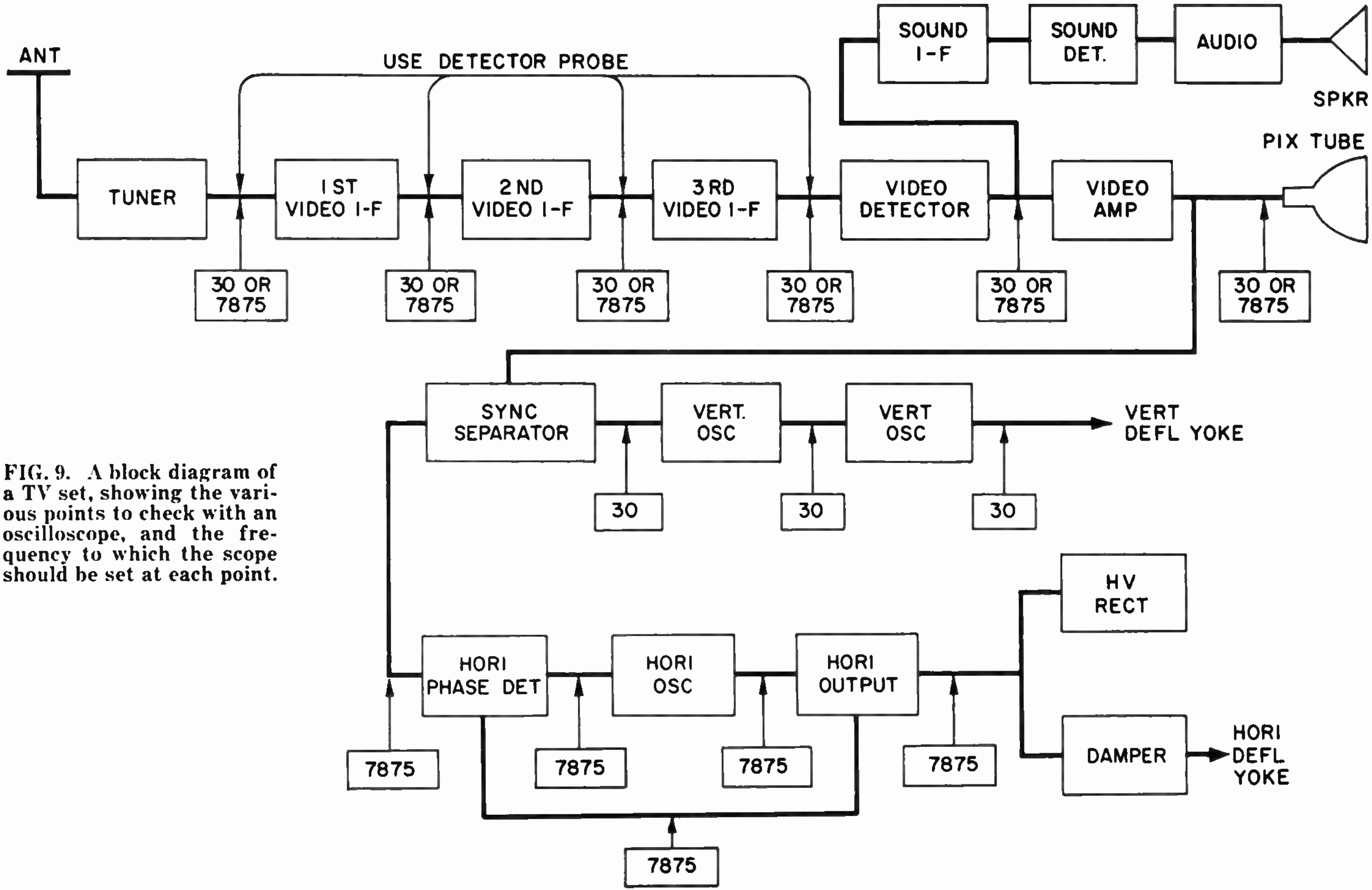


FIG. 9. A block diagram of a TV set, showing the various points to check with an oscilloscope, and the frequency to which the scope should be set at each point.

shapes and might lead you to suspect a stage that is actually operating satisfactorily.

In Fig. 9 we have shown a block diagram of a television receiver showing the various points you should check in observing the signal in a TV receiver, and the frequency that the horizontal oscillator of the scope should be set to at each point. Of course, it is not necessary to look at the signal at all of these points when servicing a set. For example, if the trouble is that the vertical sweep circuit will not remain in sync, there is no point in checking the waveshapes in the horizontal sweep system. Similarly, if you have a raster on the face of the picture tube, you know that both the horizontal and the vertical sweep circuits are working. If the defect is that there is no sound and picture but the raster is normal, you should trace the video signal through the video i-f and video amplifier stages to find the point at which the signal is lost. There would be no point in checking the sweep circuits, because they apparently are working satisfactorily, otherwise you would not have a raster on the picture tube.

BANDPASS MEASUREMENTS

Sometimes the oscilloscope is used in conjunction with a sweep generator to check the bandpass of a stage. The stage may be a video i-f stage, a video amplifier stage, or the chrominance channel in a color receiver.

When using an oscilloscope to check the response of a stage, you must refer to the manufacturer's service information to find out how the oscilloscope and sweep generator are to be connected, and what the response is supposed to be. Connecting these instruments to the circuit will affect the response of the circuit, so that the response pattern you will see on the oscilloscope will not be the same when the instruments are removed. However, if you get the response you are supposed to get with the sweep and the oscilloscope connected, it will be satisfactory when the two are disconnected from the circuit.

Simply checking the response of a stage by connecting the oscilloscope and sweep generator is of very little value if you do not have any information as to what the response should be. Manufacturers often peak one stage at a certain frequency to overcome deficiencies in other stages at this frequency. Therefore, you may obtain a very peaked response in one stage, and although you might think that this response indicates a defect, it could very well be the desired response for that particular stage.

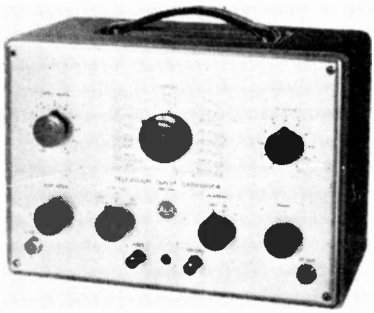
Sweep And Marker Generators

When you are aligning an AM broadcast receiver, all you need is a single-frequency signal generator that can produce an accurate signal on any of the various AM intermediate frequencies and at other key frequencies on the AM broadcast band. The broadcast-band signal generator often has 400-cycle tone modulation so that the loudspeaker can be used as an output indicator.

For accurately aligning FM and TV sets, however, an instrument called a *sweep-frequency signal generator* must be used. Instead of applying a single frequency to the input of the circuits under alignment, the sweep signal generator supplies a band of frequencies 10 to 15 megacycles wide. For example, the range of frequencies between 40 and 50 mc can be applied to the input of the i-f section, so that you can clearly see the frequency response of the system and quickly decide whether or not alignment is necessary.

The sweep signal generator does not supply this entire range of frequencies simultaneously. It produces one signal that starts at 40 mc and then gradually increases to the upper frequency limit of 50 mc. At this time, the cycle reverses, and the applied signal frequency decreases from 50 to 40 mc. This change of frequency from 40 mc to 50 mc and back to 40 mc occurs at a rate of 60 or 120 times per second.

Now, let us see what happens when this range of frequencies is applied to a wide-band amplifier that has a flat response between 40 mc and 50 mc. This is shown in Fig. 10A.



Courtesy RCA

Sweep-frequency generator.

When a 40-mc to 50-mc sweep signal is applied to the input of an amplifier that has a constant gain on all frequencies between these limits, a constant current will be produced in the output of the detector circuit. The amount of current drawn by the diode will be the same for every signal frequency that is applied at the input. When a scope is connected to the output of the diode detector, the pattern reproduced on the screen will be a straight line.

If we apply the same range of frequencies to an amplifier that has a

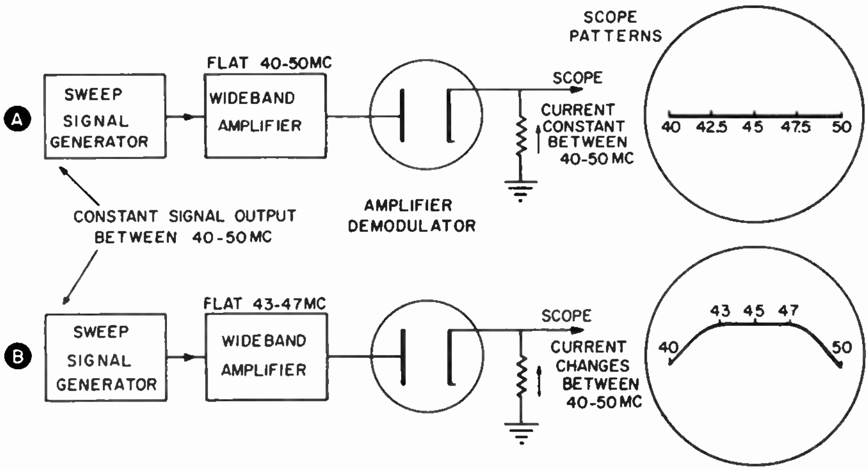


FIG. 10. Sweep frequency applied to wide-band amplifier. (A) Response flat between 40 and 50 mc. (B) Response flat between 43 and 47 mc.

constant gain between 43 mc and 47 mc, the pattern reproduced on the screen will be as shown in Fig. 10B. Notice that the diode does not draw the same current for the entire range of frequencies. Instead, the diode current gradually increases from the low value of 40 mc to a maximum value at 43 mc. This maximum current is maintained to 47 mc; in other words, the response of the amplifier is flat between 43 and 47 mc. When 47 mc is reached, the diode current gradually decreases and reaches a minimum at 50 mc. As you can see, although the amplitude of the signal applied to the input of the amplifier is constant between 40 mc and 50 mc, the diode current at the output is not uniform, because the amplifier itself has less gain at some frequencies than at other frequencies. Thus, the change in diode current indicates the relative gain of the amplifier over the range of frequencies applied to its input.

To obtain an accurate response pattern on the screen, the horizontal motion of the scanning beam must be synchronized with the changing frequency signal at the input of the amplifier. In actual practice, a sweep signal is applied also to the horizontal amplifier input terminals of the scope. The pattern on the screen then moves from left to right across the screen exactly in step with the sweep signal applied to the input of the amplifier section being aligned.

The sweep signal generator that is used to align FM and TV sets must have several important characteristics. First, the output of the sweep oscillator must produce signals that have a constant amplitude. If the amplitude of the sweep signal changes and is not constant over the entire sweep frequency range, the response pattern reproduced on the screen will not be accurate. The variations in both the sweep signal and the response of the amplifier would be present at the output of the detector. Hence, it would be hard to find how much of the response pattern on the screen would be due to the variation in the sweep generator and how much would be due to the nonlinear response of the amplifier.

Another important characteristic to look for in a sweep-frequency signal generator is the range of output levels that can be obtained from the instrument. When aligning a single tuned circuit or a single amplifier stage, the output signal level usually must be rather high to give a satisfactory pattern on the screen. On the other hand, when aligning a high-gain amplifier system, a very weak output is necessary to prevent overloading the vertical amplifier in the scope or one of the amplifiers in the system being aligned. Therefore, the output of the sweep frequency signal generator should be variable and the response must be constant for each range.

In addition to constant amplitude, the sweep-frequency signal generator should have output frequency ranges that can be set on the intermediate frequencies used in FM and TV sets, and it should produce the frequency ranges of each of the VHF television channels. Also, enough output must be available over these ranges, and the length of the sweep should be continuously variable to at least 12 to 15 megacycles. By having a wide deviation in both the i-f and VHF ranges, you can observe the response at the adjacent channel trap frequencies.

MARKER GENERATORS

Although the sweep generator fulfills all the requirements just described, it is difficult to set the controls on the instrument so that the frequency range exactly corresponds to the width and the center frequency of the response curve of the receiver being aligned. The most convenient way of indicating and adjusting the frequency of the response curve is to mark the curve with a signal from a marker generator. The marker generator signal produces a small "pip" on the response curve to indicate the frequencies represented by the curve. Because the marker-generator frequency can be varied and the marker generator is accurately calibrated, you can easily and accurately find where the picture carrier is on the curve, the location of various key frequencies, and the over-all width of the curve.

The amplitude of the marker signal can be controlled over a wide range, and the marker may be used as a single-frequency generator for spot frequency alignment. When it is used for single-frequency alignment, you can easily align tuned circuits and wave traps in a TV set by tuning the output frequency of the marker to the frequency of the circuits or traps.

Marker Injection. The marker signal can be added to the response curve in a number of ways. If the sweep generator has an internal marker, the marker signal can be inserted into the sweep signal by throwing the proper switch and adjusting the marker amplitude control. If the marker generator is a separate instrument, the signal can be applied at a suitable point in the amplifier under alignment. It can be inserted at the same point as the sweep signal or, in accordance with some manufacturers' recommendations, at some other point where there is less loading or less interaction.

The most important thing is for the marker generator to be connected at some point where it will not load or distort the response pattern of the unit under alignment. Also, the amplitude of the marker must be adjusted so that it does not change the shape of the response curve. The marker amplitude should be adjusted until the pip on the response curve can just be seen. At this amplitude, it will not

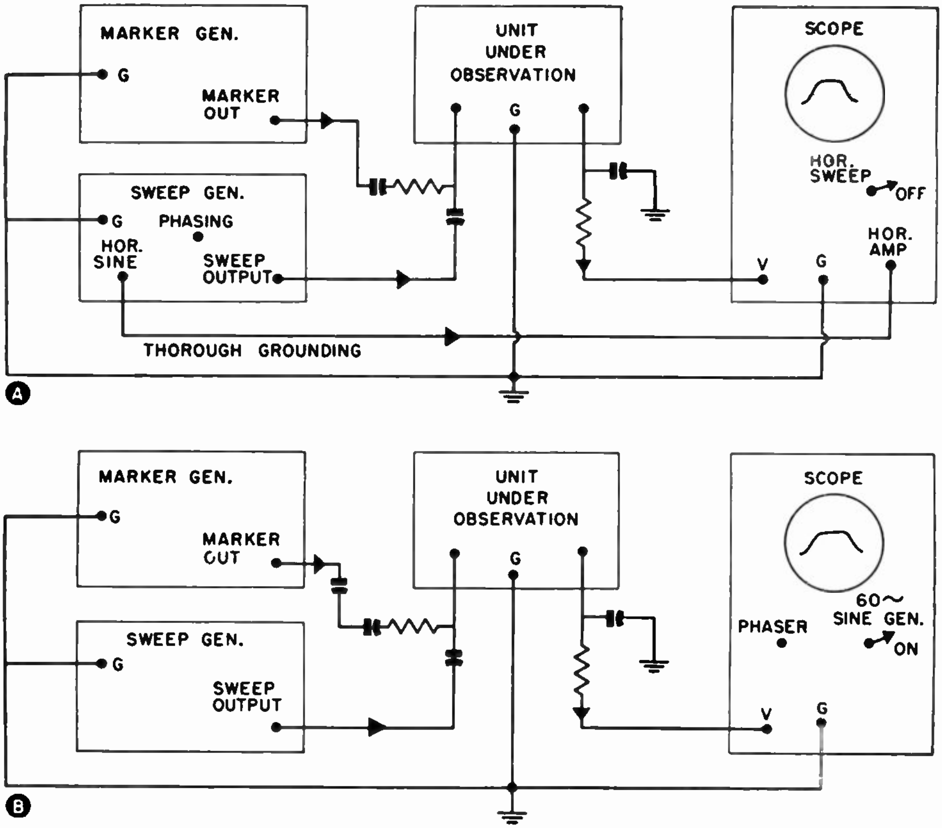


FIG. 11. Interconnection of alignment equipment.

alter the true shape of the response curve.

Usually the marker signal is applied through a blocking capacitor or an isolating resistor. However, if the marker generator has a weak output, as often occurs on the high band VHF channels, the signal can be applied directly to the unit under alignment.

To be useful in alignment work, the marker generator must be very accurate, and the frequency must be variable over a wide range. You should be able to set the marker on any position of the curve and determine the frequency at that point on the curve within a fraction of a megacycle. This is particularly important in aligning the i-f section of a color receiver. The response curve must be calibrated precisely because of the close frequency spacing between the signals on the response curve.

SWEEP-ALIGNMENT TECHNIQUES

Now that we have learned the important characteristics of the sweep and marker generators, let us see how they are used in receiver alignment work. An important consideration in aligning any FM or TV set is to make certain that the test instruments are interconnected properly to prevent false and distorted patterns. There are several methods of interconnecting test equipment. Two typical methods are shown in Fig. 11.

The most common interconnection method is shown in Fig. 11A. Instead of using the internal horizontal sweep of the scope, a sine wave generated in the sweep generator is applied to the horizontal input of the scope to control the horizontal motion of the beam. This same sine wave is used to control the deviation of the sweep oscillator in the sweep-frequency generator. Thus, the horizontal motion of the scope scanning beam is in sync with the changing frequency at the output of the sweep generator.

The sweep and marker generators are connected to the unit being aligned, at the same point; the sweep generator is connected to the horizontal amplifier input of the scope; and the signal from the unit being aligned is applied to the vertical input of the scope. There are also ground connections between all the units. If the sweep signal generator contains an internal marker generator, the separate marker unit is not necessary. The marker signal is injected into the sweep signal within the sweep generator.

If the scope has a built-in sine wave horizontal sweep circuit and an associated phaser, only two interconnections are necessary in setting up the alignment equipment, as shown in Fig. 11B. In this method, the 60-cycle sine wave sweep of the scope is turned on, and its phaser is adjusted until there is an overlapped alignment pattern on the screen. The deviation at the output of the sweep generator, of course, also follows a 60-cycle sine wave change. When the phase of the horizontal motion of the scanning beam is made to coincide with the phase of the frequency deviation, the patterns on the screen will overlap.

When sweep-aligning any receiver, it is always advisable to follow the manufacturer's procedure for the specific model—do not make alignment adjustments in a hit-or-miss manner. The accuracy with which you follow the recommended procedure will have much to do with the performance of the receiver after it has been aligned.

In checking or making any alignment adjustments, there are four very important provisions necessary. These are: a proper ground system, accurate bias and signal levels, adequate interference rejection, and proper injection of marker signals. The type of ground system often makes the difference between a satisfactory response curve and a variable and indefinite one. With a good ground system, your test units will show a true response that will not vary with placement of interconnecting leads and changes in test equipment position.

In order to get the response curves shown as typical by the manufacturer in his instructions, you must follow the manufacturer's recommendations step by step. The amplifier must be operated with the recommended bias voltages, and the signal and output levels must follow the recommended values. The response pattern will become distorted if improper bias or too much signal is applied to the stages being aligned.

There are variations in the recommended procedures and points of connection in different receivers, but the following recommendations are usually included in all manufacturers' alignment procedures.

1. Adjust the contrast and agc for proper bias and levels.

2. Apply an external or a controlled internal voltage to the bias line to set up correct operating conditions.

3. Apply a signal with as low an

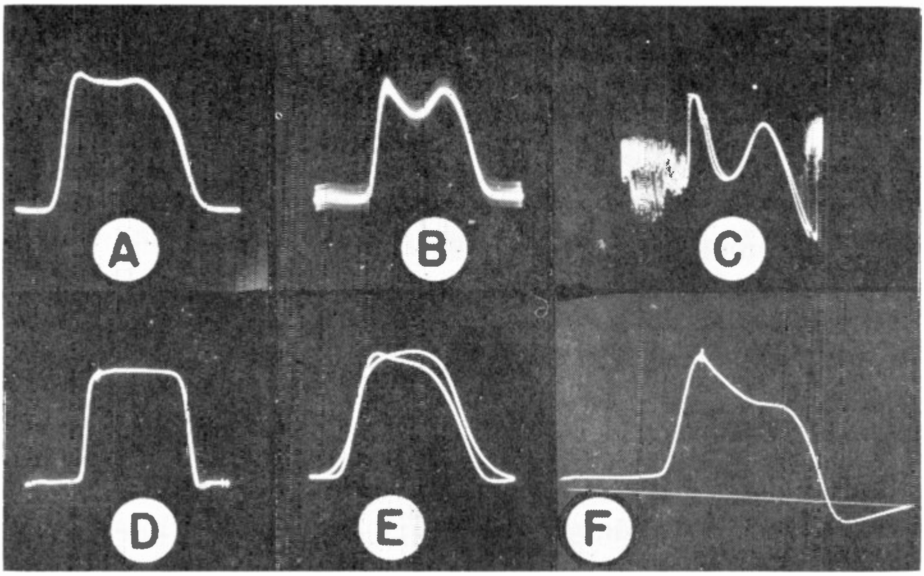


FIG. 12. Sweep response curves. (A) Normal video i-f response. (B) Insufficient output filtering. (C) Result of not following bias recommendations. (D) Too much sweep signal overloads i-f. (E) Hum pickup or inadequate grounding. (F) Pattern tilt can be caused by poor low-frequency response in scope.

amplitude as gives you a reasonably sized pattern on the oscilloscope. If the amplitude of the signal is too high, it may overload the receiver, and the response curve will be flattened.

4. Take precautions when connecting test equipment to the unit being aligned so that the equipment does not influence the circuit operation enough to upset the response curves.

It is very important to use a logical step-by-step procedure in adjusting any type of receiver. First, the test equipment must be interconnected correctly. Second, all the recommended precautions should be followed to obtain reliable response indications. Last, random adjustments of the controls and hit-or-miss tactics should be avoided. Follow the recommended procedures exactly, and do not adjust any control until you are certain what the control is and how it influences the circuit operation.

Modern wide-band circuits seldom require realignment. If you observe that the response curve of the circuit is distorted, the trouble is probably a defective component and not improper alignment. Therefore, look for defects first before you begin to align. If you merely want to "touch up" the alignment of a receiver rather than to carry out the complete alignment procedure, always work with one alignment adjustment at a time. Notice where a particular control is set, and move it on either side of its setting to see if there is any improvement in the response. Before proceeding to another control, restore the first one to its original setting. The danger in attempting to make touch-up adjustments is that you may get several controls misadjusted. When this happens, you will have to go through the entire procedure to establish normal operating conditions.

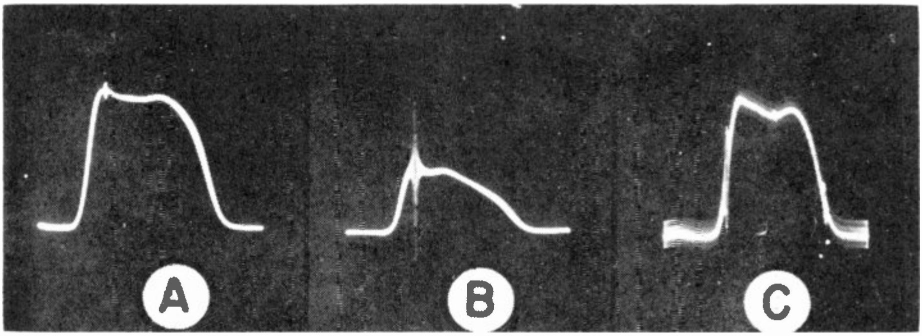


FIG. 13. (A) Normal marker setting. Marker frequency 22 mc. (B) Too strong marker. (C) Insufficient filtering.

ALIGNMENT HINTS AND PATTERNS

Fig. 12 shows some examples of incorrect response patterns that you might get if you do *not* follow the manufacturer's recommendations or do not interconnect the test equipment properly. The normal response pattern for the i-f section of a television receiver is shown in Fig. 12A.

Fig. 12B shows the type of pattern that may be obtained when there is a stray signal picked up or insufficient filtering at the output of the amplifier being aligned. You can correct this condition by applying a signal of the proper level to the input and by using an isolating resistor and/or a capacitor at the point where the scope is connected to the output. These components are shown in Fig. 11.

Fig. 12C demonstrates what can happen to the response pattern if the manufacturer's bias recommendations are not followed, even with a signal of the correct amplitude and properly connected equipment.

Fig. 12D shows what appears to be an excellent pattern. However, it is a false pattern. It was obtained by increasing the output of the sweep generator until it overloaded the i-f amplifier. Avoid this type of false response in your servicing work. Always apply just enough sweep signal to obtain a clear, usable pattern on the screen. Thus, in sweep alignment work, adjust the scope for high sensitivity and the sweep generator for minimum-to-moderate output.

Insufficient grounding or hum pick-up can cause the type of distortion shown in Fig. 12E. Notice that the patterns do not overlap, indicating that there is a variation between the signal applied to the vertical input of the scope and the sync signal applied to the horizontal input. If touching the various leads causes the shape of the response pattern to change in this way, improper grounding is also indicated.

The oscilloscope itself can produce distortion in the response curve. If it has poor low-frequency response, the response pattern will tilt as shown in Fig. 12F.

As you can see, unless all the precautions are taken and the manufacturer's recommendations are followed exactly, it will be almost impossible to align a TV receiver properly.

Improper injection of the marker signal can also distort the response pattern. Remember that we said that the marker pip should be just large enough to be seen clearly on the response curve. A normal response curve with a marker of the proper amplitude is shown in Fig. 13A. By using this marker signal and the proper point of injection, you will get an undistorted response curve, and you will be able to place the marker accurately on the curve.

If the marker signal is too strong, the response pattern will be pulled out of shape and the marker pip will be fuzzy and too large, as shown in Fig. 13B. The waveform in Fig. 13C again shows stray signal pickup and excessive marker signal. Notice that the marker signal spreads out because of insufficient filtering. This type of pattern may be obtained when the demodulator output is not properly filtered.

The oscilloscope and the sweep and marker generators are very important in TV servicing. Other instruments are also necessary if you are to do thorough and efficient work, so let us discuss some of the other instruments that are needed and find out what their requirements should be.

VTVM And Miscellaneous Test Equipment

The major use of vacuum tube voltmeters and high-resistance volt-ohmmeters is in finding defects in electronic circuits by measuring ac and dc voltages and resistance. They can be used to follow the voltage supply line from the power supply to each vacuum tube element. Because the vtvm is a high-impedance device, it can be used to check bias voltages in the various stages. In addition, if you use a radio-frequency probe with the vtvm, you can measure high-frequency signal voltages. However, in measuring high-frequency voltages, remember to connect the meter to a low-impedance point to prevent loading the circuit.

The vtvm is frequently used in aligning the i-f amplifier and frequency demodulator sections of an FM receiver and the sound section of a TV receiver. Diagrams of typical frequency discriminator and ratio detector circuits are shown in Fig. 14.

To align the i-f amplifier stages, shown in Fig. 14A, first connect the vtvm across the limiter resistor to measure the dc component of the limiter grid current. This current flow varies with the peak amplitude of the i-f signal applied to the limiter grid. With a vtvm connected in this manner, apply an unmodulated i-f signal to the input of the sound i-f amplifier stages, and tune the i-f transformers for a maximum indication on the meter.

To align the frequency demodulator stage, connect the vtvm across one leg of the discriminator output circuit. With the unmodulated i-f signal still applied to the input of the sound i-f amplifier, adjust the primary of the detector transformer for maximum reading. Next, connect the vtvm across the full output of the demodulator and tune the secondary of the detector transformer for a zero reading.

Aligning the sound i-f amplifier and ratio detector circuits used in some FM and practically all modern TV receivers is similar to the procedure just described. First, connect the vtvm

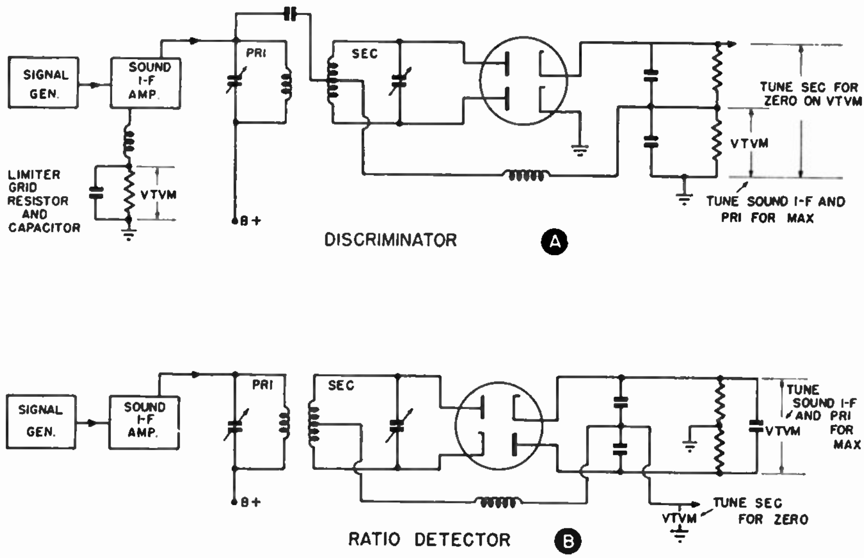


FIG. 14. Alignment of sound i-f with vtvm.

across the output of the ratio detector, as shown in Fig. 14B, and adjust the sound i-f stages and the primary of the detector transformer for maximum reading. Then, connect the vtvm between the sound take-off point and ground, and tune the secondary for minimum reading.

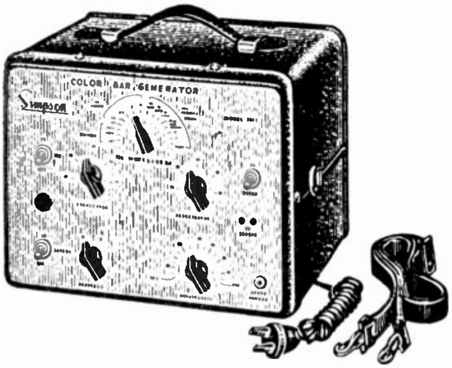
LINEARITY PATTERN GENERATOR

The linearity pattern or bar generator is used for both monochrome and color TV sets when making width, height, and linearity adjustments. The instrument forms a series of horizontal and vertical bars on the picture tube screen. The receiver controls are adjusted until the bars are uniformly spaced across or down the screen.

The bar generator contains a horizontal oscillator that operates at a lower frequency than the line rate but higher than the vertical field rate to form from 8 to 15 horizontal bars on the screen. It has a vertical oscillator that operates at a frequency higher than the line rate to form from 12 to 15 vertical bars. The horizontal and vertical bars are generated in a fixed time sequence. Therefore, in a properly adjusted receiver, they should appear evenly spaced across and down the picture tube screen, and when both the horizontal and vertical oscillators are in operation a cross-hatch pattern is produced.

Most modern bar generators include a provision for forming a white dot pattern that can be used to adjust the convergence circuits in a color television receiver. The dot pattern is formed by emphasizing and generating signals only at the time intervals that both the horizontal and vertical bar oscillators contribute signals simultaneously. These time intervals occur during the line cross-over periods of the cross-hatch pattern. Consequently, the series of dots that is formed corresponds to the positions of the horizontal and vertical crossover points.

It is possible to obtain either a modulated rf or a video signal from



Courtesy Simpson

Color bar generator.

the output of a bar generator. The frequency of the rf signal at the output can be adjusted for any channel between 2 and 6, so the instrument can be connected directly to the antenna terminals of a TV receiver.

To obtain a stationary locked-in bar or dot pattern, the generator must be synchronized by pulses from the deflection circuits of the receiver being adjusted. A pulse from the vertical deflection circuit is usually applied to the vertical sync input of the dot generator. After passing through several circuits in the generator, it is used to sync the horizontal bar oscillator, because the oscillator must operate at a frequency that is a multiple of the field rate. On the other hand, a sync pulse from the horizontal deflection circuit will sync the vertical bar oscillator, because this circuit operates at a frequency that is a multiple of the line rate.

COLOR-BAR GENERATOR

The color-bar generator is used only in checking and adjusting color TV receivers. The instrument produces vertical color bars on the screen of the color picture tube that correspond to the primary and secondary color signals and the color-difference signals.

A color-bar pattern is particularly useful in adjusting or checking the performance of the chrominance channels and the matrix sections of a color receiver. Some color-bar generators form not only the individual color bars and chrominance sub-carrier signals, but also a complete TV signal for one of the standard VHF channels. This signal can be applied to the antenna terminals of the color receiver, so that the over-all performance of the receiver can be checked.

For example, you can check the operation of the tuner and i-f section because the signal formed by the instrument contains both the picture and the sound carriers. You can also test the sound carrier traps with relation to the chrominance and luminance signals at the input of the video section.

To get proper hues in a color picture, the hue and chrominance controls must be properly adjusted. This can be done by observing the colors of the bars in the bar pattern. Finally, you can check and adjust the luminance and chrominance channels to make certain that they will faithfully pass the signal components for which they were designed.

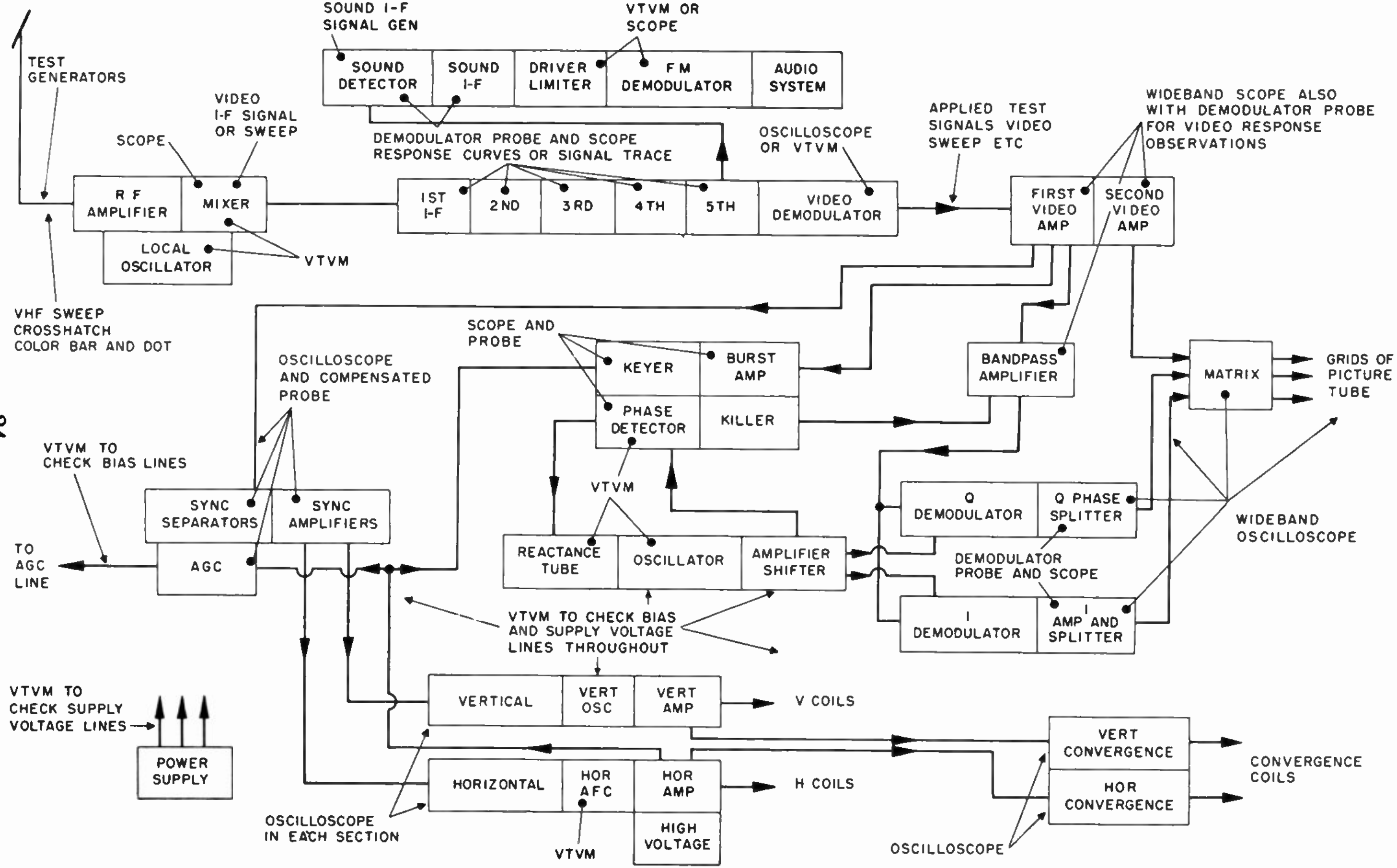


FIG. 15. Test equipment used on a color receiver.

Using The Test Equipment To Check A TV Receiver

We have discussed the requirements and operation of the various pieces of test equipment; now let us see how they can be used to check a color TV receiver. Many of the applications for the test equipment are demonstrated in the block diagram of the color receiver in Fig. 15.

As you know, the tuner, the i-f amplifier section, the sound section, and the vertical and horizontal sweep sections of a color receiver are similar to those used in monochrome receivers. Therefore, the information that we give in this discussion concerning these sections also can be applied to monochrome receivers. We will indicate the various test instruments that can be used in each section and state what precautions should be taken to get proper results.

TUNER

By applying a VHF sweep signal to the antenna input terminals of the receiver and connecting a scope to the mixer-grid test point, you can quickly and easily check the response of the tuner. The response curve on the scope screen indicates the sensitivity, the band width, and the selectivity. Many defects can be located by observing the shape of the response curve.

When connecting the scope to the mixer-grid circuit, it is often necessary to place an isolating resistor in series with the scope lead to keep from changing the characteristics of the mixer-grid tuned circuit. In some types of tuners, however, the isolating resistor already is a part of the tuner, and is in series with the line running to the recommended point of connection.

The vacuum tube voltmeter can be used in the tuner section to check the negative grid bias voltage of the local oscillator to see if the tube is oscillating with sufficient strength for efficient mixing action. The check for the strength of the oscillator signal also can be made at the grid of the mixer stage.

Finally, the vtvm can be used to check the supply voltage and bias lines running to the tuner section. Sometimes the supply connections are made through terminal strips attached to the tuner or by leads coming from the back or sides of the tuner.

VIDEO I-F SECTION

The video i-f system of a TV set will give you an opportunity to use many of the test instruments described in this reference text. Starting at the output of the tuner, there are a group of resonant circuits that couple the tuner to the input of the video i-f amplifier. Usually these circuits have overcoupled and double-humped curves. There are usually trap circuits to sharpen the skirts (the vertical portions) of the response curve. Therefore, it is necessary to align these resonant circuits precisely.

The performance of individual i-f stages can be observed by using a detector probe with the scope. For example, apply a sweep signal to the grid of the mixer and connect a scope and its detector probe to the plate of the second video i-f stage. Temporarily connect a 200-ohm composition resistor across the second i-f plate coil. This resistor will load the plate circuit so heavily that the frequency response of the stage will not affect the response pattern on the scope. The detector probe is connected to the plate instead of the grid of the second i-f to avoid loading the output of the first i-f stage.

The pattern obtained is that of the *first* i-f stage and its tuned circuits. The other i-f stages can be tested in the same way. Remember never to connect the sweep generator or detector probe directly to any tuned circuit that is being adjusted.

The scope used must have high sensitivity; otherwise there may not be sufficient gain from a single amplifier stage to produce a usable pattern on the screen.

If a detector probe is not available, connect the scope at the video detector output. When using this arrangement, load the stages between the second i-f and the video detector with resistors in order to get a true indication of the response of the input circuits. After the first i-f stages have been aligned, remove the loading resistors and align each of the other i-f stages in turn.

The video i-f section has many traps and tuned circuits that require adjustment. Some of the tuned circuits remove the sound signal component while others prevent the sound information from entering the video amplifier section of the color set. There are also a number of single-tuned resonant circuits in the stagger-tuned i-f system.

The numerous resonant circuits can be adjusted most accurately by applying a single-frequency signal to the input of the i-f amplifier. This single-frequency signal can be either tone-modulated or unmodulated, depending upon what type of output indicator is used. With an unmodulated signal, connect a vtvm to the video detector output. Set the VHF signal generator to each of the frequencies of the traps and tuned circuits, and adjust them for a minimum or maximum reading on the vtvm, depending upon whether they are traps or single tuned circuits or a stagger-tuned combination. Generally, the single-frequency unmodulated i-f signal is supplied to the grid of the mixer. However, the manufacturer may recommend a special signal application jig or capacitive coupling device for inserting the signal.

If a tone-modulated, single-frequency i-f signal is used, a scope can be connected as an output indicator in the video detector circuit. Each trap and tuned circuit can be adjusted for minimum or maximum audio modulation indication on the screen.

The vtvm can also be used to measure the bias and supply voltages in the video i-f amplifier.

Video Amplifier. The method described for the video i-f amplifier also may be used to check the response of the video amplifier section. To prevent loading of the video stages, you should use a compensated probe with the scope.

SOUND I-F SYSTEM

There are two standard methods of aligning the sound i-f section of either a monochrome or a color receiver. One, which was discussed earlier in this reference text, is to connect a single-frequency generator to the input of the sound section, and use a vtvm to align the resonant circuits of the FM sound i-f section.

The other is to apply a sound i-f sweep signal from a sweep generator to the input of the sound section, and connect the scope at the limiter grid circuit or at one section of the frequency demodulator output circuit. With the scope connected to the full output of the frequency demodulator, you can observe the actual frequency demodulator "S" curve. Of course, in the sound i-f section, the alignment procedure must be carried out carefully to obtain a minimum of intercarrier buzz interference.

It is also possible to signal-trace through the rf and i-f sections of a TV receiver with either a scope and its associated detector probe or a vtvm and its radio-frequency probe. Either a tone-modulated VHF signal or a receiver signal can be used.

The vtvm can be used in the following circuits of the receiver to trace the supply voltage and bias lines.

LUMINANCE VIDEO CHANNEL

The luminance video amplifier contains a number of resonant circuits that attenuate undesired signals and channel the various segments of the luminance and chrominance signals to the proper sections of the color receiver. In adjusting the traps and tuned circuits, you can use a tone-modulated, single-frequency signal. You can apply a tone-modulated signal at either the subcarrier frequency or the 4.5-mc sound-carrier frequency, to the input of the video amplifier and connect the detector probe from the vertical terminals of the scope to the grid of the second video amplifier. Now, adjust the tuned circuits for minimum or maximum indication on the scope as recommended by the receiver manufacturer.

It is even more important to observe the response curves in the various sections of a color receiver than of a monochrome receiver because of the critical positioning of the various signal components on the curve. To check the response of the luminance channel, apply the video sweep signal to the input of the first video amplifier, and connect the detector probe and scope to the output of the luminance amplifier. The response of the chrominance band-pass amplifier also can be obtained by connecting the scope and the detector probe to the input of the chrominance demodulators. Now, check each of the chrominance channels by connecting the scope and probe to the color difference phase splitter or amplifier in each of the chrominance channels. Of course, the video sweep signal is applied to the input of the first video amplifier for all these observations.

CHROMINANCE CHANNELS

In addition to observing the video response curves in the chrominance channels, as mentioned in the preceding section, you must also adjust the phase of the sub-carrier signals and the relative gain of the color difference channels when working on a color TV receiver. Several methods can be used.

You can connect a color-bar generator to the antenna terminals or use the signal from a TV station that is conveying the standard color-bar test chart, and check through each channel with a wide-band scope and its compensated probe. For the initial checks, the probe can be attached near the output of each color-difference channel to observe the bar signals. Then, move the scope to the grids of the tricolor picture tube to observe the bar patterns while you make the adjustments.

COLOR SYNCHRONIZING SYSTEM

The circuits in the color sync section of the color receiver can be signal-traced and adjusted by using a scope and its compensated probe. The color sync circuits use a phase-detector control system. Therefore, the vtvm can be used to adjust the phase detector and also the sub-carrier generating system.

SYNC SEPARATOR AND AMPLIFIER SECTION

The most useful instrument in signal tracing and locating defects in the horizontal and vertical sync sections of a color or a monochrome receiver is the scope and its compensated probe. The compensated probe must be used to obtain a faithful waveform reproduction and to prevent the scope from loading the circuit from which the signal is taken. The most efficient means of checking the sync pulse circuits is to observe the waveforms on the scope.

DEFLECTION AND CONVERGENCE SYSTEM

The scope with its compensated probe is ordinarily used for adjusting and testing the performance of the sweep and convergence system. You can signal-trace the vertical oscillator and amplifier sections and observe the vertical signal at the grid of the vertical sawtooth oscillator by removing the vertical oscillator tube or in some way stopping the vertical oscillation. The horizontal sync pulses at the input of the horizontal afc system may be observed by taking the horizontal oscillator out of operation. Use the vtvm to adjust the horizontal afc system.

By taking proper precautions and following the manufacturer's recommendations, you can use a scope to observe the waveforms in the vertical and horizontal output stages and in the convergence circuits.

The convergence adjustments are made by connecting a dot generator to the input of the receiver and observing the dot pattern on the picture tube screen. This is the only way in which the convergence adjustments can be made in the present color sets. The adjustments consist of various magnets on the neck of the picture tube and various potentiometers and capacitors in the convergence circuit that change or alter the shape of the waveforms. When the adjustments are made correctly, the three electron beams pass through the holes in the mask to overlap exactly—one over the other—to form a white dot.

SUMMARY

Your test instruments take much of the uncertainty out of your work. By using them, you can make critical adjustments and observations so that you can efficiently repair all types of receivers and electronic equipment. It is important for you to know how to use them. For any piece of equipment to be of maximum benefit to you, you must use it whenever possible.

It is true that the first few measurements or observations that you make with a piece of complex test equipment may take a long time. However, as you use the equipment more and more, and become accustomed to it, your speed, and the ease with which you make the adjustments, will improve. Eventually, the quality of your work and the speed with which you do it will be much improved over the hit-or-miss procedures that you would have to use without the aid of the test equipment. By using the equipment in a logical way, you will be able to do high-quality service work.

IT CAN BE DONE!

Behind ninety-nine out of one hundred statements that "it *can't* be done," is nothing but the unwillingness to do it.

And in many instances, this unwillingness is nothing but *laziness.*

To do something different—to do a thing, in a new way—would mean a little more work for a time, so the new idea is opposed.

People will say "the new idea is good but not practical"—forgetting that the only test of practicality is the test of actually trying to do it.

Of course, sooner or later the *better way* of doing a thing comes about. The assertion that a thing can't be done, only stands in the way of a shiftless man. The same idea is bound to occur to an ambitious man, and be carried out successfully.

Every successful man has succeeded by *doing things* which some people said couldn't be done! Success rests largely upon energy.

J. E. Smith.

COLOR TELEVISION

CIRCUITS

58B

RADIO-TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL

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WASHINGTON, D. C.

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STUDY SCHEDULE NO. 58

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. Introduction .... Pages 1-5

In this section you get an over-all picture of a color TV receiver.

☐ 2. The Luminance Channel .... Pages 6-9

You study the circuits used for the reception of the brightness portion (the Y signal) of the TV signal.

☐ 3. The Color Synchronization Section .... Pages 10-14

Color synchronization is based on a phase comparison technique. You study the circuits used to do this in this section.

☐ 4. The Chrominance Section .... Pages 15-31

You study circuits used in demodulating the color signal using the I and Q signals and using the color-difference signals.

☐ 5. Deflection and Convergence .... Pages 31-36

Here we take up the circuits used for deflecting and converging the three electron beams in the picture tube.

☐ 6. Answer Lesson Questions.

☐ 7. Start Studying the Next Lesson.

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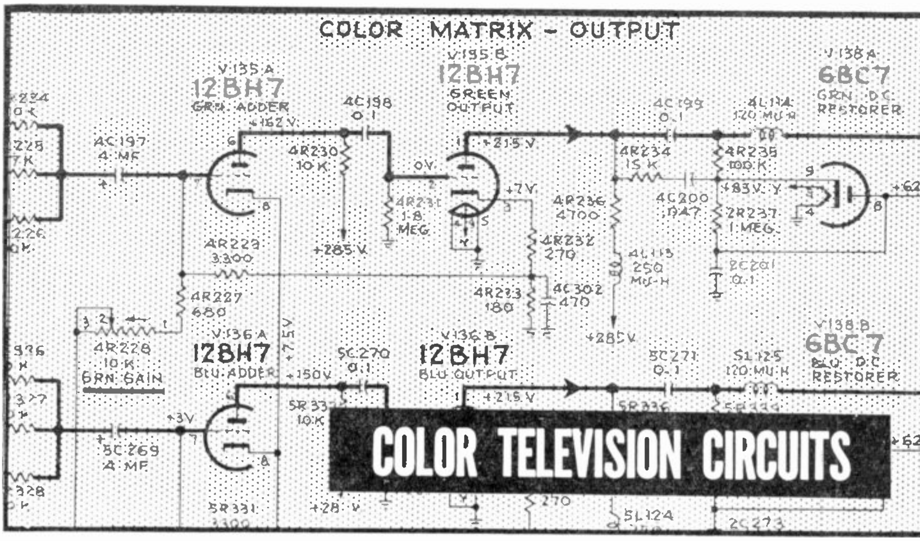


COLOR TELEVISION CIRCUITS

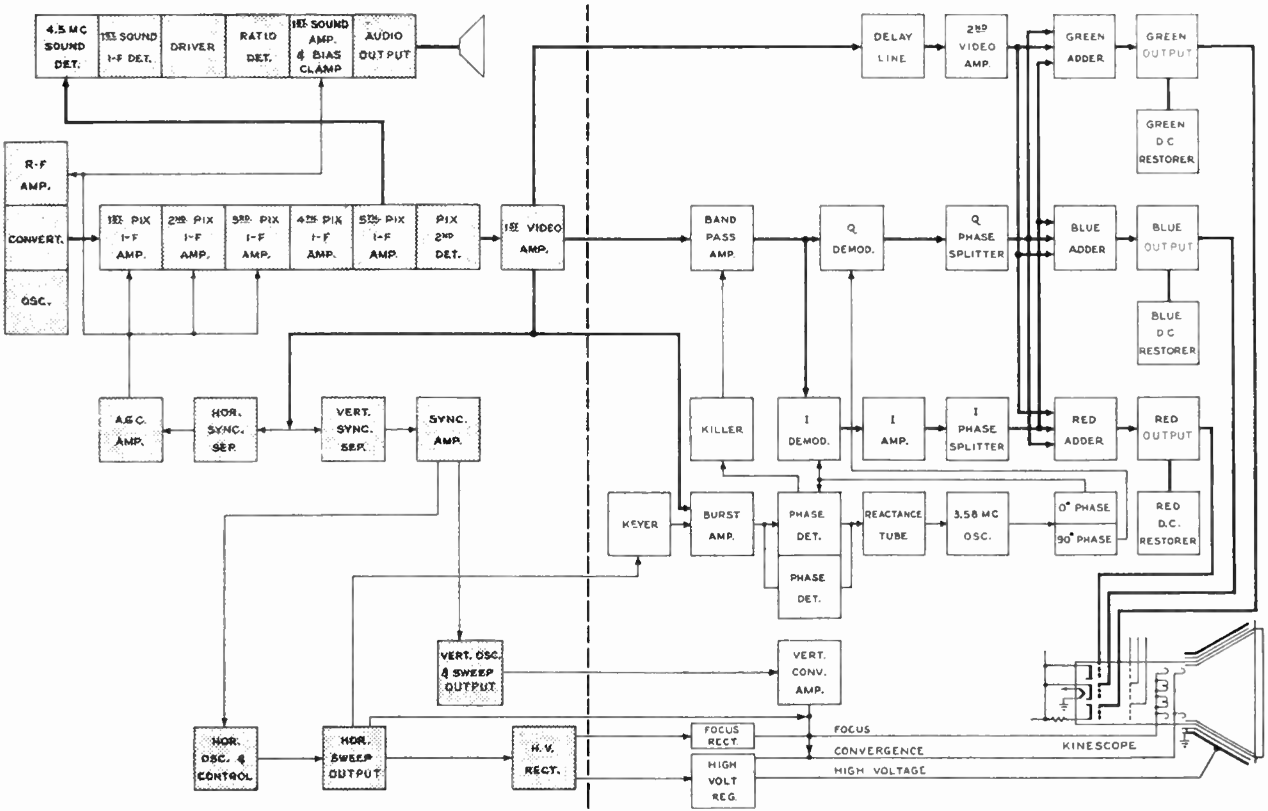
THIS lesson on color television receiver circuits expands upon the fundamental operation of the NTSC color television system described in an earlier lesson. It would be to your advantage to review the previous lesson on color television fundamentals and study the color definitions. We cannot overemphasize how important it is for you to know the exact meaning of color terms in order to follow the lesson content easily.

Many of the stages contained in color television receivers perform similar functions to those in monochrome receivers. However, they may have major or minor changes to enable them to handle the additional requirements of the color signals. You should remember this fact when you are servicing color television sets. The symptoms produced by defects in these stages may not be the same as the symptoms produced by similar defects in corresponding stages of black-and-white receivers.

This lesson is concerned primarily with the circuits that are found only in color television receivers. However, we will briefly describe those that are common to both systems and point out the variations in them. Some of the color television circuits, such as the color tuner and the color video amplifier, were discussed in previous lessons. Therefore, we will not give a detailed discussion of them here. If you are not sure that you understand how these circuits operate, go back and review them.

AN OVER-ALL PICTURE OF THE COLOR RECEIVER

A block diagram of a typical color receiver is shown in Fig. 1. The sections that are found in both black-and-white and color receivers are shaded; those that are not shaded are used exclusively in color receivers. Let us go through the re-



Courtesy RCA

FIG. 1. Block diagram of a typical color television receiver.

ceiver and describe the various stages.

At the top left-hand corner of the diagram are the tuner, the video i-f stages, and the sound channel. In monochrome receivers, the rf tuner presents few servicing problems. Color tuners probably will not require much more servicing than the tuners in monochrome receivers because they will usually have more than the required band width. The major source of trouble will probably be tube failures. Of course, the tuner must be properly aligned, because if the band width is reduced and the frequencies in the upper portion of the channel are attenuated, the color information will be lost.

The i-f amplifier system contains from 3 to 5 cascade stagger-tuned stages. The i-f amplifier must have a wide band width so that it can pass the subcarrier of 3.58 mc plus the upper sidebands (a total of 4.1 mc compared to 3 to 4 mc in black-and-white receivers) to prevent the loss of the chrominance information.

The sound take-off point in the color receiver is usually at the output of the last video i-f stage. Removing the sound carrier at this point helps prevent the 920-kc beat signal from producing interference patterns on the reproduced picture. This 920-kc signal is the difference frequency that results from beating the 3.58-mc subcarrier with the 4.5-mc sound carrier. Notice that in Fig. 1 the sound section contains two detectors. The first operates like the video detector in a monochrome receiver and beats the sound and video i-f signals together to produce a 4.5-mc sound signal. The second sound detector (the ratio detector) removes the modulation from the 4.5-mc sound i-f signals.

AGC voltage is usually applied to the tuner and the first three stages of the i-f amplifier, if the i-f system contains five stages; or to the tuner and first stage if there are only three i-f stages. A simple agc circuit is used.

The output of the video detector supplies the composite video signal to the first video amplifier of the color receiver. This stage separates the signal components and passes them into four separate channels. First, it supplies the *luminance information* (the brightness information or Y signal) to the luminance amplifier through an appropriate delay line; second, it supplies the *chrominance information* to the band-pass amplifier and on into the chrominance channels; third, it supplies *color synchronizing information* to the burst amplifier; and finally, it passes the *composite synchronizing pulses* to the sync separator stages of the color receiver.

Let us trace each of the signals to learn its basic function, and its association with the other signals in the receiver. The luminance, or Y signal, from the output of the first video amplifier is passed through a "delay line" and then is amplified by a second video amplifier before it is fed to the matrix unit. The delay line in the luminance section equalizes the time required for signals to pass through the luminance channel and through the chrominance channels. Thus, the luminance and chrominance signals arrive at the grids of the picture tube at the same time. If this arrangement were not used, the hue and saturation would not coincide with the brightness detail.

Chrominance signals are supplied through the band-pass amplifier to the I and Q color demodulators. The band-pass amplifier permits only the chrominance spectrum to be supplied to these demodulators. In the demodulators, the chrominance signal component is heterodyned with the inserted subcarriers to recover the original I and Q signals. The Q signal is supplied to a phase splitter which develops the positive and negative Q components necessary for application to the matrix unit. Since the I channel has a wider frequency response than the Q channel, the gain per stage is not so great. Consequently, an additional amplifier is needed to build up the I signal to the same level as the Q signal, before it can be applied to the I phase splitter.

In the matrix unit the luminance and chrominance signals are combined in stages called *adders* to form the three primary color signals of red, green, and blue. If the color system is functioning correctly, the proportions of the three primary color signals at the output of the receiver matrix are the same as those present at the input of the transmitting matrix. Each color channel consists of an adder stage, a video amplifier and a dc restorer. Thus, the primary color signals are built up to a suitable amplitude for application to the individual guns of the color picture tube.

Let us now trace the color synchronizing information from the output of the first video amplifier through the color sync section. The color sync sine waves riding on the back porch of the horizontal blanking pulse are applied first to a burst amplifier which amplifies this color synchronizing component only. The burst amplifier is keyed by a pulse derived from the horizontal output circuit. Thus, it conducts only during the *horizontal retrace interval*, which is when the color burst arrives. The color burst is supplied to a phase detector which compares the frequency and phase of the color burst with a locally generated subcarrier component.

The local subcarrier generator, that forms the subcarrier sine wave, is usually a crystal oscillator. The frequency and phase of the subcarrier sine wave are made to match those of the incoming sync burst by comparing these signals at the phase detector. A dc component developed by the phase detector is supplied to the grid of a reactance tube, which is connected back to the crystal oscillator. The reactance stage that is connected across the oscillator tuned circuit acts as a variable reactance to compensate for variations in the oscillator frequency. Any variation in the oscillator frequency causes a corresponding change in the reactance tube grid bias, and thus in the reactance across the tuned circuit. For example, if the oscillator drifts lower in frequency, the reactance stage will decrease its capacitive effect, and thereby increase the oscillator frequency. The subcarrier sine wave at the output of the oscillator stage is applied to the quadrature, or phase-shifting, amplifier. This stage, in turn, supplies an "in-phase" signal to the I demodulator, and a 90° out-of-phase signal to the Q demodulator. Unless the subcarrier signals are inserted with this phase relationship, demodulation cannot take place.

A color killer is also associated with the color sync circuits to turn off the band-pass amplifier when a monochrome picture is received. This circuit is controlled by the color burst signal. When a video signal is received that does not contain a color burst signal on its horizontal blanking pulse, the voltage supplied from the horizontal output transformer causes the color-killer circuit to conduct. This causes a high negative bias to be applied to the grid of the band-pass amplifier. Thus, there is no output from the chrominance channel because a monochrome signal contains no color signal.

The horizontal and vertical synchronizing information from the output of the first video amplifier is applied to separate sync separators. These synchronizing pulses are fed through a sync amplifier to the vertical and horizontal sawtooth generating circuits of the receiver. Thus far, the sync system is the same as that in a monochrome receiver. However, in addition to generating the horizontal and vertical waveforms, the horizontal and vertical deflection amplifiers in a color receiver produce convergence waveforms. These correction signals are supplied to either the convergence electrodes or the convergence coils, depending upon the type of picture tube that is used in the receiver, so that there will be proper convergence of the three beams over the entire surface of the screen.

The low- and high-voltage supplies serve the same purpose as the corresponding circuits in a monochrome receiver. However, because more tubes are used in a color receiver, the low-voltage supply must deliver higher current. The voltage for the second anode of the color picture tube also must be higher than the corresponding voltage in a black-and-white receiver. Variations in the second anode voltage, however, are much more noticeable in the color picture. Hence, a voltage regulator is needed to hold it constant.

The focus rectifier is usually used only in the color receiver. This circuit supplies several thousand volts to the focusing electrode to control the focusing of the beams on the screen.

Now that you have a general idea of the functions of the various sections in a color receiver, let us take up in detail those sections that are used only in color receivers.

The Luminance Channel

The luminance channel of the color receiver is composed of the first video amplifier stage, the delay line, and the second video amplifier stage. Its main function is to amplify the brightness detail of the color image that is to be reproduced, and to supply this Y (luminance) signal to the matrix unit.

THE FIRST VIDEO AMPLIFIER

The first video amplifier stage, in addition to supplying the Y signal to the rest of the luminance channel, is also generally the dispersal point for the chrominance and other types of control information present in the receiver color signal.

We can demonstrate how the four major signal components are emphasized and channeled to the proper sections of the receiver by studying the typical luminance video amplifier system shown in Fig. 2. The composite color video signal present on the grid of the first video amplifier has a negative sync polarity, as shown in Fig. 3A. The chrominance signal information is removed from the cathode circuit of the first video amplifier, and is applied through capacitor C14-5 and the potentiometer to the grid of the band-pass amplifier in the chrominance section of the receiver. Notice that there is a resonant circuit in the cathode circuit of the video amplifier. This trap, which is tuned to 4.5 mc, makes certain that the sound information is completely removed from the chrominance signal component.

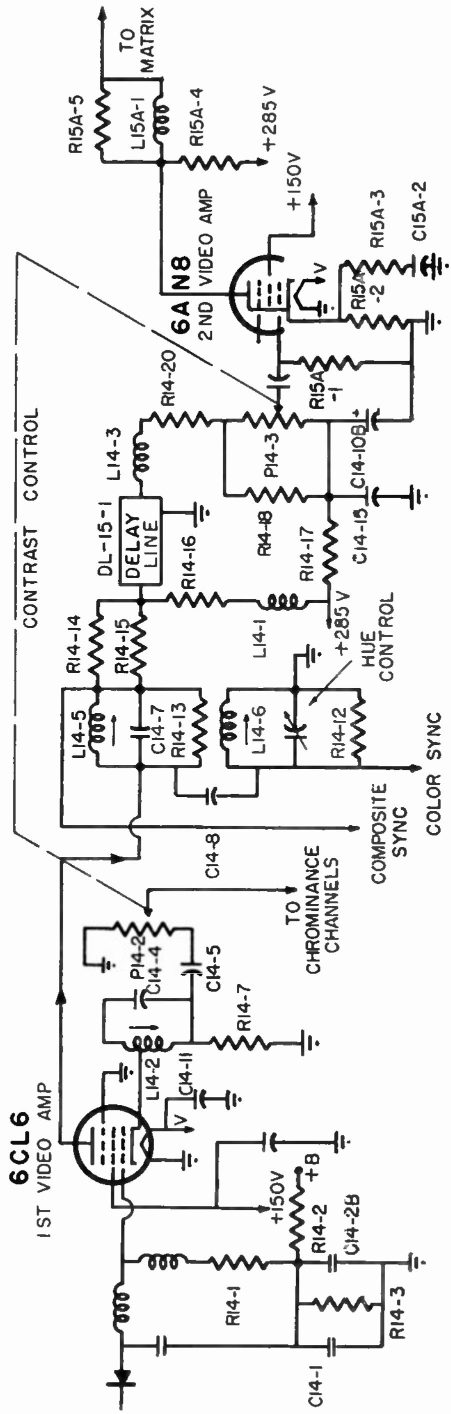
The potentiometer is ganged with another that is in the grid circuit of the second video amplifier. This dual control is referred to collectively as the *contrast control*. One part controls the amplitude of the chrominance signal component, while the second regulates the amplitude of the luminance signal component. When the receiver has been properly preadjusted, a change in the setting of the contrast control produces correct proportionate changes in both the brightness and hue-saturation amplitudes of the color signal information. The wave-form of the signal at the chrominance take-off point in the cathode circuit of the first video amplifier has the same appearance as that on the grid. Waveform A in Fig. 3 shows what the wave form would be if a series of vertical bars having the colors indicated were being scanned.

The luminance video information is removed from across the video plate load resistor R14-16 and the peaking coil L14-1, and is fed through a delay line to the grid circuit of the second video amplifier. This signal component represents the brightness detail in the color picture. Therefore, it must contain high frequency components to render that detail faithfully.

Between the plate of the first video amplifier and the plate load resistor is a double-tuned resonant circuit. This circuit, which is tuned to the subcarrier frequency of 3.58 mc, has the dual function of serving as a color sync-burst take-off point, and as an attenuator for the chrominance signal components to prevent their appearance in the luminance channel and on the grid of the second video amplifier. After the high-frequency chrominance data has been removed, the composite signal on the grid of the second video amplifier appears as shown in Fig. 3B. Notice that only the brightness information remains.

The color synchronizing information from the secondary of the double-tuned transformer (L-14-5, L14-6) is applied to the color sync section of the receiver. A small variable capacitor, called the *hue control,* which is in the secondary tuned circuit, is used to vary the phase of the color sync signal so that a fine adjustment of the hue in the reproduced picture can be made.

Composite synchronizing information for the horizontal and vertical deflection circuits is removed at the plate load resistor side of the resonant transformer primary winding. Thus, the chrominance information as well as some of the high-frequency video information is removed from the composite synchronizing signal that is supplied to the sync separators of the receiver. This sync signal waveform is shown in Fig. 3C.



SECOND VIDEO AMPLIFIER

The second video amplifier stage in the luminance channel increases the amplitude of the composite luminance signal before it is applied to the matrix unit of the receiver. R15A-4 has a comparatively high resistance, but the plate load for the second video amplifier is not the high value you might at first think. Instead, the true plate load presented to the second amplifier

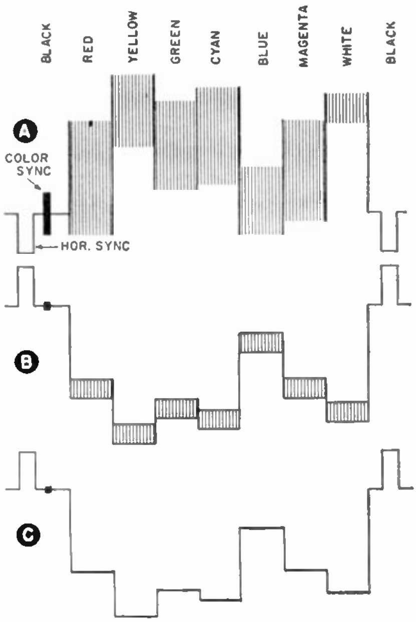


FIG. 3. Luminance channel waveforms. A, waveform at grid of first video amplifier and at chrominance take-off point; B, waveform at grid of second video amplifier; C, composite sync from first luminance amplifier.

is that contributed by the input circuit of the matrix unit.

The luminance signal that is applied to the matrix unit has a *negative* sync polarity (the same as the waveform in Fig. 3B, except opposite in polarity). However, it is referred to as a +Y luminance signal because the brightest portions of the scene are represented by the most positive swing of the luminance signal. This is opposite to our usual conception of television signal polarity, which refers to the polarity of the sync pulse. When instructions refer to +Y, —Y, +Q, or —I components of the color signal, they are assuming the *polarity of the signal that results in the highest brightness* when it arrives at the grid-cathode circuit of the picture tube. Therefore, a +Y signal is one that has a negative sync polarity, while a —Y signal is one that has a positive sync polarity.

RESPONSE CURVES

The functions of the luminance channel are also indicated by its response curves. Curve A of Fig. 4 shows that the response of the first video amplifier is flat from O up to 4.1 mc, which includes the subcarrier frequency of 3.58 mc. Because of the degenerative cathode circuit, however, the response drops to a very low value at the intercarrier frequency of 4.5 mc. The response of the luminance channel after the burst transformer is shown in curve B. Notice how the burst transformer causes a sharp drop-off of response at the subcarrier frequency of 3.58 mc. This drop-off indicates that the chrominance components are removed from the luminance signal prior to its application to the grid of the second

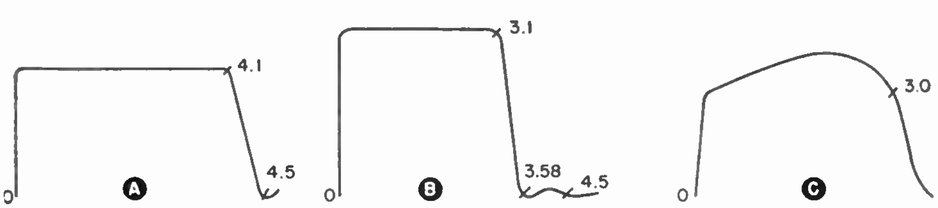


FIG. 4. Video response curves. A, first video amplifier response; B, video response after burst take-off; C, over-all video response.

video amplifier. The over-all response of the luminance channel is indicated by curve C.

DELAY LINE

The delay line is another important part of the luminance channel. It can be in the form of a length of special coaxial cable, or it can be made up of lumped coils and capacitors. The function of the delay line is to delay the luminance signal component the same amount that the two chrominance signals are delayed as they pass through the chrominance channels. The luminance and chrominance signals must arrive in proper time relation at the grids of the tricolor tube. If the luminance signal is presenting the brightness detail of a bowl of fruit, for example, the chrominance information of hue and saturation must arrive simultaneously so that the fruit will be colored correctly as its detail is being reproduced.

The time delay of a cable can be increased in two ways—by raising the distributed capacity or by increasing the inductive reactance. The inner conductor, which is usually a spiral coil, forms the inductive reactance, and a special coating and a special dielectric material form the distributed capacity. Thus, the time delay can be shortened by shortening the physical length of the transmission line.

In the luminance channel in the type of receiver which demodulates along the I and Q axes, the necessary delay is approximately 1 microsecond. It should be mentioned that the delay lines, just as regular transmission lines, must be properly terminated in a resistance equal to the characteristic impedance of the line in order to prevent standing waves. If there is a mismatch, reflections can be formed that move up and down the transmission line and introduce spurious signals into the luminance information.

As you can see, the luminance channel in the color receiver is similar in many respects to the video amplifier section of a monochrome receiver. Now let us study the operation of the chrominance channels and the stages used in synchronizing the color information contained in the transmitted color signal.

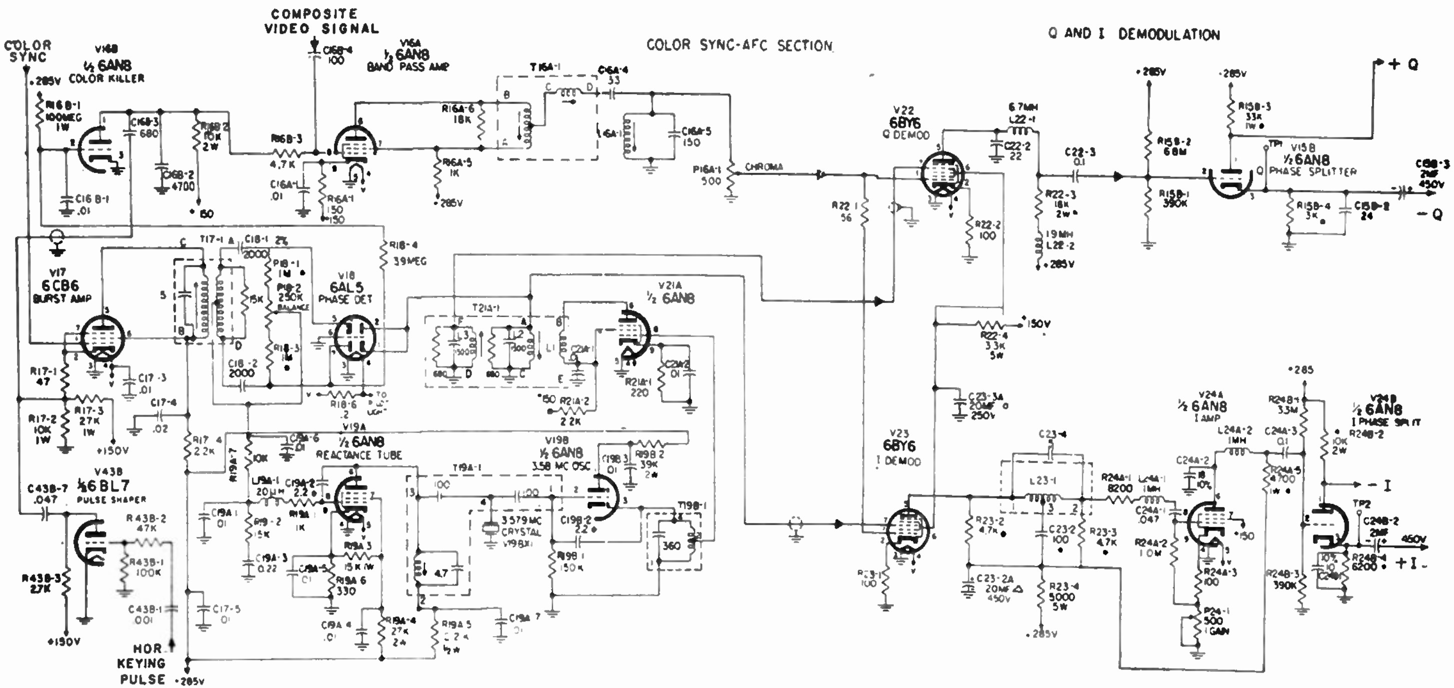


FIG. 5. Chrominance channels of CBS-Columbia color TV receiver.

Courtesy CBS

The Color Synchronization Section

The chrominance channels, which consist of a band-pass amplifier and the I and Q demodulators, recover the I and Q information from the chrominance subcarrier signal. A 3.58-mc subcarrier signal is fed to the demodulator stages from a crystal-controlled oscillator. The incoming chrominance signal and the subcarrier signal produced at the receiver are synchronized by the color burst that rides on the horizontal blanking pulse. The color-difference signals that are formed at the output of the I and Q demodulators are fed to the matrix to recover the original primary color signals.

The composite signal and the color sync signal are removed at the first video amplifier. Fig 5 shows that the composite video signal is applied to the grid of a band-pass amplifier. This amplifier blocks the lower-frequency components and permits only the chrominance frequency spectrum, between approximately 2.5 mc and 4.25 mc, to pass through to the chrominance channel. The output of the band-pass amplifier is coupled through the resonant filters and potentiometer P16A-1 to the grid circuits of the I and Q demodulators. The potentiometer, called the *chrominance control,* is used to adjust the amplitudes of the chrominance signal components supplied to the demodulators. When this adjustment is set properly, only the dual contrast control needs to be used to vary the luminance and chrominance signal levels so that the proper hue and saturation is retained when changes are made in the contrast control setting.

To recover the I and Q color-difference signals, a signal having the frequency of the original subcarrier sine wave must be generated at the receiver and re-inserted at the demodulators. Therefore, let us find out how this sine wave is generated and how it is synchronized with the incoming chrominance signal. The operation of the chrominance demodulation system will be discussed in a later section of this lesson.

OSCILLATOR STAGE

Color synchronization is based on a phase comparison technique as

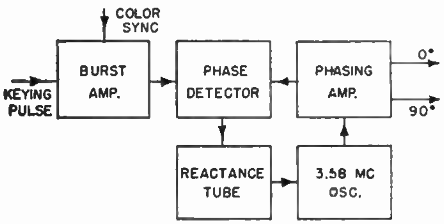


FIG. 6. Block plan of color sync system.

shown in the block diagram of Fig. 6. First, an oscillator stage forms the subcarrier sine wave that is to be inserted. A portion of this subcarrier sine wave is applied to a phase detector where it is compared with the incoming subcarrier burst. The subcarrier burst originates at the station and has a prescribed phase relationship with the I and Q color axes.

The dc voltage at the output of the phase detector depends on the phase relationship between the locally generated sine wave and the incoming subcarrier burst. As mentioned in an earlier section, this dc component is supplied to the grid of a reactance tube. The reactance tube, in turn, reflects a reactive component into the oscillator circuit, and thus regulates its frequency. The phase comparison system keeps the locally generated sine wave on frequency and in proper phase with respect to the incoming subcarrier burst.

THE BURST AMPLIFIER

The subcarrier burst enters the phase detector through a stage called the burst amplifier. Remember that the color synchronizing information is removed from the burst transformer in the first video amplifier as shown in Fig. 2 and is applied to the grid of the burst amplifier tube V17 as shown in Fig. 5. The burst amplifier is keyed by a positive pulse derived from the horizontal output circuit. This positive pulse is applied first to the grid of the pulse shaper. The pulse shaper lengthens the pulse and controls its amplitude so that it can be applied as a negative pulse to the cathode of the burst amplifier. A dc voltage is developed by the bleeder network, consisting of resistors R17-2 and R17-3, which applies a high positive voltage to the cathode. This bias keeps the burst amplifier normally cut off. However, during the horizontal retrace interval, a negative pulse arrives at the cathode of the burst amplifier and causes the stage to conduct. At this time, the subcarrier burst is also present on the grid of the burst amplifier because it occurs during the back porch interval of the horizontal blanking time. Therefore, the burst signal is amplified and appears at the output of the burst amplifier stage.

The subcarrier burst is further emphasized by the tuned transformer T17-1A in the plate circuit of the burst amplifier. This transformer is tuned to 3.58 mc and develops a strong 3.58-mc component across its secondary. Notice that the transformer secondary also is a part of the phase detector circuit. A portion of the locally generated subcarrier sine wave is applied to this same phase detector circuit. This component is obtained from transformer T21A-1 in the plate circuit of the subcarrier sine wave amplifier, tube V21A, and is applied to pins 1 and 2 of the phase detector.

THE PHASE DETECTOR

In your lessons on horizontal sync control systems and frequency modulation, you learned that the phase relationship between two applied signals determines the amount of dc voltage developed at the output of a phase detector circuit. Such is the case with the phase detector of a color receiver. In the example shown in Fig. 5, a dc voltage is developed across capacitor C19A-6 and is applied through a suitable filter circuit to the grid of the reactance tube in the form of a bias charge on capacitor C19A-1.

REACTANCE STAGE

The dc component on the grid of V19A regulates the reactive component introduced across the oscillator-tuned circuit by the reactance tube. This, in turn, regulates the frequency and phase of the crystal oscillator and holds it in proper timing with respect to the incoming sync burst.

SUBCARRIER SINE-WAVE AMPLIFIER

The output from the subcarrier sine wave crystal oscillator, V19B, is removed from the cathode and is applied to the grid of the subcarrier sine wave amplifier, V21A. Coil L1 in the plate circuit of the amplifier is inductively coupled to a dual resonant circuit. The resonant circuit containing coil L2 is tuned to the subcarrier frequency and develops the I demodulator subcarrier sine wave. At the same time, the subcarrier sine wave from this resonant circuit is applied as the phase comparison signal to the phase detector.

The output of the amplifier also contains a second resonant circuit (containing coil L3), which is inductively coupled to the first resonant circuit. As you have learned, the secondary voltage developed across a double-tuned transformer is 90° out of phase with respect to the primary voltage. Consequently, a 90° related sine wave is generated for application to the Q demodulator.

An important relationship to be established in the color receiver is the in-phase match between the locally generated subcarriers and the incoming I and Q chrominance components. The I subcarrier sine wave must be in phase with the I chrominance signal, and the Q subcarrier sine wave must be in phase with the Q chrominance signal. However, in the color fundamentals lesson, you learned that the subcarrier burst does not have the same phase as the I and Q axes. Thus, to establish the proper phase relationship between the subcarrier burst from the transmitter and the Q inserted subcarrier, we must shift the phase of the subcarrier chrominance signal a small amount. This phase shift is accomplished by the small capacitor, called the hue control, in the secondary of the burst transformer at the output of the first video amplifier, as shown in Fig. 2. The proper adjustment of this control permits the rendition of truer flesh tones and better color detail.

KEYER

Still another factor to be considered in the chrominance channels is the method used to minimize any interference between the luminance and chrominance signals. One source of difficulty is eliminated if the synchronizing information and color burst are removed from the chrominance signal as it passes through the band-pass amplifier. Thus, as shown in Fig. 5, the same positive pulse that is used to *key on* the burst amplifier is employed to *key off* the band-pass amplifier. It is applied as a negative pulse through capacitor C16B-3 to the grid of the band-pass amplifier. During the horizontal retrace intervals, the negative pulse on the grid of the band-pass amplifier blocks the passage of any synchronizing and burst information that arrives at the grid of the band-pass amplifier through capacitor C16B-4.

THE COLOR KILLER

Still another special operation in the color receiver occurs when a monochrome picture is received. Under this condition, it is advisable to key off the chrominance channel to prevent any interference with the luminance signal that is reproducing a monochrome picture on the color television picture tube screen. This action is accomplished by a *color-killer* circuit. The output of this circuit is connected to the grid of the band-pass amplifier and applies a negative dc voltage sufficiently high to cut off the amplifier when a monochrome signal is received.

A monochrome signal does not contain a subcarrier burst on its horizontal back porch, so there is no subcarrier burst at the grid of the burst amplifier to operate the phase detector. A positive voltage is developed at the junction of capacitor C18-2 and resistor R18-3, which is applied to the grid of the color killer. This results in an increase in plate current, which produces a more negative voltage on the grid of the band-pass amplifier. Thus, the negative bias that develops between grid and cathode of the band-pass amplifier is high enough to cut off the plate current.

The Chrominance Section

The waveforms in Fig. 7 demonstrate the operation of the band-pass amplifier. The signal on the grid of the stage is, of course, the same as that developed at the output of the burst video amplifier. However, after the signal passes through the band-pass filter, it appears as shown in waveform B. Observe that all the chrominance signal components have averaged themselves about the zero axis. This is necessary before the chrominance I and Q signals can be recovered. Also notice that the color burst and synchronizing information have been removed from the chrominance information. The chrominance control at the output of the band-pass amplifier stage is able to regulate the amplitude of these "chrominance bars" and can serve as a method of establishing the proper chrominance signal amplitudes to reproduce the desired saturated colors.

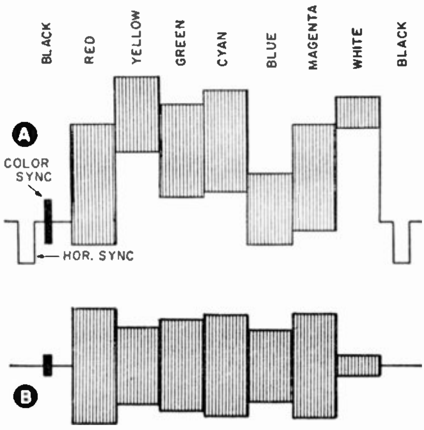


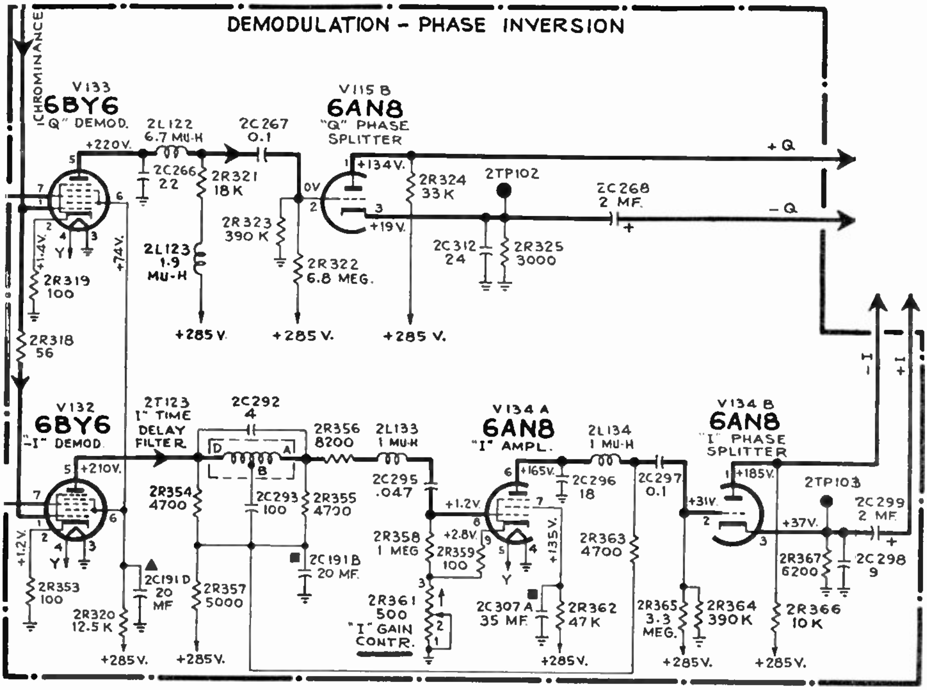
FIG. 7. Chrominance channel waveforms. A, waveform at input to chrominance band-pass amplifier. B, waveform at output of band-pass amplifier.

I AND Q DEMODULATORS

The original signals that are contained in the transmitted subcarrier sidebands are recovered at the output of the demodulator sections by heterodyning the chrominance signal from the band-pass amplifier and the subcarrier sine wave from the phasing, or quadrature amplifier. As you learned earlier, the chrominance signal, containing both chrominance components is simultaneously applied to each demodulator tube control grid. However, because of the 90° phase difference between the inserted subcarrier frequencies, one component appears at the output of one demodulator section, and the other component appears at the output of the other section.

A circuit diagram of a typical chrominance demodulation system is shown in Fig. 8. The chrominance signal is fed to the I and Q demodulator tubes together with the cw (continuous wave) subcarrier signals. By heterodyning the two signals in the demodulator stages, the I and Q chrominance components are demodulated and appear in the plate circuits of the demodulator stages.

The low-pass filter in the output of the Q demodulator has an upper frequency limit of approximately .5 mc, as shown by the response curve in Fig. 9A. This limited frequency response permits a narrow-band chrominance signal to pass through, but prevents any sideband interference from the I chrominance signal. The output of the Q demodulator then is



Courtesy RCA

FIG. 8. Demodulation-phase inversion section of RCA color TV receiver.

applied to a phase-splitting circuit. This circuit forms the positive Q and the negative Q signals required in the matrix section.

The output of the I demodulator is developed across a low-pass filter with an upper frequency limit of 1.5 mc, as shown by the curve in Fig. 9B. Actually, the output circuit functions both as a load for the development of the wide-band I signal and as a time-delay filter. To reproduce a satisfactory color picture, the luminance and chrominance signals must arrive at the matrix simultaneously. The amount of delay required in the various channels depends upon the channel band width—the wider the band width, the more delay required. No time-delay filter is used in the Q channel. A limited amount of delay is inserted in the I channel, however, and a still greater amount is used in the Y channel.

Both I and Q demodulator output filters are designed to reject the subcarrier frequency range near 3.58 mc; thus any chrominance subcarrier frequency that remains in the I and Q signals is attenuated and removed.

The signal output of the Q demodulator is higher than the output of the I demodulator because the

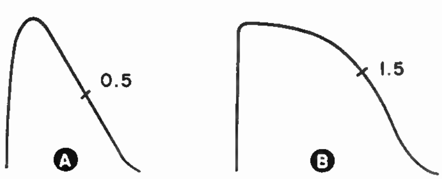


FIG. 9. Frequency response curves of Q and I demodulators. A, Q response; B, I response.

transmitted Q signal has two sidebands, while the I signal has only one. The Q sidebands add to produce a signal that is twice the amplitude of the I signal. Thus, to produce equal amplitude I and Q signals at the output of the demodulator sections, an additional stage of amplification must be used in the I channel. The proper amplitude relationships between the I and Q signals can be controlled by the degenerative gain control in the cathode circuit of the I amplifier.

As in the Q demodulator, the output of the I amplifier is applied to a phase splitter stage. Here, the positive I chrominance component is obtained from the cathode circuit, and the negative I component is obtained from the plate circuit.

To understand the operation of the chrominance demodulation system thoroughly, it is necessary to understand the phase relationships of the various color components with each other and with the color burst signal. All these relationships are shown in the color-phase diagram in Fig. 10.

Keep in mind that the color burst signal is used to synchronize the chrominance signal in the receiver with that in the transmitter. By studying the diagram, you will notice that the I signal lags the color burst signal by 57°, and that the Q signal lags the burst by 147° (57 + 90).

We can plot the positions of the primary color signals on the color-phase diagram by using the values of the primary signals that make up the I and Q chrominance signals. These values are given in the color-bar chart in Fig. 11.

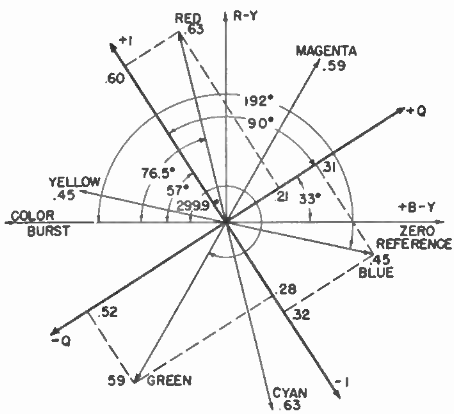


FIG. 10. Phase relationships of color signals.

To reproduce the primary colors and their complements, there must be an output signal from both demodulators for each color. Thus, for a saturated red hue, we must use a value of .60I and .21Q. The resultant vector, which is plotted on the color-phase diagram, has a value of .63. The I demodulator must detect the .60 value of the I signal, and the Q demodulator must detect the .21 value of the Q signal.

In a previous lesson, you learned that the *value* of the resultant indicated the degree of *saturation* and

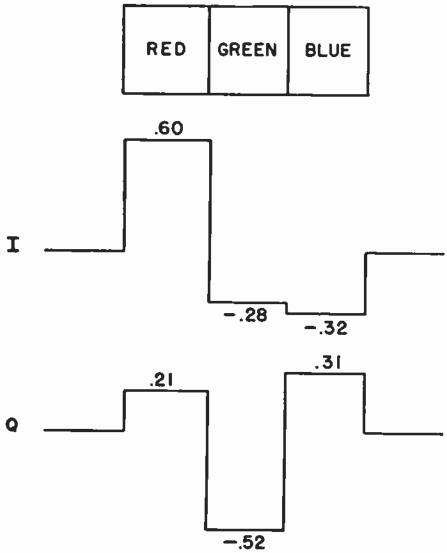


FIG. 11. The primary color signal components in the I and Q chrominance signals when bars containing saturated colors are scanned.

that the *phase* of the resultant indicated the *hue* being transmitted. When using the color burst axis as the reference line in the color-phase diagram, a fully saturated red color is transmitted each time the resultant signal lags the color-burst signal by **76.5°, with an amplitude of .63.**

Suppose we wished to transmit a saturated blue hue. According to the color bar chart, blue is composed of **—.32I and .31Q.** Notice that the Q component has a positive value, while the I component has a negative value. When plotted on the color-phase diagram, we find that a saturated blue hue has an amplitude of .45, and that it is 192° out of phase with the reference burst. This phase change indicates a change in hue.

The color-phase diagram shows not only the phase angles of the I and Q chrominance signals and the primary color signals, but also the positions of the R-Y, the B-Y, and the secondary color signals. The important thing to keep in mind is that when the chrominance signals are demodulated, the phase differences between the various color signals and the I and Q signals remain constant. For example, when a saturated blue hue is transmitted, the chrominance signal will always be 192° out of phase with the color burst signal.

Another important fact to remember is that the inserted subcarrier signals on the grids of the demodulator sections are 90° out of phase with each other. However, the inserted subcarrier signal on the number 3 grid of the I demodulator is in phase with the I portion of the composite chrominance signal or 180° out of phase with it, depending upon the hue being transmitted, and the inserted Q subcarrier signal is in phase or 180° out of phase with the Q portion of the composite chrominance signal depending upon the hue being transmitted. Because of the phase difference between the I and Q signals, the I demodulator can demodulate only the I component contained in the chrominance signal, and the Q demodulator can demodulate only the Q component contained in the chrominance signal. This is the basis on which the chrominance demodulation is accomplished.

The chrominance and subcarrier signals consist of continuous sine waves. The subcarrier frequencies are maintained at a constant amplitude and phase, but the chrominance signals are constantly varying in amplitude and phase according to the hue and saturation of the transmitted sig-

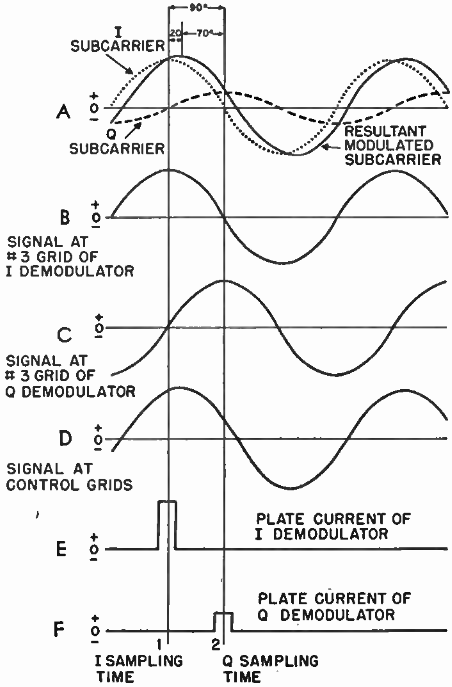


FIG. 12. The relationships between the transmitted signal and the demodulator signals for a saturated red. A shows the original I signal, the original Q signal and the resultant modulated subcarrier; B and C are the signals generated at the receiver and applied to the #3 grids of the demodulators; D is the signal applied to the #1 or control grids of the demodulators—this is the same as the resultant in A; and E and F show the plate current of the demodulators.

nal. Fig. 12 illustrates the relationships between the transmitted signal, the signals inserted at the #3 grids of the demodulators, and the plate current of the demodulators when a saturated red is being transmitted.

By using the values of I and Q which represent a saturated red hue shown in Fig. 10, we find that the resultant transmitted signal is displaced 20° from the I subcarrier component and 70° from the Q subcarrier component. These phase relationships are represented in sine wave form in Fig. 12A. Notice that the I and Q subcarrier components, as represented by the dotted and dashed lines, are 90° apart, and the resultant or modulated subcarrier **transmitted from the transmitter to the receiver has the phase indicated by the solid curve. The phase and amplitude of this resulant are determined by the relative amplitudes of the I and Q chrominance** signals.

Now, let us see how the demodulator sections interpret the amplitude and phase of the resultant modulated subcarrier signal in order to obtain the values of the original I and Q signals at the output.

Waveform B shows the sine wave that must be inserted at the #3 grid of the I demodulator to recover the I signal information. Observe that it has the same phase as the original I subcarrier signal shown as the dotted curve in Fig. 12A. Waveform C shows the subcarrier sine wave at the #3 grid of the Q demodulator. It has the same phase as the original subcarrier sine wave applied to the Q modulator at the transmitter.

The two locally inserted subcarrier sine waves are applied to the #3 grids of the demodulator tubes, and the chrominance signal shown in Fig. 12D, which is the resultant of Fig. 12A, is applied to the control grids, as shown in the demodulator circuit in Fig. 8. The amplitudes of the inserted subcarriers at the #3 grids are such that plate current flow exists *only during the crest of the positive alternation of the subcarrier sine wave* applied to the number 3 grids. In each demodulator tube the plate current flows in *pulses* with the peak amplitude determined by the amplitude of the control grid voltage at that time.

At time 1 (called the "sampling" time) when the subcarrier sine wave at the ※3 grid of the I demodulator is at its crest (waveform B), the I demodulator conducts. The amount that the I demodulator conducts depends upon the control grid voltage that exists at that instant. Waveform D shows that when the I subcarrier signal is maximum, the sine wave applied to the control grid has just passed its crest. This results in a rather large plate current pulse in the I demodulator circuit that corresponds to a value of .60I. Thus, the amplitude of the plate current pulse that flows corresponds to the control grid voltage at that moment, as illustrated by waveform E. The Q chrominance subcarrier in Fig. 12A is going through zero at that instant and therefore contributes nothing to the resultant chrominance signal at that instant. Therefore, it makes no contribution to the I demodulator output.

At time 2, the subcarrier sine wave at the ※ 3 grid of the Q demodulator, waveform C, is at its crest and causes the Q demodulator to conduct. At this interval of time the resultant subcarrier sine wave on the control grid is just finishing its positive alternation as shown in waveform D. This results in a plate current pulse in the Q demodulator tube that corresponds to the value of .21Q. This plate current pulse in the Q demodulator is shown in waveform F. At this instant the I subcarrier in Fig. 12A is passing through zero and therefore contributes nothing to the resultant chrominance signal at that instant and can make no contribution to the Q demodulator output.

Notice that the relationship between the output of the I demodulator and the output of the Q demodulator corresponds to the original relationship between the I and the Q **signal components, as shown in Fig.** 12A. An important point to recognize in understanding the operation of the chrominance demodulator is that waveform D is being applied to both control grids, but there is no interaction between I and Q components. The interaction is prevented by the 90° phase difference between the subcarrier sine waves applied to the ※3 grids (waveforms B and C). This

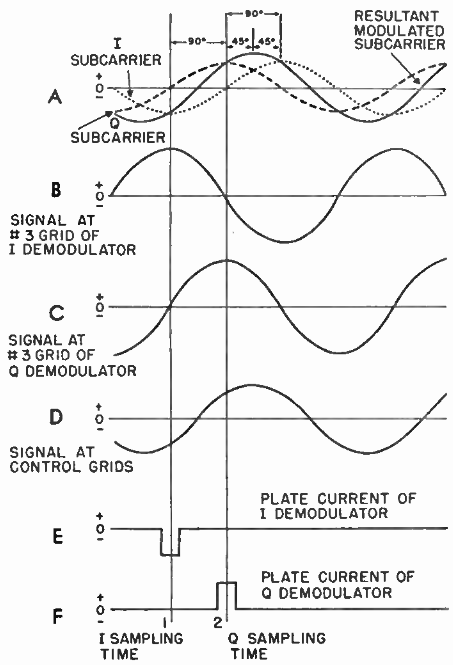


FIG. 13. The relationships between the transmitted signal and the demodulator signals for a saturated blue. Notice that B and C are the same as B and C of Fig. 12, because the signals at the ※3 grids do not change, but the incoming signal applied to the control grids is different and this determines the plate current.

phase difference makes certain that the resultant subcarrier signal is sampled at the proper intervals to evaluate the I and Q information in their respective channels.

When a blue hue is being transmitted, the subcarrier resultant signal transmitted between the transmitter and the receiver, as shown in Fig. 13, will be different in amplitude and phase with respect to the inserted subcarrier signals from the red one we have shown. The color-phase diagram in Fig. 10 shows the amplitudes of the I and Q signals and the phase relationships necessary to produce a saturated blue hue. By referring to the color-bar chart in Fig. 11, we find that the Q signal must contribute a value of .31, while the I must contribute a negative value of —.32. When these values are plotted on the color-phase diagram, the resultant has a value of .45 and is displaced approximately 45° from the I subcarrier and 45° from the Q subcarrier.

By comparing the phase relationships in Fig. 13 with those in Fig. 12, you will see that the sampling time still occurs on the positive crest of the inserted subcarrier sine waves. Figs. 13B and 13C are exactly the same as Figs. 12B and 12C, because the locally generated signals at the #3 grids of the demodulators do not change. The difference in phase between the I and Q subcarriers and the subcarrier resultant in Fig. 13, however, is not the same as in Fig. 12. At time 1, when the signal at the #3 grid of the I demodulator (waveform B) is going through its peak, the resultant is sampled on its negative alternation. At time 2, the subcarrier resultant is sampled when the signal at the #3 grid of the Q demodulator (waveform C) is going through its positive peak. As illustrated in waveforms E and F, the plate current pulses are equal in amplitude but opposite in phase. These pulses correspond to the values of —.32I and .31Q.

From the illustrations in Figs. 12 and 13, you will notice that the phase and amplitude of the resultant will depend upon the hue being transmitted. Similar diagrams may be drawn for each hue. The amplitude of the resultant varies according to changes in saturation. The important point to remember is that the chrominance sidebands in the subcarrier resultant are demodulated by the proper section of the demodulator system to obtain the original chrominance signals.

Low-pass filters in the output circuits filter the subcarrier frequency pulse components and establish the original I and Q video signals. This action is just the same as the operation of an ordinary diode detector in reproducing the original audio or video variations. The waveform drawings in Fig. 14 demonstrate how the demodulator plate current pulses, which occur at the subcarrier frequency, are filtered out to reproduce the original chrominance video information. The chrominance subcarrier is shown in A. The first pulse represents one hue, the second another. The locally generated subcarrier is shown in B and when it is added to the received subcarrier, a 3.58-mc signal similar to that shown in C is produced. The chrominance signal is then removed from the resulting 3.58-mc signal, C, producing a signal similar to D. This action is much the same as removing

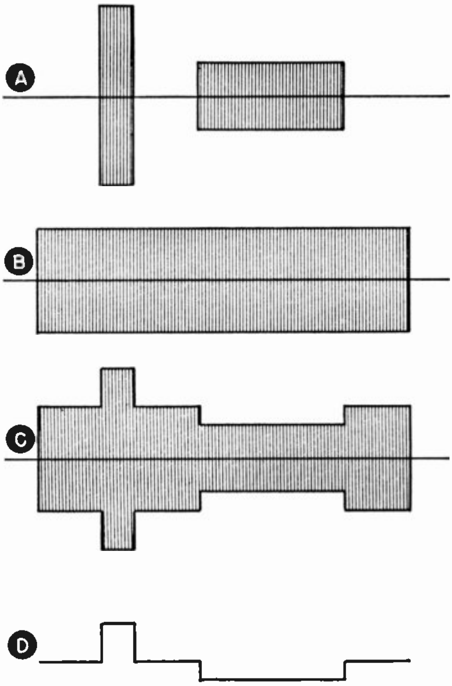


FIG. 14. Action of chrominance demodulator. A, chrominance signal; B, receiver subcarrier; C, receiver subcarrier inserted; D, chrominance signal recovered.

the audio from the rf carrier in the detector in an AM receiver.

The color demodulator is fundamentally a heterodyne circuit, and as such produces many undesired signals in its output circuit. When the chrominance sideband signal heterodynes with the inserted subcarrier, the exciting frequencies as well as sum and difference frequencies are produced in the output. The output, however, is tuned to emphasize the *difference* frequency range which contains the original chrominance signal information. The other frequencies produced are filtered out and are not developed across the output circuit of the chrominance demodulator.

The demodulator in Fig. 8 is often referred to as a synchronous detector because its operation depends on the use of a synchronized, inserted carrier signal. This inserted carrier is synchronized by the subcarrier burst that rides on the horizontal blanking pulse.

To form the original primary color signals, we must produce positive and negative I and Q signals at the output of the chrominance demodulation system. These opposite-polarity signals are removed from the plate-cathode circuits of the phase-splitter stages, and are applied to the receiver matrix section.

Matrix and Picture Tube Circuits. The matrix unit of the color receiver combines the Y, I, and Q signals to form the primary color signals of red, green, and blue. Each primary color signal is amplified, and after the dc component of average brightness is restored, it is applied to the grid circuit of the tri-color picture tube. Each color channel, as shown in Fig. 15, consists of a dual triode amplifier and a dc restorer. Feedback is used with each dual triode video amplifier to obtain a flat frequency response. Although the plate resistor for the first triode video amplifier has a value of 10,000 ohms, there is no peaking coil associated with the output circuit. The feedback link from the cathode of the second video amplifier to the grid of the first video amplifier retains a flat frequency response. The feedback link is such that there is more feedback at low frequencies than at high frequencies to compensate exactly for the shunt capacity losses in the vacuum tube stages. There is a shunt

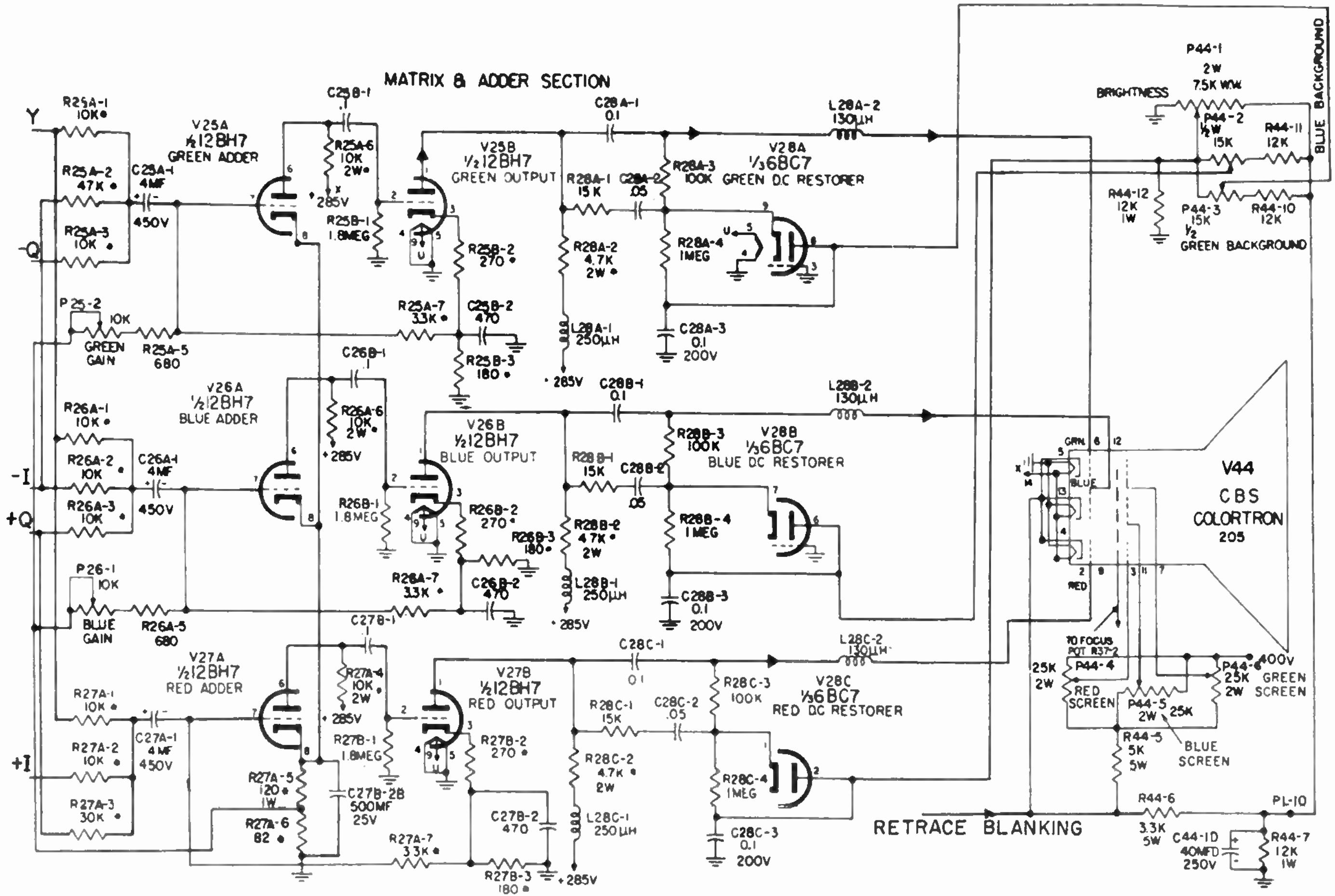


FIG. 15. CBS color matrix and picture tube circuit.

Courtesy CBS

peaking coil, however, in the plate circuit of the second video stage.

The three amplifier channels differ in one respect. Video gain controls (P25-2 and P26-1) are associated with the green and blue channels as a part of the feedback link. There is no gain control associated with the red channel, which operates at full gain because the red phosphors of the picture tube screen require much stronger excitation than do the green and blue phosphors.

The actual formation of each primary color signal is accomplished by the voltage divider network at the input to each channel. The I, Q, and Y signals are supplied to the divider network. The resistors that form the network combine the three signals in proper proportion to form the original primary color signals of red, blue, and green, depending upon the amplitude of the applied signals and the values of the resistors.

A conventional diode dc restorer is used with each channel and its corresponding electron gun. The plates of the diode restorer tubes are returned to a dc voltage source for proper setting of the brightness bias of each gun.

The brightness control circuits consist of a master brightness control, potentiometer P44-1; and individual brightness controls for the blue and green guns, potentiometers P44-2 and P44-3. The master brightness control simultaneously regulates the dc bias, and thus the over-all brightness, on all three grids of the tri-color electron gun, while the individual blue and green background controls are used to adjust the bias on the blue and green grids. Thus, the proper settings of the green and blue background controls with respect to the fixed red bias establish the proper relative bias settings on the three guns.

The three cathodes of the picture tube guns are in parallel and are returned to a junction point on the bleeder network that supplies proper voltages to the various electrodes of the tri-color tube. Retrace blanking pulses are also applied to the cathodes of the picture tube.

Controlled dc voltages also must be applied to the individual accelerating electrodes of the guns to compensate for any variations in the guns and in the primary color dots. This is accomplished by using three potentiometers, P44-4, P44-5, and P44-6. Thus, equal brightness excitation results in a true neutral or half-tone rendition when the three guns are excited by equal signal levels of red, green, and blue. The screen and background controls must be adjusted to produce true half-tone and color hues, regardless of the over-all brightness setting of the color picture tube.

COLOR-DIFFERENCE DEMODULATOR

In the synchronous demodulation system described in the preceding section, the I and Q color-difference axes are used to develop the chrominance signals in the wide-band I channel and in the narrow-band Q channel. It is possible, however, to develop color-difference signals directly in a color receiver without using the I and Q axes technique.

In an earlier lesson we mentioned that the I and Q signals were originally derived from color-difference signals at the transmitter. Therefore, if the subcarriers inserted at the receiver are in phase with the original color-difference axes instead of with the I and Q axes, we can detect the actual color-difference signals at the receiver demodulator. This technique is often used in the narrow-band, economy-type color receivers. The color-difference signals, R-Y and B-Y, are developed at the output of the demodulator. Then, portions of these signals are used in the matrix to form the G-Y color-difference signal.

With the three signals in this form, it is a simple matter to derive the original primary color signals of R, G, and B by introducing the luminance signal component Y into each of the color-difference signals. For example, (R-Y)+Y will give us R, the red primary color signal.

It is not necessary to use a matrixing unit or vacuum tube circuit to combine the luminance and chrominance signals. In fact, the combining of the basic luminance and chrominance components can be accomplished within the color picture tube by supplying the chrominance signal components to the grids and the luminance signal to the parallel cathodes of the picture tube gun. The luminance or Y signal conveys the brightness detail in the reproduced color picture, while the color-difference signals contribute the hue and saturation.

Although the chrominance subcarrier component from the transmitter is based on the I and Q axes, the transmitted signal also contains the color-difference information because there is a fixed relationship between these signal components as shown in the color phase diagram in Fig. 10. Thus, by matching the phase of the subcarrier signals at the receiver with the color-difference axes instead of with the I and Q axes, we can obtain the R-Y and B-Y signals at the output of the demodulation system.

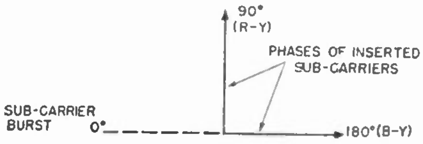


FIG. 16. Demodulation along color difference axes (B-Y) and (R-Y).

Notice in Fig. 16 that the locally generated subcarrier that is inserted in phase with the B-Y color-difference signal, is 180° out of phase with the incoming color burst signal. Another locally generated subcarrier sine wave in the receiver is applied through a 90° phase shifter in phase with the R-Y color-difference signal. Thus, by properly phasing the inserted subcarrier signals at the receiver, we obtain the R-Y component at the output of one demodulator section, and the B-Y component at the output of the other demodulator.

One disadvantage of the color-difference method of demodulation is that the band width in the chrominance channel must be limited to prevent interaction between I and Q sideband components. This means that less color detail can be obtained with the color-difference method of detection than with the I and Q method. Also, detection along the I and Q axes produces more life-like flesh tones in the reproduced picture.

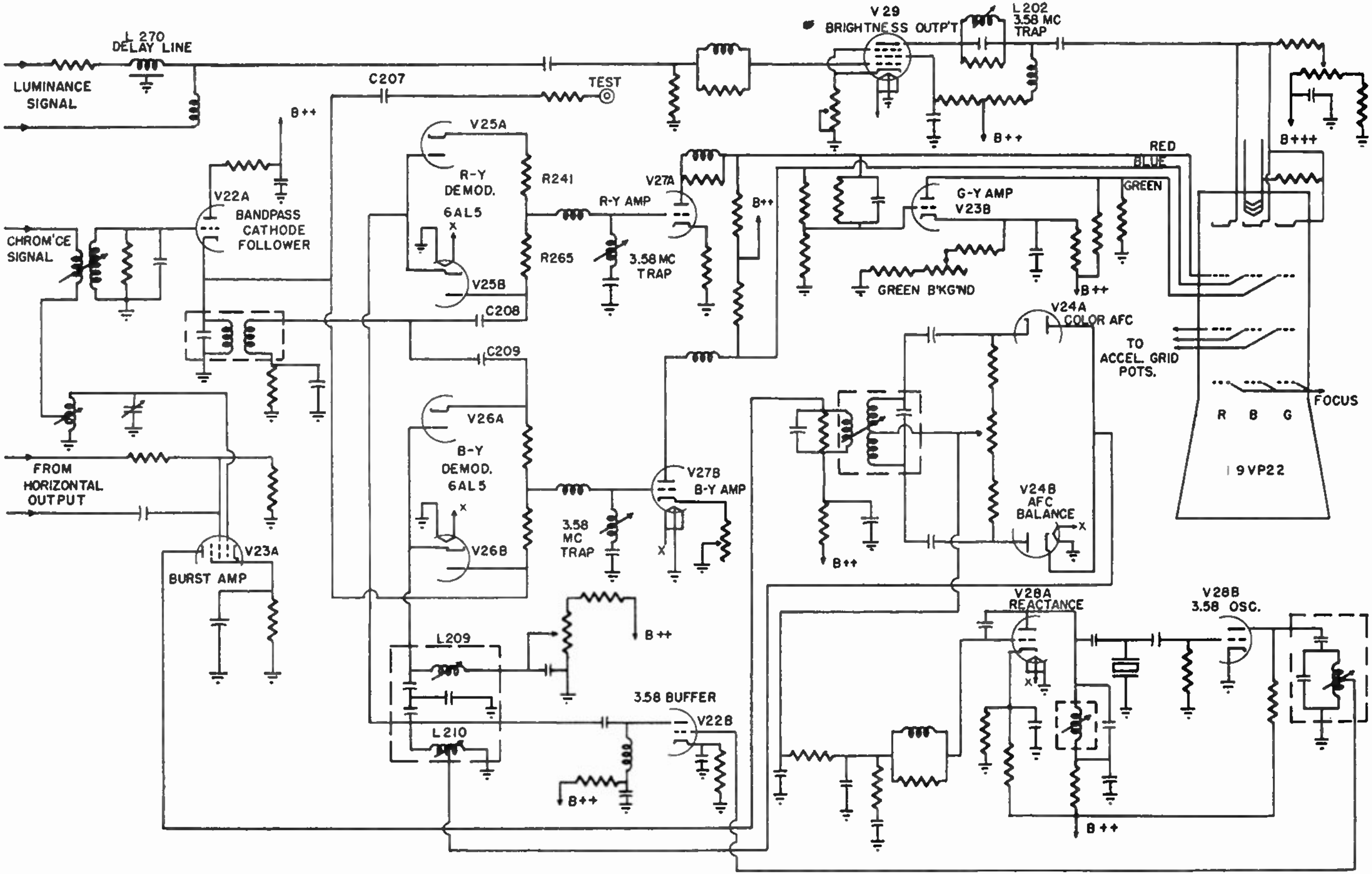


FIG. 17. Motorola chrominance channels.

The major advantage of the color-difference detection method along the R-Y and B-Y axes is the simplicity and ease with which the basic primary color signals can be formed at the guns of the picture tube. An elaborate matrix system is not necessary, and the proper proportions of signals can be obtained by regulating the over-all gain of the color-difference channels in the receiver.

Using Dual-Diode Demodulators. The demodulators used in some color-difference demodulation systems are similar to the I and Q demodulators described earlier. However, color-difference demodulation can also be obtained by using dual-diodes instead of multi-grid tubes. A circuit of this type is shown in Fig. 17.

The chrominance signal from the video amplifier section passes through a band-pass amplifier which amplifies the chrominance spectrum and rejects lower frequency luminance signals. After leaving the band-pass amplifier, the chrominance signal is applied to a band-pass cathode-follower, tube V22A, which couples the signal into the demodulator circuit. A bi-filar winding in the cathode circuit acts as an unbalance-to-balance transformer to develop chrominance components of equal amplitude but opposite polarity. One chrominance signal is supplied to the R-Y demodulator through capacitors C207 and C208 and the other to the B-Y demodulator through capacitors C209 and C210.

In the demodulation process, a subcarrier sine wave is generated by a crystal oscillator, tube V28B, and is applied to the demodulator stages through a buffer amplifier, tube V22B. The subcarrier component developed across inductor L210 is applied to the R-Y demodulator; a sine wave 90° out of phase is developed across inductor L209 for application to the B-Y demodulator.

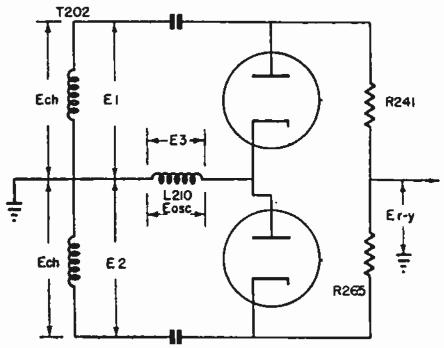


FIG. 18. Basic diode demodulator.

The dual-diode demodulator is connected much like a ratio detector for FM and has some similar characteristics. A simplified schematic of the R-Y demodulator is shown in Fig. 18. The received chrominance signal is taken from the cathode of V22A (Fig. 17) and applied to one half of T202. The secondary winding of T202 is coupled to the primary winding so that a voltage is induced in it. The voltage applied to the primary is shown as E1 in Fig. 18 and the voltage in the secondary as E2. These two voltages are in phase.

The incoming chrominance subcarrier is a resultant that represents two signals, R-Y, and B-Y, 90° out of phase. In the R-Y demodulator, it is necessary to evaluate the R-Y axis and prevent the B-Y axis from contributing any output. You have learned in your FM lessons that a ratio detector produces zero output when there is a 90° phase difference between E1 and E3 and between E2 and E3. In Fig. 18, the locally generated inserted subcarrier (E3) will be in phase with the R-Y signal and 90° out of phase with the B-Y signal, so the B-Y chrominance subcarrier information develops no signal across output resistors R241 and R265. This prevents the B-Y color-difference component from interfering with the desired R-Y color-difference component that must be developed at the output of the R-Y demodulator.

An incoming R-Y subcarrier component will have the same phase as E3. There will then be maximum output from the demodulator. The polarity of the demodulator output is determined by the polarity of the R-Y chrominance signal. Remember we discussed earlier how the hue of the color information determines the polarity of the subcarrier sideband at the output of the balanced modulator. Remember too that the angle of each color-difference axis remains fixed and only its amplitude and polarity change with the chrominance video information. These changes in the amplitude and polarity of the R-Y subcarrier component at the demodulator result in the recovery of the original amplitude and polarity of the chrominance video information.

An opposite relation exists at the B-Y demodulator to produce the B-Y color-difference component. Here the B-Y signal is in phase with the inserted subcarrier, while the R-Y signal is 90° out of phase.

Let us refer again to Fig. 17. The low-pass filters at the output of each demodulator amplify the difference frequencies and develop the original R-Y and B-Y color-difference video signals. A series-resonant trap in each output circuit attenuates the 3.58-mc subcarrier frequency. After the color-difference signals are amplified, they are applied to the red and blue grids of the tri-color gun.

Proper proportions of the R-Y and B-Y signals are supplied to the G-Y signal former and amplifier. As you have learned, the third color-difference signal can be formed in a color system by adding and inverting the other two color-difference signals. This is the task of the G-Y amplifier, tube V23B. The output from this amplifier is fed to the control grid of the green gun.

The luminance signal reaches the brightness output stage V29 through the delay line, and then is applied to the cathodes of the tri-color gun. A parallel resonant trap (L202) in the plate circuit attenuates any 3.58-mc subcarrier frequency that may still remain in the Y signal. Luminance and chrominance signals combine in the gun to form the original primary color signals and to modulate the three scanning beams accordingly.

DUAL-TRIODE DEMODULATOR

Until the circuits used in color television receivers are as standardized as those in monochrome receivers, there will be many variations in the color circuits and in the methods used to obtain the primary color signals. In our discussion of chrominance demodulation systems, we have considered two types—the synchronous detector system which uses two multigrid tubes, and the color-difference system which uses four diodes to accomplish the demodulation process.

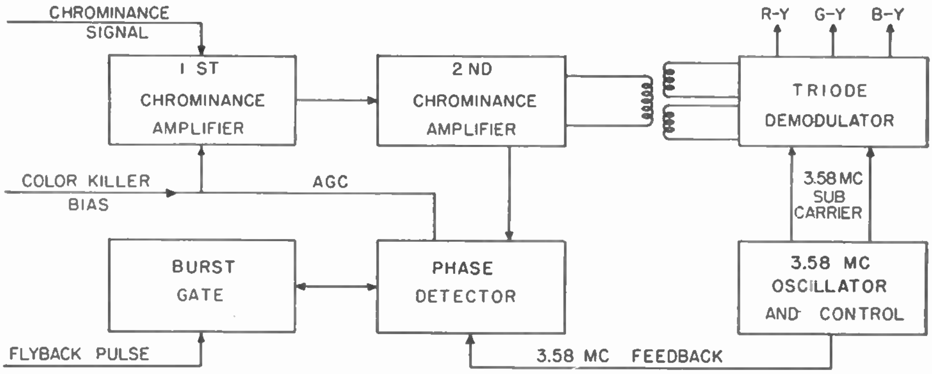


FIG. 19. Block diagram of the circuits associated with the triode demodulator.

However, there is a color demodulator circuit which uses a single dual-triode tube to detect both components in the chrominance subcarrier signal.

As with either of the demodulator circuits described previously, either the I and Q, or the R-Y and B-Y axes may be detected by this circuit. Also, a combination of R-Y and Q axes may be detected by this circuit to obtain the three color-difference signals. The axes along which detection occurs, of course, depends upon the phase relationships of the local subcarrier signals and the band width of the output filters. The circuit that we will discuss in this section uses the R-Y and B-Y axes.

Fig. 19 shows the circuits associated with this type of demodulator. Notice that two stages of amplification are used before the transmitted chrominance subcarrier signal is applied to the plate circuit of the dual triode tube. This additional amplification is necessary to provide sufficient driving power to the demodulator. Stability is obtained in the circuits by removing the color burst signal from the second chrominance amplifier stage and by using agc bias to control the gain of the first chrominance amplifier stage.

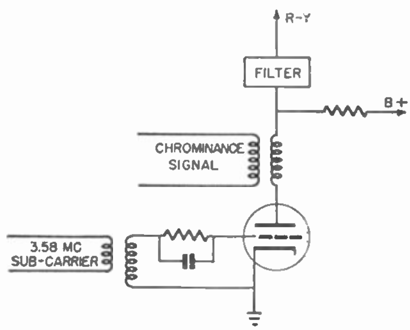


FIG. 20. Simplified diagram of one section of the triode demodulator.

A simplified diagram of one of the triode sections of the demodulator is shown in Fig. 20. Notice that the locally generated 3.58-mc subcarrier signal is inserted between the cathode and the grid of the tube and that the chrominance signal is inductively coupled into the plate circuit. The operation of this circuit is much like the conventional multi-grid demodulator circuit described earlier because the two signals are *mixed*, or heterodyned, (one in the grid circuit and one in the plate circuit) to produce the difference signal in the output. A filter circuit between the transformer winding and the grid of the color picture tube removes the locally generated 3.58-mc signal and the color subcarrier from the chrominance signal.

The complete circuit diagram of the dual-triode demodulator is shown in Fig. 21. The dual-secondary transformer in the plate circuits feeds 90° out-of-phase chrominance signals to the plates of the tube. The transformer in the grid circuit feeds 90° out-of-phase locally generated signals to the grids. These signals are mixed, and the color-difference signals appear at the output.

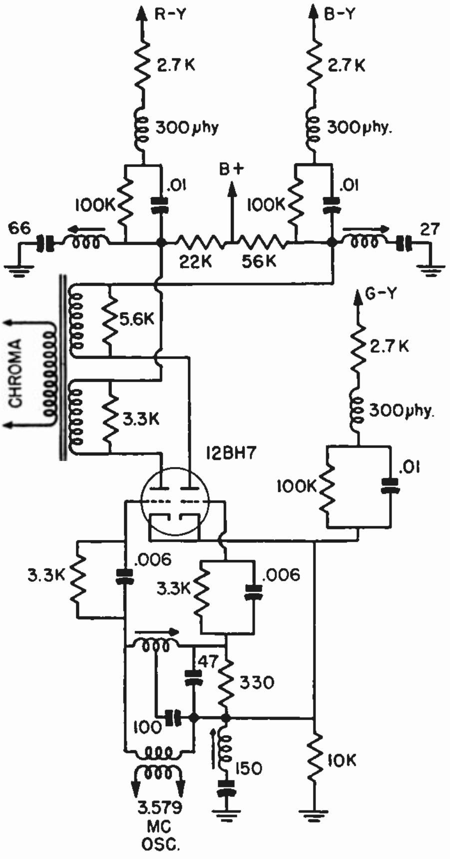


FIG. 21. Complete circuit diagram of the dual-triode demodulator.

The signal amplitudes required to reproduce the primary color signals in the color picture tube are not equal, so there must be a variation in the turns ratios of the two secondary windings of the chrominance transformer and in the values of the two plate load resistors. When the phase and amplitude of the subcarrier signals on the grids and the values of the plate loads and transformer windings are correct, the red and blue color-difference signals can be demodulated.

The circuit in Fig. 21 further simplifies the color receiver circuits by eliminating the additional step necessary to form the G-Y signal. The green matrixing action is performed directly in the cathode circuit of the tube. The cathodes are connected together, and because the total cathode current is determined by the R-Y and B-Y signals, the green color-difference signal appears directly at the output of the cathodes. Consequently, the dual-triode demodulator performs both demodulating and matrixing.

No dc restorer circuits are needed between the demodulator and the picture tube grids because dc coupling is used throughout the circuit. The three color-difference signals are applied directly to the grids of the picture tube, and the brightness signal is dc-coupled to the cathodes. The Y signal and the three color-difference signals add inside the picture tube to produce a full-color image on the screen.

The Deflection and Convergence System

In the color receiver, the sync and inter-sync separators and the horizontal and vertical sawtooth generators are just like those used in the monochrome system. The synchronizing information is removed at the first video amplifier in the luminance channel and is supplied to the vertical and horizontal sync separators of the receiver.

DEFLECTION SYSTEM

Even the deflection output stages are similar in some respects to those used in monochrome receivers. Therefore, in Fig. 22, we will stress the sections that differ from those in the monochrome system. The earlier sections of the sync and sweep systems are shown in simple blocks.

The deflection output stages are identical up to the plates of the output tubes. The vertical output stage must incorporate a means of supplying a vertical waveform to the convergence stages, and the horizontal output transformer and high-voltage circuits must be designed to provide both the high dc voltage necessary for the color tube, and a horizontal waveform to the convergence circuits.

Parallel output tubes are used in the horizontal deflection system because of the high current required to obtain full horizontal motion of the scanning beams of the color picture tube. Notice that the horizontal output transformer and the horizontal damper tube are similar to those found in monochrome receivers. However, to obtain the wide variety of voltages and pulse components used in the color receiver, the horizontal transformer usually contains many more taps.

The high-voltage circuit is more elaborate than that used in conventional monochrome receivers. The high-voltage is rectified by the voltage multiplier circuit consisting of tube V38 and the output diode V39. This arrangement produces the necessary high voltage for the color tube (between 20,000 and 30,000 volts).

Since the adjustments and convergence in the color receiver are so dependent on a constant source of high voltage, it is necessary to have a regulator tube in the high-voltage section. In Fig. 22, the grid of the regulator tube is connected back to the bleeder network (potentiometer P37-4). When the voltage at the arm of the potentiometer changes with operating variables, the regulator causes a compensating adjustment of the high-voltage output. In this way, the high-voltage applied to the color tube remains constant. This prevents the convergence and other picture tube adjustments from drifting with line voltage and circuit changes.

Another circuit that is seldom found in monochrome receivers supplies a high potential to the focus electrode

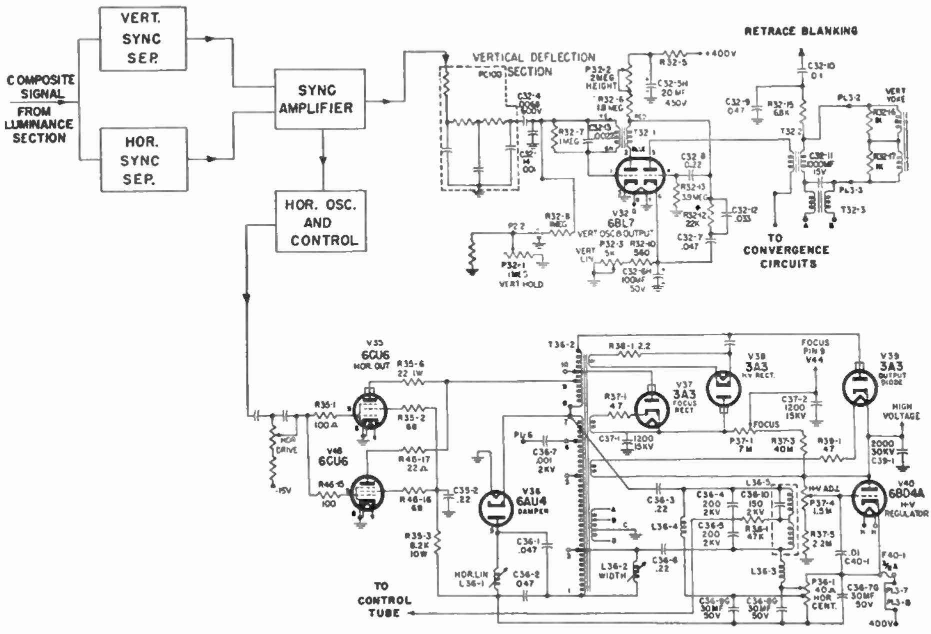


FIG. 22. Deflection system of a CBS-Columbia color receiver.

of the tri-color tube to keep the electron beams focused on the phosphor dots. Thus, the focus rectifier tube, V37, receives a pulse from tap 10 on the horizontal output transformer. This pulse is rectified by the tube, and is supplied to the color tube through the focus potentiometer P37-1.

CONVERGENCE

In this lesson, we will discuss the convergence circuits that are used with color picture tubes having external convergence coils. You will notice that the circuits are elaborate, and that one of the circuits we describe uses a triode tube section for each set of convergence coils. The basic idea of dynamic convergence and the results obtained are the same regardless of the methods used to apply the convergence waveforms.

The diagram in Fig. 22 shows that the vertical convergence voltages are obtained from the primary side of the vertical output transformer, and that the horizontal convergence voltages are obtained from a special winding marked A, B, C, and D on the horizontal output transformer. These waveforms, in the form of pulses, are applied to the input of the convergence system. To obtain proper convergence and focusing over the entire surface of the shadow mask, the focus and convergence waveforms must vary at the horizontal and vertical scanning rates. Since there are three convergence coils, one for each electron gun, similar waveforms must be generated for each of the three convergence coils.

The convergence of the three scanning beams in the color picture tube depends not only on the proper adjustment of the various dc electrode voltages and applied signals, but also on the special convergence waveforms in the three external convergence coils. The proper dc adjustment of the convergence circuits is referred to as "static convergence", while the proper adjustment of the correction waveform is referred to as "dynamic convergence". The static adjustments are made to cause the three beams to converge at the center of the screen, and the dynamic adjustments are made to produce convergence over the entire screen.

Dynamic convergence is necessary because the electron beams must travel a greater distance from the gun to the outer portions of the screen than from the gun to the center of the screen. Hence, a changing magnetic field must be provided to exert a varying influence on the three scanning beams so that when they scan the outer portion of the raster they are made to reach a convergence point at a greater distance from the gun. This changing magnetic field is obtained by applying a correction waveform to the convergence coil. The magnetic field varies in accordance with the shape of the waveform applied.

A typical tubeless circuit that is used in some receivers to produce proper dynamic convergence waveforms for the convergence coils is shown in Fig. 23. The simplified circuit of Fig. 24 demonstrates the basic construction of the convergence waveforms and the operation of the convergence circuit. In this set, a sine wave applied to the convergence coil at the horizontal scanning rate will produce a magnetic field that will give proper horizontal convergence, and a parabolic wave applied to the

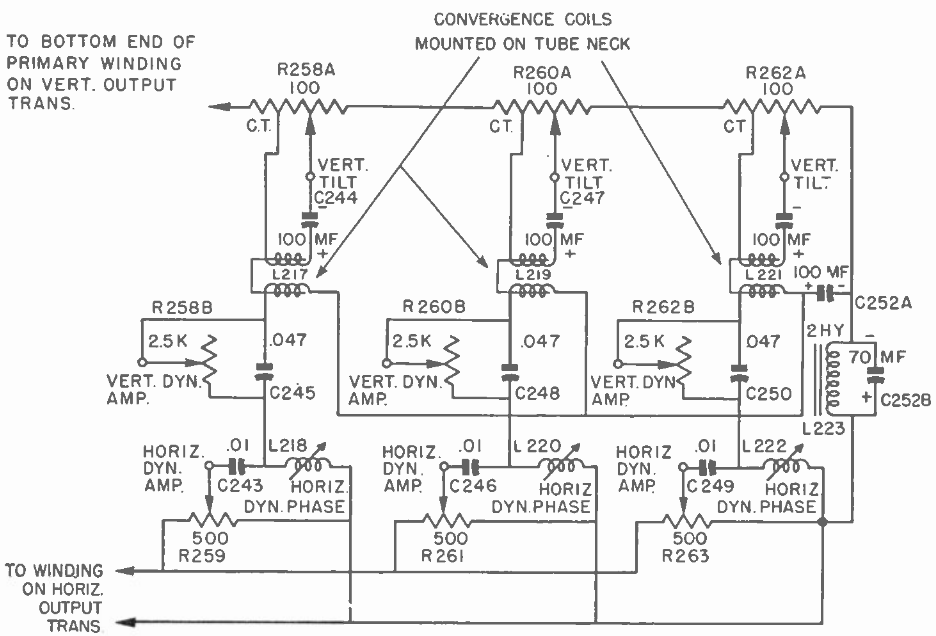


FIG. 23. Motorola dynamic convergence circuit.

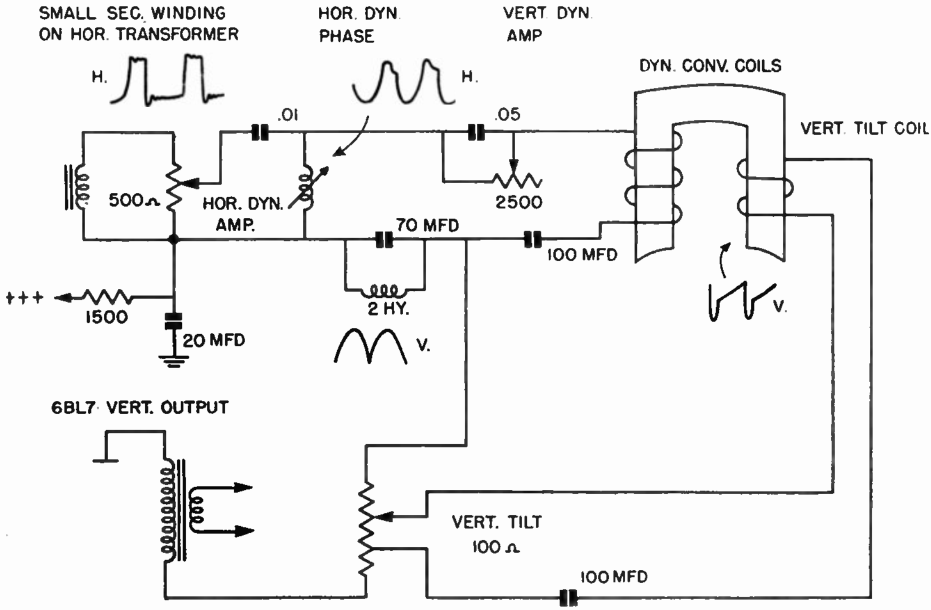


FIG. 24. Simplified diagram of circuit shown in Fig. 23.

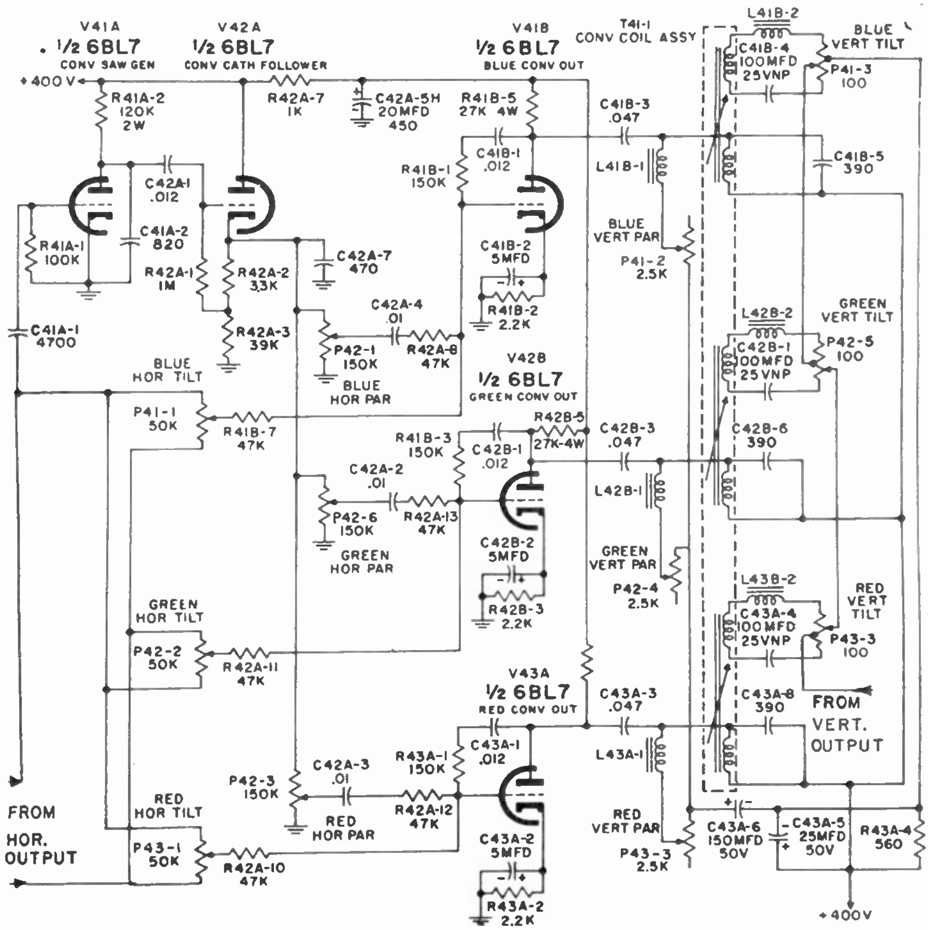
coil at the vertical scanning rate will give proper vertical convergence. Let us see how these waveshapes are obtained.

The horizontal convergence waveform in the simplified convergence circuit is formed by a pulse from a special winding on the horizontal output transformer. It is applied through a potentiometer (which regulates the amplitude of the resultant convergence waveform) to a series resonant circuit that converts the pulse into a sine wave current. The resonant circuit, which is composed of a .01-mfd capacitor and the horizontal-dynamic coil, is tuned to the horizontal line frequency. Therefore, when this waveform is applied to one of the convergence coils, it provides horizontal convergence correction over the entire screen area.

In adjusting the convergence circuit, you may find that one control influences the convergence near the center area of the screen, while a second control affects the convergence at the outer portions of the screen. However, by varying the settings of the two controls, it is possible to obtain practically true convergence along a horizontal line of the raster.

The vertical convergence waveform is formed from the pulse-sawtooth in the primary of the vertical output transformer. It is applied across the parallel resonant circuit consisting of the 70-mfd capacitor and the 2-henry choke to form a parabolic current wave shape.

The combined parabolic wave and sine wave is applied to the first convergence coil to provide the required horizontal and vertical dynamic convergence over the entire screen. There is a second convergence coil, called the



CONVERGENCE SECTION

Courtesy CBS

FIG. 25. Convergence circuits of CBS-Columbia color TV receiver.

"vertical tilt coil", to which a sawtooth of variable amplitude and positive or negative polarity is applied, to correct for vertical tilt.

The entire circuit of Fig. 24 is duplicated for each gun in the picture tube. Such an arrangement permits precise adjustment of each beam to obtain precise convergence settings.

A more elaborate convergence system is shown in Fig. 25. This system has special forming circuits as well as individual convergence amplifiers for the horizontal convergence waveforms. The horizontal convergence waveforms are again derived from a pulse removed from a special winding on the horizontal output transformer. This pulse is applied to a group of three potentiometers referred to as tilt controls. From there the pulses are applied through shaping circuits to the grids of the convergence output amplifiers.

The horizontal pulse is also applied to the grid of the convergence sawtooth generator V41A, where a horizontal sawtooth is developed in the plate circuit. This is supplied to a convergence cathode follower which adds the horizontal sawtooth to the waveforms being applied to the grids of the convergence output stage. Hence, a controlled parabolic waveform is developed in the plate circuits of the three convergence output tubes.

The convergence output stages supply these waveforms separately to the three pairs of convergence coils. Again the waveforms in each pair of coils can be adjusted separately so that true convergence can be obtained over the entire surface.

The vertical convergence excitation is derived from the primary side of the vertical output transformer, as in the previous example. It is also applied to the separate vertical tilt coils through a group of three potentiometers, P41-3, P42-5, and P43-3. Another component is introduced in series from the vertical parabola controls and series inductors, to the first coil of each convergence pair. This is the parabolic waveform that is required for vertical convergence correction.

The subject of obtaining true convergence and making proper adjustments will be discussed in detail in a later lesson.

Lesson Questions

Be sure to number your Answer Sheet 58B.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of lessons before new ones can reach you.

1. If a defect in the tuner of a color receiver reduces the band width so that the frequencies in the upper portion of the band are lost, what will the result be?

2. What will be the frequency of the interference signal produced if the sound i-f and color subcarrier signals beat together in the video detector?

3. What will happen if a short in the delay line shorts the line out of the circuit?

4. What is the purpose of the hue control?

5. What is the purpose of the reactance tube used with the 3.58-mc crystal oscillator?

6. What is the purpose of the burst amplifier in a color receiver?

7. What is the purpose of the color killer?

8. Why is the output from the Q demodulator higher than the output from the I demodulator?

9. What is the function of the matrix unit of the color receiver?

10. What is the disadvantage of the color-difference method of demodulation?

COMPETITION

When a competitor opens a shop in your neighborhood, your first reactions are probably the same as those of most people—you feel that he is "cutting in" on your trade and that, by fair or foul means, he may run you out of business. However, there is another view to take of this problem.

First, forget your fears! A mind frozen by mistrust and hate is incapable of reasoning; it will lead you to the very downfall you fear. Face the facts: someone else is in the same business, so you must make your services so much *better* than his that you get your share of the work.

Welcome the competition as a spur—something to force you to your best efforts—something to make you become more careful, more efficient, more alert. You will find that honest competition adds enjoyment to your work.

And, another thing, force your competitor to rise to *your* level to survive—don't stoop to his. Do your best work and you'll find that your fears were not justified—there is plenty of business for the man who can deliver the goods!

J. E. Smith

HOW TV ANTENNAS WORK

59B

RADIO—TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE No. 59

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. **Introduction** .... **Pages 1-2**

A general picture of why the TV antenna is an important part of the TV system.

☐ 2. **Behavior of TV Signals** .... **Pages 2-7**

You study the characteristics of TV signals, and the differences between VHF and UHF signals.

☐ 3. **Basic TV Antennas** .... **Pages 7-16**

A discussion of the simple dipole and the folded dipole is given here.

☐ 4. **Choosing the Proper Antenna** .... **Pages 16-30**

You learn the important considerations for choosing antennas for use in primary signal areas, secondary signal areas, and fringe areas, and also for color television.

☐ 5. **Transmission Lines** .... **Pages 30-36**

You study the different types of lines and the problems of matching them to the set and to the antenna.

☐ 6. **Answer Lesson Questions.**

☐ 7. **Start Studying the Next Lesson.**

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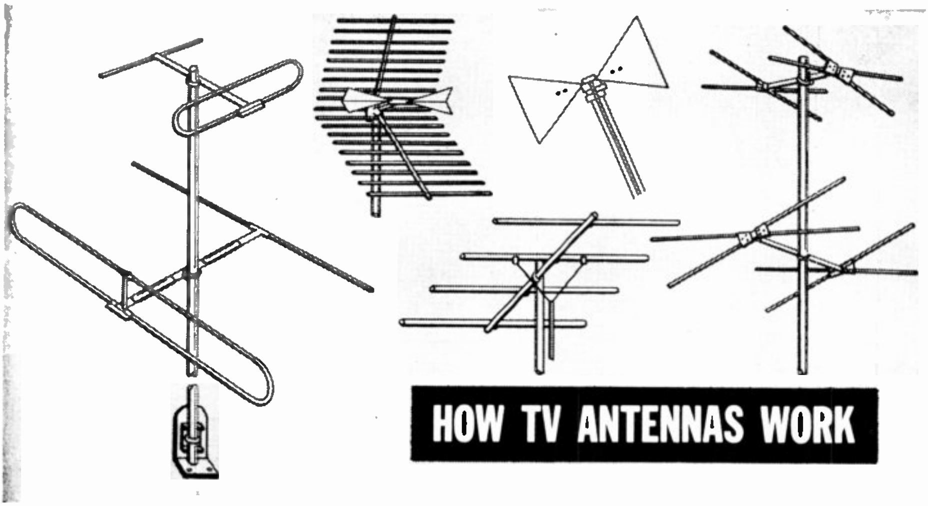
1960 EDITION

Printed in U.S.A.



HOW TV ANTENNAS WORK

THE TV antenna system is a very important part of the complete TV installation. No matter how good the set may be, it cannot produce a satisfactory picture unless the signal fed to it by the antenna is sufficiently strong and free from undesired interference. The human eye is very sensitive to fine detail, and it is therefore important that the TV antenna system be able to accept the entire band of frequencies that make up the television signal without destroying or distorting the characteristics of any part of that signal.

Furthermore, it is important for the TV antenna to have sufficient directivity to pick up the desired signal but reject any undesired signals coming from other directions. This is particularly important in large cities where nearby buildings may reflect the signal and cause ghosts or multiple images in the picture.

To obtain maximum signal transfer between the antenna system and the receiver, the antenna itself must be matched to the transmission line, and the transmission line must be matched to the receiver input circuit. Therefore, an antenna with the proper impedance must be chosen, and the transmission line must be chosen to match both the antenna and the receiver input circuit, or some means of obtaining these matches must be provided. If both VHF and UHF signals are to be received, a matching system must be provided so that the two antenna systems can work together without undesired interference.

In weak signal areas, special high-gain antennas that will pick up as much of the signal as possible must be used. Also, in many cases, preamplifiers—generally called boosters—must be used.

Three bands of frequencies are used for television: two in the VHF range, and an extremely wide one in the UHF range. The lower frequency

VHF band extends from 54 to 88 mc; the higher, from 174 to 216 mc. The UHF band extends from 470 to 890 mc. In some areas, it is possible to pick up signals in each of these bands if the proper antenna system is used. Naturally, the owner of a TV receiver wants to receive as many stations as possible, and wants an antenna system with a frequency response broad enough to cover all the channels used in his immediate area.

Knowledge of TV antennas is important to the practicing serviceman so that he can choose the proper kind of antenna for a particular reception area, and so that he can install the antenna properly for maximum signal at the receiver input.

Before studying characteristics of various TV antennas, it is important for you to have a thorough understanding of the behavior of the TV signal. That understanding makes it easier to see how the antenna responds to the signal.

Behavior Of TV Signals

The signals in the broadcast-band frequency range travel along the ground or bounce back and forth between the earth and the Kennelly-Heaviside layer. Signals at the frequency range used for television, however, behave differently. They act more like light waves, the resemblance becoming more pronounced as the frequency is increased. That is, these high-frequency signals travel in relatively straight lines from the transmitting antenna to the receiving antenna. They do not bend around hills or other obstructions as lower-frequency radio signals do, nor are they normally reflected by the Kennelly-Heaviside layer. Therefore, television reception is not generally possible at extremely great distances, because the signals will not bend around the earth. (As explained a little later, there is some slight bending, but it cannot be depended upon to give satisfactory reception all the time.)

As a result of this characteristic, the distance over which a television signal can be received is very limited. Also, the distance generally depends upon the height of the transmitting antenna and the height of the receiving antenna. The best results are generally obtained when each is as high as possible.

An illustration of a true line-of-sight signal is shown in Fig. 1A. As you can see, the signals from the transmitting antenna travel in a straight line P1 to the receiving antenna.

Those that pass the receiving antenna continue on out into space and never return to earth. Notice that if either the transmitter or the receiving antenna were slightly less elevated, the curvature of the earth would interrupt the line of sight between them and thus prevent reception.

As it happens, however, there is a certain amount of refraction (bending) of VHF signals. As a result of this bending, VHF television signals can travel slightly farther than they could if they were strictly line-of-sight. This is illustrated in Fig. 1B, where P2 is a curved path actually taken by the signal. Comparing the length of P2 with that of P1, you can readily see that the curved path permits signals to be received over a greater distance. The actual increase of receiving distance is not proportionately as great as shown here, because the curve of the earth has been greatly exaggerated in these drawings. The increase in receiving distance caused by the refraction of the VHF signals, however, is appreciable.

In some locations, this bending of the television signal causes odd effects. For example, it is sometimes possible to receive a satisfactory signal with the antenna mounted a certain height above the ground, but impossible to receive a signal with the antenna mounted higher. This effect occurs because if the antenna is mounted too high, the television signal misses it entirely.

Refraction does not greatly affect UHF signals, and the distance over which these signals can be received is even more severely limited. However, reflection does affect the UHF signal, often allowing reception where there is no line-of-sight between the transmitting antenna and the receiving antenna.

REFLECTIONS

Waves used to transmit television signals can be reflected from conductive material. If they strike a building, for example, they will be reflected from the metal structure of the building just as a light beam would be reflected from a mirror. (Some prefer to consider that the metallic structure of the building in such a case acts as an antenna that absorbs the signal and then re-radiates it. Whichever explanation you prefer, the effect is the same; the radio waves take on a new direction after striking the building.)

The reflection of the television signal is sometimes helpful and sometimes extremely annoying for the man attempting to erect a receiving antenna. It is helpful in those cases in which it permits television reception

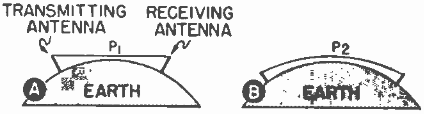


FIG. 1. The slight refraction of TV signals in air permits reception over distances that are longer than the line-of-sight path.

at points where it would be impossible to receive signals without the reflection. Suppose, for example, there is a large building between the transmitter and the location at which you are attempting to install a television antenna. If you cannot get the receiving antenna above the obstructing building, direct reception of the television signal will be impossible. You may, however, be able to pick up the signal by pointing the antenna toward some building or other object that will reflect the signal. In fact, this is a very common occurrence in installations made in large cities.

An example of another location in

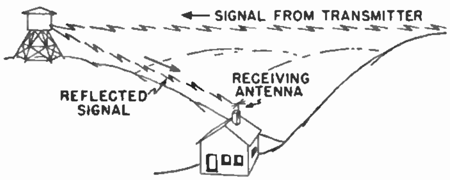
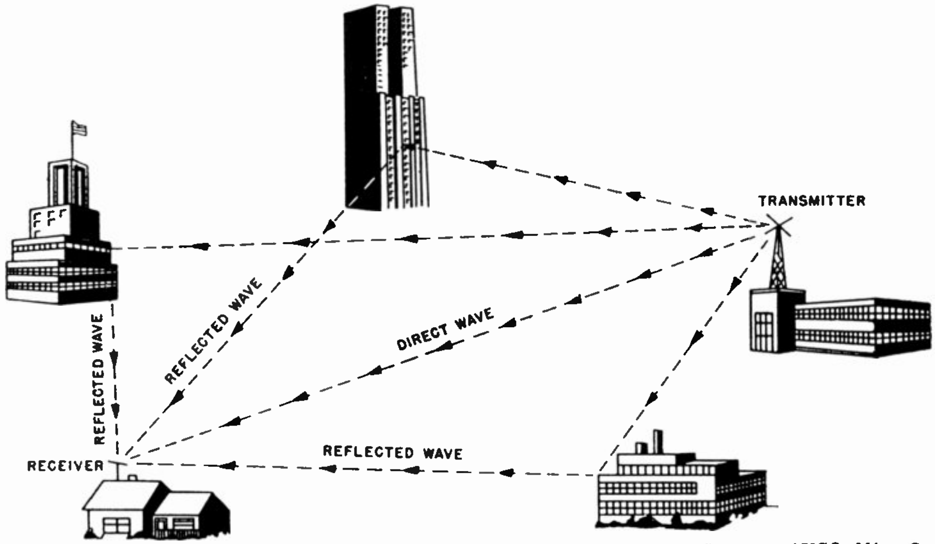


FIG. 2. How a reflected signal may give reception at a location not reached by the direct signal.

which a reflected signal is very helpful is shown in Fig. 2. Here the receiving antenna is located in a deep valley. The direct signal from the transmitter cannot reach the receiving antenna that is down in the valley. However, the water tower on the hill at the left in this figure is in the line of direct signal, and since it is metallic, it reflects the signal down into the valley to the receiving antenna.

In such cases, reflected signals are certainly helpful. Suppose, however, that the location at which you are installing a receiving antenna is such that you get a perfectly good signal directly from the transmitter, but that you also get one or more reflected signals from the same station that have traveled over different paths to reach the receiving antenna. Such a state of affairs is illustrated in Fig. 3. As you can see by examining this figure, the direct wave from the transmitter to the receiver travels through a considerably shorter distance than any of the waves reflected from the various buildings. Radio waves, even though they travel at the speed of light (186,000 miles per second), require a measurable length of time to get from one point to another. Therefore, the reflected waves will arrive at the receiving antenna a short time later than the direct wave, the time difference depending on the relative length of the paths. A radio wave traveling at the speed of light moves



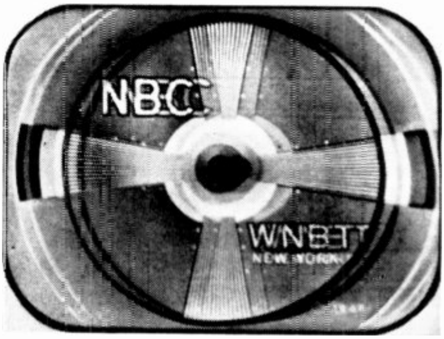
Courtesy AVCO Mfg. Co.

FIG. 3. How reflected signals can cause multi-path reception, which may produce ghosts.

at the rate of 985 feet per microsecond (a microsecond is a millionth of a second), so a wave that travels over a path that is approximately a thousand feet longer than the direct path will arrive at the receiving antenna a microsecond later than the direct wave does.

This sounds like a very small interval of time, but its effect on a television receiver is appreciable. The scanning beam of a 20-inch picture tube travels across the face of the tube at the rate of .266 inch per microsecond. Therefore, a reflected wave that reaches the receiving antenna one microsecond later than the direct wave produces a picture on the tube that is .266 inch (or a little more than ¼ inch) to the right of the picture produced by the direct wave. If you are looking at the picture, you will see the basic picture—the one produced by the direct wave—and a superimposed image of the same picture shifted ¼ inch to the right. This effect is noticeable and rather distressing.

A multiple image of this sort, shown in Fig. 4, is called a ghost. It is possible for there to be several ghosts if there are several reflecting paths. In fact, there can be one for each path. It is not necessary that the time difference between the direct and the reflected signal be as great as a microsecond to produce a noticeable ghost. If the reflected wave arrives .19 microsecond later than the direct wave, the effect will be quite apparent. The time difference of .19 microsecond means that the reflected wave has traveled approximately 187 feet farther than the direct wave. As a matter of fact, a path difference of as little as 70 feet will produce a blurring in the right-hand edge of the picture, although a distinct ghost will not be produced.



Courtesy RCA

FIG. 4. Ghosts.

Ghosts are always injurious to the quality of the received picture. The distortion may be only slight if the strength of the reflected signal is low. If the reflected signal is as strong as the direct signal, however, the picture quality will be poor. If many ghosts are received, the effect will produce gray outlines of the picture rather than distinctly separate images.

Ghosts caused by multiple-path reception can usually be eliminated by orienting the antenna so that only the direct wave is received, if the antenna has sufficient directivity. If the antenna does not have sufficient directivity, however, it may be impossible to clear up the problem by reorienting the antenna. In that case, it will be necessary to use a more directional antenna.

Highly directional antennas are particularly important for UHF reception, because UHF signals are more likely to bounce off metallic objects and cause multiple-path reception.

Improper matching between the antenna and the receiver can also produce ghosts because of reflections within the transmission line that connects the antenna to the receiver. Suppose that a 100-ft. transmission line connects the antenna to the receiver. Suppose, too, that all of the signal sent down the transmission line to the receiver does not enter the receiver, but that part of it is reflected back up the transmission line to the antenna and then reflected down the line again to the receiver. If this happens, the part of the signal that was reflected up and down the line will have traveled 200 feet farther than did the signal that went straight down the line to the receiver. A path difference of this length will produce a ghost in the picture.

UHF SIGNALS

Though UHF TV signals behave in basically the same way as the VHF signals, there are certain differences that must be considered in installing TV antennas. A knowledge of these differences is particularly important in obtaining the best possible UHF reception.

All television signals decrease in strength rather rapidly as they move out from the transmitting antenna. The UHF signals, however, decrease more rapidly than the VHF ones because of the higher frequencies involved. That is, the UHF signals are absorbed by the earth and by surrounding objects more readily than the VHF signals.

Also, reflection is more of a problem in UHF reception because the amount of reflection depends upon the size of the reflecting object in proportion to the signal wavelength, and a small object that would not reflect a VHF signal will often reflect a UHF signal.

Signal absorption by grounded objects is also a problem in the UHF range. For example, the UHF lead-in must be kept as far as possible from grounded objects to prevent excessive signal loss, and special types of lead-in must be used in some installations.

POLARIZATION OF TV SIGNALS

A radio wave consists of an electric field and a magnetic field that are at right angles to one another. In radio and television work, we usually consider only the electrical field when we are discussing the direction of a wave. Furthermore, we generally deal with a "plane polarized" form of this field—that is, one that lies all in one plane, which may be at any angle to the earth's surface.

From earlier lessons, you know that a voltage is induced in an antenna when it is in an electric field. If the antenna is in the same plane as the field, the voltage induced in it is a maximum; if it is at some angle with respect to the plane of the field, less voltage is induced in the antenna. Therefore, maximum efficiency is obtained when the antenna is mounted in the same plane as the electric field of the radio wave.

Television signals are transmitted so that the electric lines of the wave are horizontal with respect to the earth's surface. For this reason, television signals are said to be "horizontally polarized." There are several reasons for using horizontal polarization, chief of which is that most noise signals are vertically polarized. Therefore, a horizontal antenna will pick up television signals most efficiently, and, at the same time, pick up noise signals poorly. For this reason, television antennas are usually mounted horizontally.

Basic TV Antennas

Now that you have some basic information on TV signals and some of the reception problems, you are ready to study the actual TV antennas used to receive signals, beginning with the simple dipole.

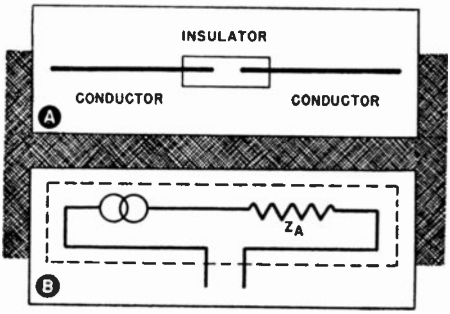


FIG. 5. A dipole antenna and its electrical equivalent.

DIPOLES

The dipole antenna shown in Fig. 5A consists of two cylindrical metal rods mounted so that they are in line with one another but not in contact. This is the basic antenna used in the study of all more elaborate types, in predicting the behavior of more elaborate antennas, and—in many cases—as part of more elaborate antennas.

An exact mathematical analysis of the behavior of a dipole is both difficult and complicated. Fortunately, it is not necessary to make such an analysis for our purposes. As a practical matter, we can consider a dipole (or any other receiving antenna for that matter) to be a generator having an impedance ZA, as shown in Fig. 5B. Of course, the energy furnished by this "generator" is actually induced in it by the television signal so it has the characteristics of the received signal.

The impedance ZA of the antenna depends on the length of the antenna with respect to the wavelength (λ) of the signal being received. If the antenna is exactly half a wavelength, its impedance is approximately 72 ohms; if it is a full wavelength, its impedance is approximately 2000 ohms; and if it is 3/2 wavelengths, its impedance is approximately 90 ohms. In each of these cases, the impedance is pure resistance.

If the wavelength of the received signal is such that the length of the antenna is between one-half and one full wavelength, its impedance is a combination of inductance and resistance, and the value is between 72 and 2000 ohms; if it is between one wavelength and 3/2 wavelengths, its impedance is a combination of capacity and resistance and has a value between 2000 and 90 ohms.

Notice that the impedance of the antenna varies with the physical length of the antenna in proportion to the wavelength of the signal being received.

The impedance of a simple dipole like that shown in Fig. 5A varies rather quickly as the frequency of the received signal is varied. Therefore, reception of a signal only slightly separated from the design frequency of the antenna will prevent proper matching between the antenna and the feed line.

The dipole antenna is connected to a receiver through a two-conductor transmission line as shown in Fig. 6. As the black arrows show, the flow of signal current in the two conductors of the transmission line is in opposite directions at any instant.

Because the two conductors are closely spaced, however, any currents that flow in them because of direct pickup by the line itself are in the same direction in each line at any instant, as shown by the white arrows. These latter currents flow through the antenna transformer in the receiver in opposite directions and cancel. Therefore, they produce no effect at the input of the set. Thus, the television signal delivered to the set is picked up only by the dipole; the length of transmission line theoretically does not affect the signal pickup. Also, noise signals picked up by the line will cancel. There are practical reasons for keeping the transmission line as short as possible, however, and these will be explained later in this lesson.

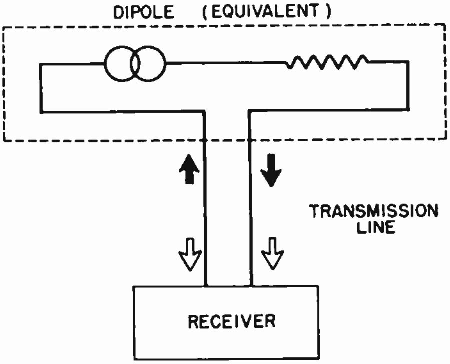


FIG. 6. A two-conductor transmission line passes signal currents (black arrows) from the dipole to the receiver, but tends to cancel signals picked up by the line itself (white arrows).

Radiation Patterns. The radiation pattern of an antenna shows the distribution of the field strength of an antenna if it were used for transmitting. At the same time, it shows how well the antenna will receive from each direction.

Fig. 7 shows the radiation pattern

of the dipole when it is operating as a half-wave, as a full-wave, and as a three-half-wave antenna. In each case, the dipole remains the same physical length, but the frequency of the incoming signal changes.

Fig. 7A shows the radiation pattern of a half-wave dipole. Notice that there is no pickup off the ends of the dipole and there is maximum pickup at right angles to it. Also, notice that both halves of the pattern are the same size; this shows that the antenna picks up equally well from the front and the back.

pole was cut (that is, if the dipole is one wavelength long for the received signal), the antenna has a radiation pattern like that shown in Fig. 7B. This pattern has four elongated lobes, which are at the angles shown with respect to the dipole. Again, there is no pickup at the ends of the antenna. There is, however, a major change. Notice that there is no pickup directly in front of or directly in back of the dipole as far as the signals of this wavelength are concerned.

The two small dotted lobes at right angles to the dipole show how the

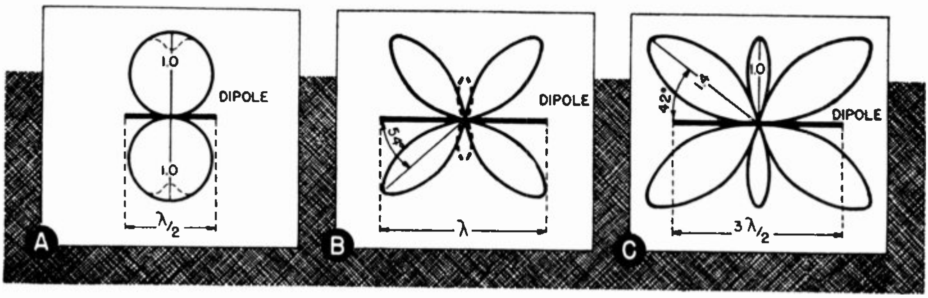


FIG. 7. In these illustrations of the radiation patterns of a dipole as a half-wave, full-wave, and three-half-wave antenna, the dipole remains the same physical length, but the frequency of the signal it is receiving changes.

A half-wave dipole is used as a standard reference antenna in determining the relative worth of more complicated types of antennas. Notice that each lobe of the half-wave dipole has been assigned the value 1.0. The dotted lobes in Fig. 7A show how the radiation pattern starts to change for signals of shorter wavelength.

Engineers measure the pickup of any antenna by comparing it with a simple dipole like that shown in Fig. 5A.

If the frequency of the received signal is twice that for which the di-

radiation pattern begins to change for signals at still shorter wavelengths. As the wavelength of the received signal becomes shorter, with the dipole remaining the same physical length, lobes begin to appear at right angles to the dipole. When the wavelength of the received signal becomes so short that the dipole is three half wavelengths long, the radiation pattern has the shape shown in Fig. 7C. Although the reception at right angles to the dipole is as good as it is for a half-wave dipole, the signal reception at angles of 42° from the dipole is even better: The center line of each of these side lobes has a value of 1.4, meaning that the pickup in these directions is 1.4 times as great as the maximum pickup of a half-wave dipole in its best direction. In other words, the pickup in the directions of the side lobes is about 2 db greater than the pickup at right angles to a half-wave dipole.

Remember, each dipole shown in Fig. 7 is the same length in terms of inches. Its length in terms of wavelength increases only because the wavelength of the received signal decreases.

If the wavelength of the received signal becomes even shorter, more lobes will appear in the radiation pattern; each time the dipole becomes a half wavelength longer, one more lobe will be produced on each side of the antenna.

In the early days of television, simple dipoles were frequently used. In fact, most of the early sets were designed with 72-ohm impedance input circuits that would match coaxial cable and a simple dipole. Modern TV antennas, however, are more complex, even in strong signal areas. Today, a combination of a folded dipole and a parasitic element that shapes the radiation pattern is most popular.

The study of the basic dipole, however, is important in understanding the theory of antennas.

The simple dipole is used in most UHF antennas. A somewhat more complex matching system, called a T-match, is used to provide satisfactory signal transfer between the simple dipole and the 300-ohm transmission line.

Now that you are familiar with the basic television antenna, the simple dipole, you can study more complex types. Before you do, however, there is one further point to be considered. As mentioned earlier, the dipole can be considered as a generator with an internal impedance ZA. It is also possible, and sometimes more convenient, to consider the antenna as a series-resonant circuit with an inductance L, a capacity C, and a resistance R, as shown in Fig. 8. The values of L and C are such that the circuit is resonant at the frequency for which the antenna is half a wavelength long.

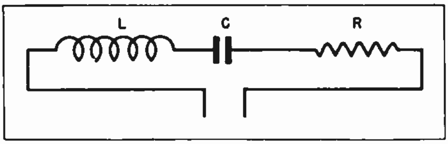


FIG. 8. A dipole can be considered to be a resonant circuit.

FOLDED DIPOLES

A common form of television antenna, known as the "folded dipole" is shown in Fig. 9. It consists of a single rod or tube that is bent into the shape shown. In use, the antenna is mounted with the long side parallel to the earth and the unbroken long side on top. The transmission line is connected to the two ends of the antenna as shown.

Such an antenna has the same radiation pattern as a simple dipole that is half as long as the perimeter of the folded dipole. For example, a dipole cut for channel 2 (54 to 60 mc) is about 8.2 feet long. A folded dipole made by bending a rod 16.4 feet long will have the same radiation pattern at the channel 2 frequency; in fact, as far as the radiation pattern is concerned, we could consider the two to be the same at all frequencies. In other words, the two will resonate to the same frequency and have identical radiation patterns.

We can, therefore, find out all we want to know about the radiation pattern of any folded dipole by studying the pattern of a simple dipole that is resonant to the same frequency, meaning one that is half as long as the perimeter of the folded dipole. Or, if we wish to make a folded dipole that will have the same radiation pattern as a particular simple dipole, we can do this by making it out of a rod that is twice as long as the simple dipole.

There are two reasons for using a folded dipole instead of a simple dipole that is the same as far as radiation pattern is concerned. First, the folded dipole has a higher impedance than a simple dipole at resonance; second, the folded dipole has a somewhat broader frequency response than the equivalent simple dipole.

The impedance of a folded dipole depends upon the spacing between the two long sides. The usual kind is made with a spacing of 1/64 of a wavelength, which gives an impedance of approximately 300 ohms at resonance—four times as great as that of a simple dipole. This spacing is used for most folded dipoles, and the 300-ohm transmission line designed to match the folded dipole is available.

It is important to remember that a proper impedance match between the antenna and the line permits maximum transfer of power from the antenna to the line.

As mentioned earlier, the impedance of a simple dipole depends upon the frequency of the incoming signal, since it is this frequency that determines whether the lengths of the antenna will be equal to half a wavelength, one wavelength, three half wavelengths or some other length. For frequencies above resonance, the impedance of a dipole increases rather rapidly. The impedance of a folded dipole also depends upon the frequency of the incoming signal; over a fairly wide range of frequencies above resonance, however, its impedance does not change as rapidly as that of a simple dipole. In other words, the impedance of a folded dipole is more

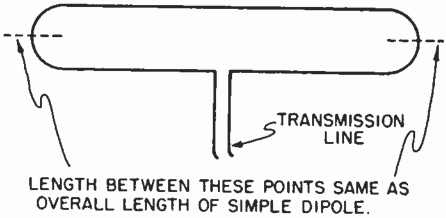


FIG. 9. A folded dipole antenna.

nearly constant than that of a simple dipole over a range of frequencies off resonance.

Suppose that we have a simple dipole and a folded dipole, each of which is perfectly matched to its own transmission line. With respect to the amount of signal power delivered to a receiver, these two antennas will be the same at their resonant frequency. At frequencies above resonance, the impedances of each will change; consequently, neither will be perfectly matched to its transmission line, and the amount of power each will deliver to a receiver will therefore decrease. Since the relative impedance changes in the simple dipole will be greater than in the folded dipole, however, the mismatch between the simple dipole and its transmission line will be greater. For this reason, the power that the simple dipole will deliver to a receiver will decrease faster at off-resonance frequencies. Over ranges of frequencies above resonance, therefore, a folded dipole will furnish more power to a receiver than a simple dipole. This is an important consideration when an antenna is used for reception on more than one channel.

For this reason, engineers say that a folded dipole has a wider frequency response than a simple dipole. This does not mean that a folded dipole picks up over a wider range than a simple dipole; their pickup is the same at all frequencies, since they have the same radiation patterns. It does mean, however, that a folded dipole and its transmission line will furnish more power to a receiver than a simple dipole and its transmission line over a range of above-resonance frequencies.

This effect does not hold at all frequencies, because the impedance of a folded dipole rises very sharply at frequencies near its resonant frequency—that is, at frequencies where its length is approximately equal to one wavelength. This is not too important, however, because the frequency for which a low-band antenna is one wavelength long occurs in the frequency range between the two VHF television bands.

At three times its resonant frequency, that is, at a frequency for which the folded dipole is the equivalent of three half wavelengths, the folded dipole has an impedance of about 100 ohms. It has a somewhat wider response than a simple dipole at fre-

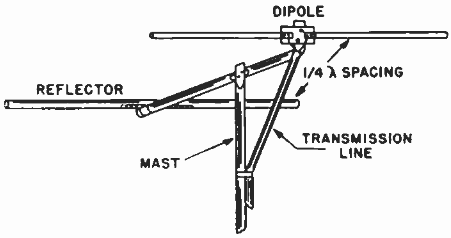


FIG. 10. An antenna using a parasitic element, called a reflector.

quencies greater than this, though the effect is not as marked as it is at frequencies close to resonance.

Because of its relatively wide frequency response, the folded dipole is one of the most popular types for use in complex multi-element arrays for VHF use. As mentioned previously, the simple dipole is the preferred type for use in UHF arrays. Also, a folded dipole made of 300-ohm line is frequently used for local reception of a TV signal.

PARASITIC ELEMENTS

A parasitic element is a metal rod or wire that is mounted near an antenna for the purpose of changing the radiation pattern. Such a parasitic element is not connected to the transmission line or to the antenna. It produces an effect on the radiation pattern of the antenna because it picks up the signal and re-radiates it, changing the phase. This re-radiated signal is then picked up by the antenna. The antenna therefore has two signals induced in it: The original signal and the one re-radiated from the parasitic. These two may add to produce a stronger combined signal, or they may partially cancel each other to produce a weaker signal, depending upon the phase relationship between the two. As a result, the radiation pattern of an antenna that has a parasitic element mounted near it is different from that of the antenna alone.

The effect of a parasitic element on the radiation pattern of a dipole depends upon the length of the parasitic element, on the spacing between the parasitic and the dipole, and on the frequency of the incoming signal. It is possible to get almost any desired pattern by choosing the proper element length and the proper spacing.

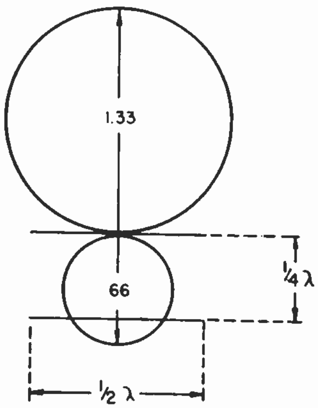


FIG. 11. Radiation pattern for a dipole and reflector.

An example of an antenna using a parasitic element is shown in Fig. 10. Here an element called a "reflector" is placed parallel to the dipole in the horizontal plane. The reflector is about 5% longer than the dipole. The spacing between the dipole and the reflector is usually one-quarter wavelength at the frequency for which the dipole is resonant, though spacings as close as .15 wavelength are used in special cases. The radiation pattern at the resonant frequency for a folded dipole and reflector spaced one-quarter wavelength apart is shown in Fig. 11. As you can see, the addition of the reflector increases the pickup considerably on one side and decreases it considerably on the other, the decrease being on the reflector side of the combination.

When a reflector is added to a half-wave dipole antenna, we say that the antenna has gain. That is, the pickup of a dipole and reflector is greater than the pickup of the simple dipole. This is illustrated by the forward lobe of the radiation pattern shown in Fig. 11. Notice that this forward lobe has a value of 1.33 as compared with the forward lobe having a value of 1.0 for the simple half-wave dipole.

Fig. 12 shows the radiation pattern for the combination when it is operated at three times the resonant frequency. Notice that the spacing between the antenna and the reflector is now three-fourths wavelength. This is explained by the fact that the spacing between them is fixed at one-fourth wavelength when the antenna is erected; since the wavelength of the incoming signal is only one-third the original wavelength when the antenna is operating at three times the resonant frequency, the spacing, which is fixed in terms of inches, becomes three times as great in terms of wavelength. You can see, the center forward lobe is considerably larger, and the center backward lobe is considerably smaller than they are in the radiation pattern of the dipole alone.

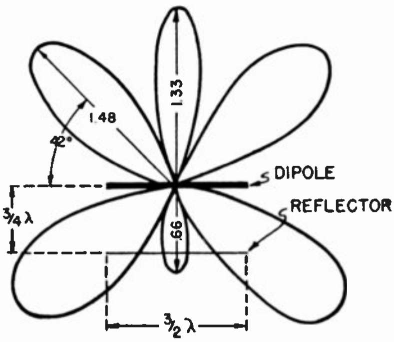


FIG. 12. The radiation pattern of a dipole and reflector operating as a three-half-wave antenna.

Since the combination of a dipole and a reflector picks up better in one direction than in another, particularly at the resonant frequency, it is said to be a directional antenna, or it is said to have directivity. Because the major lobe has a value greater than 1.0, the antenna is said to have gain in that particular direction. This indicates that the antenna would pick up more of the signal than a dipole cut for that frequency would.

The combination can be made even more directional by adding another parasitic element on the opposite side of the dipole from the reflector and parallel to both of them (see Fig. 13). This element, called a "director," is about 4% shorter than the dipole and is spaced one-fourth wavelength or less from it. The radiation pattern for a director-dipole-reflector combination at the resonant frequency is shown in Fig. 14. Notice that the addition of the director lengthens and narrows the forward lobe and further shortens the backward lobe.

The impedance of a dipole is decreased to about 60 ohms by the addition of a parasitic element spaced one-fourth wavelength from it. Its impedance can be brought back to about 72 ohms by reducing the spacing to something less than one-fourth wavelength. Notice that this applies in the case of a simple dipole used as a basic receiving element in the parasitic array. If a folded dipole is used as a

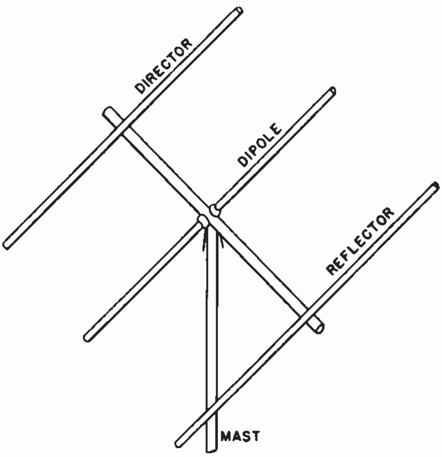


FIG. 13. A dipole with director and reflector.

basic antenna, there is a corresponding impedance reduction when parasitic elements are added.

The increased forward pickup caused by adding parasitic elements to a dipole makes the combination very useful in areas that are some distance from a television station. Such antennas, however, are also very frequently used when the signal strength is high; here their decreased backward pickup is the characteristic that makes them desirable. In a location where there are strong reflected signals that can cause ghosts in a picture, a properly oriented parasitic array may be able to pick out the desired signal and ignore the reflected ones, thus eliminating the ghosts.

All parasitic arrays consisting of a dipole connected to the transmission line plus three or more positive elements—usually one reflector and a number of directors—are called "Yagis."

Unfortunately, the increased directivity and antenna gain produced by the use of parasitic elements are accompanied by a decreased broadness in response. This is generally true of any directional antenna arrays, although some are worse than others in this respect. Some directional antennas have frequency responses so narrow that they will not pick up equally all frequencies in a 6-megacycle television signal. This fact, of course, rules such antennas out for television use, no matter what their other characteristics may be, since uneven response over the frequency range of a single channel would cause distortion of some portion of the TV signal.

In some cases, however, carefully designed antennas of extremely high

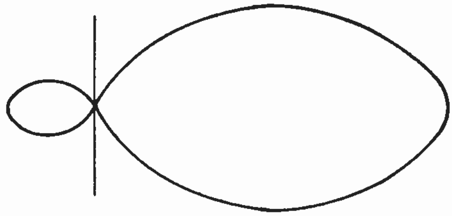


FIG. 14. Radiation pattern of dipole with reflector and director shown in Fig. 13.

gain are built for use on a single channel. In general, those antennas have just enough response to cover the particular channel for which they are designed. Therefore, the antenna will do an excellent job on the one channel for which it was designed, but will not give satisfactory results on other channels. These antennas are designed for use in extreme fringe areas where high gain is the primary consideration.

Additional gain can also be obtained by mounting two identical antennas one above the other and spacing them so that proper phasing is maintained. Such an arrangement is called a "stacked array."

Choosing the Proper Antenna

The antennas you have studied so far are the basic ones. There are many other types in general use, but a great majority of installations consist of a simple dipole or a folded dipole, with one or more parasitic elements.

Naturally, the demand for television receivers is greatest where television offers the greatest variety of entertainment; therefore, most receivers are located in areas where there are two or more stations. For such receivers, it is necessary to erect an antenna that will pick up all the available stations and pick them up equally well.

How complex an antenna must be depends upon many things, such as the signal strength in the area where the set is used, the direction of the station or stations from the receiver location, whether or not reflected signals are present at the location, the sensitivity of the set, how much electrical noise there is at the point where the installation is to be made; all of these play a part in determining what antenna will be satisfactory. You will study all these factors and several others.

Generally, television reception areas can be divided into three classes: 1. primary service areas; 2. secondary service areas (up to fifty miles from the station); 3. fringe areas (more than fifty miles from the station). Because the reception problems are likely to be different for each area, it is generally necessary to discuss these reception areas in terms of the type of antenna required to give satisfactory results in each. Of course, it is virtually impossible to give exact information on the type of antenna that will be required in each particular case, but a knowledge of the various types of antennas that are used by other servicemen, plus an understanding of why different types are used is sure to help you in choosing the proper antenna for use in a particular situation.

The problem of choosing the proper antenna may be further complicated by the possible use of both VHF and UHF in a single area. In the following portion of the text, general specifications on the type of antenna for use in the service area—both VHF and UHF—will be given. Additional information on installing both types of antennas together will also be given.

PRIMARY SERVICE AREAS

Reception areas within ten or fifteen miles of the transmitting station are called primary service areas. In these areas the type of antenna used is not usually a very great problem.

Indoor Antennas. In recent years, many television receiver manufacturers have included built-in antennas with the receiver itself. These antennas have varied in complexity from folded dipoles made of 300-ohm twin lead mounted inside the cabinet to rather elaborate antennas with a separate tuning control on the front panel.

These antennas will sometimes give satisfactory results when the receiver is in the same city with the transmitting station, and when a relatively straight path exists between the receiver and the television station. Ghosts, however, are a great problem with the simple built-in antennas.

When you install a receiver that has a built-in antenna, you must be sure to try the receiver in various parts of the room where it is to be used because moving the receiver (with the antenna inside) only a few feet in one direction or the other may improve reception considerably. Also, you should try turning the receiver to various positions to obtain the best possible reception.

The primary disadvantage of a built-in antenna is the lack of sufficient room inside the cabinet to in-

Courtesy Technical Appliance Corp.

FIG. 15. A widely used form of indoor antenna.

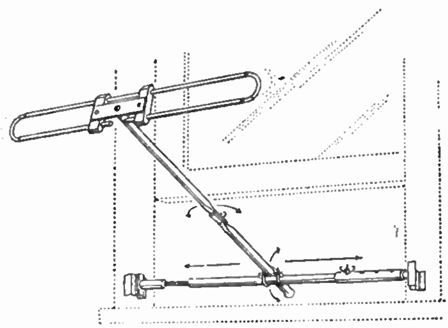
stall an antenna long enough to resonate at the frequency of the incoming signal. Furthermore, it is often difficult to place the antenna where the best signal is received simply because the receiver would not satisfactorily blend with the rest of the furniture if it were placed in the desired location. Also, it may be difficult or impossible to eliminate reflections with a built-in antenna.

A slightly more elaborate indoor antenna that will often give good results in an area where the signal strength is high is shown in Fig. 15. This antenna consists of two telescoped metal rods secured to a base through a pivot. These rods are electrically insulated from each other and are connected to the two leads of the transmission line. The angle between the two rods can be changed at will, and the length of the rods can easily be changed by pulling out the telescoped sections. The whole antenna can be rotated simply by picking it up and turning it.

The effective length of this antenna depends on the distance between the tips of the two rods. Thus, lengthening the rods or increasing the angle between them makes the antenna resonant at a lower frequency, and shorting the rods or decreasing the angle between them makes it resonant at a higher frequency. Usually, it is necessary to adjust either the length or the angle when the set is tuned from one channel to another.

One of the most important advantages of these antennas (which are usually called *rabbit ears*) is the possibility of moving the antenna away from the receiver itself if desired. That is, the antenna can be set on a nearby table if the set owner finds that more satisfactory results are obtained. This is not, of course, possible with a built-in antenna.

Lately, more elaborate "rabbit ears" with tuning controls and special sections for UHF reception have appeared on the market. If properly adjusted by the set owner, these antennas will sometimes give satisfactory results when the signal strength is unusually high.



Courtesy Insuline Corp. of America

FIG. 16. An adjustable window antenna.

Window Antennas. A window antenna usually gives better results than an indoor antenna, however, particularly when it can be placed in a window that is on the same side of the building as the transmitter. A typical window antenna is shown in Fig. 16. As you can see, it is a folded dipole that is mounted on a very short mast. At the other end of the mast is a cross bar that can be secured to the window frame, usually by extending the ends of the bar to wedge it across the frame.

This antenna has a response like that of any other folded dipole. The ends of the one shown in Fig. 16 can be extended to make the antenna resonant to a lower frequency if desired. This is usually done, if at all, only when the antenna is first installed, since it is inconvenient to change the length thereafter.

As mentioned previously, it is usually better to install a window antenna on the side of the building that faces the transmitter. However, it is sometimes possible to pick up an adequate signal on the other side of the building if buildings or other objects reflect the signal toward that side.

Many other forms of indoor and window antennas have been developed. Generally speaking, there is little to recommend one kind over another. The only way to tell whether a particular type will be satisfactory in a particular location is to try it there.

Indoor antennas are not generally satisfactory for UHF reception because the signal is greatly attenuated in passing through the building itself and because there are so many reflections inside the building.

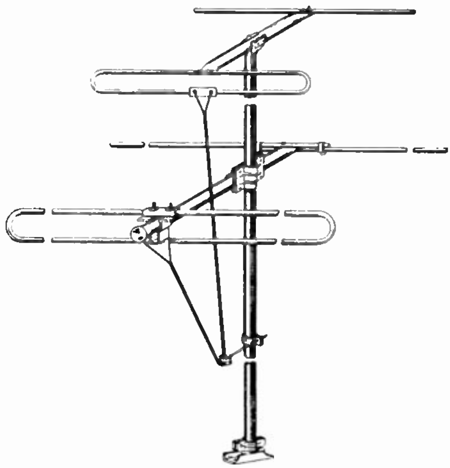
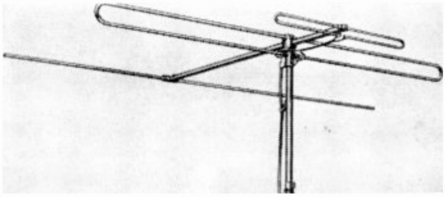


FIG. 17. A two-bay folded dipole and reflector combination. The larger section is used for low-band (channels 2 through 6) reception, and the smaller section for high-band (channels 7 through 13) reception. The two sections can be individually oriented.

Outside Antennas. The most common type of outside antenna for use in a primary service area where more than one station is to be received is the antenna shown in Fig. 17. This is called a "two-bay" folded dipole.

Notice that the lower section of this antenna is much larger than the upper part. The larger section is designed to have maximum response on the low channels of the VHF range, 2 through 6; the upper section is designed to have maximum response on the high channels, 7 through 13. The two sections, or bays, are connected together with a length of transmission line, and then connected to a single lead-in. The transmission line used between the two sections should be about 36 inches long, and the trans-



Courtesy American Phenolic Corp.

FIG. 18. Another form of two-band antenna.

mission line connecting the antennas to the receiver must be connected to the larger section. No special matching section is needed between the two bays.

The high-channel section of the antenna is generally mounted at the top of the mast to take advantage of the additional height. As mentioned previously, the signal reduction becomes greater as the frequency is increased; therefore, it is important for the high-frequency antenna to be mounted as high as possible.

In some particular cases, however, it is advantageous to put the low-channel section of the antenna at the top of the mast, particularly when the low-channel stations are at a greater distance from the receiving location than the high-channel ones.

Also notice that the individual sections or bays of the antenna can be individually oriented for best response. This feature is very important when the high-channel stations and the low-channel stations are in different directions from the receiving location.

A slightly different version of the two-band folded dipole and reflector that has been widely used is shown in Fig. 18. Notice that the major lobes of both the high-band and the low-band antenna point in the same direction, as shown in Fig. 19. For this reason, this antenna is not too popular because the high-channel section and the low-channel section cannot be individually oriented for best reception. When all of the channels are in the same general direction, this antenna gives very satisfactory results.

UHF Reception in Primary Areas. As mentioned previously, indoor antennas are not generally satisfactory for UHF reception because the signal is usually severely attenuated in passing through the sides of the building, and because reflections occur inside the building itself.

A UHF antenna must have extremely wide frequency response, be-

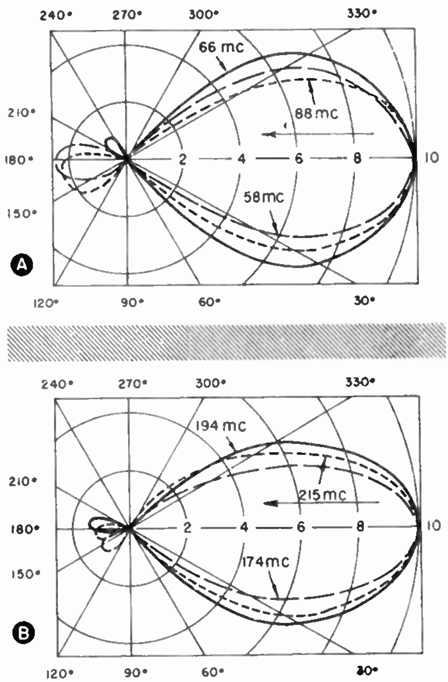


FIG. 19. The radiation patterns of the antenna shown in Fig. 18 for the low and high bands.

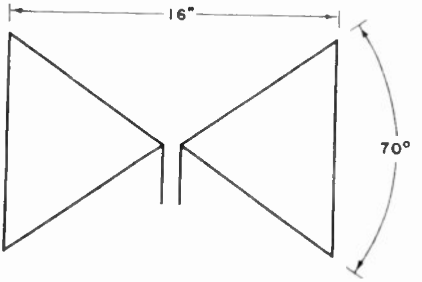
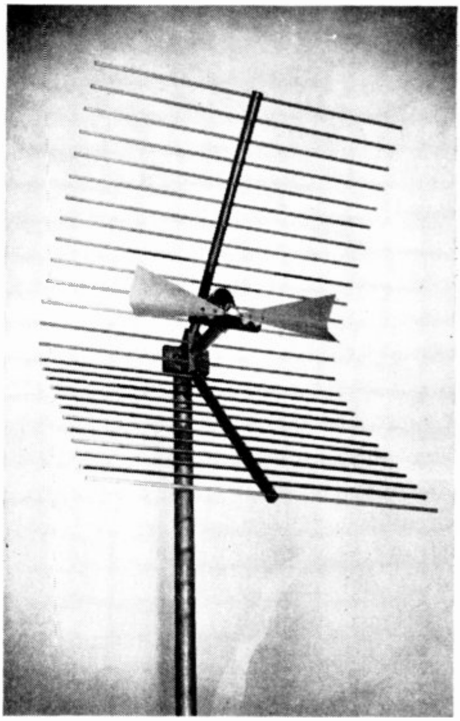


FIG. 20. Typical dimensions for a UHF bow-tie or fan antenna.

cause the UHF band itself is so wide. Furthermore, good directivity is necessary to prevent the appearance of ghosts in the picture, and the antenna and its lead-in must be properly installed to maintain the losses at the lowest possible level.



Courtesy RCA

FIG. 21. A corner reflector and bow-tie antenna.

To obtain the broad response necessary for UHF reception, the simple dipole is modified by måking it "thicker." That is, the effective size of the dipole is increased by using a tapered construction like that shown in Fig. 20. Because of the shape, this type of antenna is called a "bow-tie." One lead of the transmission line connects to each triangle.

Although the individual sections of such an antenna can be made from solid pieces of metal, perforated sheets or screen wire are sometimes used to decrease the wind resistance.

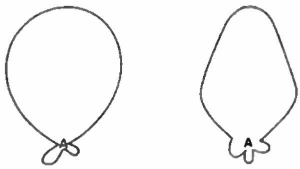


FIG. 22. Reception patterns for a corner reflector and bow-tie antenna at 500 mc (left) and 850 mc (right).

The increased width of this type of dipole in comparison with one made from a single rod reduces the Q of the antenna so that the resonant peak is broader. This reduces the output at resonance, but it also provides a better impedance match to the transmission line over a wide band of frequencies.

Because multiple-path reception is such a problem on the UHF channels, a bow-tie antenna is almost never used alone. Instead, it is used as a basic element in a more elaborate array. The extra directivity and gain provided by parasitic elements is very important on the UHF channels.

One of the most common types of UHF antennas, a bow-tie with a corner reflector, is shown in Fig. 21.

Although the gain of this antenna is very high in comparison with the gain of VHF antennas commonly used in primary service areas, the directivity and the extra gain are very important. Fig. 22 shows the directivity patterns of the bow-tie with a corner reflector. Notice the extremely small back lobe. Although the forward lobe is somewhat broader than is generally desirable, satisfactory results can be obtained if the antenna is properly oriented. Its directivity in the vertical direction is very good so that ground reflections are no problem.

The bow-tie and reflector UHF antenna is an excellent one for use in primary service areas because it has good directivity, high gain, and is easy to mount.

SECONDARY SERVICE AREAS

Reception areas between 15 and 50 miles from a VHF station or between 10 and 30 miles from a UHF station are generally considered secondary service areas. This term is not too well defined, however, and the real definition of a secondary service area depends in part on the surrounding terrain. For example, in mountainous sections, the secondary service area may begin 5 miles or less from the station.

The television signal, although originally transmitted with horizontal polarization, will become partially vertically polarized traveling through space because of reflections and other effects. In other words, the television signal at a remote location will have both a horizontal and a vertical component. To take advantage of all the signal reaching the particular location, the antenna must be able to pick up both components. A conical antenna is an excellent antenna for use in areas where the signal has both horizontal and vertical components. A stacked conical is shown in Fig. 23. The stacking of the two bays results in a greater signal pickup than a single bay would have.

In many cases, the noise level at the particular location will affect the choice of antenna. Since most noise signals are vertically polarized, if the noise level is high, a horizontal antenna must be used to prevent excessive noise pickup. Therefore, a single bay conical should not be used in areas where the noise level is high. However, a stacked conical will often work satisfactorily because the two bays are arranged so that the pickup of a signal having only a vertical component is low, while at the same time the pickup of signals that are not completely horizontally polarized is maximum.

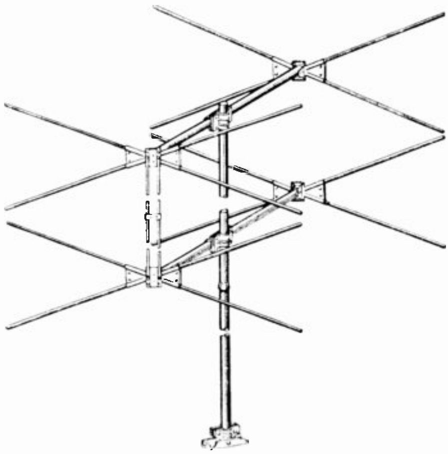


FIG. 23. A conical antenna.

In secondary service areas where noise is a problem, an antenna like that shown in Fig. 24 is often used. Notice that this is simply a stacked version of the two-bay folded dipole and reflector mentioned previously. Stacking the two antennas and maintaining the proper spacing between them, however, increases the gain and sharpens the forward response of the antenna. Again, notice that the high-band section and the low-band section can be individually oriented for best response from the particular stations.

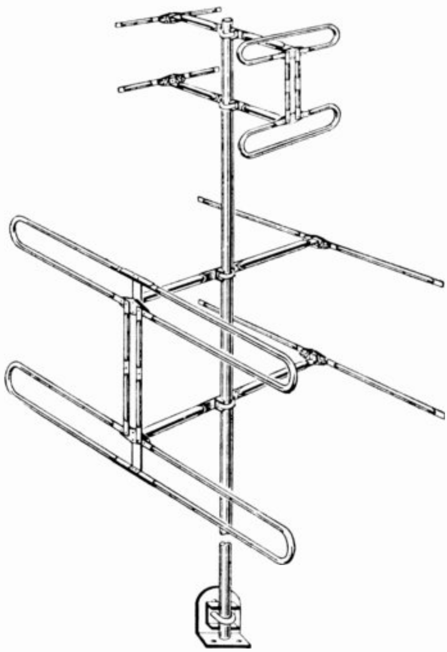
The most important characteristics of an antenna for use in the secondary service area are medium gain and wide band response. Both the antennas described above meet these qualifications and can therefore be used in areas where there are several TV stations in operation. However, if the stations are located in different directions, it may be necessary to use a rotator to turn the antenna for best signal pickup from the desired station. Also, you must always consider the mechanical problem of mounting the antenna. Both of these antennas are relatively easy to mount.

UHF Reception in Secondary Areas. In secondary service areas, the bow-tie and corner reflector mentioned for the primary service area is generally satisfactory for UHF reception, provided it is properly installed. In fact, the care exercised in installing the antenna is the most important single factor in secondary service area UHF reception.

In some instances you will find that a parabolic reflector will give greater signal pickup and better results at greater distances from the UHF station than the corner reflector. A dipole with a parabolic reflector is shown in Fig. 25. If the antenna is mounted high enough, it will give satisfactory results.

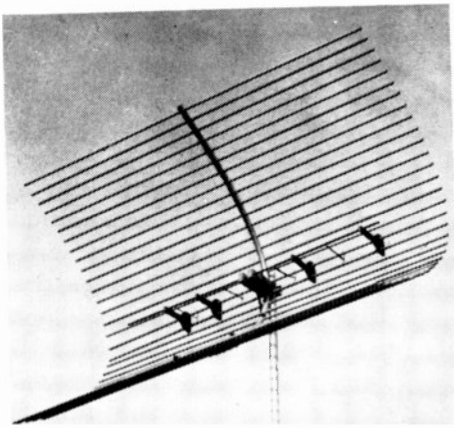
Also, UHF Yagi antennas are often used. Special Yagis designed to give satisfactory response over the entire UHF band are now available. These antennas are designed for use with the common 300-ohm transmission line. Further information on the proper lead-in for UHF use will be given in a later section of this book.

A typical UHF Yagi antenna is shown in Fig. 26, and the radiation pattern at 550 megacycles is shown in Fig. 27. Notice the almost complete



Courtesy JFD Mfg. Co., Inc.

FIG. 24. Low-band and high-band stacked arrays mounted on the same mast.

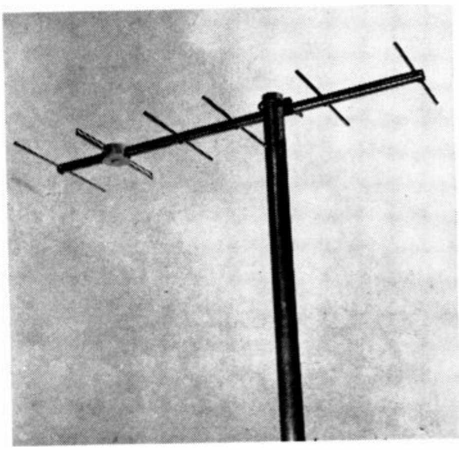


Courtesy Tele-Tech

FIG. 25. Antenna with parabolic reflector.

absence of the backward lobe and the extremely sharp forward lobe.

Installation is seldom a problem with UHF arrays, because the entire antenna is extremely small. It is important, however, that the antenna be mounted securely so that it cannot move in the wind. Even slight movement of the antenna will often cause



Courtesy RCA

FIG. 26. UHF Yagi antenna.

annoying changes in signal strength and consequent picture flicker.

When installing the UHF antenna, it may be necessary to try the antenna in several different positions on the customer's roof to obtain best results. There will undoubtedly be cases when the antenna will have to be carried all over a customer's roof before a satisfactory spot can be found where best reception with minimum interference is obtained.

FRINGE AREAS

There is no definite technical definition of a fringe area, but it is generally considered to be any area that is more than 50 miles from a VHF

FIG. 27. Typical Yagi reception pattern at 550 mc.

station or more than 30 miles from a UHF station. Special precautions are necessary when installing antennas in such areas, both to pick up a satisfactory signal and to prevent local noise from interfering with reception. Installation techniques are very important.

A fringe area antenna must be mounted as high as possible. For this purpose, special masts with elaborate arrangements to prevent swaying in high winds must be used.

If the receiving location is in a deep valley between two hills or mountains, it is often worth while to mount the antenna as high as possible on the mountain or hill and use a long transmission line.

One system that is often used advantageously in fringe areas is a high-gain antenna with a somewhat restricted band width. The antenna is peaked for maximum gain at the video carrier frequency. This type of antenna gives a somewhat stronger signal at the carrier frequency than a broad-band antenna and also reduces response at higher video frequencies where most of the noise signal picked up in fringe areas is located. Of course, some of the higher video-frequency signal components may be lost when this type of antenna is used, but the reduction of picture interference usually more than compensates for the loss of picture detail. Many of the high-gain single-channel antennas designed for fringe area installations are peaked at the video carrier frequency.

The use of antenna rotators and preamplifiers (boosters) is common in fringe areas. Lately, special boosters in weatherproof cases designed to be mounted on the mast at the antenna itself have become very popular. A typical booster of this type is shown in Fig. 28. By amplifying the signal before any noise picked up by the line has been added to it, the signal-to-noise ratio of the receiver can be improved, and satisfactory results can often be obtained in areas where it would otherwise be impossible.

An antenna rotator allows the set owner to orient the antenna so that best possible reception is obtained from a particular channel. An antenna rotator is a low-speed reversible motor mechanically coupled to the mast, with a control box at the receiver. This allows the viewer to orient the antenna for best possible reception on each channel.

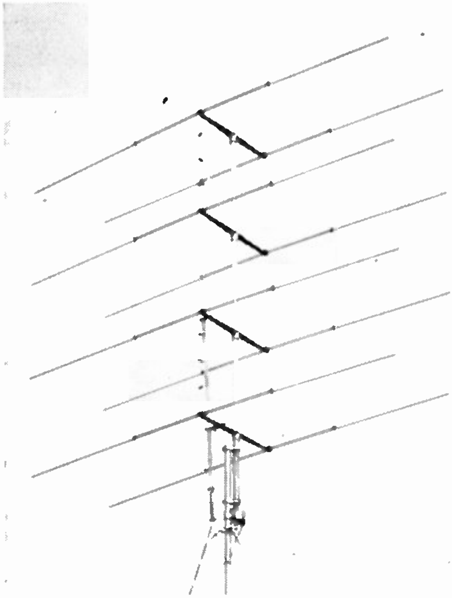
Satisfactory reception can often be obtained with a single high-gain antenna similar to the one shown in Fig. 29. When an antenna of this type is used with a rotator and a booster, weak signals can be picked up from any direction.

Courtesy Electro-Voice

FIG. 28. A booster designed for installation at the top of the antenna mast.

In areas where the signal is quite weak, it is sometimes necessary to use a separate antenna and transmission line for each channel and to provide a switching arrangement for connecting the proper antenna to the receiver.

The Yagi antenna is an excellent one for use where the signal is weak,

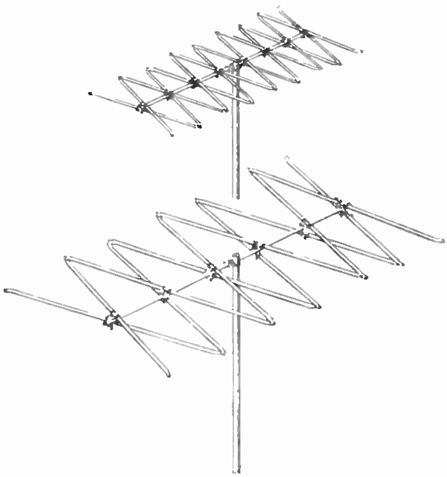


Courtesy LaPointe Plascomold Corp.

FIG. 29. A four-bay stacked array.

because of its extremely high gain and excellent directivity. In areas where there is only one station, it is more economical to use a Yagi type antenna than an all-channel antenna such as shown in Fig. 29. A typical Yagi antenna designed for VHF use is shown in Fig. 30. This antenna consists of a dipole, a reflector, and two directors. (In some cases, more directors are used, with a consequent increase in gain and decrease in frequency response.) The dipole in this array differs from others you have studied in that it is made of one continuous rod rather than a pair of rods. The two leads from the transmission line are connected to this rod at points an equal distance from the center. At first glance it would appear that the transmission line is shorted when it is connected to the antenna in this manner; actually, however, because of distributed capacity and inductance of the rod, there is an impedance between the two leads of the transmission line. Most manufacturers install mounting tabs for connecting the transmission line to the dipole and provide instructions for "fanning" the line (spreading it apart) so that it can be connected for proper impedance matching.

As you would expect, this antenna has a very limited band width. As a matter of fact, most Yagis for VHF use are generally designed for reception of a particular channel and cannot be satisfactorily used for reception of other channels. When you order such an antenna, therefore, you must specify the channel for which it is to be used since the spacing between the elements and the length of the elements differ for every channel.



Courtesy Trio Mfg. Co.

The Zig-Zag high and low-band VHF antennas for fringe areas. Upper one covers channels 7-13, lower covers channels 2-6. A special harness is used to connect these antennas to a single lead-in.

Some of the very latest VHF Yagis, however, have been designed with lower Q and greater band width. These "wide-band Yagis" will generally give satisfactory results over a group of channels. Of course, the gain of a Yagi designed for multi-channel use is not as high as that of a Yagi designed for single-channel reception, but the added band width is a great convenience, particularly in those areas mid-way between two large cities. In such areas, signals are often available on adjacent channels: 2 and 3, 3 and 4, etc.

Stacked arrays are still very popular in fringe areas. Many manufacturers can provide stacking bars for

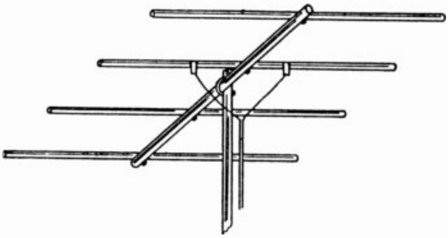


FIG. 30. A Yagi antenna.

mounting their simpler antennas one above the other to achieve extra gain and directivity.

New fringe area antennas appear on the market from time to time. To judge the performance of each new type accurately, you must try it in your particular location. Remember that the surrounding terrain will often affect the performance of an antenna.

UHF Reception in Fringe Areas. UHF reception is generally impossible more than 75 miles from the station. The fringe area for UHF is usually considered to be the area from 30 to 75 miles from the station.

In UHF fringe areas, stacked arrays are most common. Two or more Yagis with suitable matching bars are quite popular. A stacked array consisting of two Yagis is shown in Fig. 31. Each Yagi consists of a folded dipole with a reflector and four directors. Stacked corner-reflector arrays are also quite popular.

In UHF fringe areas, the installation itself is of major importance. Mounting the antenna where the strongest signal is received, orienting the antenna properly, and keeping the lead-in as far as possible from grounded objects all contribute to improved performance.

COLOR TV ANTENNAS

The basic antenna systems for color television reception do not differ from those for monochrome reception. The choice of antenna type and accessories and the care with which the antenna installation is made is more important in color reception.

Four antenna characteristics are

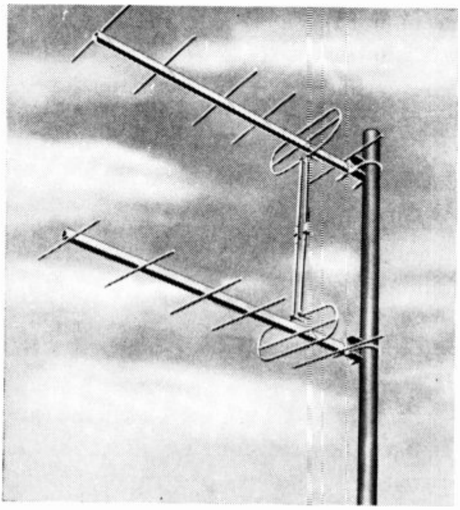
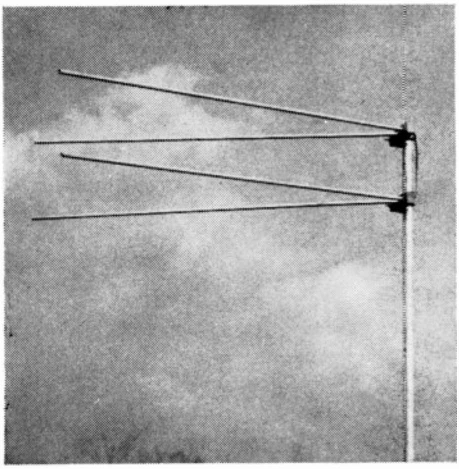


FIG. 31. A stacked Yagi array.



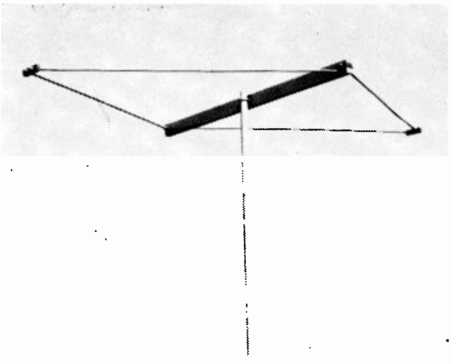
Courtesy Tele-Tech
Stacked V antennas for UHF.

important in the reception of the color signal. These are band width, gain, radiation pattern, and stray resonant conditions.

The response of an antenna can vary from 2 to 3 db over the 6-megacycle channel occupied by the color signal without any serious influence on the color picture quality. The danger lies in an accumulated response drop-off through a number of receiver stages. For example, a small attenuation at the antenna, the transmission line, the tuner, and the i-f system can result in a very serious over-all distortion. Thus, it is important to retain as flat a response as possible in each of the individual segments of a color receiving system. Antennas designed for color reception should have a broadband response without sharp dips anywhere in the TV channels.

Proper matching between the antenna, the transmission line, and in particular, the receiver input, is also important. If the transmission line impedance is not equal to the receiver input impedance, part of the signal traveling down the transmission line will be reflected back up the line setting up a series of voltage loops and nodes on the line called standing waves. The ratio of the voltage maximum at a loop to the voltage maximum at a node is called the standing-wave ratio. Poor standing-wave conditions on the transmission line can make the antenna system frequency-selective. By this we mean one range of frequencies is attenuated more than another range of frequencies because the loops and troughs of the standing waves on the transmission line depend on the frequency. It is possible for a much weaker signal to be delivered to the tuner input from one end of the channel than from the other. Since the chrominance information is at the opposite end of the bandpass from the picture carrier, either the picture carrier or the chrominance information could be seriously attenuated.

Antenna gain is also an important characteristic in weak signal areas. The fringe area antenna cannot be peaked at the picture carrier fre-



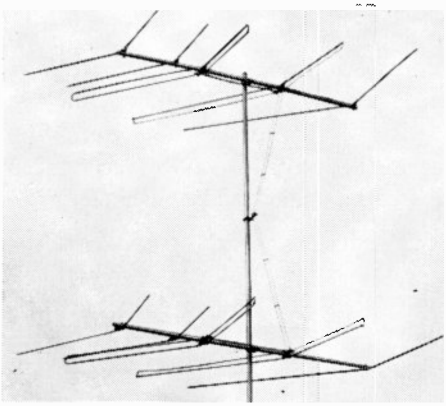
Courtesy RCA
UHF rhombic antenna.

quency because it must have equal sensitivity to the picture carrier range and to the chrominance signal range, if a color picture of good quality is to be reproduced. Thus, the narrow band techniques which are helpful in obtaining usable pictures in fringe areas cannot be employed. This throws an additional burden on the antenna system.

Stray resonant conditions in the antenna system can also affect the reception of a color signal adversely. On occasion, dips are placed on the response curve of an antenna system by stray resonant lengths that depend on the element spacing, cross-arm lengths, and tie-rod dimensions. Likewise, the placement of the antenna near metallic surfaces of resonant length can produce these dips in the response curve. Reception of a color signal at UHF frequencies can be more affected by these conditions because of poorer standing-wave ratios with UHF band equipment and the fact that very short physical lengths of metallic pieces become resonant in the UHF band.

A good radiation pattern is important in obtaining the best color picture in an area with propagation problems. A response pattern that has peak sensitivity in just a single direction and only minor secondary sensitivity lobes is preferable. As we have learned, with such a pattern, the pickup of interference or reflections is far less than it would be with an antenna having equal pickup from both sides. Remember that in the reception of a color picture, the presence of interference or reflections not only influences the brightness detail but the hue and saturation of the color image as well. Thus, the influence of noise and interference is the same as in monochrome reception, with the additional disturbance such interference can cause in the chrominance channels.

Antenna orientation is an important consideration. Improper antenna orientation can cause picture smear or introduction of transients into the picture. These defects produce brightness defects on the color image plus hue and saturation disturbances.



Courtesy Technical Appliance Corp.

Twelve-channel antenna designed for both color and monochrome reception in primary signal areas.

In summary, a well-planned and carefully installed antenna system is necessary for best color reception. Most of the present VHF and UHF antennas are quite satisfactory for color reception.

Although it may seem that a strong signal is best for color television, too strong a signal may actually be detrimental. If the signal is too strong, the high agc voltage may change the response of the rf amplifier so the color information may be attenuated or lost completely. Also, excessive signal may increase the standing-wave ratio, reducing the signal amplitude at some frequencies in the channel.

These difficulties resulting from excessive signal strength can be corrected by inserting a resistor-type attenuator pad between the receiver and the transmission line. The exact amount of attenuation required for best results can be determined experimentally. When it is necessary to add an attenuator for best color reception, the attenuator usually will have no adverse affect on the reception of black and white television.

Transmission Lines

The lead-in used to connect an antenna to a television set is called transmission line. Three types of these lines—coaxial, twin-lead, and shielded twin-lead—are in use. We shall first learn the physical characteristics of these lines, then study their electrical operation as carriers of rf current.

Like any other conductors, transmission lines have distributed inductance and capacity. A line therefore has impedance when it is carrying rf current. In television, we are concerned with the "characteristic" or "surge" impedance of a line, which is the input impedance of an infinitely long section of that particular line. This characteristic impedance is determined by the physical construction of the line and by the electrical properties of the material used in it.

Other important properties of a transmission line are its attenuation, which is usually stated in db per 100 feet for signals of various frequencies, and its ability to reject interference. We shall discuss each of these factors in the following description of the three main types of television transmission lines.

TYPES OF LINE

Coaxial Line. The coaxial line, shown in Fig. 32, consists of a wire surrounded coaxially by a tube of flexible metal braid that is spaced evenly from the wire by insulating material. The center wire and the outer braid (which is covered with waterproof insulation) are the two conductors in this line.

The diameter of the wire, the distance between the wire and the braid, and the dielectric constant of the insulating material determine the impedance of a coaxial line. The kind commonly used in television installations (sold under the code number RG59U) has an impedance of 72 ohms. Its attenuation is 2.2 db at 40 mc, 3.75 db at 100 mc, and 5.6 db at 200 mc per 100-ft length.

When coaxial line is used, the metal braid is grounded at the receiver. It therefore acts as a shield around the central wire, reducing interference pickup considerably. Because of this ground connection, the line should be used only with a set having an unbalanced input.

The two most important advantages of coaxial cable, or "coax" as it is commonly called, are its relative freedom from interference pickup on the line itself and its ability to serve as its own lightning arrester. (If the shield is properly grounded, lightning will jump through the insulator surrounding the center conductor and return to ground before it reaches the receiver input.) The greatest disadvantage is the high attenuation ratio as the frequency is increased.

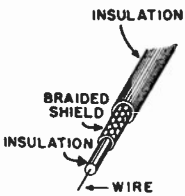


FIG. 32. A typical coaxial transmission line.

Twin-Lead Line. The twin-lead line, shown in Fig. 33, consists of two flexible wires molded into a flat ribbon of plastic insulating material. The impedance of the line depends upon the diameter of the wires, the spacing between them, and the dielectric constant of the insulation. The kind most commonly used in television installations has an impedance of 300 ohms, although 150-ohm and 72-ohm twin-lead line can also be obtained.

The 300-ohm type has an attenuation of 1.1 db at 40 mc, 2.1 db at 100 mc, and 3.6 db at 200 mc, per 100-foot length. As you can see, its attenuation is far less than that of coaxial cable, a factor that can be very important in an installation made where the signal strength is low. It does not have as much ability to reject noise pickup as coaxial line, however.

Twin-lead is very popular because it matches the most common receiver input impedance, 300 ohms, and it is easy to install. Also, the cost of twin-lead is quite low. The attenuation is quite low when the line is kept dry and free from soot. If the line becomes wet, however, the losses increase alarmingly, particularly at UHF frequencies. In fact, the wet loss jumps to about 20 db per 100 feet in the UHF band. This means that only one-tenth of the antenna signal voltage would reach the receiver. Therefore, this type of line cannot be used for UHF.

Tubular Twin-Lead. This special type of twin-lead was originally designed to prevent excessive "wet" loss in the line. The original type was as shown in Fig. 34. Notice that the center space is hollow so that there is practically an air dielectric between the two wires.

This type of twin-lead has a low attenuation figure whether wet or dry.

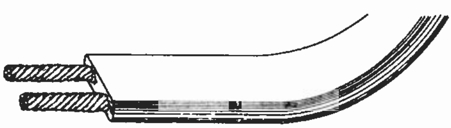


FIG. 33. An unshielded twin-lead transmission line.

It does, however, have a tendency to fill with water if the upper end of the line is not sealed. Even if it is, a certain amount of moisture collects inside the line due to condensation, and a drain hole must be provided at the bottom of the line. Another type of tubular twin-lead, instead of having a hollow center, is filled with a dielectric material that has characteristics similar to those of air.

This type of line has low loss, whether wet or dry, and has the added advantage of freedom from losses due to collection of moisture inside the line. Tubular twin-lead with the center insulator is generally preferred for UHF.

Shielded Twin-Lead Line. If it were made in the conventional manner, a 300-ohm shielded twin-lead line would have to be extremely large in diameter, because the shield would have to be spaced far away from the conductors to reduce the capacity between them. However, the shielded twin-lead line, shown in Fig. 35, is reasonably small and yet has an impedance of 300 ohms.

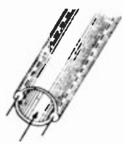


FIG. 34. Tubular twin-lead with hollow center.

The two conductors used in this line are crimped into a series of sawtooth sections. In manufacture, a tube of polyethylene (a plastic insulator) is extruded around each of these conductors. Each conductor touches the tube in which it is encased only at the points of the sawtooth; otherwise, the conductor is surrounded only by air. The effect of this construction is to reduce the capacity between the two conductors and the capacity between the conductors and the shield, because air has a lower dielectric constant than any other insulator. The line can therefore have a 300-ohm impedance and yet be reasonably small in cross-sectional diameter.

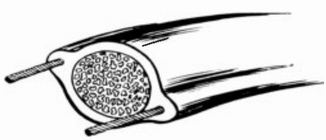
The two conductors in their polyethylene tubes are enclosed in a shield of flexible braid, which is in turn enclosed in a thermoplastic insulating jacket. This shield is grounded when the line is installed and therefore permits the line to have as good interference rejection as coaxial line.

The attenuation of this line is 2.4 db at 50 mc, 3.4 db at 100 mc, and 4.6 db at 200 mc, per 100-foot length —slightly less than that of 72-ohm coaxial cable.

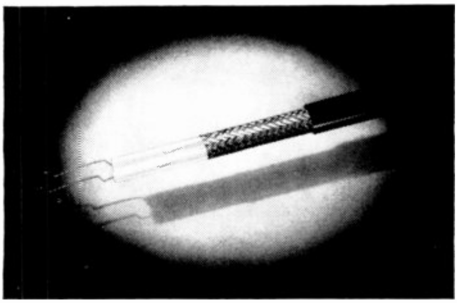
Now that we have learned what practical transmission lines are like, let us learn how they operate when rf flows through them.

LINE REFLECTIONS

We mentioned earlier that the three important characteristics of a transmission line are its ability to reject interference, its attenuation, and its surge impedance. What effect the first two of these have on our choice of a transmission line can be stated simply. Generally speaking, we want as little attenuation in the transmission line as possible. All other factors being equal, therefore, unshielded twin-lead line is the best one to choose for an installation. If interference is a



Tubular twin-lead with polystyrene center.



Courtesy Federal Tel. and Radio Corp.

FIG. 35. A shielded 300-ohm twin-lead transmission line.

problem, however, a shielded line must be used in spite of its greater attenuation.

Now, let us see why the impedance of a line is important.

The job of a transmission line is to deliver a signal to a load. It can do so efficiently only if the load is resistive and has an ohmic value equal to the surge impedance of the line. If the load has reactance, or if its resistance is not equal to the impedance of the line, a phenomenon known as "reflection" occurs; part of the signal that comes along the line to the load is returned, or reflected, back to the line, setting up a series of voltage loops and nodes along the line as the reflected signal adds to or subtracts from the original signal as the two are alternately in phase and out of phase. The series of loops and nodes are referred to as standing waves.

To see what effect such a reflection has in a practical case, let us suppose we have a 72-ohm line connected to the input of a set that has a 300-ohm input impedance. (Some sets have input impedances of 72 ohms, others have input impedances of 300 ohms, while still others may have input impedances of either 72 or 300 ohms.) Suppose, too, that the line is connected to a folded dipole that has an impedance of 300 ohms.

A signal picked up by the antenna is fed into the line and travels down to the set. Because the line and the set have different impedances (that is, their impedances are not matched), only part of the signal is fed into the line. This reflected signal travels back up the line to the antenna. Because of the mismatch between the antenna and line impedances, part of this reflected signal is reflected again; it travels back down the line and again appears at the input of the set.

If the line is 50 feet long, the part of the signal that has been reflected twice has traveled 100 feet farther than the part that was fed into the set at the time of the first reflection. (For convenience in reference, let's call the former the reflected signal and the latter the original signal.) Because of this difference in path length, the reflected signal will be slightly out of phase with the original signal; since both are applied to the input of the set, this phase difference will cause blurring of the picture. In other words, line reflections caused by mismatches of impedance at the ends of the line produce exactly the same effect as that produced by multi-path reception. Severe ghosts can be produced by such mismatching, because it is perfectly possible for a strong signal to be reflected up and down the line several times, thus causing several out-of-phase signals to be applied to the input of the set.

Such reflections cannot occur if the impedance of the transmission line matches the input impedance of the set, because then all the signal that comes down the line will be absorbed by the set. If there is a proper impedance match at this end of the line, it does not matter whether there is a match between the antenna and the line as far as reflections are concerned. Therefore, one important thing to remember about a transmission line is that *its impedance must match the input impedance of the set if ghosts are to be avoided.*

ANTENNA MATCHING

Whether or not the antenna impedance is matched to that of the line is not important as far as reflections are concerned, as we have just pointed out. However, the lack of an impedance match will have an effect on the transfer of the signal from the antenna to the line.

We mentioned earlier that the antenna can be considered to be a generator and the transmission line its load. You know from previous studies that the greatest transfer of power between a generator and its load occurs when the two are matched in impedance. Therefore, an impedance mismatch between the antenna and the line will give less than a maximum transfer of signal power from the antenna to the line.

As far as the antenna is concerned, a line that is properly matched in impedance at the receiver end will be an infinite line—that is, its actual impedance will be equal to its surge impedance at all frequencies. Therefore, we could be sure of getting a maximum transfer of signal at all frequencies if we could match the impedance of the antenna to that of a properly terminated line at all frequencies.

Unfortunately, this cannot be done. As you learned earlier in this lesson, the impedance of an antenna depends upon the frequency of the received signal. An antenna can be made to have a fixed impedance for one frequency but not for all. Even a wide-band antenna will vary rather considerably in impedance over the television bands.

Fortunately, this fact seldom causes any problems in the metropolitan areas where most installations are made. There the signal strength is almost invariably high enough so that part of the received signal can be wasted without affecting reception. In such areas, usually the only impedance match of importance is that between the line and the set; as long as this match is made, it does not matter much whether the line and the antenna are matched. If they are not, part of the signal will be wasted, but there will still be enough to operate the set satisfactorily in most cases.

As a matter of fact, the antenna and the transmission line are often deliberately mismatched in areas of high signal strength where there are several stations. The purpose of doing so is to make reception fairly uniform over a wide band. If a 300-ohm line is used with a 72-ohm dipole, for example, there will be a 4-to-1 mismatch

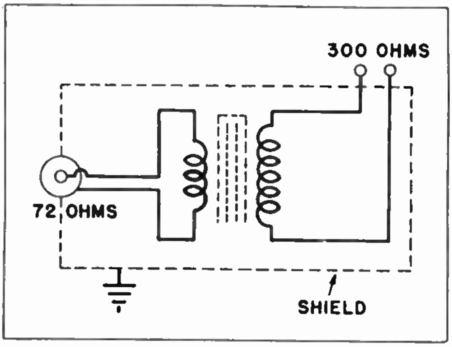


FIG. 36. A transformer for matching 72 ohms to 300 ohms.

at the frequency for which the dipole is cut. This will cause a loss of signal for that station; since the signal strength is high, however, this loss is not serious. At higher frequencies, where the dipole does not pick up as well, its impedance will increase. The impedance match between the antenna and the line will therefore improve, and the consequent improvement in signal transfer will partially compensate for the reduced response of the antenna.

This effect can be produced, by the way, only if the impedance of the antenna at resonance is lower than that of the line. The reverse of this condition (having the impedance of the line lower than that of the antenna) will not produce any helpful effect, because the impedance of an antenna always rises at off-resonance frequencies; therefore, the mismatch between the line and the antenna will get worse as the frequency increases.

In fringe areas, where every bit of signal is needed, the match between the antenna and the line becomes very important. In this respect, it is fortunate that it is usually necessary to use a separate antenna for each station in such areas, because each antenna and line can then be matched individually for a particular frequency. As we have just pointed out, this is the only way in which a perfect match can be secured.

Most antennas designed today will match 300-ohm line directly. If the basic antenna has low impedance, a matching section that provides a 300-ohm antenna output is generally included as part of the antenna itself. This tendency of the manufacturers has greatly simplified the serviceman's job of installing TV antennas.

In general, you can use a 300-ohm antenna and 300-ohm transmission line in all installations. When this procedure is followed, there is no problem of matching.

As most modern receivers also provide a 72-ohm input when the shield of the coaxial cable is connected to the receiver chassis, and the center conductor is connected to one of the antenna terminals, use of a 72-ohm antenna and transmission line seldom leads to a matching problem.

If the receiver input will not match the line impedance directly—for example, if the receiver input is 72 ohms and the transmission line is 300 ohms—you can use a matching transformer like that shown in Fig. 36. Incidentally, the transformer can be used either way: to match 72-ohm line to a 300-ohm input, or to match 300-ohm line to a 72-ohm input.

On some receivers, separate inputs are provided for connecting the UHF antenna and the VHF antenna. When this feature is provided, it is usually best to use separate lead-ins from the individual antennas. If only one pair of input terminals are provided on the receiver, however, the UHF antenna and the VHF antenna must be connected together. They cannot be connected directly, however, and a special matching network must be used to prevent excessive loss.

A complete matching network for connecting a low-band VHF antenna, a high-band VHF antenna, and a UHF antenna to a single lead-in is shown in Fig. 37. This network isolates the individual antennas and keeps losses at a minimum.

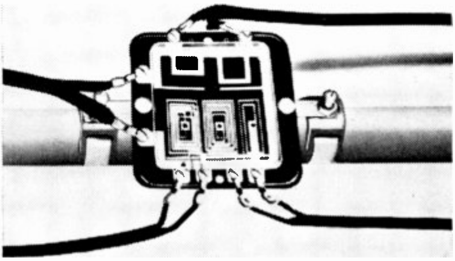


FIG. 37. Matching network for connecting a low-band VHF antenna, a high-band VHF antenna, and a UHF antenna to a single lead-in.

As mentioned previously, most modern TV antennas have the necessary matching devices built in as part of the antenna itself. If special instructions for matching the antenna to a particular type of transmission line are necessary, those instructions will be included with the antenna.

Lesson Questions

Be sure to number your Answer Sheet 59B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. How does refraction (bending) affect the distance at which a television signal can be received?

2. Assuming sufficient antenna directivity, how can ghosts caused by multiple-path reception be eliminated?

3. What is the impedance of a *folded dipole* operated at its resonant frequency?

4. What is the primary disadvantage of a built-in antenna?

5. Are indoor UHF antennas generally satisfactory?

6. What is the most common type of outside antenna for use in a primary service area?

7. What is the most important factor to consider in choosing an antenna for color reception?

8. Which has the highest loss: coaxial line, twin-lead, or shielded twin-lead?

9. What type of lead-in is preferred for UHF use?

10. Proper impedance matching between the antenna and the transmission line is important: (a) to obtain maximum signal transfer, (b) to prevent ghosts.

SHOULD YOU DEPEND ON LUCK?

Accident—chance—luck—have very little bearing upon the production of any great result or true success in life. Of course, there have been many discoveries and accomplishments which may seem to be the result of "luck."

For instance: Newton "discovered" the law of gravity by watching an apple fall from a tree. Galileo "invented" the telescope after hearing of a toy constructed by a spectacle-maker. Brown "invented" the suspension bridge after watching a spider throw its web.

But these discoveries and inventions were made by men trained to take advantage of what they observed. Thousands of untrained men had seen the same things and paid no attention.

The new discoveries in Radio—Television—Electronics will be made by men trained to take advantage of what they observe.

J. E. Smith

INSTALLATION AND ADJUSTMENT OF TV RECEIVERS

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STUDY SCHEDULE No. 60

For each study step, read the assigned pages first at your usual speed, then re-read slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ **1. Introduction .... Pages 1-2**

The over-all installation and adjustment procedure is discussed in this section.

☐ **2. Adjustment .... Pages 3-13**

When and how to adjust both operating and non-operating controls is explained in this section.

☐ **3. Installation .... Pages 13-21**

How to locate the set in the customer's home, connect and orient the antenna, and make final adjustments are explained in this section.

☐ **4. Interference .... Pages 22-31**

The various types of interference that might be encountered by the serviceman and how to eliminate them are discussed here.

☐ **5. Special Installations .... Pages 31-36**

Making special installations to meet the problems created in areas where unusual signal or voltage conditions exist is explained in this section.

☐ **6. Answer Lesson Questions.**

☐ **7. Start studying the next Lesson.**

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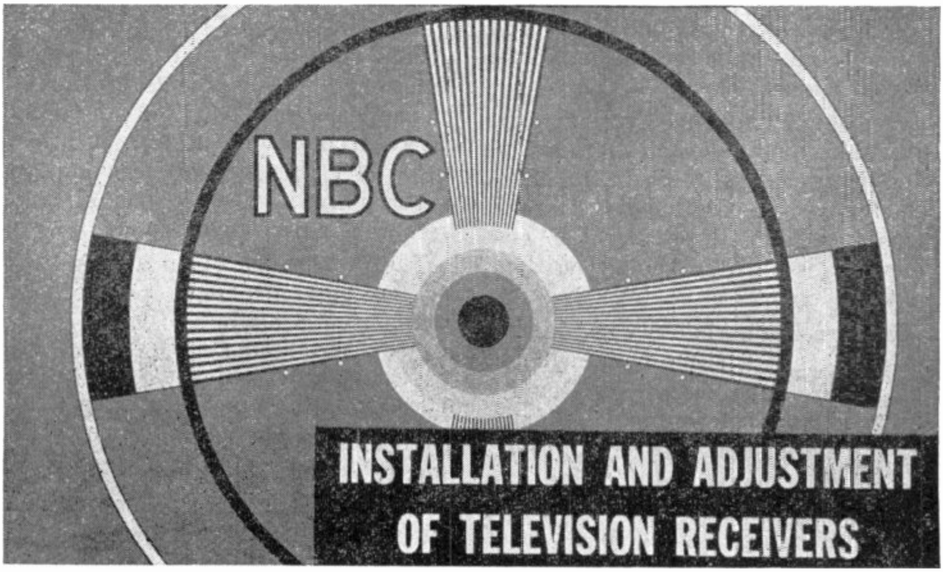


INSTALLATION AND ADJUSTMENT OF TELEVISION RECEIVERS

ALTHOUGH the technical aspect of the installation and adjustment of TV receivers is relatively simple, installation is sometimes a difficult job because it must be done under the watchful eye of the customer. The customer usually demands that the set work as well in his home as it did in the show room, but there are many factors involved in the operation of the TV set that may be different in the show room and in the customer's home. Propagation, interference, line voltage, and lighting conditions may all be different in the home from those in the shop where the customer bought the set; yet it is the serviceman's job when installing the set either to duplicate the quality of the picture the customer saw in the show room or to satisfy the customer that existing conditions make this impossible. This second alternative is apt to be more difficult because most customers have little or no understanding of the many problems involved.

Because of the difficulties just mentioned, it is essential that the serviceman making an installation literally "know all the answers." He must know exactly where all of the controls are located and which controls to adjust for any picture corrections that are necessary, so that he can go about his business briskly and efficiently and make all necessary adjustments in an absolute minimum of time. If too much time is spent in adjustment, the customer is apt to think there is a defect in the receiver and demand that he be given another one.

The customer must also be instructed in the use of the operating controls on the front of the receiver. These instructions must be given in simple, non-technical, understandable language. The serviceman should not leave until he is absolutely sure that the customer knows how to operate the set. After showing him how, the serviceman should have the new owner manipulate the controls to be sure that he knows the purpose of each. If the customer does not know exactly how to operate the controls, the serviceman may be called upon to make unnecessary and unprofitable service calls until the customer does learn.

Over-all Procedure. To insure the least difficulty on installation, a systematic procedure must be followed. The first phase of this procedure is unpacking and inspecting the new television set. This should be done in the shop.

Most receivers come packed in cartons with all of the tubes, including the picture tube, installed. Remove the set from its carton and remove all of the packing material. Next, inspect the set thoroughly for any damage that might have occurred during shipping. Check to see that all tubes are in their sockets and check the connections at the high voltage lead on the picture tube, the speaker plug, and the antenna. After having inspected the set for damaged parts or loose connections and corrected any defects found, you are ready for the second step in the installation and adjustment process.

The initial adjustment of the receiver should also be done in the shop. This avoids a long, time-consuming procedure in the customer's home that might worry him. It also assures you that the receiver will work when you install it in the customer's home; any difficulties will then be caused by external conditions rather than some failure in the receiver.

A third step in the procedure is to deliver the set to the customer's home and install it in a location that is satisfactory to the customer and insures optimum viewing conditions. If possible, it is best to put the set back in its carton when handling it during delivery. This will prevent damage to the cabinet.

The last step in the procedure is a final adjustment in the customer's home and the elimination of any interference that may be caused by external conditions in that location. Generally, this step can be carried out rapidly if the set has already been well adjusted in the shop.

The installation of an antenna for the set may also be a part of the installation procedure. The orientation of the antenna is a part of the last step in the installation procedure, that of readjustment and interference elimination in the customer's home.

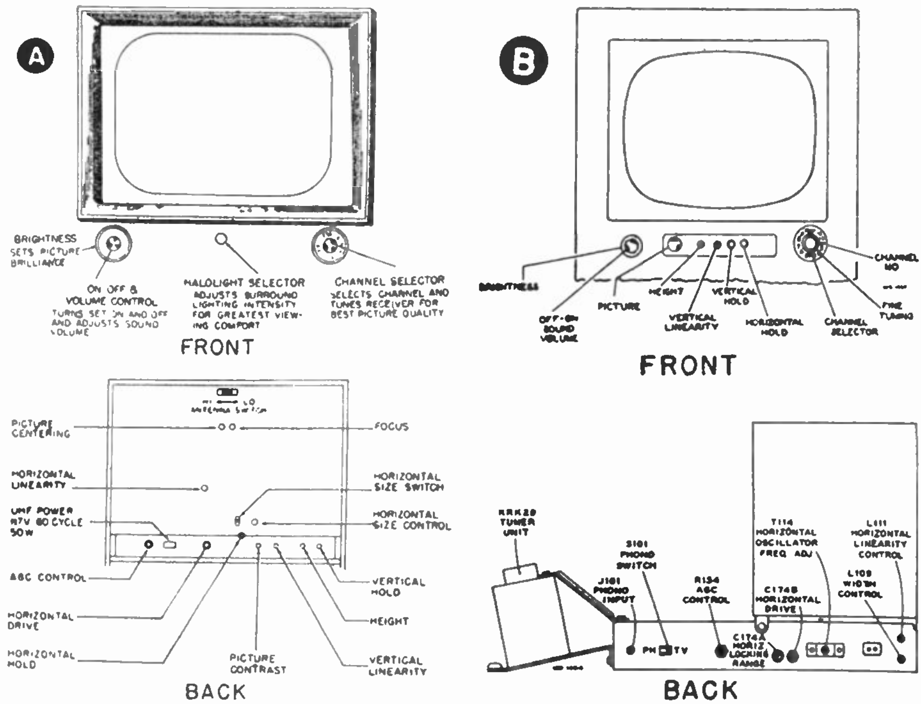
The four steps listed above outline the general procedure for any normal installation. However, there are some special conditions that may make the installation somewhat different, or you may wish to make commercial or custom installations. Before making any installation, you should check to see if there are any special conditions that would require extra equipment or a different type of TV set. If the location in which you are about to install a set has dc power or power of some frequency other than 60 cycles, a special installation might be required. If the installation is in an area where the signal strength is excessive, you may have to attenuate the signal on installing the set. When you are making a commercial installation you may have to hunt down noise sources created by the extra electrical equipment found in taverns, restaurants, etc. It is well to acquaint yourself with all of these conditions as far as possible before delivering the set to the installation site. This may avoid lengthy installation time and possible trips back to the shop for extra equipment needed to meet these conditions.

Adjustments

There are two main types of adjustments found on the modern television receiver. They are the operating controls, those which the set owner manipulates in the normal operation of the set; and the non-operating controls, those which normally are not changed after initial adjustment by the technician installing the set. Table I lists these controls. However, there is some difference of opinion among manufacturers as to which controls should be classified as operating controls

CONTROL	LOCATION	TYPE
Channel Selector	Front	Electrical, Knob
Fine Tuning	Front	Electrical, Knob
Volume	Front	Electrical, Knob
Tone	Front	Electrical, Knob
Contrast or Picture	Front, Front (Under cover), Rear Chassis	Electrical, Knob or Shaft
Horizontal or Horizontal Hold	Front, Front (Under cover), or Rear Chassis	Electrical, Knob or Shaft
Vertical or Vertical Hold	Front (Under cover), Rear Chassis	Electrical, Knob or Shaft
Focus	Front (Under cover), Rear Chassis, or Tube Neck	Electrical, Knob or Shaft Mechanical Focus Coil or Magnet
Brightness or Brilliance	Front, Front (Under cover), or Rear Chassis	Electrical, Knob or Shaft
RF Oscillator Adj.	Front (Under tuning knobs)	Electrical, Slug
Width or Horizontal Size	Rear Chassis	Electrical, Lever Electrical, Slug
Vertical Linearity	Front (Under cover), or Rear Chassis	Electrical, Shaft
Horizontal Linearity	Rear Chassis	Electrical, Slug or Lever
Horizontal Drive	Rear Chassis	Electrical, Shaft or Capacitor
Horizontal Lock or Horiz. Locking Range	Rear Chassis	Electrical, Capacitor
Horizontal Frequency	Rear Chassis	Electrical, Slug
Height or Vertical Size	Rear Chassis	Electrical, Shaft
Sync Stability or Noise Gate	Rear Chassis	Electrical, Shaft or Knob
AGC or Range Finder	Rear Chassis	Electrical, Shaft, Knob, or Switch
Ion Trap	Tube Neck	Mechanical
Picture Positioning Lever (Focus Magnet or Coil)	Tube Neck	Mechanical
Pincushion Magnet	Tube Neck	Mechanical
Deflection Yoke (Tilt Correction)	Tube Neck	Mechanical

TABLE I



Courtesy Sylvania *Courtesy RCA*

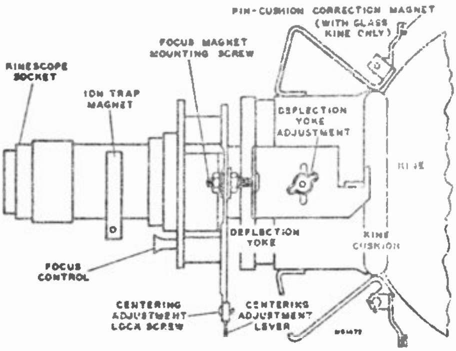
FIG. 1. Two typical arrangements for the location of controls.

and which should be classified as non-operating controls. Therefore, some controls such as focus, brightness, and vertical and horizontal hold are found on the front of the set with the operating controls on some models and on the back of the set with the non-operating controls on others. Of course, the channel selector switch, fine tuning, and volume controls are always classified as operating controls and are adjusted with knobs on the front or side of the set.

There are two possible locations for non-operating controls. Some of them are always on the rear of the chassis; other mechanical adjustments are on the neck of the picture tube.

You are not apt to find all of the controls listed in Table I on any one set, because this table is designed to cover as many models as possible. Some models have more adjustments than others. This table also gives the function, the possible locations, and the type of adjustment for each control. If the location is apt to vary from one model to another, the most likely locations are listed. Under the column headed "type" it is indicated whether or not the control is an electrical or a mechanical device, and whether it is operated by means of a knob, a shaft, a lever, or a screwdriver-adjusted slug. For controls that vary in type from one set to another, there may be more than one listing in the "type" column. Fig 1. shows two typical arrangements for the location of controls. In the Sylvania set, Fig. 1A, the controls on the front consist of the on-off-volume, brightness, channel selector, fine tuning, and surround-lighting controls. All other controls are considered non-operating by this manufacturer and placed either on the rear of the chassis or on the neck of the tube. The arrangement shown in the RCA set in Fig. 1B is becoming more popular. Here, some of the controls that used to be considered non-operating controls have been brought up to the front of the set and hidden under a hinged cover. Thus, the adjustments indicated can be made from the front of the set by the owner while watching the picture. Fig. 2 shows the location of controls on the neck of the picture tube.

As we have already mentioned, the initial adjustment of a new television set should be made in the shop. Once the set has been well adjusted in the shop, you know that the set itself is in good operating condition and any failure to operate properly in the customer's home when it is delivered is generally caused by conditions existing at that location.



Courtesy RCA

FIG. 2. Top view of a typical picture tube (kinescope) neck, showing adjustments.

Therefore, the only adjustments that need be made in the customer's home will be those necessary to adapt the set to conditions there.

In addition to adjusting new sets, you will often be called upon to readjust old sets, because many component parts in a television set slowly change value as they age. An adjustment check should be standard practice after every repair. If the set has been adjusted to compensate for the slow change in value of a part as it ages and then that component finally breaks down and you replace it, obviously, readjustment will be required. Making sure that every set that leaves your shop or that you leave in the customer's home is well adjusted will save you many profitless service calls.

Adjustment Procedure. In general, adjustments are made in accordance with the requirements indicated by the picture that appears on the tube. However, for new sets, a logical and systematic procedure should be followed to check all adjustments before the set is delivered to the customer. For readjustment and adjustments after repairs, only those indicated by the quality of the picture need be made.

The first step in the adjustment of a new receiver, after it has been unpacked and visually checked for any damage or defects, is to turn the set on and get as good a picture as possible with the operating controls. From this picture you can generally tell what non-operating controls are most in need of adjustment; some adjustments should be made in any event. The rf oscillator slug for each channel received in the area, the ion trap, and the agc control should be adjusted regardless of the quality of the picture received, before making any non-operating adjustments. After the non-

Courtesy Philco

FIG. 3. Maladjusted brightness control might result in a picture like this.

operating adjustments and the regularly required adjustments for a new set have been made the non-operating adjustments that position the picture should be made if necessary. These are usually on the neck of the picture tube.

After you have made the necessary adjustments to the components on the neck of the picture tube, you should adjust the non-operating controls on the back of the chassis. However, this procedure is not rigid beyond the dictates of common sense. If, for instance, you cannot get a synchronized picture with the operating controls, obviously you must adjust some of the non-operating controls at least until you can get a picture. In general, the following sequence of adjustment can be followed when adjusting a new set for delivery:

1. Operating controls.
2. Non-operating controls as required for a steady picture.
3. Ion trap. (To avoid damaging the picture tube this adjustment must be made as soon as possible after turning the set on.)
4. RF oscillator slugs.
5. Picture positioning and size controls.
6. Other non-operating controls for optimum picture quality.

The theory of operation of most of the adjustment controls has been discussed in previous lessons. Therefore, they will not be discussed again in any great detail. Our main concern here is to observe the effect of the various controls on the picture, without going into the details of the circuitry which causes that effect.

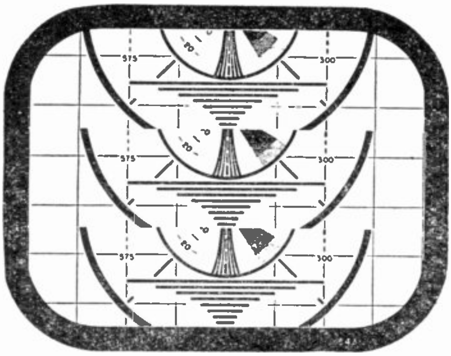
The function of many of the controls found on television sets is obvious from their labels. However, there are others whose function is not necessarily obvious. All controls are discussed here in terms of their function.

Courtesy RCA

FIG. 4. Maladjustment of the focus coil or focus control will produce a blurred picture.

GETTING A PICTURE

The first step in the adjustment procedure is to connect an antenna, plug in the set, turn it on, and select a local channel with the channel-selector switch. Turn the volume and contrast controls to normal levels and turn the fine tuning to the point where the best picture is obtained. On some new sets this is all that will be required to obtain a reasonably good picture. However, as we have already said, there are some adjustments that must be made, and most of the others should be checked



Courtesy Belmont Radio Corp.

FIG. 5. Maladjustment of the vertical hold produces a picture like this that runs up or down at a rate that depends upon how severe the maladjustment is.

just to make certain that they are working and will operate properly if adjustment is required when the set is in the customer's home.

It is possible that you will not be able to get any picture at all with the operating controls, particularly if they do not include the brightness control. If you can get no picture by manipulating the tuning and contrast controls, turn up the brightness control until there is a picture or at least a raster on the face of the tube. If no raster appears on the tube, the ion trap may be so far out of adjustment that the electron beam is not striking the face of the tube. Whether there is raster or not, the next step in the adjustment procedures should always be to adjust the ion trap. If this is not done promptly, damage to the tube might result.

To summarize the first step in adjustment, the operating controls, and those that are sometimes considered operating and sometimes non-operating, are listed here with brief instructions for their setting.

1. On-Off control. The On-Off switch is usually a part of the sound volume control. Turn this knob until the switch clicks on and then set it for a comfortable listening level.

2. Channel selector switch. Set for desired channel.

3. Fine tuning control. Rotate until best picture is obtained.

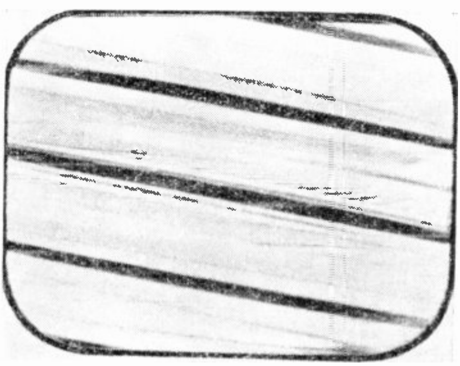
4. Contrast control. Adjust for most pleasing difference between light and dark areas.

5. Brightness control. Adjust for most pleasing level of brightness. Fig. 3 shows the effect of a misadjusted brightness control.

6. Focus control. After fine tuning control has been adjusted for best picture, adjust the focus control for clear, sharp picture detail. Fig. 4 shows the effect of a misadjusted focus control. Focus may be adjusted with an operating control from the front, a non-operating control at the rear, or by repositioning the focus coil or magnet on the tube neck.

7. Vertical hold. Stops picture from rolling up or down. Adjust until the picture moves slowly up and stops. See Fig. 5.

8. Horizontal hold. This control stops the picture from tearing or slipping horizontally. Adjust to the point at which the picture does not tear or slip when switching from one channel to another. See Fig. 6.



Courtesy RCA

FIG. 6. Maladjustment of horizontal hold may produce a picture like this.

ADJUSTING THE PICTURE

Ion Trap Adjustment. The ion trap must be adjusted quickly to produce a visible raster on the face of the tube. If this is not done promptly after the set is turned on, the second anode of the picture tube (which is struck by the electron beam until the ion trap is properly adjusted) may be seriously damaged or ruined. To make this initial adjustment of the ion trap magnet, rotate it or slide it back and forth a short distance until at least a fairly bright raster is produced on the face of the tube.

To adjust the ion trap magnet, set the brightness control for normal brightness or maximum brightness if a normal level cannot be reached. Move the magnet back to the base of the tube neck, then move it forward, rotating it slightly in either direction until maximum brightness is reached. Reset the brightness control for normal brightness, and adjust the focus control for good focus. Then readjust the ion trap magnet for maximum brightness.

There may be two points of maximum brightness. If so, use the setting nearer the tube base.

If the corners of the picture are shaded, be sure that the ion trap has been properly adjusted for maximum brightness, but do not sacrifice picture brightness to remove corner shading. The elimination of shaded corners will be discussed in a later section.

RF Slug Adjustment. Although tuning the oscillator slug may seem to be rightfully a part of the alignment procedure rather than of adjustment, when preparing new sets for delivery a check of this adjustment should be made. By making this check before proceeding with any further adjustments, you will make sure that you are not trying to compensate for misalignment of the rf section with other controls.

To make this adjustment, set the channel-selector switch to the desired channel and the fine-tuning knob midway in its range. On most sets, this adjustment is made through a hole underneath the channel-selector switch and fine tuning knob. Therefore, remove them and, with a nonmetallic alignment tool, adjust the slug for best picture. Only a slight rotation of the slug will usually be required. Be careful not to turn it too far, or it will fall out of the coil. Be sure to tune for best picture rather than maximum sound—these may not be at the same point. This adjustment must be made for each channel to be received.

The procedure outlined above can be used only for receivers having turret type tuners. Most modern receivers use this type of tuner. Sets using different tuners do not generally require this adjustment.

AGC and Sync Stability or Noise Gate Controls. Some sets have non-operating agc controls and noise gate controls. The first usually determines the amount of agc that is developed and fed back to the rf and i-f amplifiers. This control often goes under a different label. It may be labeled "DX range finder" or "Local-Distance" or some other name that would indicate that it is to be adjusted under abnormal signal conditions. On some sets the agc control consists of, or is used in conjunction with, a switch that will completely eliminate the agc voltage when switched into the "distant" position.

The noise gate control adjusts the bias on a grid in a combination sync separator and noise limiter tube. This control may be set to improve sync stability in fringe areas or noisy local areas. Both of these adjustments should be made for optimum picture quality and stability on all channels to be received. Both settings should be kept as low as possible to get a satisfactory picture.

Focus and Picture Positioning Controls. Adjustments for properly positioning the picture on the face of the picture tube are usually on the neck of the tube. They consist of some means of changing the position of the focus coil and deflection yoke.

Focus. You may consider the focus coil as a sort of nozzle that directs the stream of electrons flowing through the neck of the tube. The nozzle is opened or closed by decreasing or increasing the amount of current flowing through the coil. Thus, where focus is an electrical adjustment, it usually consists of a potentiometer that controls the current flow through the coil. Focus may also be a mechanical adjustment. When this is the case, the focus control is a non-operating control that changes the position of the focus coil on the tube neck. In other words, the nozzle cannot be opened or closed, but it can be moved closer to or farther from the screen.

Where focus is a mechanical adjustment, a permanent magnet is often used instead of a coil.

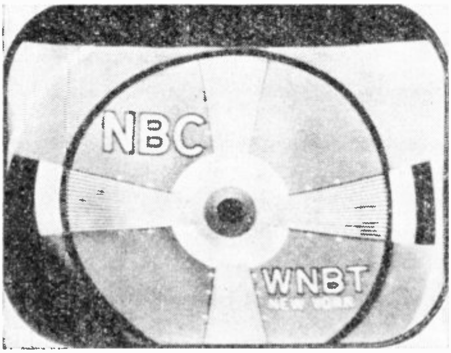
Focus should be adjusted by carefully observing the scanning lines in the raster on the face of the picture tube. When the focus is properly adjusted there is maximum distinction between the scanning lines and the spaces between them. If the adjustment is electrical, slowly turn it first in one direction and then the other until the point of maximum distinction is reached. If focus is mechanical, the same procedure applies, except that the adjustment will consist of moving the coil or magnet back and forth on the neck of the picture tube. The back-and-forth motion of the coil is often accomplished by turning a flexible shaft, which is terminated in a screw threaded through a tapped hole in the magnet assembly. When the shaft is turned, the focus magnet rides back or forward on the screw, depending on the direction of shaft rotation.

Vertical and Horizontal Position. It is obvious, when you consider the focus coil as a nozzle, that it can control not only the concentration of the electron beam, but also the direction. Therefore, the focus coil is used to position the picture on the screen.

In many sets the picture is moved by tilting the focus coil up or down or from one side or the other as required to center the picture. However, it is not essential to move the coil itself, if you can change the position of its magnetic field. Some sets have a metal plate mounted on the front of the focus coil which can be moved up, down or sideways to change the shape of the magnetic field through the neck of the tube the same as actually tilting the coil would. In any event you will usually find a picture positioning lever on the neck of the tube, which you will manipulate until the picture is centered. It may be necessary to refocus the picture after it has been positioned.

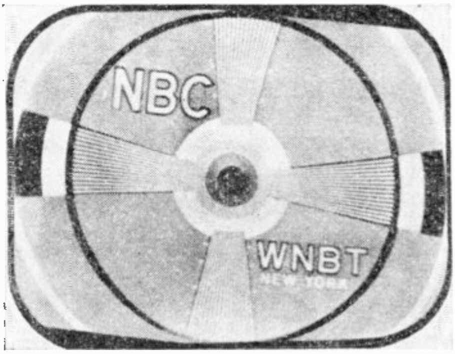
Whenever the picture position is adjusted, the ion trap should be readjusted as already described. If corners of the picture remain shaded after you have readjusted the ion trap (see Fig. 7), move the deflection yoke assembly as far forward as possible, then readjust the ion trap.

Picture Tilt. If the picture is not square on the face of the tube (see



Courtesy RCA

FIG. 7. Incorrect adjustment of the ion trap magnet and focus coil. Note shaded lower left-hand corner.



Courtesy RCA

FIG. 8. A tilted picture of this kind means that the deflection yoke is rotated from its correct position.

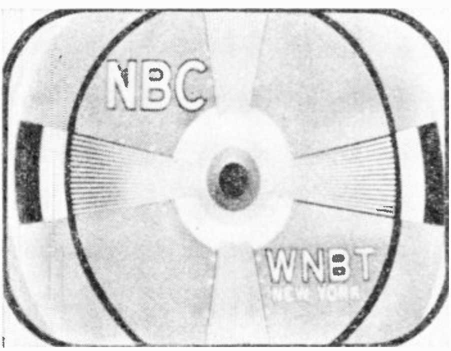
Fig. 8), square it by rotating the deflection yoke assembly in the proper direction. Always readjust the ion trap after making any other adjustments on the neck of the tube.

Picture Size Adjustment. Width and height adjustments are provided to make the picture fit the viewing mask. These adjustments should be made with the set in the cabinet so that the picture fits the mask rather than the tube.

If the picture is of incorrect height, adjust the *height* or *vertical size* control, whichever it is called, until the picture fits the mask vertically. It will be necessary to adjust *vertical linearity* and height at the same time. If the top or bottom of the picture is cramped or flattened, the vertical linearity should be adjusted. Fig. 9 shows a test pattern of incorrect height, and Fig. 10 shows a test pattern in which the vertical linearity is maladjusted.

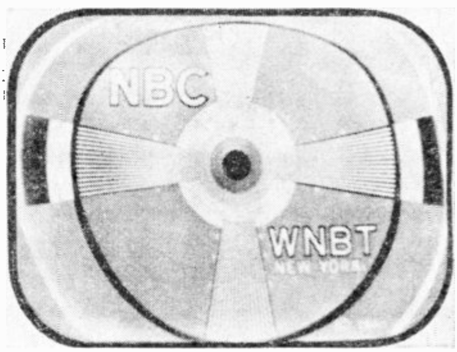
When vertical linearity is off, it is usually necessary to adjust the vertical linearity and height controls alternately until the picture is linear and fits the screen.

If the picture is too wide or too narrow there are three controls to be adjusted: horizontal drive, horizontal linearity and width. First, adjust the horizontal drive control until the picture is as near as possible to the



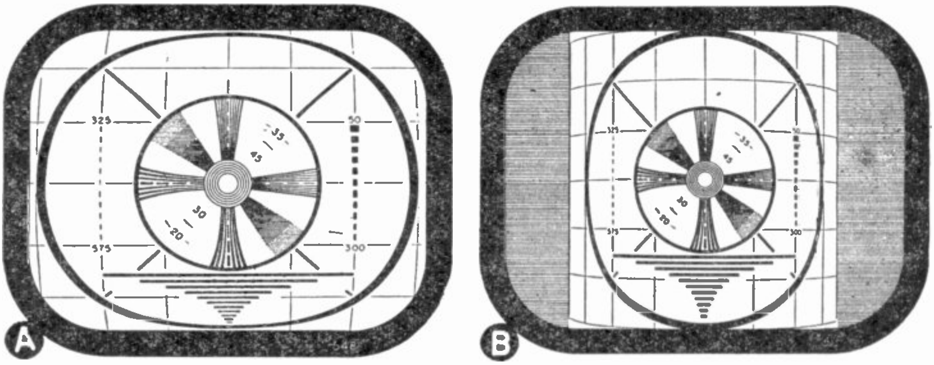
Courtesy RCA

FIG. 9. Incorrect height adjustment may make the picture too high.



Courtesy RCA

FIG. 10. Maladjustment of the vertical linearity control may give this effect.



Courtesy Belmont Radio Corp.

FIG. 11. Picture too wide (A), and too narrow (B).

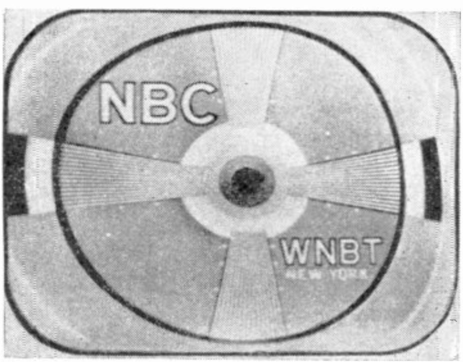
correct width. (Fig. 11 shows pictures that are too wide and too narrow.) Next, adjust the horizontal linearity control to correct for any cramping at one side or the other of the picture. (A non-linear picture is shown in Fig. 12.) Adjusting the linearity is apt to affect the width of the picture. Use the width control to readjust the picture to proper width. If a vertical white line (see Fig. 13) appears in the picture, readjust the drive control until the line disappears. If necessary, readjust the width and linearity controls alternately until the picture is linear and fits the mask.

Replacing the Picture Tube. When a picture tube is replaced the ion trap, focus coil or magnet, and deflection yoke must be adjusted. In addition to these adjustments there are some precautions that must be observed.

When procuring a replacement picture tube you must be sure that the new tube has the same physical dimensions as the old one. It must also use the same type of ion trap and have the same deflection angle.

Removing the picture tube. Most TV sets in use today have the picture tube mounted completely on the chassis with no mechanical connection to the cabinet. To remove the picture tube from the chassis proceed as follows:

1. Remove the tube socket from



Courtesy RCA

FIG. 12. Incorrect adjustment of horizontal linearity control.

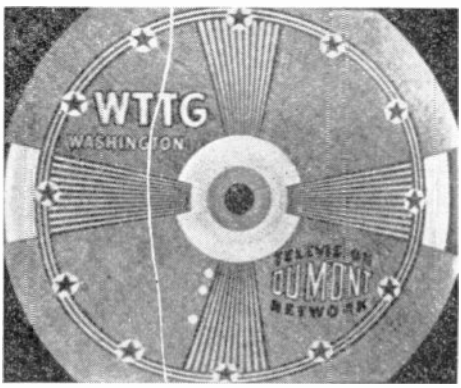


FIG. 13. Vertical white line indicates the need for horizontal drive adjustment.

the tube base. (If the socket is rigidly mounted on the chassis, omit this step.)

2. Remove the ion trap.

3. Remove the strap that holds the front of the picture tube to the chassis.

4. Remove the picture tube from the chassis by pulling it straight out from the front of the chassis so that no strain is placed on the neck of the tube.

Installing the picture tube. To install the picture tube, proceed as follows:

1. Carefully insert the neck of the picture tube in the deflection yoke assembly and push the tube into place.

2. Install the strap over the front of the tube, but do not tighten.

3. Push the tube back so that the flare of the tube fits snugly against the deflection yoke assembly, and tighten the strap while holding the tube in this position.

4. Place the ion trap all the way back, next to the tube base, on the neck of the picture tube.

5. Connect the tube socket to the tube base.

6. Turn the set on, and adjust the ion trap.

7. Adjust focus, and position the picture.

8. If corners of the picture are shaded, check to see that the deflection yoke fits firmly against the flare of the tube. If it does not, re-position the yoke and readjust the ion trap.

Horizontal Oscillator and Drive Adjustment. Both *horizontal hold and horizontal lock* adjustments have some effect on the frequency of the horizontal oscillator and hence affect horizontal synchronization. The *horizontal drive* control determines the amplitude of the signal sent from the horizontal oscillator to the horizontal amplifier. Since there is some interaction between the horizontal lock and horizontal drive controls, the adjustment of these controls is often combined in one procedure, and the need for their readjustment is determined by the response of the *horizontal hold control.* Generally speaking, you should be able to rotate the horizontal hold control through a minimum of half its range without the picture going out of sync. If you cannot do this, it is a reasonable indication that the horizontal lock needs adjustment.

Each manufacturer recommends a specific procedure for horizontal oscillator adjustments which should be followed. However, the procedure given here may be considered one that is generally applicable to most receivers.

Throw the picture out of sync by turning the horizontal hold control all the way to the left, the horizontal drive control (this may be a potentiometer shaft or a trimmer capacitor screw) fully to the right, and the horizontal lock adjustment to the right until the picture falls out of sync when the channel-selector switch is switched from one channel to another. With the picture out of sync, turn the horizontal lock control slowly to the left until the picture falls into sync. If a vertical white line appears on the picture, as in Fig. 13, turn the horizontal drive control to the left until the line disappears. If necessary, readjust width and linearity. Check the horizontal adjustment by rotating the horizontal hold control to see that the picture will stay in sync when switched off channel and on again, through at least half the range of the horizontal hold control.

Correction or Pincushion Magnets. Television sets with large screen picture tubes often have small magnets mounted just forward of the deflection yoke to compensate for pincushion effect (curvature of the sides of the picture or corners of the picture bent inward). A picture or test pattern having straight vertical lines near the edge of the picture is best for making this adjustment. These magnets may be adjusted individually to compensate for curvature on whichever side of the picture it occurs. To adjust the magnet, it is best to start with it in back close to the deflection yoke and move it slowly forward until the curve near the side of the picture is minimized. If the magnets are moved too far forward, the corners of the picture will bend inward and become shaded. If they are too far back, the sides of the picture will curve.

Installation

Once the set has been thoroughly checked and carefully adjusted in the shop, you are ready to install it in the customer's home. This procedure includes connecting the set to its permanent antenna and orienting the antenna to produce the best possible performance.

The first step in making an installation is, of course, to take the set from the shop to the customer's home. If the shop is a moderately large one, it will usually have delivery men to do this, with the installation crew coming to the customer's home after the set has been delivered. In small shops the installation crew may also make deliveries.

Special precautions should be taken in transporting a receiver from the shop to the customer's home. As far as possible, it should be kept level at all times to prevent any of its parts from shifting position. To prevent its finish from being damaged, the set should be handled like any other piece of fine furniture. It should be protected by quilted pads while it is in the delivery truck, and it should be held by bands or ropes to keep it from shifting around or perhaps falling over while the truck is moving.

INSTALLING THE RECEIVER

The location of the set inside the home is, of course, up to the customer. If he chooses a very poor location, however, you should point out the disadvantages of the location in a tactful manner and suggest a better one. Remember, if the customer gets eye strain from watching a set that is in a poor location, he will be apt to blame the set rather than its position.

Lighting. In general, a set should not be placed so that a bright light (such as from a window or from lamps) is behind it or near it, as at A in Fig. 14. The eye will automatically adjust itself to the brightness level of the bright light rather than to the brightness level of the picture, with the result that the picture will seem dark. Neither should the set be located so direct rays of a light can fall upon the face of the picture tube, as at B in Fig. 14. If they do, the apparent contrast and brilliance of the picture will be reduced, and there may be reflections and glare from the tube face and from the protective glass in front of the tube. Preferably, the set should

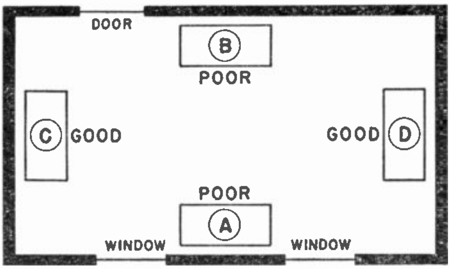


FIG. 14. Two good and two poor positions for a television set. Position A is poor because the bright light from the windows will distract the eye; position B is poor because light from the windows will be reflected from the cover glass and the picture tube.

be located so that the direct rays of any light entering the room will be at right angles to the line of vision of the person watching the set. Hence, from a lighting viewpoint, positions C and D in Fig. 14 are good.

To make viewing easy on the eye over extended periods of time, the room in which the set is located should be well lighted from some indirect source. Ideally, the surfaces near the set should be almost as brightly lighted as the middle or darker grays of the scene on the picture tube. One set manufacturer helps solve this problem by encircling the picture with an illuminated tube called "Halo Light." The intensity of the light from this tube can be controlled by the set owner so that, to some extent, ambient light conditions are built into the set and may be adjusted for maximum viewing comfort. A complete absence of light in the room other than that from the picture on the television screen is very hard on the eyes.

The set should also be placed so that none of its viewers will have to watch the picture at too great an angle. A typical good location both from a lighting and a seating viewpoint is shown in Fig. 15. People sitting on the sofa or the chairs have a good view of the face of the set.

During the day, light from the windows will illuminate the room without lighting the face of the picture tube too much, particularly if venetian blinds are installed on the windows. At night, light from the adjacent room may be allowed to come through the door, or indirect light sources may be fastened on the wall in which the door is set. This arrangement is therefore good both from the standpoint of furnishing light at right angles to the line of vision and from that of placing all viewers at some reasonable angle with respect to the picture tube. You must bear in mind, however, that you will rarely find the ideal conditions pictured here unless the set owner sets aside one room of his house exclusively for television viewing. Usually the set will be installed in the living room where many other activities take place. Therefore, location will have to be a compromise between the best viewing conditions and furniture arrangement and family living habits.

Ventilation. Always keep in mind the fact that many components in a set may prove unstable or may deteriorate rapidly if they are subjected to excessive heat. Since the set becomes quite warm in normal use,

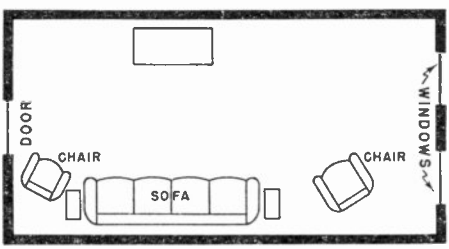


FIG. 15. A good room arrangement for watching television. All light sources are approximately at right angles to the line between the viewers and the set.

it should be located so that it can have enough ventilation. It should not be placed close to radiators or other sources of external heat, nor should any ventilation holes in the receiver cabinet be blocked by doilies or scarves. It should be several inches out from the wall to allow heat to escape through the back.

If the set is a table model and has ventilation holes in the bottom, as many do, be sure that the table is strong enough to hold the set and that the ventilation holes will not be blocked.

The proper height for a table model set depends somewhat on the furniture in the room. With ordinary living room furniture, the center of the tube face should be about forty inches from the floor. If the furniture is very low, however, the set should be somewhat lower than this so that it can be watched comfortably.

Viewing Distance. One other factor that should be considered is the distance from the set to the chair or sofa from which it will be watched. The optimum viewing distance for each size of picture is equal to 6 to 8 times the height of the picture. Table II lists the best viewing distances for pictures of different sizes. The viewing distance may be greater or less than the optimum distance, of course, but it is desirable to place the set so that most of the seats will be somewhere near the right distance for the picture size.

Perhaps you feel that it is not really the business of the installer of the set to determine where it should be placed. Remember, however, that a television set is not like a radio receiver; it cannot be moved about a room readily, because its location is more or less fixed by the placement of the transmission line. Therefore, if it

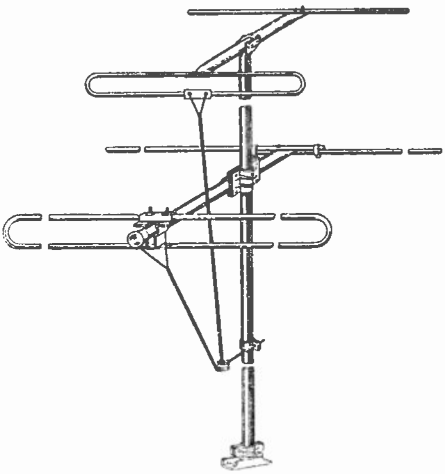
Picture Tube Size	Approximate Viewing Distance
12 inches	4 ft.— 5½ ft.
14 inches	4½ ft.— 6½ ft.
16 inches	5 ft.— 7 ft.
17 inches	5 ft.— 7 ft.
20 inches	8 ft.—11 ft.
30 inches	11 ft.—15½ ft.

TABLE II

turns out that the customer is not satisfied with the location of his set, he will either call you back to change it or attempt to do the job himself—and in the latter case he may damage the set or the transmission line. A poor location for the set may therefore result in your getting a call-back that could have been avoided if you had placed the set in a better location in the first place. If the customer has a service contract with you or your firm, he will expect you to change the location of the set free of charge. Therefore, you will be better off to see that the set is in a good location from the start.

INSTALLING THE ANTENNA

Once the location of the receiver has been selected and agreed upon, the next step is to install the antenna, connect it to the set and orient it for best reception on all stations to be received. If you are working in a strong signal area, this step will often be eliminated because indoor antennas will give satisfactory reception and the improvement obtained by using an outdoor antenna would not justify the added expense to the customer. If an indoor antenna is used, you need only connect it to the set and find its length and position of best reception for the various channels received. Be sure that the customer knows how to adjust the indoor antenna for best reception.



Courtesy Technical Appliance Corp.

FIG. 16. A typical two-band television antenna.

Where an outdoor antenna is required, antenna installation and orientation is somewhat more complicated and requires a crew of at least two men. The general procedure for installing an outdoor antenna is first to select a good location and mount the antenna so that it is held securely in place but the mast is not clamped down so tight that it cannot be rotated. The transmission line should be permanently connected to the antenna at this time, but not clamped to the mast; only a temporary connection to the receiver should be made.

The next step is to orient the antenna for optimum reception on all channels that are available in the area. At the same time this is done, the final adjustments to the receiver can be made as required.

The final step is to clamp the antenna permanently in the best position found during orientation, secure the transmission lines with stand-off insulators, and make a permanent connection to the set.

Erecting the antenna. The type of antenna that you put up will usually be a compromise between what the signal conditions demand and what the customer is willing to pay for. In a previous lesson you learned the characteristics of the various types of antennas, and from that knowledge you should be able to select the most suitable antenna for a given signal condition. Probably the most common type of installation will consist of a mast mounted on some part of the roof or chimney with a high and low band antenna on the mast. Of course, there are some instances where an expensive tower installation or a long mast with guy wires may be necessary and others where only one antenna is required on the mast, but the two antennas mounted on a single mast which is attached to the roof of the house is probably the commonest type of installation. Therefore we will describe such an installation briefly here.

A typical two-band television antenna is shown in Fig. 16. Such an antenna is usually of fairly light construction and the mast will be either aluminum or thin-wall conduit, so that if the mast is not over six or eight feet long the whole thing can be assembled on the ground and then pulled up to the roof for installation. The first step would be to assemble the antenna as shown in Fig. 16, with one exception. Do not tie the transmission line connecting the two antennas down tightly with a clamp as shown. This line should be permanently connected to both antennas, but the clamp should not be added until both antennas have been oriented.

Also permanently connect one end of a reel of transmission line to the antenna while it is still on the ground.

The next step is to raise the antenna to the roof. This usually requires a minimum of two men. Tie two ropes to the antenna assembly; one at the top for a man on the roof to use to pull it up, and the other somewhere near the bottom for the man on the ground to use to hold it away from the wall of the house. Arrange the reel of transmission line so that it will reel off freely as the antenna is pulled up to the roof. Be careful not to damage or bend the folded dipoles or reflectors, which are made of much lighter tubing than the mast or the cross sections.

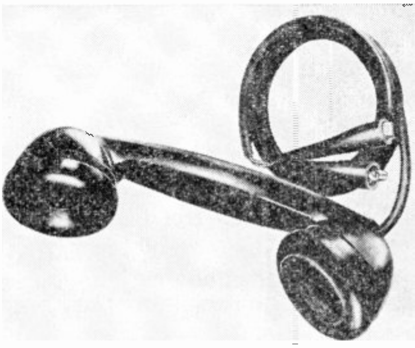
An alternative to assembling the antenna on the ground is to take all the various parts to the roof where the antenna is to be mounted, and assemble it there. This could be done by one man, but frequently the shape of the roof at the installation site is such that it is very inconvenient, if not impossible, to work on the roof with both hands free. The fewer tools the man on the roof has to handle, the fewer he will drop and have to climb back down for or have brought back up to him.

Once the antenna is mounted on the roof with any of the standard clamps that are made for the various types of mounting, tighten the clamp just enough to hold the antenna in place temporarily, because you will have to rotate the mast when orienting the antennas. After mounting the antenna temporarily, decide what route the transmission line will take to the receiver and measure off enough line to reach the receiver. Be generous; it is better to waste a few feet of transmission line when the line is finally clamped down and permanently installed than to have to make a splice in the line. When the antenna is temporarily installed and the transmission line is connected to the receiver, you are ready to orient the antenna.

Orienting the antenna. The antenna must be oriented to produce the best possible reception from each of the stations in the vicinity. If the antenna is equipped with a rotator, of course, finding the right orientation is no problem; the customer will turn the antenna to bring in the best picture each time he tunes in a different station. If the antenna is to remain in one place, however, it must usually be carefully oriented before the installation is completed so that the reception on all stations will be equally good.

Orientation of the antenna is generally a two-man job. There must be one man on the roof to turn the antenna, and there must be another at the receiver to watch the effect of turning it. These two men must have some way of communicating with each other so that the man turning the antenna can learn what happens when he turns it. A telephone like that shown in Fig. 17 is frequently used for this purpose.

This particular telephone is sound operated. A sound-operated telephone is equipped with a high-output magnetic microphone that is capable of operating a telephone receiver over a considerable distance without ampli-



Courtesy Wheeler Insulated Wire Co., Inc.

FIG. 17. A sound-powered telephone handset.

fication. The chief advantage of such phones is that they require no external power source. Conventional battery-operated telephones are, of course, perfectly usable.

Some installation crews clip their sound-powered telephones across the ends of the transmission line, thus saving themselves the trouble of having an extra inter-connecting line between the antenna position and the set position. However, connecting the telephone across the line may affect the characteristics of the line and thus impair the quality of the picture, thereby making it difficult to judge how good the picture is. For this reason we recommend that you have a separate connecting line between the two telephones.

There are many possible systems you can use to find the right orientation for the antenna. The one we are going to describe, however, is easy to follow and has proved to be very satisfactory.

Note in Fig. 16 that the high-frequency antenna is so connected to the mast that it cannot be rotated without turning the mast. Therefore, you should orient the high-frequency antenna first by turning the mast. Then you can orient the low-frequency antenna by rotating the antenna assembly on the mast. Even if the high-frequency antenna were clamped to the mast so that it could be turned without turning the mast, this is still the best method, because it would be difficult to reach up through the low-frequency assembly and turn the high-frequency antenna.

Let us assume that you are the man turning the antenna. First, orient the antenna so that it faces north (that is, points its rods east and west), and have your assistant at the receiver tune in the lowest frequency station that can be received in the high-frequency band (channels 7 to 13). Then have your assistant describe the quality of the picture to you as you rotate the antenna. For example, as the antenna is rotated, your assistant may make a report something like this: "Faint picture. Getting better—better—good picture—getting worse—no picture."

You must keep a record of picture quality versus antenna position as you rotate the antenna. A convenient way to do so is to use a chart like the one shown in Fig. 18. Mark a heavy line on the chart to represent the direction the antenna is turned when the reception is reported to be good, and make a broken line to show those directions in which the picture is reported to be poor or non-existent. If the picture is reported to have ghosts in it, draw a wiggly line to show the directions in which the ghosts appear.

After you have made a complete rotation of the antenna in this manner, you will have a chart that shows how well the antenna receives that particular station in all of its possible positions. Next, repeat the process with the station next higher in

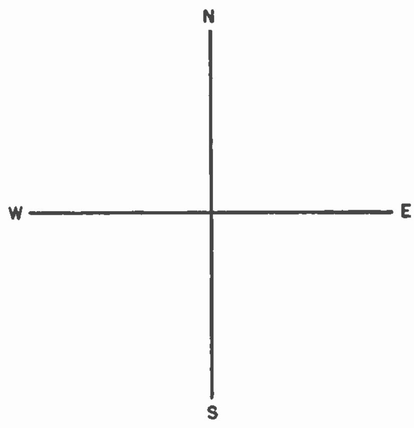
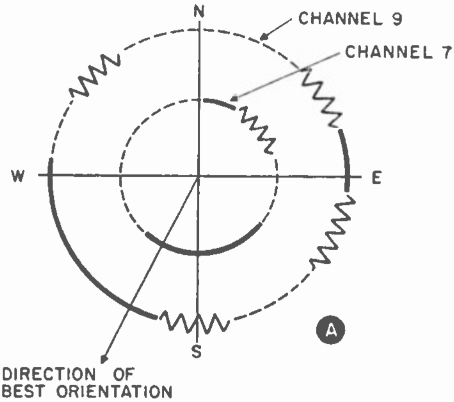


FIG. 18. Use a simple chart of this sort to help you determine the best orientation.



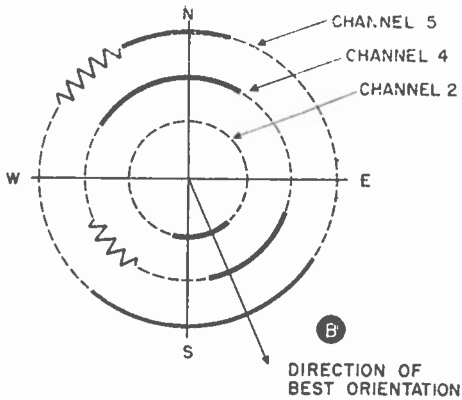


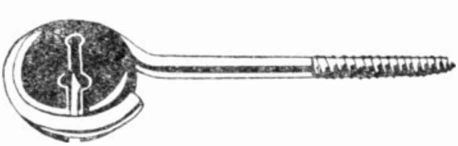
FIG. 19. Completed orientation charts for high band (A) and low band (B) antennas.

frequency tuned in. Draw another line outside the first one to show how well the second station is received. If there are more than two stations, repeat the process again for each.

Let us assume that only channels 7 and 9 are to be received on the high band. Fig. 19A shows what the completed chart for the high-frequency antenna might look like. If this were the chart that you obtained, you would rotate the mast until the high frequency antenna faced slightly south of southwest, have your assistant check reception on both channels and, if reception is good, tighten the clamp on the mast so that it is permanently mounted in this position. Once the high-frequency antenna is oriented, you must repeat essentially the same process to orient the low-frequency antenna, but this time you rotate the antenna on the mast. Fig. 19B shows what the orientation chart for a low-frequency antenna receiving channels 2, 4, and 5 might look like. If you were to obtain a chart that looked like this, you would rotate the antenna until it faced about halfway between south and southeast, have your assistant check reception on all three channels, and then tighten the clamp holding the antenna on the mast so that the antenna is permanently mounted in this position.

Once the antenna itself is mounted permanently in its proper position, you are ready for the final step of the installation, securing the transmission line and permanently connecting it to the receiver. If unshielded transmission line is used, it should be spaced out from the mast with a stand-off insulator as shown in Fig. 16. Similar stand-off insulators are available for running the line down the side of the house, as shown in Fig. 20.

The transmission lines should be led as directly as possible from the antenna to the receiver. Unshielded twin-lead line should be twisted once every foot, to reduce pickup of local interference; shielded line can be run straight.



Courtesy Phoenix Electronics, Inc.

FIG. 20. Stand-off insulator for twin-lead line.

Whenever possible, it is advisable to bring the line in through the basement and through the floor in back of the set. This will make it unnecessary to run long lengths of line through the house. To make an installation of this sort, the line may be brought down the side of the house to a basement window. You can then drill the casement of the window and bring the line in through it. Just before the line is brought into the house, a lightning arrester should be connected to it. You can then bring the line over from the window to the point where the hole is drilled in the floor at the rear of the set.

The owner may prefer the transmission line to be brought directly into the room in which the set is located without going through the basement, or the installation may be made in a house that has no basement. If so, bring the line through a hole drilled in the casement of the window, mounting the lightning arrester outside the window. From the window, lead the line along the baseboard to the set. If it is a shielded line, secure it to the baseboard with staples; if it is unshielded twin lead, you can drive fiber-headed tacks through the center of the insulating ribbon to secure it.

Whenever you drill a hole through the casement of a window to bring a transmission line through, be sure to slant the line downward from the inside of the house. This will prevent rain from coming in along the line.

It may be possible to bring unshielded twin lead in between the two halves of the window. This will make it unnecessary for you to drill a hole through the casement.

A shielded line can be secured to the side of the house without fear that its characteristics will be changed thereby. Unshielded twin-lead line, however, should be fastened to the house with stand-off insulators. The type shown in Fig. 20 is well suited to this use. If the house has masonry walls, you must drill holes and insert plugs in them for the screws.

The location of the transmission line with respect to its surroundings is often important. In addition to being run as directly as possible from the antenna to the set, the line should also be removed as much as possible from sources of interference. For example, a transmission line brought down the back of a house away from the street is much less likely to pick up ignition interference than one that is brought down the street side of the house. It is also wise to make sure that the transmission line is not in some location where it can be damaged easily—in particular, it should be kept out of reach of children.

FINAL ADJUSTMENT

After the antenna has been installed, oriented, and permanently connected to the receiver, you are ready for the last step of the installation process—final adjustment. If a thorough adjustment was made at the shop before the receiver was delivered, the final adjustment will be simply and rapidly accomplished. There are two general types of adjustment that will have to be made. The first is readjusting controls that might have slipped or been knocked out of adjustment in the handling of the set. For example, the ion trap may slip a bit. The second is making those adjustments that help compensate for signal conditions which may differ at the installation site from those that existed at the shop. These are usually agc and sync stabilization adjustments.

Any interference that shows up should be eliminated at this time. The problem of interference elimination is discussed in another section of this lesson.

As a final performance test, check reception on each station to be received. The set should be thoroughly warmed up before you make this check.

After the foregoing checks and adjustments are made, the only thing that remains to be done is to make sure that the customer knows how to operate the set.

Customer Instruction. When the installation has been completed, you must show the customer exactly how to operate the set. If the manufacturer supplies a customer manual, see that he gets a copy. If the customer has never owned a television set before, have him tune in each station to make sure that he knows how to adjust all the controls. Don't just show him how the controls should be adjusted—show him the effect of maladjustment of a control, such as the fine tuning or contrast control, and then show him how to correct it. In other words, take time to make sure that the customer will be able to operate the set to his own satisfaction; you will be saving yourself a call-back or two by doing so.

As a matter of plain common sense. don't compare the performance of your customer's set unfavorably with that of other models. Even if the set is not the best one, don't mention that fact. Tell him what he can expect in the way of reception without saying that he could get better reception with a better set. Remember, he is convinced the set is a good one, or he would not have bought it.

Some customers will want to know exactly how the set works. You should do your best to tell him what he wants to know in language that he understands. If he appears to have a good technical background, you may be able to be fairly detailed in your explanation. If, on the other hand, he has no knowledge of electricity, you'll only be wasting time if you attempt to describe the operation of the set from the technical viewpoint. No matter how simple you make your explanation, however, be careful not to give him any misinformation. He may quote your explanation to his friends. If you have misled him, and someone points this fact out to him, he will bear you a certain amount of ill will.

If you install a set during the day when there is not much on in the way of programs, it will be a very good idea for you to make an appointment to drop back some evening to see how the set is working. Doing so will let you check up on the way the customer is operating the set as well as on the performance of the set itself.

Interference

If, during the orientation of an antenna, you find interference, you should eliminate the interference before completing the installation. Sometimes reorienting or relocating the antenna, or rerouting the transmission line will solve an interference problem. It is for this reason that you were instructed not to secure the transmission line until orientation had been completed.

When interference cannot be removed by moving the antenna or transmission line, there are some special steps that can be taken to eliminate it. However, before you can eliminate interference by any of the special means, you must be able to identify its source. Fortunately this is not too difficult because the various types of interference have characteristic patterns that are visible on the picture tube screen.

There are two general types of interference—blanket and station. By blanket interference we mean interference such as ignition noise that does not have an identifiable regular frequency. Station interference, as the name implies, is usually of an identifiable frequency and can be removed with resonant circuits such as stubs or traps.

A reconsideration of the television raster will help you understand the patterns that will result in the picture from interference of a constant or nearly constant frequency. You will recall that a field consists of 262.5 lines repeated at a frequency of 60 cycles per second. Thus, the horizontal deflection frequency is 15,750 cycles per second. Therefore, if an ac signal of a frequency lower than the horizontal deflection frequency is applied to the grid circuit of the cathode ray tube, it will affect at least one complete line of the picture. The lower the frequency, the more lines it will affect. Thus, frequencies less than the horizontal deflection frequency produce horizontal bars in the raster, and the frequency of the interference is roughly 60 times the number of bars produced.

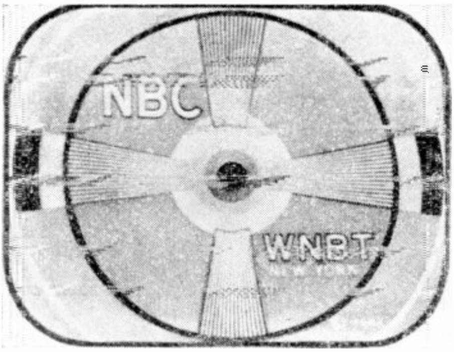
If an interference frequency higher than the horizontal deflection frequency is applied to the grid circuit of the picture tube, it will affect only a portion of each scanning line and thus produce vertical bars. The frequency of this interference will be roughly equal to the horizontal deflection frequency times the number of bars. It follows, of course, that interfering signals of varying frequency will produce lines or bars that are irregular rather than straight. You will recognize all of these symptoms in illustrations used to show the effects of interference from various sources, later in this lesson.

BLANKET INTERFERENCE

By blanket interference we mean signals that interfere with television reception but cannot be eliminated by inserting traps or stubs at the antenna input terminals of the television set. This type of interference disrupts television reception regardless of its frequency. Therefore, when present, it is apt to appear on all channels.

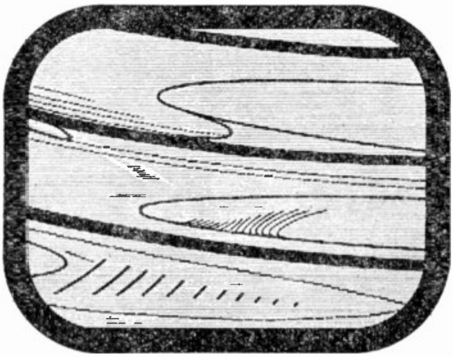
The principal type of blanket interference is noise. AM broadcast station interference is also included in this type because even though it is of a fixed, constant frequency, its strength, rather than its frequency, causes interference.

Noise. Noise interference usually has its source in some sort of electric



Courtesy RCA

FIG. 21A. Ignition interference causes streaks of this kind across the picture.



Courtesy Belmont Radio Corp.

FIG. 21B. Heavy ignition interference may make the set lose horizontal sync, as shown here.

arc such as are created in the spark-plugs in an ignition system, at the brushes of a motor, or the contacts of a vibrator. It can be picked up by the television receiver either through the power line or through the antenna. Fig. 21 shows the characteristic effects of light and heavy ignition interference.

If the noise is being picked up by the antenna or antenna lead-in, you may sometimes be able to eliminate it by relocating the antenna or transmission line or using a shielded line. Placing the antenna as high as possible may help. Installing a booster may help if the interference is noticeable simply because the signal is weak. However, if the noise is being picked up by the antenna, the booster will not help because it will amplify the noise as well as the incoming signal.

When the noise source is some piece of equipment in the house in which the television set is installed, the interference frequently enters the set through the power line. Such things as ultra-violet lamps, neon signs, electric razors, and similar spark-producing devices will all introduce noise into the power line. To eliminate this interference, locate the offending piece of equipment and insert a line filter such as is shown in Fig. 22 between it and the power line. If you cannot locate the noise source, insert the filter between the receiver and the power outlet.

AM Broadcast Interference. If the television set is located close to a strong AM broadcasting station, the broadcast station may cause interference that looks something like a wire mesh across the face of the cathode ray tube. This interference occurs because of the strength of the AM broadcast signal rather than the frequency characteristics of it. Therefore it cannot be eliminated with ordinary resonant traps or stubs.

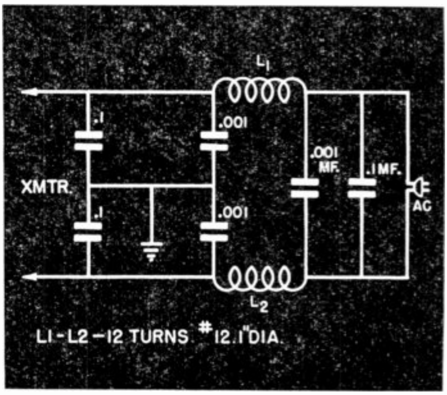


FIG. 22. An rf filter of this type will help keep interference signals out of the power line.

Moving and reorienting the TV antenna is not apt to help much, either, because the AM signal blankets the area. The most effective method of reducing this interference is to use a high-pass filter such as the one shown in Fig. 23. It is best to connect this filter directly to the tuner rather than to the antenna terminals at the back of the set. This is because there is a long piece of transmission line connecting the antenna terminals to the tuner which might pick up the AM broadcast interference.

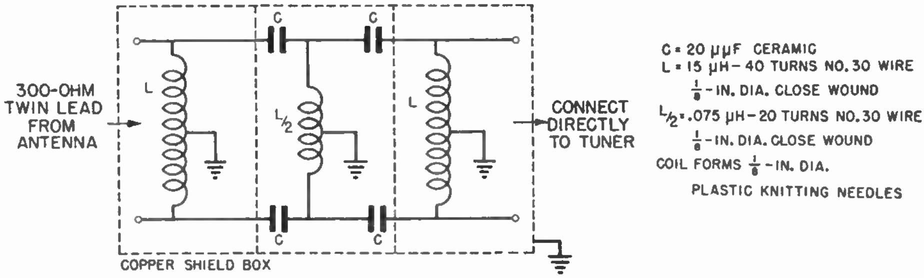


FIG. 23. Use of this high-pass filter will reduce interference caused by a powerful nearby AM broadcast station.

STATION INTERFERENCE

The term station interference is used here to denote interference that is originating at a known or determinable source and is of a frequency that is known or can be determined and can be eliminated through the use of traps or stubs.

Before studying the various sources of station interference, it is well to become familiar with the general nature of the devices used to remove it. Since the frequency of this type of interference is either known or determinable, it is obvious that we can take advantage of the characteristics of resonant circuits to remove it.

Stubs and Traps. If we know the frequency of the interfering signal, we can connect a series resonant circuit tuned to that frequency across the antenna terminals of the television receiver and, since at resonance the circuit offers low impedance, effectively short out the interference. A parallel resonant circuit, tuned to the interfering frequency and connected in series with the transmission line, would also achieve a similar effect by attenuating the interference, because at resonance it presents a high impedance.

A piece of transmission line cut to the correct length will act as a series resonant circuit. Such a piece of line (which, since it is rather short, is called a "stub") can therefore be connected across the antenna terminals of a set to eliminate interference.

Two types of stubs may be used: the "open" and the "shorted" stub.

The shorted stub is about a half wave length long at the frequency of the signal to be eliminated. The open stub, on the other hand, is approximately one quarter of a wave length long.

To make a shorted stub, the ends of the transmission line are stripped clean of insulation, twisted together, and soldered to form a short circuit at the end of the line. An open stub is made simply by cutting off the correct length of transmission line, leaving the ends open. Obviously an

CHANNEL CAUSING INTERFERENCE	STARTING LENGTH OF STUB	
	OPEN 300Ω LINE TO SET	SHORTED 300Ω LINE TO SET
2,3	45"	90"
4	40"	80"
5,6	35"	70"
FM	30"	60"
7-13	16"	32"

FIG. 24. Starting lengths for stubs made from 300-ohm twin-lead transmission line.

open stub is much easier to make. Furthermore, it is easier to work with, because a stub must be adjusted in length to make it perform properly after it has been connected to the set; and it is much simpler just to snip a bit off the end of an open stub than it is to connect the ends of a shorted stub again after cutting a piece off it.

When you use a stub, start with one that is longer than is needed. The starting lengths for stubs made of 300-ohm-twin-lead line are given in Fig. 24, for various channels. Connect the stub to the antenna terminals of the set, then cut off half-inch sections from its end until there is some noticeable effect upon the interference. As soon as you begin to notice an effect, reduce the length of the sections you cut off to a quarter inch or less. If you reach a point where the interference is completely eliminated, stop.

In most cases, however, it will be impossible to eliminate the interference completely. Instead, as you continue to cut off lengths of the stub, you will find that the interference first decreases, then begins to increase again. When this happens, you will have made the stub too short, and you will have to start over again. This time, however, you will know approximately how long the stub should be, and you will be able to recognize when you have made it the length that produces maximum interference elimination.

During your adjustments of its length, the stub should be placed as nearly as possible in the position that it will occupy after you have finished. Changing the position of the stub frequently has an effect upon its performance. Another reason for not changing the position of the stub as you adjust its length is that its performance may be affected by nearby objects.

An adjustable transmission line stub may be made by connecting a length of transmission line to the antenna terminals of the TV set, and wrapping a piece of aluminum or tin foil around it. The piece of foil effectively shorts the line, even though it does not actually touch the conductors of the line. Therefore, the effective length of the stub can be adjusted by sliding the foil back and forth along the stub line until a position is found that clears up or minimizes the interference.

The use of a stub will cause a change in the rf response curve of the front end of a set on channels close to the frequency to which the stub is tuned. In some cases this will cause smearing of the picture.

This effect can be prevented by inserting a small capacitor in series with each line of the stub at the point where it fastens to the front end or antenna input of the receiver. These capacitors should have capacities of 5 mmf for stubs used in the low TV band and the FM band and about 2 mmf for stubs used in the high band. Inserting these capacitors makes the stub a series-parallel tuned trap that is much sharper in response and will not affect the

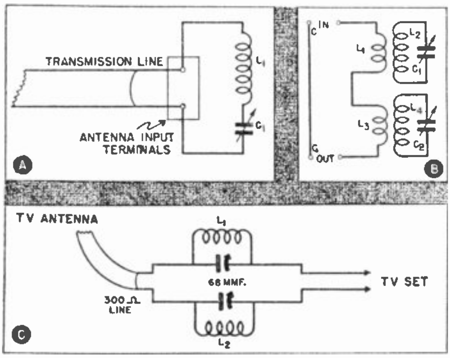


FIG. 25. Three types of wave trap. (A) series resonant; (B) absorption; (C) parallel resonant.

response curve of the front end of the set unless the stub is tuned directly to the channel. The addition of capacitors may make it necessary to use a longer piece of line for the stub.

Wave Traps. If the station causing the interference is comparatively low in frequency, a transmission line stub may have to be impracticably long to eliminate the interference. In such cases, you should use a wave trap tuned to the frequency of the interfering station instead of a stub. Wave traps are even used for some of the higher-frequency stations to avoid the need for having an extra piece of transmission line hanging from the set.

A series resonant wave trap connected directly across the antenna input terminals is shown in Fig. 25A. Electrically, this is approximately the same as the quarter-wave open stub or the half-wave shorted stub previously described.

A wave trap of this sort is often not as effective as an absorption trap, because the attenuation it produces in the undesired signal depends upon how low its impedance becomes at resonance in comparison to that of the receiver. Since the input of a receiver has a comparatively low impedance, a series trap may not be able to become low enough in impedance to produce sufficient attenuation of the undesired signal.

The absorption trap shown in Fig. 25B is commercially available. The transmission line from the antenna is connected to the terminals marked "in" on the wave trap and the transmission line from the receiver is connected to the terminals marked "out." Thus, coils L1 and L3 are inserted in series with the transmission line. Coil L2, tuned by capacitor C1, is coupled to coil L1; and coil L4, tuned by capacitor C2, is coupled to L3, L2-C1 and L4-C2 thus act as absorption wave traps, absorbing energy from the line at the frequency to which they are tuned. To use this trap, all you need to do is connect it in the transmission line and adjust C1 and C2 until the interference is minimized.

Three different types of wave traps are shown in Fig. 25. Fig. 25C shows how parallel resonant wave traps can be used. Notice that a trap is connected directly in series with each conductor of the transmission line. Since each wave trap has a very high impedance at its resonant frequency, most of the interfering signal will be dropped across the traps and very little will be applied to the receiver input terminals.

Now that you know how stubs and traps are used, let us look at the various types of interference they can eliminate.

FM Interference. There are two types of FM interference that you may encounter. The first type is second harmonic interference. The second harmonics of the FM band, 88 to 108 mc, coincide almost exactly with the fundamental frequencies of the upper portion of the VHF television band (channels 7 to 13).

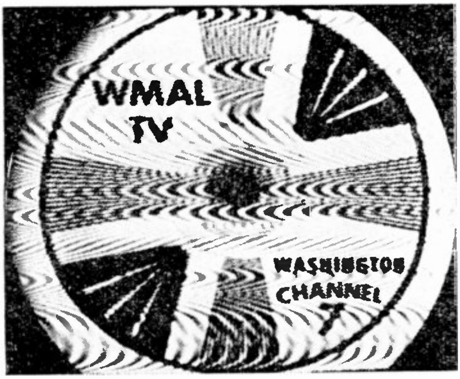


FIG. 26. Wavy interference of this sort that is continually changing is characteristic of FM interference. The variations in the pattern produced are caused by the continually changing frequency of the interfering signal.

Therefore, it is quite possible for the second harmonics of an FM station to be close enough to the frequency of one of the television stations to cause serious interference as shown in Fig. 26. In some cases the harmonic might coincide exactly with the television picture carrier frequency.

Where FM second harmonic interference comes in right on top of the TV signal, it is impossible to eliminate it with a stub or wave trap, because the stub or trap would eliminate the television signal as well as the interference. About the only solution to this problem is to use a highly directive antenna and orient it so that the pickup from the FM station will be at a minimum.

The second type of interference that can be caused by an FM station is image interference. Channel 2 is particularly subject to this type of interference.

In a typical receiver having an i-f frequency of 25.75 mc, the local oscillator frequency is 81 mc (the picture carrier frequency 55.25 plus 25.75). If an interference signal exactly 25.75 mc higher than the local oscillator frequency is picked up, it can beat with the local oscillator to produce an i-f signal, called an image. The incoming signal required to produce an image on channel 2 is 106.75 mc (81 + 25.75), which is well within the FM broadcast band.

A trap or stub tuned to the frequency of the interfering signal (106.75 mc for Channel 2) will eliminate this type of interference. A quarter wave open stub is perhaps the most commonly used. It is as effective as any other device in eliminating this interference, and it is easy to make and adjust. To make such a stub, start with a section of transmission line about 32 inches long, and then shorten it as has already been described. Reorienting the antenna or increasing the signal strength of the TV signal with a booster may help eliminate this type of interference.

Local Oscillator Interference. Fig. 27 shows how interference from the local oscillator of another tele-

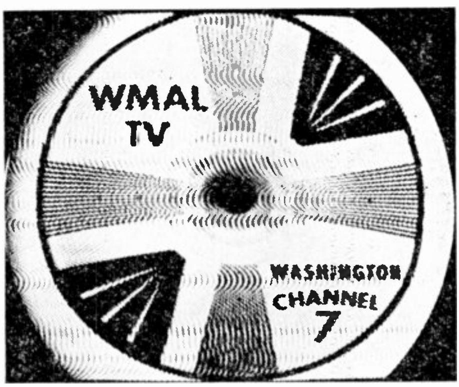


FIG. 27. Interference produced by the local oscillator of a nearby TV or FM set. The number and positions of the lines will change when the tuning of the interfering oscillator is changed. When the tuning operation stops, the pattern may change to that in Fig. 28.

INTERFERING RECEIVER		INTERFERES WITH	
TUNED TO CHANNEL	OSCILLATOR FREQUENCY (MC)	CHANNEL	FREQUENCY RANGE (MC)
2	81	5	76-82
3	87	6	82-88
7	201	11	198-204
8	207	12	204-210
9	213	13	210-216

TABLE III. The oscillator frequencies radiated from a TV receiver with a 25.75-mc i-f, which might interfere with reception at another receiver.

vision or FM receiver appears on the television screen. This interference is usually caused when the television antenna of the interfering receiver radiates signals from its local oscillator. Table III shows how a receiver tuned to channels 2, 3, 7, 8, or 9 might interfere with a receiver tuned to 5, 6, 11, 12, or 13. This type of interference is not always picked up by the antenna but sometimes is picked up directly from a nearby set.

Here again the frequency of the interfering signal is apt to be too close to the desired signal to be removed with traps or stubs. If the interference is caused by direct pickup, shielding the transmission line or the receiver may help, but there is little that can be done to eliminate it at the receiver that is picking up the interference.

The best place to eliminate this type of interference is at the interfering receiver. Those signals are radiated because there is insufficient isolation between the oscillator stage of the interfering receiver and the antenna. The easiest way to eliminate the interference is to install a booster amplifier between the antenna input of the interfering set and the antenna.

Amateur Interference. There are three ways in which an amateur transmitter might interfere with TV reception. There may be excessive harmonic radiation from the amateur transmitter at a television channel frequency, the amateur transmitter signal may be close enough to the TV i-f to get directly into the i-f stages, or the amateur station may be operating on a frequency close enough to the television frequency signal to get through a set with poor selectivity.

Harmonic interference is probably the most common type of amateur

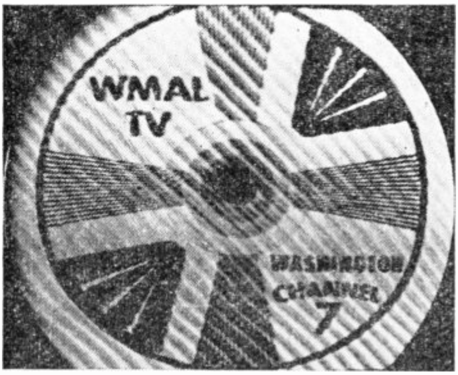


FIG. 28. Harmonics from an amateur or any other AM transmitter may produce regular lines of this sort.

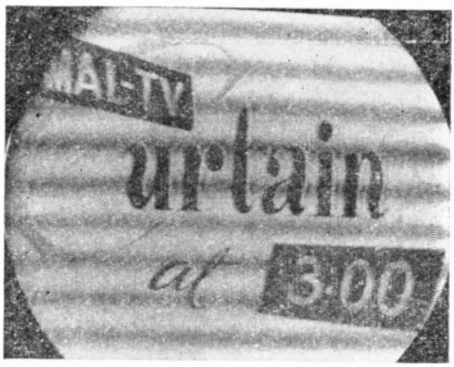


FIG. 29. Another form of interference that may be produced by an amateur or other AM transmitter.

AMATEUR FREQ. (mc)	X 2 (mc)	X 3 (mc)	X 4 (mc)	X 5 (mc)	X 6 (mc)	X 7 (mc)	X 8 (mc)	X 9 (mc)	X 10 (mc)
3.5	7	10.5	14.0	17.5	21.0	24.5	28.0	31.5	35.0
7.0	14	21	28	35	42	49*	56*	63*	70*
14.0	28	42	56*	70*	84*	98	112	126	140
21.0	42	63*	84*	105	126	147	168	189*	210*
27.0	54*	81*	108	135	162	189*	216*	243	
28.0	56*	84*	112	140	168	196*	224		
50.0	100	150	200*						

FIG. 30. Chart of the harmonics of the most popular amateur frequencies. Those that have an asterisk beside them fall in one of the TV channels.

interference. Fig. 28 shows the effect harmonic interference may produce on the television picture. In some instances horizontal lines like those shown in Fig. 29 may appear. The chart in Fig. 30 shows which harmonics of the most widely used amateur bands fall into the TV channels.

A quarter-wave shorted stub cut to the fundamental frequency of the amateur transmitter and installed at the interfering transmitter is effective in the elimination of even harmonic interference. It acts as a parallel resonant circuit (high impedance) at the fundamantal frequency. At even harmonics it acts as a series resonant circuit and will effectively reduce even harmonic pickup.

An even more effective method of eliminating harmonic interference is to install a low-pass filter at the output of the interfering transmitter. These filters, which are commercially available, suppress all radiation from the transmitter that is higher in frequency than the fundamental band of operating frequencies.

If the harmonic radiation is coming from one of the buffer stages rather than the antenna of the transmitter, the remedy is to shield the transmitter completely. In addition to the shielding, a power line filter similar to the one shown in Fig. 22 should be used.

A strong signal from an amateur transmitter operating on the 21 or 28 mc amateur band is close enough to the i-f frequency of some TV receivers that it may get through the front end into the i-f amplifier. Many TV sets have i-f traps in the front end that can be adjusted to eliminate such interference or to reduce it to a minimum. If you encounter such interference in a set that does not have an i-f trap, you should add one. An effective series resonant trap to be installed across the transmission line can be made with 14 turns of No. 22 enameled wire on a ¾-inch diameter form with windings spaced to fill about ¾ inches of length. This coil connected in series with a variable capacitor having a rating of 15 to 20 mmf makes an effective series resonant trap.

Another, and usually more effective, method of eliminating this type of interference is to install a commercial high-pass filter at the television set. Such a filter allows the set to receive only signals higher than 54 mc (low side of channel 2), and thus eliminates the possibility of interference at i-f frequencies.

Co-channel Interference. It is possible that a television receiver may be geographically located so that it receives two stations from different cities that are operating on the same channel. Theoretically both stations should be operating on exactly the same frequency, but they may easily differ by a few hundred cycles and still be well within the frequency limit set by the FCC. When the two stations differ slightly, a beat note will be developed, that causes interference which looks like that shown in Fig. 29. The number of bars developed depends on the difference in frequency of the two carriers. If the two carriers are close enough together that the difference is less than 60 cycles, no visible bars will be produced, but unless the two carriers are exactly synchronized, there will be an annoying variation in the brightness of the picture.

The only way to eliminate such interference at the receiver is to use a highly directive antenna and orient it for the least interference.

Adjacent-Channel Interference. A television receiver might also be geographically located so that it receives television signals on adjacent channels. In any given city, channel allocations are usually such that there are no two stations in that city on adjacent channels, channels 4 and 5, 6 and 7 are exceptions because there are gaps in the frequency spectrum between these channels. However, where two adjacent channels may be received, interference is likely to be caused by the picture carrier of the channel above the selected one or the sound carrier of the channel below it.

For example, let us suppose that a television receiver with a 27.65 mc i-f is located so that it can receive both channel 3 and channel 4. The receiver oscillator frequency on channel 3 will be 87 mc. If the front end of the receiver has a sufficiently broad response, and it is quite apt to, the 67.25-mc picture carrier from channel 4 will beat with the 87-mc oscillator frequency, producing a 19.25-mc signal that might be passed through the i-f stages and cause interference. However, the i-f sections of modern receivers are usually sufficiently selective to prevent this interference.

Suppose that the same receiver could receive channel 2 as well as channel 3. Here the 59.75-mc sound carrier from channel 2 might beat against the 87-mc oscillator to produce a 27.25-mc signal which is much more likely to get through the i-f stages and cause interference than the 19.25-mc signal.

There are various methods of eliminating or minimizing this type of interference. Some receivers contain adjacent channel sound and picture traps that, when properly adjusted, are very effective in eliminating it. A directive antenna that is carefully oriented may also reduce pickup from the interfering channel to such a low level that the interference will not be objectionable. A stub cut to a frequency near that of the interfering station may attenuate the interference satisfactorily.

Set Design. The manufacturers of TV receivers are quite aware of the interference problems that are encountered in the field, and are constantly attempting to eliminate, as far as possible, the characteristics of the television set which make it subject to these various types of interference. As we have already mentioned, many sets are produced with built-in traps for eliminating adjacent-channel interference and i-f interference.

You will note that many of the various types of interference are caused by signals developed in the i-f range of 21 to 27 mc. FM, local oscillator, amateur, and adjacent channel interference are all sometimes possible because the i-f of the television set is in the 21 to 27 mc range. To eliminate many causes of interference some set manufacturers are producing sets with an i-f of 45 mc. This makes a considerable reduction in the number of possible types of interference that might be encountered on installation.

Although we have discussed a large number of different types of interference, the situation is really not as bad as it might appear to be. Television broadcasters and manufacturers are constantly seeking ways to eliminate interference. Therefore, it is quite possible that you might install quite a number of new receivers without running into any of the interference problems that we have discussed.

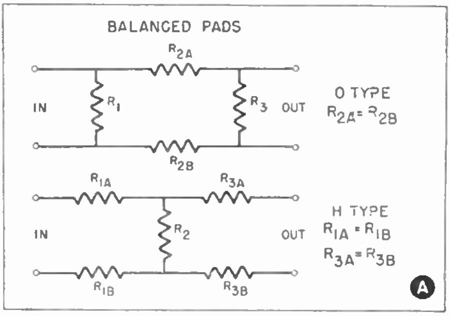
Special Installation

We have covered the routine problems that you may encounter in an ordinary installation in the customer's home. However, there may be signal, line voltage, or noise conditions at the site of the installation that present some special problems. Some servicemen may never encounter the problems discussed here, but on the other hand some one of the problems discussed here may be encountered daily by others. In any event a knowledge of the special installations discussed here should prepare you to make TV installations under almost any conditions that you might encounter.

STRONG SIGNAL AREAS

It is possible that you might make a TV installation in an area where the signal strength from one or more stations is excessive. There are two conditions that might exist. First, the signal strength from all stations received might be excessive, and second, which is more likely, the signal strength from only some of the stations might be excessive.

To reduce the signal strength of all stations received, you should use a pad that will retain the correct impedance matching for the transmission line but reduce the signal strength. Two types of pads that may be used are shown in Fig. 31A. The chart at Fig. 31B gives resistance values for the O type pad. It may seem that it would be simpler to use series



DB ATTENUATION	300-OHM IMPEDANCE O PAD		
	R1	R2	R3
6	1000	100	1000
12	470	300	470
18	390	560	390
24	330	1000	330
30	310	2200	310

B

(ALL R VALUES ARE IN OHMS)

FIG. 31. Pads of the type shown at A may be connected between antenna terminals and 300-ohm twin lead to attenuate all incoming signals. The chart at B gives resistance values in an O type pad for several levels of attenuation.

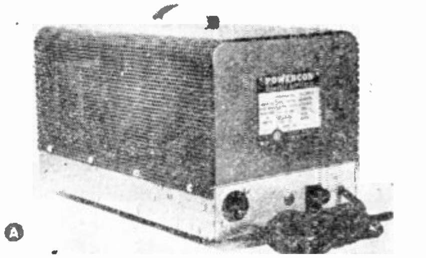
resistors than to use either of the pads shown, but if this were done, the transmission line would no longer be terminated with the correct impedance.

If the signal strength is not excessive on all channels, pads cannot be used, because a pad will reduce the strength of all signals equally. Instead, use parallel resonant wave traps tuned to the frequency of the over-strong station. These should be connected as shown in Fig. 25C. If coaxial transmission line is used, only one trap connected to the center conductor is necessary.

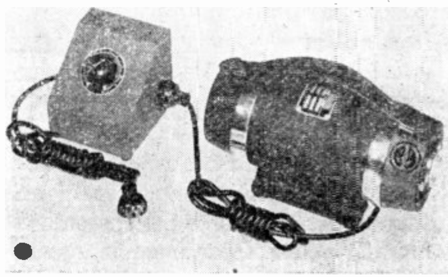
INSTALLATIONS IN DC AREAS

In some cities there are areas where direct current rather than the conventional 60-cycle ac power is supplied. Installation of a TV set in these areas presents a problem, because neither the transformer type nor the transformerless type will operate on a dc supply. As you know, ac is required to operate a transformer, and the transformerless type of set uses the voltage doubler arrangement, which will not operate on dc.

If a television set is to be used where only dc is available, some means must be used to convert the dc to 60-cycle ac before it is applied to the set. No matter how you do this, it is expensive. There are two devices that may be used to make this conversion. One is an inverter, which consists of a vibrator transformer and a suitable filter assembly, and the other is a rotary converter, which consists of a dc motor and an ac generator assembled on a common shaft. A typical inverter is shown at Fig. 32A, and a typical rotary converter at 32B.



Courtesy Cornell-Dubilier Electric Co.



Courtesy Carter Motor Co.

FIG. 32. Either an inverter (A) or a rotary converter (B) can be used to change dc to 60-cycle ac. The control at the left in B controls speed and hence frequency output of the rotary converter.

Some inverters have the disadvantage that they have a tendency to vary in frequency, which may cause undesirable voltage variations in the TV set. However, inverters are available that can be synchronized with a field frequency of the TV signal so that their outputs are constant in frequency.

The output frequency of the rotary converter has less tendency to vary if the dc voltage supplied to it is reasonably constant in amplitude. It is also controllable. A speed control can be used on the motor section of the rotary converter so that the output frequency can be adjusted. The faster the motor runs, the higher the output frequency will be.

In selecting a device to convert dc to ac, make sure that the unit can supply the ac at the proper voltage and frequency and also that it is large enough to furnish the current needed to operate the TV set. A TV receiver usually has a current requirement of several amperes at approximately 115 to 120 volts, 60-cycle ac.

Many inverters and converters are given both an intermittent-duty and a continuous-duty rating. Be sure that the continuous-duty rating is high enough to handle the requirements of the TV set, because the set will probably be used for several hours during an evening. A device designed to supply the required current under intermittent conditions only would not be capable of handling the load.

INSTALLATION IN 25-CYCLE AREAS

Some areas are supplied with 25-cycle ac power rather than the more conventional 60 cycle. A receiver using a power transformer designed for 60-cycle operation will not work satisfactorily on 25-cycle power, because there is not sufficient iron and copper in the transformer. If such operation is attempted, the transformer will soon burn out.

The transformerless type of television receiver using voltage multiplier circuits to obtain the necessary B-supply voltages will operate on 25 cycles, but if it is designed for 60-cycle operation the filter capacitors in the power supply should be replaced with capacitors of higher value for proper filtering of the B+ voltage.

There are sets designed specifically for operation on 25 cycles. Therefore if the customer wants a new set installed, all that is necessary is to see that he has purchased a set of the proper design.

There may be instances where the customer has moved from a 60-cycle area and brought his television set with him. In this case the conversion may be simpler and less expensive for the customer than the purchase of a set designed for 25-cycle operation. If the set is the transformer type, it will be necessary to use a frequency converter or else replace the power transformer with one designed for 25-cycle operation. If a satisfactory power transformer is available, the installation of a new power transformer is the cheaper alternative, but if one needs to be specially wound it may be just as cheap to purchase a rotary converter. If the set is the transformerless type, it is only necessary to change the filter capacitors, as we have already said.

COMMERCIAL INSTALLATIONS

The installation of a television set in an establishment such as a tavern or a restaurant does not present any problems that differ greatly from those encountered in a normal residential installation, but it does present more of them. This is particularly true in the case of noise interference, because a tavern or restaurant usually contains many more electrical devices than the ordinary home—automatic phonographs, refrigerators, electric washing machines, neon signs, and fluorescent lights, for example. Considerable interference may be radiated by one or more of these devices. If you notice that the noise level is comparatively high in the TV set, the interfering device can be identified by shutting off the various electrically operated machines one at a time. If you notice that the noise goes down when a certain machine is shut off, that machine is generating at least part of the interference. You can probably reduce the interference from such machines by using a suitable filter in the power line to the device.

Noise pick-up in the transmission line from such devices or from nearby automobiles can be kept to a minimum by using shielded transmission lines. For this reason a shielded line is far superior to an unshielded line for a commercial installation.

Since people are often more careless about equipment in a commercial establishment than they are in a private home, make sure that the transmission line is securely fastened in place. If it is not, it may be kicked or pulled loose accidentally, or some one may be injured by tripping over it. It is also a good idea to run the transmission line in such a manner that it will be as inconspicuous as possible.

MULTIPLE ANTENNA OUTLETS

There are several conditions under which it is desirable, if not absolutely necessary, to operate more than one TV receiver from a single antenna. In your own service shop you would probably find it convenient to have

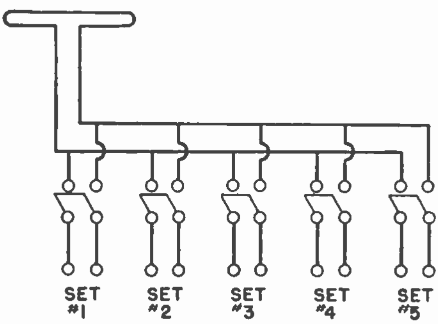
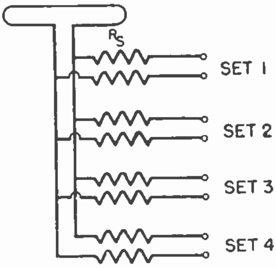


FIG. 33. A system of multiple antenna outlets which allows only one receiver at a time to be connected to the line.



NO. SETS	Rs
2	150 Ω
3	300 Ω
4	450 Ω

FIG. 34. With this type of installation, several sets can be connected to the same line at the same time.

more than one antenna outlet without having to erect another antenna. In a dealer's showroom it is almost essential to be able to demonstrate more than one set at a time. If he has a large showroom in which four or five sets might be connected for demonstration, a separate antenna for each set is out of the question. Many apartment house owners want a multiple outlet system to avoid having a hodge podge of antennas on their roofs. Even in many private homes there are two television sets which the home owner would prefer to operate from a single antenna, rather than install a second one.

Fig. 33 shows an economical method of providing multiple outlets where it is convenient to have antenna connections at various locations but only one set need be connected to the antenna at any one time. In some cases this type of installation is satisfactory for a small service shop or dealership.

Fig. 34 shows a simple way in which several receivers can be connected to a 300-ohm line. The matching networks shown permit the transmission line to be terminated in its characteristic impedance with the result that ghosts resulting from mismatch are avoided.

It is necessary to know the relative signal strength in a particular area

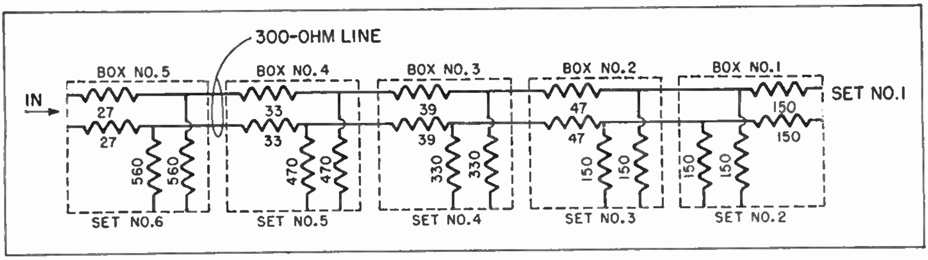


FIG. 35. This matching network can be used to permit as many as 6 sets to be connected to the same line.

before you can tell whether it is practical to connect 2, 3, or 4 receivers to the same antenna, because the total signal delivered by the antenna is divided equally among the sets. If there are two sets, for example, only half the signal fed to the line by the antenna is applied to each of them; if there are three, only one-third the signal is applied to each; and so on.

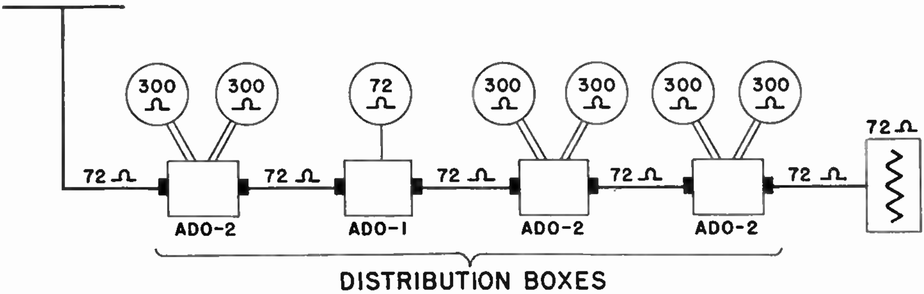
The circuit in Fig. 35 shows a complete matching network that can be used to connect as many as six separate receivers to the same transmission line. The network constants are such that signals of equal strength will be delivered to each receiver.

If fewer than six sets are to be connected to this network, the extra distribution boxes should be disconnected to keep the network in balance. For example, if only five sets are to be used, box No. 1 should be removed. The sets should then be connected to the positions marked set No. 3, set No. 4, set No. 5, and set No. 6. The fifth set should be connected to the leads that went to box No. 1. Similarly, if only four receivers are to be used, boxes No. 1 and No. 2 should be removed, and so forth.

In small apartment houses, systems like those shown in Figs. 34 and 35 may be suitable. A more elaborate system must generally be used for a large apartment house, however, because of the larger number of sets to be connected to the antenna.

Several systems have been devised to answer the problem of apartment house installations. One of these is the Jerrold "Mul-TV Antenna System," which we shall describe briefly.

The simplest form of the Jerrold system is shown in block diagram form in Fig. 36. As you can see, it



Courtesy Jerrold Electronics Corp.

FIG. 36. A block diagram of the Jerrold Mul-TV antenna system intended for use in apartment installations.

consists of a series of distribution boxes coupled to each other and to the antenna by 72-ohm coaxial transmission line. (For convenience in reference, we shall call this the distribution line.) A 72-ohm terminating resistor is connected across the end of the line.

Two kinds of distribution boxes, called ADO-1 and ADO-2 by the manufacturer, are used in this system. The ADO-1 is used to couple one 72-ohm set to the line, the ADO-2 to couple two 300-ohm sets to it. Either kind of box can be used anywhere in the system, so 72-ohm and 300-ohm receivers can be connected to the line in any proportion.

Each distribution box contains a cathode-follower amplifier and its power supply. The input of each box is connected across the distribution line; since this input consists of the grid circuit of the cathode follower and therefore has a high impedance, it attenuates the signal in the distribution line only slightly. For this reason a great many boxes can be connected to the line.

The output of each box is taken from the cathode circuit of the cathode follower. Therefore, the only connection between the input and the output is through the internal capacities of the tube, which are low. For this reason there is practically no backward transmission (from output to input) of signals through the distribution boxes. This means that any signal feeding back from the local oscillator of a set that is connected to the output of a distribution box will be very severely attenuated before it is applied to the distribution line of the system. The distribution boxes thus act as decoupling devices to prevent the receivers connected to them from interfering with each other.

The manufacturer of this system offers several accessories that can be used to adapt it to meet various needs. For example, there is a matching transformer that permits the 72-ohm distribution line of the system to be matched to a 300-ohm line if necessary.

Another accessory device is a channel amplifier that is intended for use in low-signal areas or in installations in which the run of the coaxial distribution line is so long that the signal is attenuated too much. This amplifier contains four-plug-in amplifier strips, each of which is a 2-tube rf amplifier that is designed to handle a particular channel. There is an individual gain control for each strip, an arrangement that permits the outputs of all the strips to be adjusted to the same level. These individual outputs are applied to a mixing network from which they are fed to the main distribution line of the system.

Each amplifier strip of this device has its own input. If an individual antenna is used for each station that is to be picked up, the transmission line from each antenna can be connected to the appropriate amplifier input. If a single antenna is to be used for all stations, however, an antenna matching network offered by the manufacturer must be used.

Another network offered by the manufacturer is the reverse of the one just described. It is intended to be used to couple the transmission lines from as many as six individual antennas to the single coaxial distribution line of the system. It is used only with unamplified systems, of course.

Finally, the manufacturer offers noise filters for each TV channel for use with amplified systems. Each is installed just ahead of the amplifier for that channel.

Lesson Questions

Be sure to number your Answer Sheet 60B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next Lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of Lessons before new ones can reach you.

1. List the four major steps in the normal television installation.

2. Why should the new set be adjusted in the shop before it is delivered to the customer's home?

3. List those adjustments that should always be made on a new set, regardless of the quality of the picture received before they are made.

4. Why should the ion trap adjustment always be made on new sets?

5. Name two adjustments that might remove shading from the corners of the television picture.

6. Which kind of resonant circuit does an open quarter-wave stub act like: (1) a *parallel* resonant circuit; or (2) a *series* resonant circuit?

7. If a carrier of the channel *below* the one to which the set is tuned causes interference, which ONE of the following traps should you adjust: (a) *the sound trap*, (b) *the adjacent-channel sound trap*, or (c) *the adjacent-channel picture trap?*

8. If the signal from one station is excessively strong at a particular location, how can you reduce its strength without affecting the response of the set for other stations?

9. What change should be made in a 60-cycle transformerless type of television set using voltage doublers for B-supply voltage, to adapt it for use on 25-cycle current?

10. What is the reason that shielded transmission line is used more in commercial TV installations than in ordinary residential installations?

MAKE DECISIONS

It is a very fine thing to have an "open mind." But it is a fine thing ONLY if you have the ability to make a *decision* after considering all sides of a question.

Failure to make a decision after reasonable consideration of all facts will quickly mark a man as being unfit for any position of responsibility.

So practice making clearcut, well thought out decisions.

Not all your decisions will be correct. No one is perfect. But if you get the habit of making decisions, experience will develop your judgment to a point where more and more of your decisions will be right.

J. M. Smith

INSTALLATION AND ADJUSTMENT OF COLOR TV RECEIVERS

61B

RADIO—TELEVISION SERVICING

PIONEER HOME STUDY RADIO-TV SCHOOL
NRI

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

ESTABLISHED 1914

STUDY SCHEDULE No. 61

For each study step, read the assigned pages first at your usual speed, then re-read slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

☐ 1. **Introduction** .... **Pages 1-5**

In this section we discuss choosing the location and installing the color receiver in the customer's home.

☐ 2. **Complete Adjustment Procedure** .... **Pages 5-20**

Here we take up each of the color picture tube accessories and adjustments, and picture tube replacement.

☐ 3. **Color Test Equipment** .... **Pages 21-24**

Some test instruments such as the dot-pattern generator and the color-bar generator are needed for color servicing that are not used in monochrome servicing. You study these here.

☐ 4. **Servicing Color Receivers** .... **Pages 25-32**

In this section you will learn about both monochrome defects and chrominance defects in a color receiver.

☐ 5. **Answer Lesson Questions.**

☐ 6. **Start Studying the Next Lesson.**

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1960 EDITION

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INSTALLATION AND ADJUSTMENT OF COLOR TV RECEIVERS

LIKE the circuits in early monochrome receivers, the circuits in the present color television receivers vary considerably. Color television is a comparatively new field, commercially, and more improvements in the circuit design and in the design of the color picture tube itself will have to be made before the circuits become standardized, as they are in the present black-and-white receivers.

The differences in the present color receivers, of course, cause variations in the adjustments and in the adjustment methods. However, all receivers, regardless of their circuitry, contain essentially the same major adjustments. The noticeable and important variations exist in the receiver alignment.

We will not discuss color receiver alignment in this lesson, because any procedure that we might give would apply to one model only. Therefore, if you have to align a color receiver, we recommend that you obtain the manufacturer's service information for that particular model, and follow the instructions step by step.

The primary purpose of this lesson is to describe the adjustments necessary to obtain a satisfactory picture and to get the receiver in proper operating condition in the customer's home. In other words, the instructions apply to a new color television receiver. From your study of the color receiver circuits, you know that the color receiver is more elaborate than a monochrome receiver. Therefore, the adjustment procedure must be more exacting and involved than for a monochrome receiver. The procedures described in this lesson will be of a general nature. They are designed to acquaint you with the various adjustments and accessories that you will not find in monochrome receivers.

There are relatively few color receivers in use at present. However, the number should increase steadily as improvements are made, and the cost of the receivers is reduced. As more improvements are made in the design of new receivers, the circuits, and hence the adjustments, will be refined and simplified. Although it is doubtful whether color receivers will ever be as easy to adjust as the present monochrome receivers, you should be able to understand and cope with any of the new adjustment procedures.

In addition to the adjustment procedures, we will discuss briefly the test equipment used exclusively in adjusting and aligning color receivers. Finally, to give you an idea of how the servicing procedures on color receivers are carried out and in what way they are similar to those for monochrome receivers, we will discuss some of the defects that you may encounter in your servicing work, and indicate how to recognize them by observing the reproduced image on the screen and by using various test instruments.

Now let us begin our discussion of the color receiver by describing some of the precautions to be taken and the methods used to install a receiver in a customer's home. You will find that in many respects the installation is the same as for a standard black-and-white receiver.

INSTALLATION

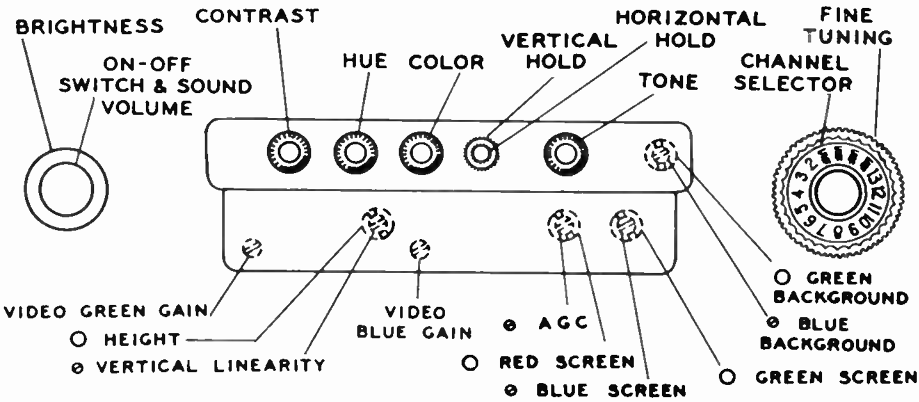
Each color receiver is adjusted at the factory. However, it is difficult to pre-set a color receiver so that it will give a perfect picture on the screen immediately after it is installed in the customer's home. It will be your responsibility, therefore, to know how to make the adjustments, and to instruct the customer on how to operate the receiver.

You can avoid call-backs by taking time to demonstrate the receiver adjustment procedure. Explain the purpose of the various controls to the customer, and indicate those he can adjust, such as the hue, contrast, and color controls. Be sure to emphasize that he will misadjust the receiver if he tampers with any of the other controls. Stress particularly that good color reproduction depends upon the proper adjustment of both the monochrome and the color controls. It may be possible to tune a black-and-white receiver carelessly and still obtain a satisfactory picture. Color receiver adjustments, however, *must* be made carefully and accurately.

Most color receivers manufactured at present are shipped with the picture tube in place and all the components (the yoke, the convergence assembly, etc.) mounted on the neck of the tube. Earlier color receivers, however, were shipped with these components, including the picture tube, in a separate carton. When installing this receiver, it was necessary to install the tube in the cabinet and the components on the tube neck before any adjustments could be made.

In many respects, the installation of a recent-model color-television receiver is comparable to the installation of a standard black-and-white receiver. After removing it from the carton, you should give some thought to the proper location of the receiver with respect to the windows, interior lighting, antenna connections, and the electrical outlet.

Light falling directly on the picture tube screen from windows or strong room lighting has an influence on the apparent colors in the reproduced pic-



Courtesy RCA

FIG. 1. Location of controls on a typical color TV receiver.

tures. Colored lights and tinted lamp shades can contribute adverse shading on the reproduced color image. Generally, it is preferable to view the color picture with conventional white room lighting and to position the receiver so that it is not facing the windows.

After installing the receiver turn it on and attempt to tune in a black-and-white program according to the following instructions. Notice that you use the usual monochrome controls (the channel selector, fine-tuning, brightness, and contrast). You may find, however, that more adjustments will have to be made before the receiver is operating perfectly. Remember, the receiver must be properly adjusted to receive a black-and-white picture before you can accurately adjust the color controls. The color tuning procedure will be given later in this section.

The locations of the various controls on the front of a typical receiver are shown in Fig. 1. Refer to this illustration as we go through the adjustment procedures. Remember that although the locations of the controls on color receivers vary, the tuning procedures are essentially the same, regardless of the make and model of the color set.

With the channel selector switch set to the desired channel, turn the receiver on, and advance the volume control (sound) to approximately mid-position. Turn the color control fully counter-clockwise. This step is taken to permit proper monochrome adjustment before color is added to the picture.

Advance the contrast control to approximately mid-position, and turn up the brightness control to obtain suitable screen illumination. Then adjust the fine-tuning control for the best picture quality and the volume control for suitable loudness. If necessary, adjust the vertical and horizontal hold controls to obtain a stationary picture. Readjust the contrast and brightness controls for best picture contrast. The average set owner has a tendency to turn the brightness and contrast controls too high. A high contrast setting causes a loss of the half-tone range in the reproduced picture.

Finally, adjust the tone control for most pleasing sound. After the receiver has been in operation for some time, or after it is turned on again after an idle period, it may be necessary to readjust the fine-tuning and the contrast controls. This is normal, and you should instruct the customer accordingly.

You probably noticed that the adjustment procedure just described is almost identical to that used for any monochrome receiver. In fact, when a color receiver is reproducing a monochrome signal, it is essentially a black-and-white receiver. Only those circuits that are common to both monochrome and color receivers operate at this time. Therefore you would expect the adjustments to be similar.

Before the receiver can reproduce a satisfactory color picture, it must be properly adjusted for monochrome reception. After making the monochrome adjustments just described, turn the channel selector to a color broadcast or to a station that is transmitting a color *stripe* on its standard monochrome test pattern. The color stripe is formed by a special signal consisting of two 8-cycle bursts, one at the beginning and another at the end of each horizontal scanning line of the monochrome video information. These signals produce a greenish-yellow stripe on each side edge of the picture. On monochrome receivers, these color stripes appear as two shadowy vertical bars without color. When the color circuits are properly adjusted, the color stripe will have the characteristic greenish-yellow hue. The color stripe is particularly helpful when you are adjusting color receivers in the customer's home, because if you use it, you do not have to use a color-bar generator.

With a color signal available, adjust the color controls as follows: Turn up the color control to approximately two-thirds of maximum. Adjust the fine-tuning control for the best color picture—a picture that has a minimum of sound bars. The fine-tuning control must be adjusted very carefully to keep sound interference in the picture at a minimum. When the fine-tuning control is set properly, the pattern produced on the screen by interference between the chrominance and sound carriers is not noticeable at a normal viewing distance if the receiver is aligned correctly.

If the fine-tuning control is turned too far in the opposite direction, however, the chrominance subcarrier spectrum is attenuated, and there is inadequate coloring in the reproduced picture. When instructing the customer in the proper tuning procedure, demonstrate the effects of proper and improper settings of the fine-tuning control.

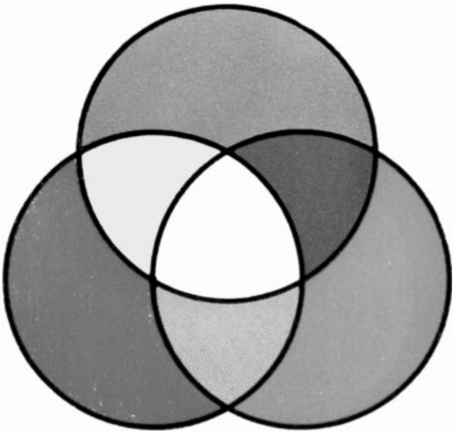
Finally, adjust the color control for the desired saturation or strength of the color component in the reproduced picture, and the hue control for the truest reds, blues, etc. Without a color that can be used as a reference, it may be difficult to obtain true hues in the reproduced picture. Everyone is familiar with the color of the human skin. Therefore, if you adjust the hue and color controls until the reproduced image has the most life-like flesh tones, the other colors will be accurately reproduced.

The preceding tuning procedures are used to tune a color receiver that is properly adjusted and operating normally. You may find that many more adjustments will have to be made when the color receiver is installed for the first time because some of the factory adjustments (particularly the positions of the components on the color picture tube neck) have moved during alignment.

Complete Adjustment Procedure

Before adjusting a color receiver in a customer's home, you should have some experience in manipulating the controls so that you will have an idea of how to proceed. In particular, you should be able to tell whether or not a receiver is operating satisfactorily. This means that you must know what each control is supposed to do and be able to recognize the primary and secondary colors. Much of your success in adjusting and servicing color television receivers will depend upon your knowledge of these colors.

Color television receiver adjustments are very critical, and it usually takes much longer to obtain peak performance than on a monochrome receiver. The alignment procedure, especially, must be made according to the manufacturer's recommendations for each particular model. However, many other adjustments vary only slightly, regardless of the type of color receiver. Therefore, with small variations, the adjustment procedures described in this section can be applied to almost any model. After studying this procedure you should have an idea of what to expect when you are called in to adjust a color set.

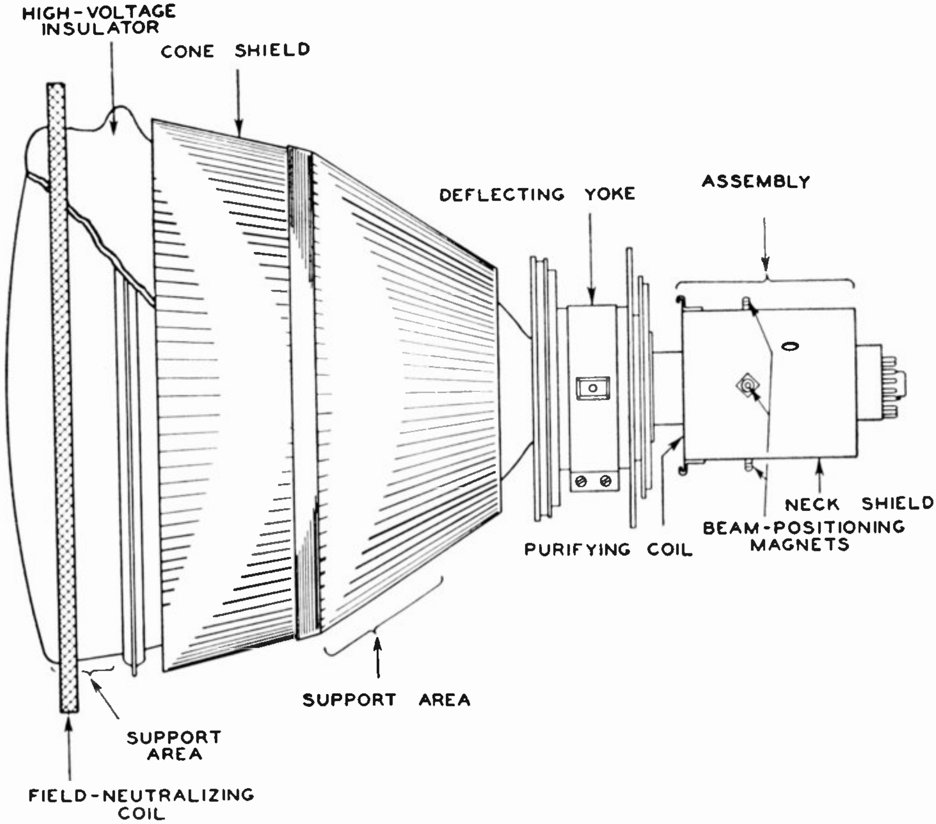


The secondary colors yellow, magenta, and cyan are formed by combining the primary colors blue, green, and red. Combining all three forms white.

PICTURE TUBE ACCESSORIES

The accessories on the neck of a typical picture tube in a monochrome receiver usually consist of a deflection yoke, a centering magnet, and an ion trap. These components are relatively easy to adjust. However, there are several additional components on the neck of a tri-color picture tube, and more attention has to be paid to positioning a good color picture. Each adjustment, to some extent, affects the reproduced picture. In addition, many of the adjustmenfs react on one another; and for this reason it requires much more time to adjust a color receiver properly.

Before discussing the adjustment procedures for the various accessories on the tri-color picture tube, let us briefly describe each component and find out how it affects the scanning beams in the tube. You are already acquainted with the positions of these



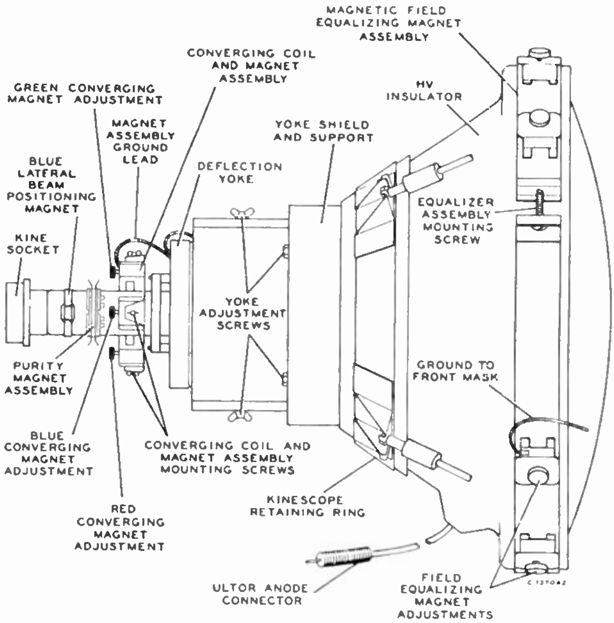
Courtesy RCA

FIG. 2. Components on a tri-color tube using electrostatic convergence.

components from the discussion in a previous lesson.

The tri-color tube shown in Fig. 2 is the type that contains an internal convergence electrode (electrostatic convergence). This tube uses individual magnets to position the beams during the convergence procedure. Fig. 3 shows the correct placement of the components on a color picture tube that uses an external convergence coil (magnetic convergence). Beginning at the picture tube socket, the first accessory that we encounter is the blue beam-positioning magnet, which is used to move the scanning beam from the blue gun in a lateral direction during the convergence adjustments. The single magnet represents a simplification over the three-magnet type shown in Fig. 2. The method used to converge the three scanning beams will be discussed in detail later in this lesson.

Now, let us see how the blue beam-positioning magnet is able to move the blue scanning beam laterally. The blue gun of the tri-color picture tube, unlike the green and red guns, contains a pole piece which serves to complete the magnetic field created by the magnet through the gun and back to the magnet. This is shown in Fig. 4. When the magnet is posi-

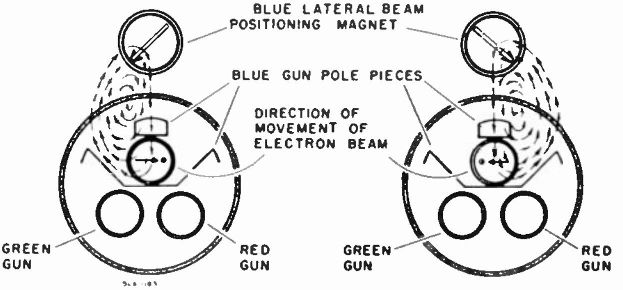


Courtesy RCA

FIG. 3. Components on a color tube using magnetic convergence.

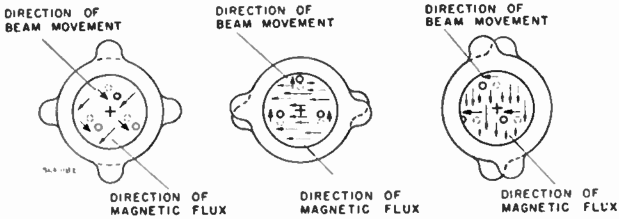
tioned so that the magnetic flux is greater on one side of the pole piece than on the other side, the electron beam is deflected in a direction that is perpendicular to the flux. By rotating the magnet, the position of the magnetic flux can be varied to move the beam laterally in either direction.

Purity Magnet Assembly. Next to the blue beam-positioning magnet is an assembly consisting of two ring-type permanent magnets used to control the three electron beams so that they pass through the shadow mask and excite only the centers of their respective phosphor dots on the screen. The magnetic field produced by these magnets is uniform. Because the magnets are in the shape of flat discs, the magnetic field can be varied either by rotating both at the same time or one with respect to the other. When the magnets are positioned so that their magnetic flux adds, the effect on the scanning beams is maximum. The action of the purity magnet assembly on the beams is shown in Fig. 5. The arrows indicate that the three beams, as a group, can be moved in any direction.



Courtesy RCA

FIG. 4. Action of the blue lateral beam-positioning magnet.



Courtesy RCA

FIG. 5. Action of purity magnet on electron beam.

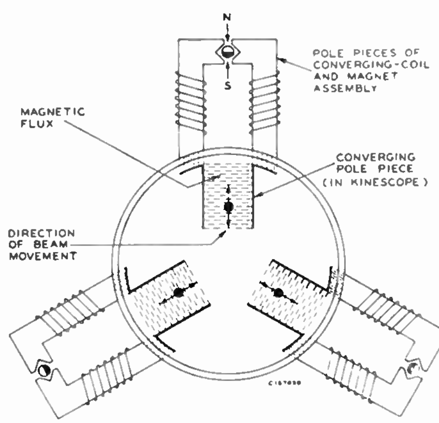
Convergence Assembly. By far the most difficult adjustments to make are the convergence adjustments. These are made to bring the three electron beams together at the proper point on the shadow mask to prevent color fringing and misregistration of the reproduced colors.

Probably the most important reason for making the convergence adjustments is to compensate for the varying distances that the beams must travel to reach the center, top, bottom, and sides of the screen. In addition, unequal grid bias is applied to the individual electron guns to compensate for the variations in the phosphors that are used on the screen. Without the convergence adjustments, the beams would not converge correctly. If the convergence is not properly adjusted, the images on the screen will be outlined by one or more of the primary colors.

The location of the convergence assembly for the magnetic convergence type of picture tube is shown in Fig. 3. Proper convergence of the three beams at any point on the mask in this tube is accomplished by applying special waveforms to the horizontal and vertical windings of each coil. These waveforms, which are synchronized with the horizontal and vertical scanning rates, produce a varying magnetic flux between the pole pieces of the electron gun that changes the cross-over points according to the distance between the guns and the various points on the mask. A simplified drawing of the convergence coil and magnet assembly is shown in Fig. 6.

With the convergence assembly positioned over the electron guns, the magnetic flux causes the beams to move in a perpendicular direction as indicated by the arrows. The magnetic field also can be varied by rotating the cylindrical magnets that are positioned in the gap between the pole pieces of each convergence coil. By manually rotating this cylindrical magnet, the magnetic flux between the converging pole pieces can be varied to move the electron beam in either direction.

Convergence in the electrostatic convergence type of picture tube in Fig. 2 is similar to the process just



Courtesy RCA

FIG. 6. Convergence coil and magnet assembly.

described. However, instead of applying controlled waveforms to individual coils, the horizontal and vertical correction voltages are applied to an electrode within the tube. These waveforms react on the electron beams to give proper convergence over the entire screen.

Deflection Yoke. The deflection yoke used on the tri-color picture tube is essentially the same as the yoke used in monochrome receivers. Both are cosine wound, and both must be adjusted to obtain correct deflection of the electron beams.

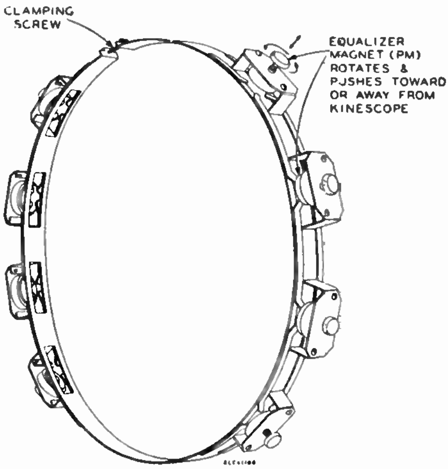
The deflection yoke in a color receiver must move three electron beams, and, because of the higher anode voltages, it is usually larger than the corresponding yoke in a monochrome receiver. In addition, to minimize the effect of the yoke's magnetic field on the electron beams as they pass through the bell portion of the tube, the turns near the ends of the windings are positioned vertically with respect to the other windings.

Field Neutralizing Assembly. Stray magnetic fields around the face plate of the color picture tube can cause color impurity at the edges of the raster. To eliminate this undesirable effect, a means of equalizing or neutralizing these fields is provided around the front rim of the picture tube.

In the earlier color receivers, the neutralizing adjustment was made by passing a dc voltage through a neutralizing coil. In later model receivers, however, a magnetic field equalizer, consisting of a band of soft iron to act as a pole piece and eight circular permanent magnets, is placed around the rim. Each of the permanent magnets can be moved toward or away from the picture tube, and the entire assembly, as shown in Fig. 7, can be rotated. When the equalizer magnet assembly is adjusted properly, it effectively neutralizes the undesirable magnetic fields, and permits the beams to strike their phosphor dots properly to ensure correct color purity.

PICTURE TUBE REPLACEMENT

In your service work, you may be required to replace the picture tube



Courtesy RCA

FIG. 7. Color equalizer magnet assembly.

in a color receiver. Therefore, before we describe how to adjust the components on the neck of the picture tube, let us discuss the replacement procedure.

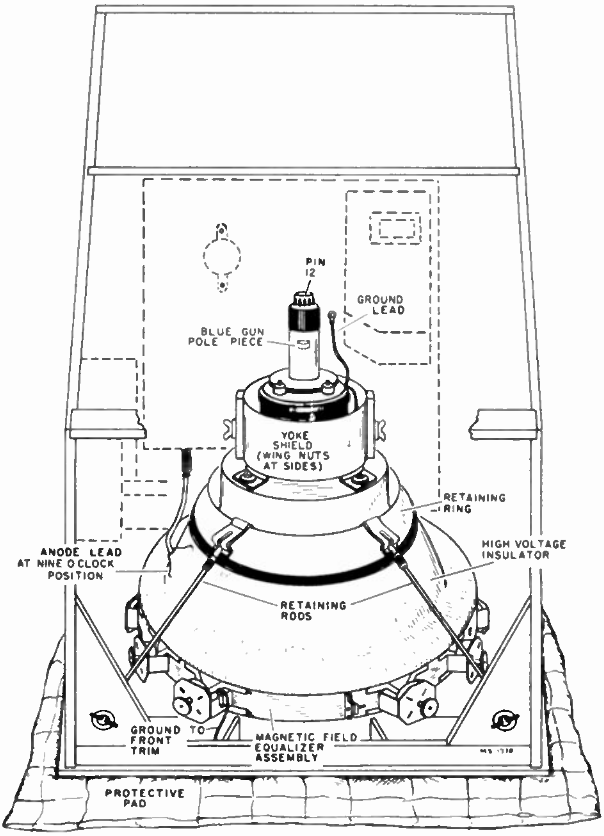
The same precautions must be taken when handling a color picture tube as with a monochrome picture tube. When removing the picture tube from the receiver or from the shipping carton, always wear shatter-proof goggles. Also, always pick up and carry a color picture tube by the bell—never by the neck.

It is usually easier to remove and replace a color picture tube if the receiver is turned face downward on a protective pad. However, before turning the receiver on its face, make sure the chassis is securely bolted to the cabinet. Also make sure the set will rest on the cabinet and not on the knobs on the front of the receiver. Some receiver manufacturers advise removing the chassis from the cabinet. In other receivers, the picture tube can be replaced more easily if the chassis remains in the cabinet.

As explained previously, the components on the tube neck will depend upon the tube type—whether it is an electrostatic convergence type or an electromagnetic convergence type. Nevertheless, both types have a mumetal shield (a metal shield that has been processed to eliminate magnetic disturbances), a retaining ring assembly, a deflection yoke, a color purity assembly, and a type of beam-positioning adjustment.

Be certain to discharge the picture tube before handling it in any way. This applies to the tubes received from the manufacturer as well as those in the receivers. Picture tubes are able to hold an electric charge for some time. Although the charge is not severe enough to be fatal, it may startle you and cause you to drop the tube.

To remove the picture tube shown in Fig. 8, the receiver must first be



Courtesy RCA

FIG. 8. How the picture tube is mounted in the cabinet.

laid face down. Next, remove the components from the tube neck, and loosen the four retaining rod thumb screws. The rods are connected between the retaining ring on the picture tube and the front of the receiver to support the picture tube and hold it in the proper position.

After the rods are removed, slide the retaining ring and yoke assembly off the neck. Unclip the ground lead from the equalizer magnet assembly, if the tube contains this assembly; loosen the clamping screw (see Fig. 7); and remove the equalizer magnet assembly. Lift off the mumetal shield and the plastic insulator that is located between the shield and the picture tube.

Grasp the picture tube by the flange near the screen or face, and lift directly upward. Place the picture tube face down on a protective pad.

To install the new picture tube, remove it from its carton, observing the precautions described previously. Place the picture tube in position inside the cabinet so that the blue gun pole piece near pin 12 on the tube socket is toward the top of the cabinet. Install the insulator over the picture tube and position the high-voltage anode lead so that it is on the side nearest the high-voltage supply. Place the magnetic field-equalizing assembly in position, and tighten the clamping screw. Make certain, however, that the screw is not too tight.

Place the mumetal shield and the yoke, which contains the retaining ring assembly in some receivers, over the neck of the tube, and secure the tube in place by using the retaining rods. Tighten the thumb screws just finger-tight. After the rods are in place you may return the receiver to an upright position. Be certain to position the yoke so that the wing nuts are located on either side with the leads toward the bottom.

Next, slide the other components into position, and install the tube socket. Check to see that all the ground leads are in place and that the high-voltage lead is connected at the high-voltage power supply. Insert the plugs into the proper sockets, and adjust the components according to the information given in the following section.

The first time you replace a color picture tube you may encounter some difficulty, because of the number of components on the tube neck. However, if you make a note of the positions of each component so that you can install them back in the same order, you should not have any trouble. Of course, the ease with which you replace the picture tube and make the required adjustments will increase with experience.

ADJUSTMENT PROCEDURES

The adjustment procedures required to obtain peak performance from a color television receiver can be classified in five major categories. These are monochrome, high voltage, color purity, balance, and convergence adjustments. The monochrome adjustments such as linearity, drive, width, height, and other adjustments common to both color and monochrome receivers have been discussed in previous lessons and will not be discussed here.

Before making the purity, balance, and convergence adjustments in a color television receiver, you should be sure that the correct voltage is applied to the high-voltage anode, because a number of critical picture tube adjustments depend upon a very accurate and stable high-voltage supply. The voltage values, depending on the make of the picture tube used in the receiver, range from 19,500 volts to 25,000 volts. Therefore, use a vacuum tube voltmeter with a high-voltage probe that is capable of measuring voltages to 30,000 volts when checking the output of the high-voltage power supply.

To adjust the high voltage in some color television receivers properly, you must also measure the current drawn by the high-voltage supply. This is done, usually, by removing the fuse in the low B+ lead and connecting a 0-500 milliammeter to the fuse terminals. In other receivers this measurement is not necessary. When the current meter connection is required, adjust the horizontal drive and the linearity controls for a minimum meter indication.

In all receivers, set the contrast and brightness controls at minimum. Then measure the voltage at the cathode of the final high-voltage rectifier tube with a high-voltage probe attached to a vacuum-tube voltmeter. When making the reading, set the horizontal hold control so that the raster is locked in when a signal is being received. Finally, adjust the high-voltage control, usually a potentiometer, until the value recommended by the manufacturer is indicated on the vtvm. Remember, the high voltage supplied to the picture tube anode must be checked and adjusted before carrying out any other receiver adjustments.

After the monochrome and high voltage adjustments are made, there are three major procedures to be followed in adjusting the picture tube and color circuits. These steps are *purity, balance,* and *convergence.*

Color Purity. The purity adjustment controls the fidelity of the hues produced on the picture tube screen by correctly positioning the three electron beams as a group. When the center of the beam triangle coincides exactly with the center of the phosphor dot trio, each beam will strike the precise center of its phosphor dot. When the adjustment is made correctly, the hues will be faithfully reproduced on the screen of the tri-color tube. The purity adjustment is similar to the centering adjustment used with some types of monochrome picture tubes.

The position and strength of the purity field is regulated either by an external purity magnet or by an external purity coil. The magnet is used with the magnetic convergence tube, while the coil is used with the electrostatic convergence tube.

The position of the yoke also has an influence on the purity of the reproduced colors. Therefore, you must move the yoke slightly forward or backward in addition to adjusting the purity assembly.

To make the purity adjustments on the electromagnetic convergence type picture tube, shown in Fig. 3, first set all the magnets in the field equalizing assembly at their maximum distance from the picture tube. Then set the contrast control fully counter-clockwise and the brightness control fully clockwise. Set the red screen control to the fully clockwise

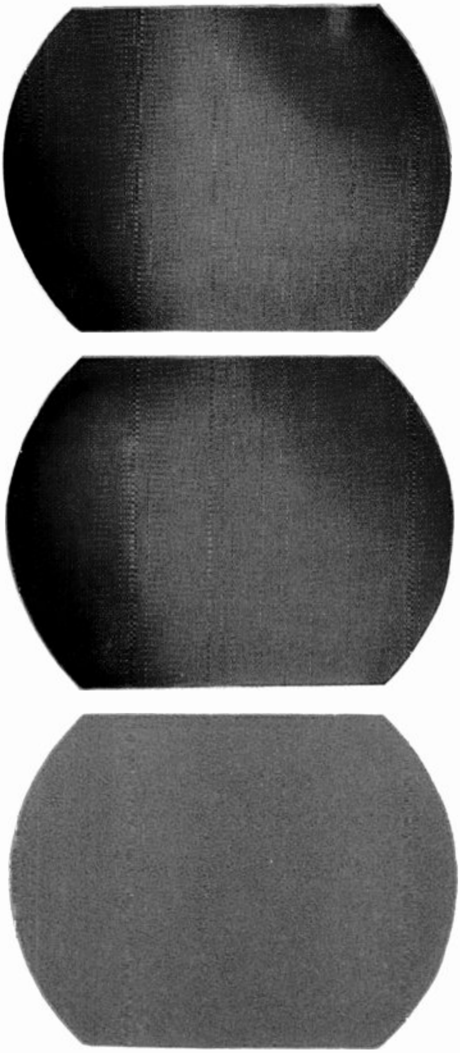


FIG. 9. Above, incorrect purity adjustment; center, better purity; below, correct purity.

position and the green and blue screen controls fully counter-clockwise. At this point, the raster should appear as shown at the top in Fig. 9.

Rotate one or both of the rings of the purity magnet by the tabs, or rotate the entire assembly to achieve minimum color contamination of the red field. Adjust the yoke also by moving it forward or backward on the neck of the tube. The yoke can be moved after loosening the wing nuts at each side of the yoke housing. These are shown in Fig. 3. Position the yoke for minimum color contamination of the red field.

At this point in the purity adjustments the raster should be red, but there probably will be some color contamination around the outer edges, as shown in the center in Fig. 9. It is important that the raster have a uniform red hue as shown at the bottom in Fig. 9. Readjust the yoke and the purity magnets until the red color is as uniform as possible. However, you may have to compromise—especially at the outer edges. Advance the green and blue screen controls individually and check the purity of the blue and green fields.

Now adjust all three screen controls to produce a low-level white raster. If the white raster shows some color contamination in the center of the screen, you might adjust the yoke and purity magnets again. Usually a slight adjustment is all that is necessary.

Color contamination at the outer edges of the raster may be improved by adjusting the magnets on the color equalizer assembly. Select the magnet nearest the contaminated area, and push it closer to the picture tube. Rotate the magnet for the desired effect.

The purity adjustment procedure in a receiver which has a picture tube using internal convergence electrodes (electrostatic convergence) is similar to the procedure just described. However, instead of the purity magnet, this tube usually has a purity coil.

The components on the neck of this type of color picture tube were shown in Fig. 2.

When making the purity adjustments in some color television receivers, the individual electron beams can be turned on and off by switches at the rear of the chassis. In others, the beams are controlled by adjusting the screen controls. However, to make the purity adjustments in either type of receiver, adjust the green and blue screen controls to minimum (or turn off the green and blue switches), and advance the *red* screen control to maximum. If the tube uses a neutralizing coil instead of an equalizing magnet assembly around the outer rim of the screen, disconnect it by removing the plug.

Loosen the bolts that hold the yoke in place, and slide the yoke back as far as possible. In Fig. 2 notice that three beam-positioning magnets are also contained in the housing with the purity coil. Rotate these magnets to their outermost positions.

Adjust the position of the purity coil and the current applied to the coil with the cross-purity control (sometimes called the color-purity control) to obtain the most uniform red in the center of the tube face. Refer to Fig. 9. Plug in the field neutralizing coil, and move the yoke assembly forward until the most uniform red raster is produced. If there is contamination at the edges, vary the current in the neutralizing coil by adjusting the field neutralizing control. Check the purity of the blue and green fields by turning the red screen control fully counter-clockwise and advancing the blue and green controls separately. If color contamination exists, a compromise must be made in the yoke and purity coil adjustments.

Balance Adjustments. The picture tube adjustment that controls the proper brightness excitation of the phosphor dots is called *balance*. Usually this is adjusted at the same time as the purity adjustments. When the balance adjustments are made properly, the hues in the color picture are true and vivid, and there is a minimum of color contamination in a monochrome picture. The balance adjustment procedure involves setting the control grid bias and accelerating electrode voltages of the tri-color tube so that true whites are obtained (no color contamination) at low and high brightness levels.

The balance adjustment is usually made while a black-and-white picture is being reproduced on the picture tube screen. First, advance the brightness control fully clockwise and the contrast control fully counter-clockwise. Tune to a station that is transmitting a black-and-white picture, and adjust the blue and green video gain controls clockwise until the monochrome picture is free of any *over-all color cast* as in Fig. 10. Dis-

FIG. 10. Proper white balance.

regard any localized color fringing in the picture.

Rotate the brightness control counter-clockwise to produce a very dark picture on the screen. Adjust the blue and green background controls for a uniform low-level monochrome picture that is free of all color cast. When the controls are adjusted properly, the picture should remain black and white as the brightness control is rotated throughout its range. Repeat the gain and background adjustments, if necessary, to achieve this.

CONVERGENCE ADJUSTMENTS

The purity control governs the overall position of the three beams as a group, and the convergence control governs their individual positions with respect to each other. With one electron gun, as in the standard monochrome picture tube, the only problem is to position and focus the beam in the exact center of the screen. The tri-color tube, however, contains three electron beams which must converge and pass through the same holes in the shadow mask to strike the proper phosphor dots. Misconvergence produces individual colors at the edges of all the objects in a monochrome picture, and improper color fringing in a color picture.

To make the convergence adjustments, a signal, which is generated by a piece of test equipment called a white-dot generator, is applied to the receiver input or to the input circuit of the video amplifier section to produce primary color dots or squares over the entire raster area. An example of the dot pattern is shown in Fig. 11. The adjustments are made to converge these dots into a series of white dots.

There must be two types of convergence adjustments, regardless of the type of tri-color tube used in the receiver—*static* and *dynamic.* If the color tube contains an internal convergence electrode, static convergence is accomplished with a set of dc adjustments and beam-positioning magnets that align the three beams with respect to each other. The beam-positioning magnets cause the beams

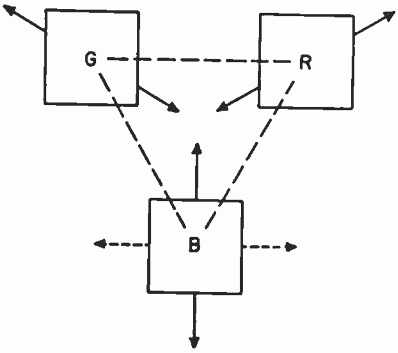


FIG. 11. Dot movement pattern.

to move in the directions indicated by the solid arrows in Fig. 11. By correctly positioning the magnets and adjusting the dc convergence voltage applied to the internal convergence electrode, the three beams can be made to produce a white dot pattern in the *center* portion of the screen.

Static convergence in tri-color tubes having external convergence coils is accomplished by adjusting the cylindrical magnets associated with each convergence assembly and by correctly positioning the blue beam-positioning magnet over the blue gun. The cylindrical magnets can be rotated to vary the magnetic fields and cause the electron beams to move in the directions indicated by the solid arrows in Fig. 11. The additional blue beam-positioning magnet is adjusted to obtain the horizontal motion of the blue electron beam. These magnets are adjusted and positioned to converge a red, green, and blue dot pattern into a white dot pattern in the center of the screen.

Dynamic convergence adjustments are made to produce the *same* faithful dot convergence over the *entire* raster area by applying special horizontal and vertical waveforms to the individual convergence coils (or to the convergence electrode). Each waveform is controllable in amplitude, phase, and shape. The phase must be the same as that of the horizontal and vertical deflection signals, and the shape and amplitude must correspond to the curvature of the screen to compensate for the varying distances the beam must travel between the guns and the various sections of the screen.

Before making any convergence adjustments on either type of color picture tube, connect a dot generator to the proper point in the receiver to produce a synchronized dot pattern on the screen. The synchronizing signals are obtained from the horizontal and vertical deflection circuits in the receiver. Clip the "horizontal lead" from the dot generator to the insulation on one of the leads in the deflection yoke cable. This will supply the correct horizontal deflection waveform to the dot generator. Vertical synchronization is obtained from the signal applied to the cathode of the red gun. Therefore, attach the "vertical lead" to the insulation of this lead at the picture tube socket. If the dot generator has internal vertical sync, omit this connection.

Connect the "ground lead" to the receiver chassis, and the "output lead" to the delay line near the second video amplifier tube. However, be certain that the "output lead" does not short to the chassis because this point is at B+ potential. Then, set the receiver to obtain a signal from some channel to provide the standard sync pulses for the dot generator.

Static Convergence. Pre-set the red, green, and blue horizontal and vertical amplitude controls to minimum (fully counter-clockwise), and the red, green, and blue vertical tilt controls to mid-range. Adjust the three convergence magnets and the blue beam-positioning magnet as explained earlier to produce a properly converged white dot at the *center* of the screen.

At this point the dot pattern should appear as shown in Fig. 12, which represents a line of dots through the center of the screen horizontally and vertically. Actually, the dot triangles will cover the screen. The center dots will be converged, but there will be misconvergence at the sides and at the top and bottom of the screen. The dot triangles may not necessarily be equilateral triangles as in the illustration, but you should obtain approximately the pattern shown.

Dynamic Convergence. After the dot is converged at the center of the screen, vertical and horizontal dynamic convergence adjustments must be made to produce properly converged dots at the edges. Fig. 12 shows the approximate positions of the rows of dots that should be used for reference purposes during the convergence adjustments. The dynamic convergence controls on some color receivers are located on the front panel, while in other receivers the convergence circuits and controls are contained in a separate chassis. An example of the latter type is shown in Fig. 13. Refer to this illustration as we discuss the adjustment procedure.

Vertical Convergence. The *vertical* row of dots nearest the center of the screen must be converged first. Turn the red vertical amplitude control, shown in Fig. 13, fully clockwise, and adjust the red vertical tilt control for maximum displacement of the red dots from the blue dots at the center of the screen. Turn the green vertical amplitude control fully clockwise, and adjust the green vertical tilt control for a maximum displacement of the green dots. You will notice that these adjustments cause the dots to move in opposite directions.

Unless the grid of the blue gun in the picture tube is grounded, it will be difficult to see the spacing between the red and green dots. Therefore, either ground the blue grid at the rear of the chassis (provisions have been made to ground the individual grids) or turn the switch that con-

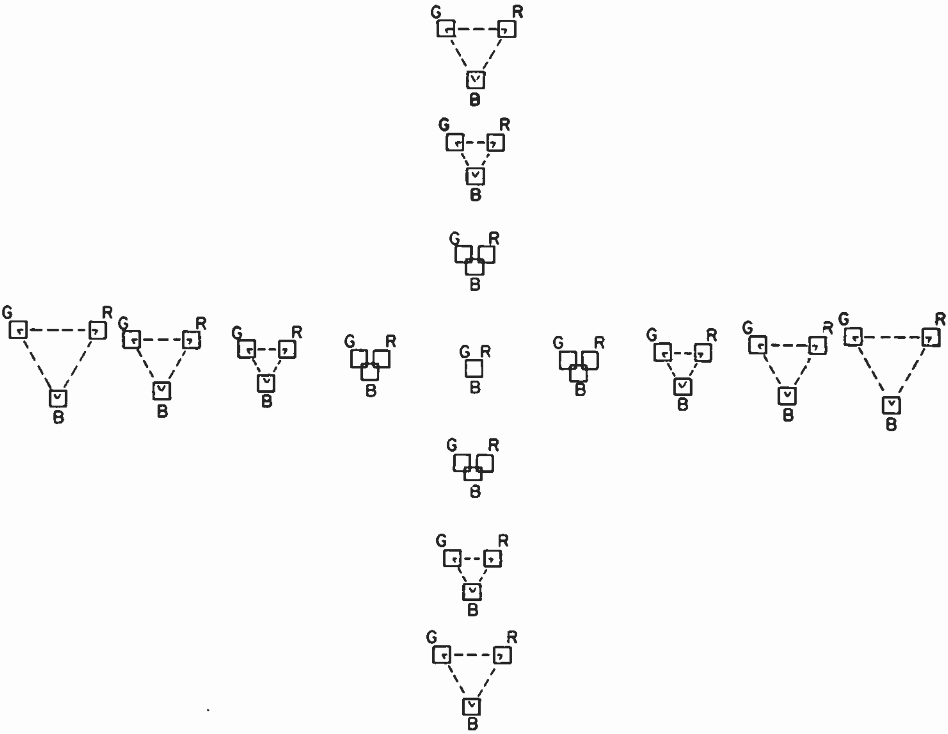
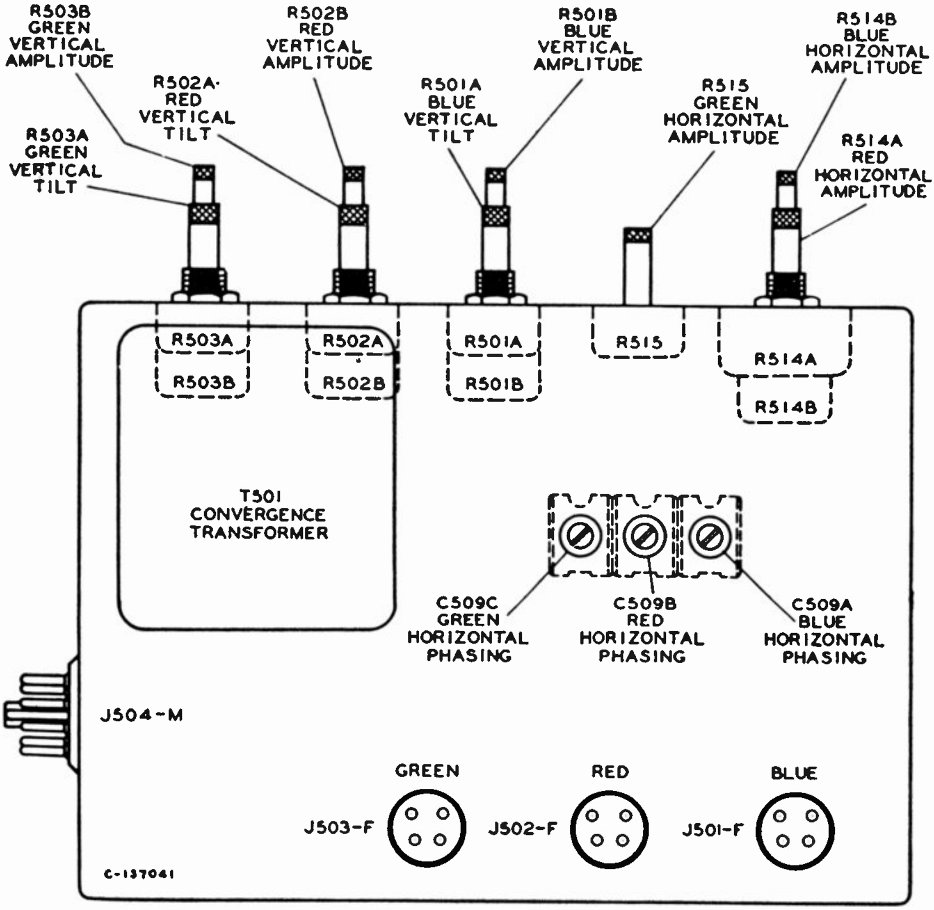


FIG. 12. Proper static convergence.



Courtesy RCA

FIG. 13. Convergence chassis showing adjustments.

trols the blue gun to the off position. Follow either procedure, depending upon the type of receiver that you are adjusting.

With the blue gun inoperative, the center row of vertical dots will appear as shown in Fig. 14A. Adjust the red and green vertical amplitude controls to produce straight vertical lines of red and green dots equally displaced from each other, as shown in Fig. 14B. Converge the two rows of dots, using the red and green convergence magnet adjustments, to produce a single vertical row of yellow dots. The rows of red and green dots move in the directions indicated in the illustration. If the red and green dots appear displaced at the top or bottom, readjust the red and green vertical amplitude and tilt controls.

Turn on the blue grid, and set the blue vertical amplitude control fully clockwise. Alternately adjust the blue vertical tilt and amplitude controls until the displacement of the blue dots is uniform with respect to the yellow dots along the entire ver-

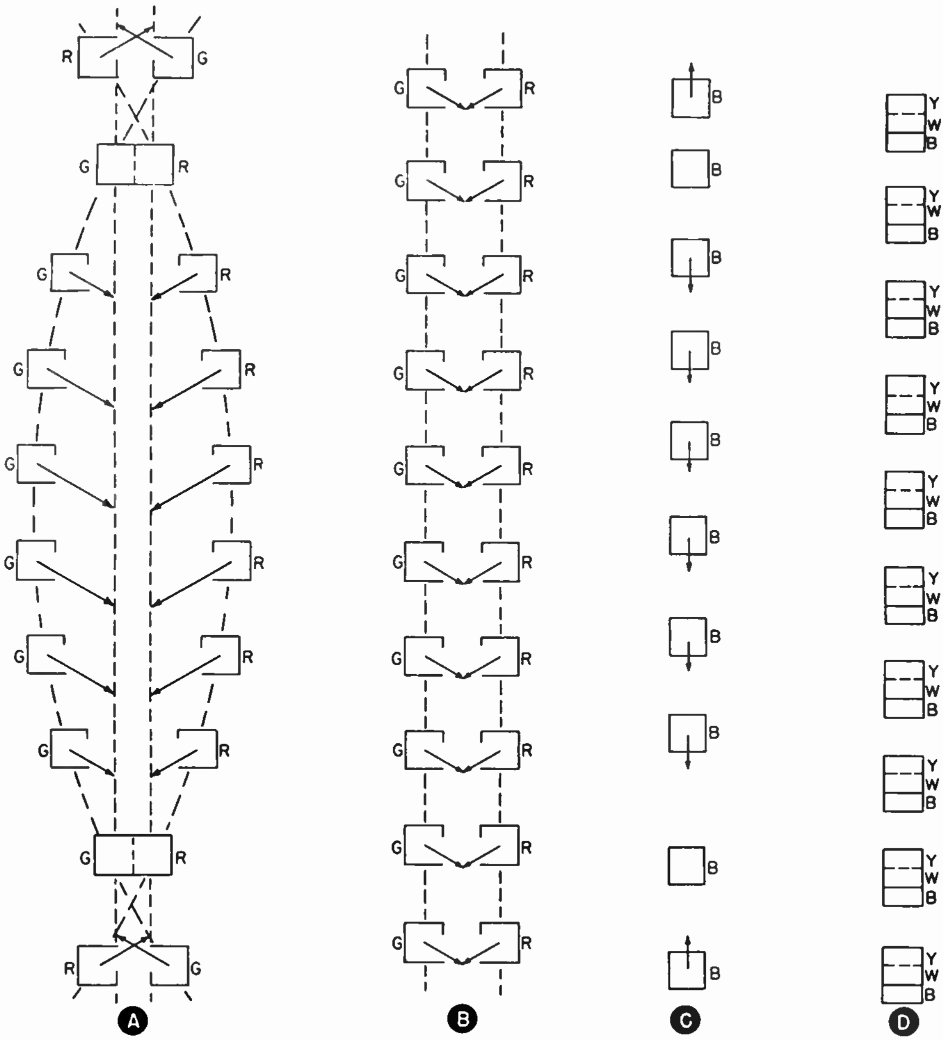


FIG. 14. Vertical dynamic convergence.

tical center line. The dots move in the directions shown in Fig. 14C. Adjust the blue convergence magnet and the blue beam-positioning magnet until the blue dots fall on the row of yellow dots, forming a single vertical row of dots as in Fig. 14D.

Horizontal Convergence. The horizontal convergence adjustment procedure is approximately the same as that for vertical convergence. However, the *horizontal* row of dots nearest the center of the screen, illustrated in Fig. 12, is used for the reference. When the horizontal convergence controls are adjusted, the dots move as indicated in Fig. 15A.

Turn the blue horizontal amplitude control fully clockwise and adjust the blue horizontal phasing control to

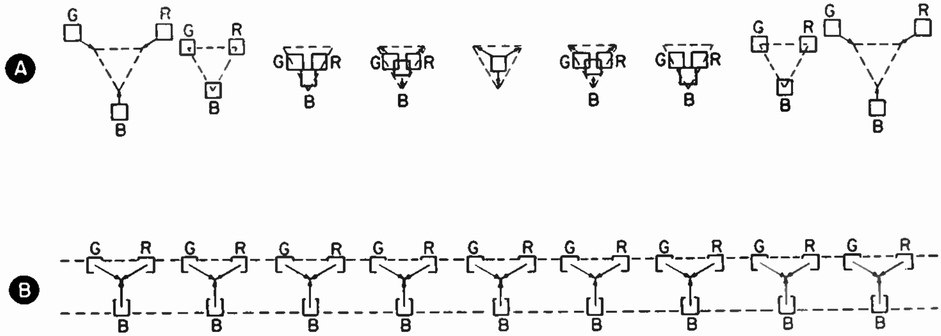


FIG. 15. Horizontal dynamic convergence patterns.

produce maximum downward displacement of the blue dots at the center of the screen. Alternately adjust the blue horizontal phasing and the blue horizontal amplitude controls to produce a straight horizontal line of blue dots across the screen.

Ground the red grid of the picture tube at the rear of the chassis, and alternately adjust the green horizontal amplitude and phasing controls to produce a uniform displacement of the entire center line of green dots with respect to the center line of blue dots.

Ground the blue grid and remove the grounding lead from the red grid of the picture tube. Adjust the red horizontal amplitude and phasing controls to produce uniform displacement of the center line of red dots with respect to the center line of the green dots. Remove the ground lead from the blue grid, and the dot pattern should appear as in Fig. 15B.

The dots must now be converged to form a single line of white dots. To do this, short out the blue grid once more, and adjust the green and red convergence magnets until a single center line of yellow dots is produced. Finally, remove the ground from the blue grid, and adjust the blue convergence magnet and blue beam-positioning magnet to move the blue dots onto the yellow dots, producing white dots. After you have carried out these adjustments, a dot pattern should now show maximum convergence, both horizontally and vertically, over the entire screen.

Color Test Equipment

Because a color television receiver has many of the same circuits found in a monochrome receiver, you will need all the test equipment ordinarily used to service black-and-white receivers. If you have had some experience in servicing monochrome receivers, you will have no difficulty in servicing these sections in a color receiver. However, to adjust and check the chrominance sections of a color television receiver properly, you will need two additional pieces of test equipment—a color-bar generator and a white-dot generator.

You learned in the preceding sections that a white-dot signal generator is used in making convergence adjustments. The instrument produces signals which form a dot pattern on the picture tube screen. A test instrument similar to the white-dot generator can be obtained that will form not only a dot pattern, but also horizontal and vertical bars and a cross-hatch pattern for making horizontal and vertical linearity adjustments. An instrument of this type will be discussed later in this section.

Adjustments in the chrominance section of a color receiver can be made most efficiently with a color-bar generator. This instrument forms a signal which produces a group of vertical color bars across the picture tube screen. With the color-bar generator connected to the proper test point in the color receiver as instructed in the manufacturer's service information, the generator will produce from 10 to 16 different color signals which correspond to all the primary and secondary color signals, the color-difference signals, the I and Q signals, and black and white. By observing the color of the bars, you can accurately adjust the chrominance section to produce faithful color reproduction.

In addition to the white-dot and color-bar generators, you will need the equipment that is ordinarily used in servicing monochrome receivers, such as a sweep generator, a marker generator, a vtvm, and an oscilloscope. These test units must have stricter tolerances, however, if they are to be used effectively in color television work. For example, the oscilloscope must have a wide-band response up to 4 or 5 mc so that you can observe the chrominance sidebands above 3.8 mc. Accurately calibrated marker generators are necessary in performing the more critical alignment work required in color receivers. Because the frequencies are closely spaced on the response curve, the marker generator must be very accurate. This accuracy is obtained usually by using a crystal-controlled oscillator.

The video sweep generator used in color television alignment must not only supply a linear sweep over the i-f and VHF ranges, but also it must produce the video sweep range between 0 and 5 or 6 mc. However, if the frequency output of the rf-if sweep generator that you have been using in monochrome receiver alignment is flat, it can be used, together with a wide-band oscilloscope, to check the low-gain circuits by adding

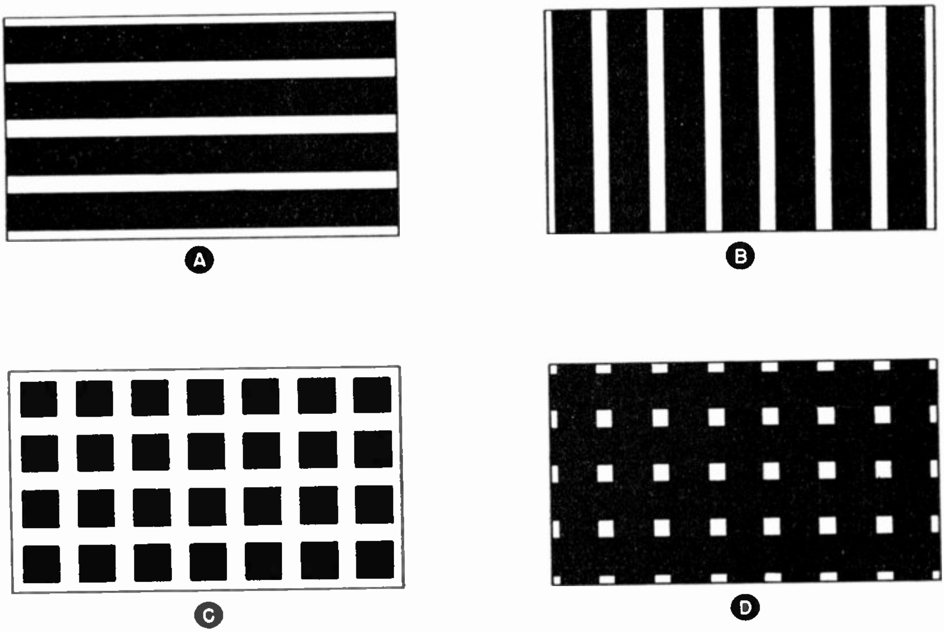


FIG. 16. Bar and dot patterns. A, horizontal bars; B, vertical bars; C, cross-hatch pattern; D, dot pattern converged.

a chromatic amplifier with a high-frequency probe. This instrument, which is usually a two-stage, wide-band rf amplifier, is connected to the various chrominance circuits under test, such as the Y channel and matrix circuits. The chromatic amplifier boosts the signal strength until it is high enough to obtain full deflection on the oscilloscope. Of course, additional amplification is not needed in many of the stages. This test instrument is used only in the very low-gain circuits.

From your study of monochrome receiver alignment and adjustment, you should have an idea of how to use all the test instruments that we have just described, with the exception of the white-dot and the color-bar generators. Therefore we will briefly describe these instruments and find out how they are used in adjusting and aligning color television receivers. As stated previously, we will not take up color receiver alignment in this lesson. The alignment instructions should be obtained from the manufacturer for each model.

DOT-PATTERN GENERATOR

A combination bar and dot generator, which is often used in color television work, will form a dot pattern for convergence adjustments, and also can generate signals which produce horizontal and vertical lines, and cross-hatch patterns for making linearity adjustments on either a color or a monochrome receiver.

To produce the bar patterns on the screen, the horizontal and vertical oscillators in the generator must operate at a prescribed frequency with respect to the horizontal and vertical scanning rates. For example, to produce a number of horizontal bars on the screen, the horizontal oscillator must operate at a frequency that is lower than the line rate but higher than the vertical rate. Fig. 16A is an illustration of the pattern that would appear on the picture tube screen when the test instrument is adjusted to produce horizontal bars. In most dot-pattern generators, the number of horizontal bars is somewhere between 8 and 15.

To produce the vertical bar pattern shown in Fig. 16B, the vertical oscillator must operate at a frequency that is higher than the line rate. As the scanning beam travels across and down one line of the raster, the pulse signals from the vertical oscillator change the line illumination so that a series of vertical bars appears on the screen. The usual number of vertical bars is 12.

If the receiver is properly adjusted, the bars will be evenly spaced across and down the screen, because they are generated in a prescribed and fixed time sequence. If this even spacing does not exist, it indicates non-linearity in the deflection systems of the receiver.

The cross-hatch pattern, shown in Fig. 16C, is formed when both horizontal and vertical bar oscillators are in operation. This pattern again can be used in making horizontal and vertical linearity adjustments simultaneously, and for checking the overall linearity of the horizontal and vertical circuits.

To form a dot pattern on the picture tube screen, the generator circuits must emphasize and generate signals only at the time intervals during which both the horizontal and vertical bar oscillators are contributing signals simultaneously. These time intervals occur when the lines cross in the cross-hatch pattern. Thus, the dots shown in Fig. 16D correspond to the positions of the horizontal and vertical cross-over points.

The dot pattern is used primarily in making horizontal and vertical convergence adjustments in color receivers. However, it can also be used to determine non-linearity in the horizontal and vertical circuits by observing the spacings between the dots over the picture tube screen.

COLOR-BAR GENERATOR

The color-bar generator produces signals that form a number of vertical color bars on the screen of the picture tube. These bars are useful in adjusting and checking the performance of the chrominance channels and the matrix section of the color receiver. The color-bar patterns produced by one type of color-bar generator is illustrated in Fig. 17.

The color-bar pattern in Fig. 17 is composed of ten vertical bars that extend from the top to the bottom of the screen. The first and the tenth are partly cut off at the extreme edge of the screen. Notice that the spaces

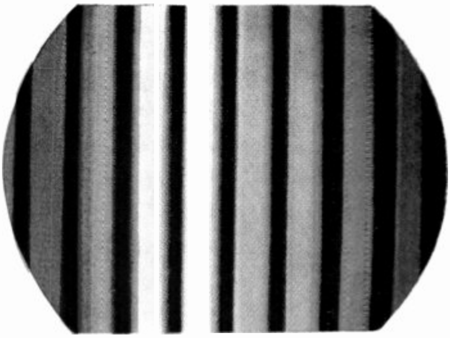


FIG. 17. Color-bar pattern produced by one type of color-bar generator.

between the bars contain no color. You can use this half-tone background, therefore, to compare the color levels and the background brightness. From left to right, the colors of the bars are dull yellowish-orange, orange (I), bright red (R-Y), bluish-red, magenta (Q), blue (B-Y), greenish-blue, cyan (-I), bluish-green —(R-Y), and dark green.

The circuits in the color-bar generator transmit signals that correspond in phase and amplitude to each hue during the interval of one line of picture information. The signal usually contains 8 cycles of the subcarrier frequency for each hue to be reproduced.

Definite hues are reproduced because the signal from the color-bar generator corresponds to the individual chrominance signals in both phase and amplitude. By studying the positions of the various color signals on the diagram in Fig. 18, you can see that all the chrominance signals used in color television transmission are spaced approximately 30° apart. Thus, by taking a sample, consisting of 8 cycles of the subcarrier signal, at each of these points, the hues can be reproduced on the tri-color tube screen.

Sampling occurs because the output of the crystal-controlled bar oscillator is applied to a circuit which produces a pulse signal having a

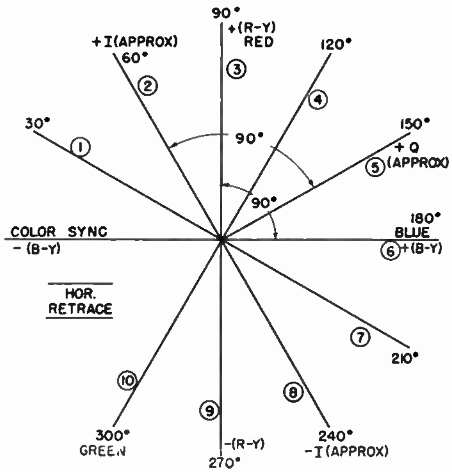


FIG. 18. Vector relationships of signals produced by color bar generator. Each vector is numbered to correspond to one bar.

fundamental frequency that is twelve times as high as the line rate (or approximately 189 kc). The output of this circuit is used to key the subcarrier signal from the subcarrier oscillator. Each time the pulse signal is produced by the circuit, eight cycles of the subcarrier signal are fed to the color receiver.

Many color-bar generators are able to produce not only the chrominance signals, but also the subcarrier signal similar to that sent from the transmitter. Therefore, the instrument can be connected to the antenna terminals. However, other color-bar generators must be used in the chrominance sections only.

Servicing Color Receivers

Servicing a color television receiver is no more difficult than servicing a monochrome receiver, if you understand how the receiver operates. Of course, a color receiver contains many more circuits than a monochrome receiver. However, you can use essentially the same localization procedure by observing how the defect or disturbance affects the image on the picture tube screen. After some practice you will be able to isolate the defect quickly to just a few stages.

At this time you are probably unfamiliar with what to expect from a properly adjusted color receiver. Many apparent defects in the color image may not be due to circuit failures or troubles at all, but to improper receiver adjustments. As pointed out previously, the operation and adjustment procedures required for a color receiver are more precise and involved than for a monochrome receiver. Therefore, beware of diagnosing circuit defects before you make certain that the color adjustments have not drifted or been made improperly.

Before we discuss the servicing techniques that can be used in locating defects in the circuits that handle the color information, let us point out some defects that require the same servicing techniques as in black-and-white receivers. If you are familiar with the operation of these circuits in the monochrome system, you should have no difficulty in servicing them in the color receiver. As we go through the test procedures, some of the tests and servicing techniques will be familiar to you, because they were discussed in other lessons in this course.

MONOCHROME DEFECTS

As in monochrome receivers, the major source of trouble in the color receiver is defective tubes. This is even more true in the color receiver because additional tubes are required to take care of the color portion of the reproduced picture. Therefore, before carrying out any specific tests in a color receiver, check the tubes for burned-out filaments, low emission, and internal shorts. Notice that this is the same procedure as for servicing monochrome receivers and radio receivers as well.

You should have no difficulty in servicing the low-voltage power supply in the color receiver. The high-voltage supply should not be difficult if you understand the operation of the corresponding circuit in monochrome receivers. If you suspect trouble in this section of the color receiver, measure the high voltage at the cathode of the high-voltage rectifier tube, using a vacuum-tube voltmeter and a high-voltage probe. If the voltage is low, or if there is no voltage at this point, turn the receiver off, and make continuity and resistance checks throughout the high-voltage section with an ohmmeter. Before using the ohmmeter, however, make certain that the condensers are discharged. Also, when measuring the high voltage at the cathode of the high-voltage rectifier tube, turn the set off and allow enough time for the condensers to discharge before removing the meter lead from the high-voltage terminal.

Defects in the horizontal and vertical sync and sweep circuits in both color and monochrome receivers will produce the same type of raster disturbance. Complete failure of the vertical sweep circuits will cause a horizontal line to appear; complete failure of the horizontal sweep circuits will cause the entire raster to disappear, because the high voltage is obtained by the flyback action of the horizontal sweep, and if there is no sweep there will be no high voltage.

In a color receiver, defects in the horizontal and vertical sweep circuits also affect the convergence. If the circuits are functioning improperly, use an oscilloscope to view the waveforms through the circuit.

A defect in the sync circuits also can be located by observing the shape of the vertical or horizontal sync pulses from the sync take-off point through the sync system to the vertical and horizontal sweep amplifiers. If the video signal sync take-off point is distorted, you should check the video detector and any video stages that may be used between the detector and the sync take-off point. If these stages are operating properly, there may be a defect in the tuner or the video i-f amplifier.

The procedure used in servicing the sound section of a color receiver is similar to that used in a monochrome receiver. For example, if the receiver has a normal picture but no sound, begin at the sound take-off point and trace the sound through to the loudspeaker. Color receivers usually use an intercarrier sound system; the sound take-off point is either at the last i-f stage or at the video detector.

If the sound is normal, but there is no picture, or a poorly synchronized picture when a monochrome signal is tuned in, look for a defect in the luminance or the sync sections. The servicing procedures required to locate these troubles are the same as you would use in standard monochrome receivers. Therefore, the experience that you have gained in servicing and locating troubles in monochrome receivers will be invaluable to you in repairing similar defects in the corresponding sections of a color receiver.

CHROMINANCE DEFECTS

Disturbances that influence purity, balance, and convergence can make themselves apparent as monochrome defects. For example, improper convergence will cause a monochrome picture to appear to be outlined in one of the primary or secondary colors, as shown in Fig. 19. If a part of the picture is tinted or if one side shows a tint of one color and the other side a tint of another color, the purity adjustments should be checked.

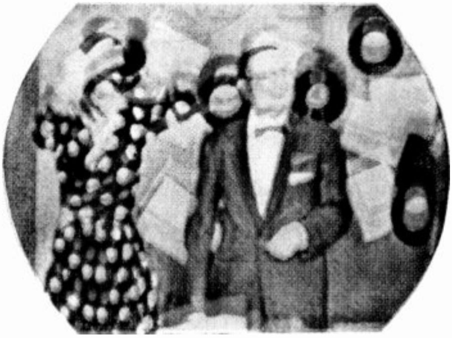


FIG. 19. Influence of improper convergence on a monochrome picture.

If the entire picture is tinted one color, the red, green, and blue guns are not balanced.

To determine if there is a raster disturbance, set the color receiver to an unused channel, and turn the contrast control to minimum. Turn the brightness control to maximum, and you should obtain a normal gray raster. If there is color contamination in a part of the raster, the purity adjustments should be checked. If the entire raster is tinted, the balance adjustments should be checked. Check the purity by turning the blue and green screen controls to minimum and the red control to maximum. You should obtain a uniform red raster. Check the blue and green fields by turning the red screen control counter-clockwise and advancing the blue and green screen controls separately. If you obtain uniform primary colors over the entire raster, the purity adjustments have been made properly.

The balance adjustments also must be made correctly to obtain a black-and-white monochrome picture rather than a picture tinted red or one of the other primary colors. When the beams are properly balanced, the raster should remain gray regardless of the setting of the brightness and contrast controls. With a signal from a dot generator applied to the receiver, the resultant pattern on the screen at low and high brightness should appear as shown in Fig. 20.

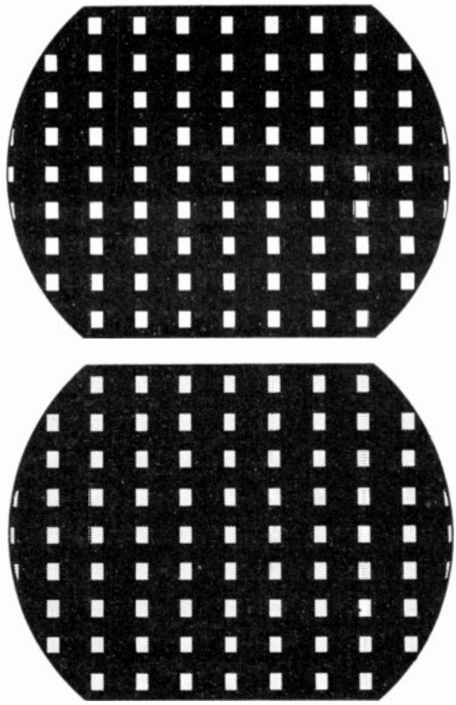


FIG. 20. Correct white balance adjustments. Above, correct white highlight adjustment; below, correct white low-light adjustment.

Color fringing or outlining in a monochrome picture can be caused by defects in the convergence circuits. Connect a bar-pattern signal generator to the receiver, and set the controls to produce a cross-hatch pattern on the screen. Misconvergence will be indicated if color fringing appears around the edges of the bars. If you cannot converge the beam regardless of how much you adjust the convergence controls, use an oscilloscope and observe the waveforms throughout the convergence circuits. You may find that the convergence waveforms are distorted.

Before the convergence adjustments can be made properly, the correct voltage value must be applied to the high-voltage anode of the picture tube. Measure the voltage with a vtvm and a high-voltage probe, and adjust it to the value recommended by the manufacturer.

If you cannot locate the trouble by checking the purity, balance, and convergence, the defect may be in the luminance channel of the receiver. For example, if the tube in the second video amplifier has weak emission, insufficient luminance signal will be fed to the picture tube grids. Remember that the luminance signal passes through two video amplifier stages and the matrix section to the grids of the color picture tube. A defect in either video amplifier will influence the signals reaching all the picture tube guns in the same manner. In addition, even the monochrome version of the picture will have insufficient contrast.

Although a luminance channel defect affects all three colors, a defect in the matrix section will confine itself to just a single color. Before deciding that the trouble is due to a matrix circuit defect, however, try readjusting the blue and green gain and background controls. Unless the matrix controls are adjusted correctly, the proper proportions of the primary color signals will not be fed to the grids of the picture tube. If the color contamination cannot be eliminated, one of the signals is weak or missing. Therefore, short out two of the control grids and observe the remaining primary color image on the screen. With the blue and green grids shorted to the receiver chassis, a strong red image should appear on the screen. With the red and green grids shorted, the image should be blue. Finally, a green image should be reproduced on the screen when the red and blue grids are shorted to the chassis. If one of the primary colors is absent or weak, there is a defect in that section of the matrix unit.

If you thoroughly understand the operation of the color receiver, you can usually isolate the defect to one of the matrix sections merely by observing the nature of the color tinting. For example, if the blue signal is missing or weak at the control grid of the blue gun, the reproduced picture will have a yellowish tint because the red and green dots are excited normally. If the red signal is weak or absent, the reproduced picture is likely to have a complementary cyan tint, and if the green primary color signal is missing, the picture would have a magenta tint.

Another type of color contamination can occur if the color-killer circuit is not operating. The color-killer section should produce a voltage which turns off the band-pass amplifier during reception of a monochrome signal. If this section permits the luminance information to pass through the chrominance channels, a fine background of colored dots will appear on the screen. This indicates that the picture tube grids are being modulated by signal components from the chrominance channel.

If a normal monochrome picture is received free of color contamination, but a color picture signal cannot be reproduced faithfully, there is a defect in the chrominance sections of the receiver. Color circuit defects can be classed in three main categories: no color, poor color synchronization, and improper hues.

Defects in the color sync circuits can result in improper hues or color instability. Generally, improper adjustments produce improper hues, as shown in Fig. 21A, while poor color sync stability caused by a circuit defect produces a continuously chang-

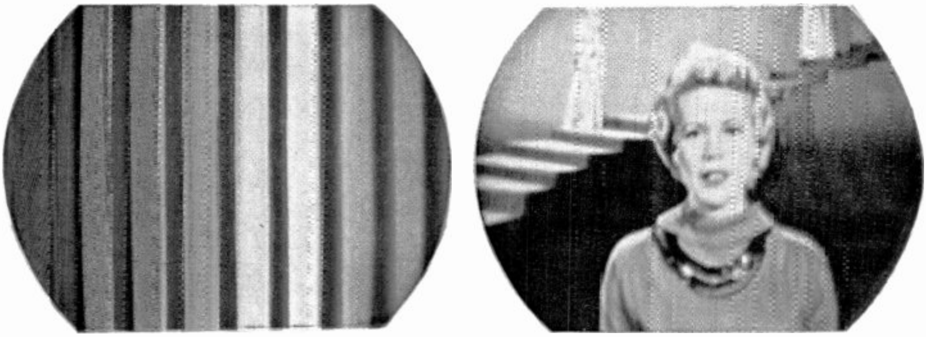


FIG. 21A. Incorrect hue control adjustment.

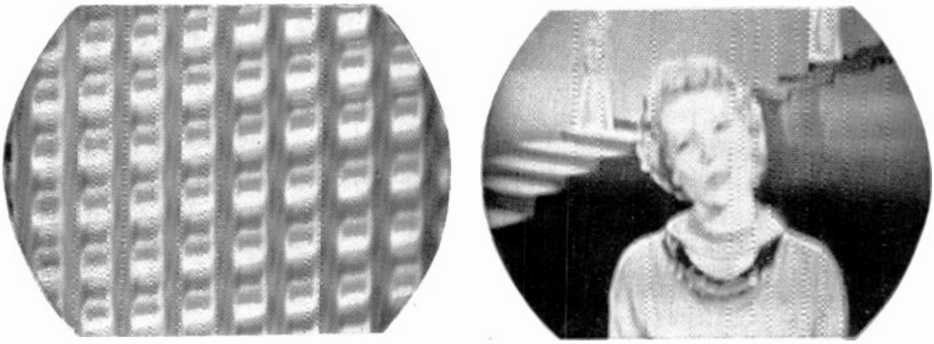


FIG. 21B. Loss of color sync.

FIG. 21C. Normal picture.

ing color pattern, as shown in Fig. 21B. A normal picture is shown in Fig. 21C. Notice how flesh tones are reproduced most faithfully when the receiver is in peak operating condition.

A color-bar generator is useful in locating defects in the chrominance

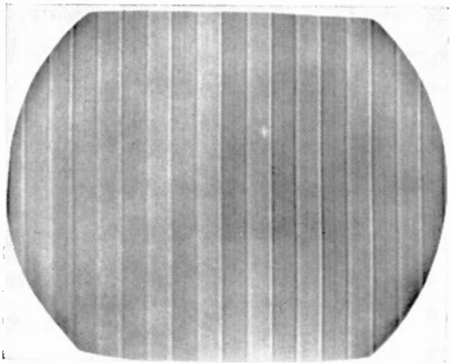


FIG. 22. **Color-bar generator pattern with color missing.**

channels because the signal output from this instrument can be fed into the various sections, and the resultant hues can be seen on the screen. By studying the colors, you will be able to detect which channel is probably at fault.

If the chrominance channels are not operating properly, the color bar pattern shown in Fig. 22 will appear on the screen. Of course, both the chrominance signal and the locally generated subcarrier sine waves must be present at the grids of the demodulator tubes before the chrominance channels will function. A defect in the bandpass amplifier or an inoperative bandpass amplifier resulting from a failure in the color phase detector circuit could prevent chrominance signals from reaching the demodulators. If the crystal subcarrier oscillator or its succeeding amplifier is inoperative, the inserted subcarrier signals will be removed. Consequently, the chrominance signals would not be developed in the demodulator output circuits.

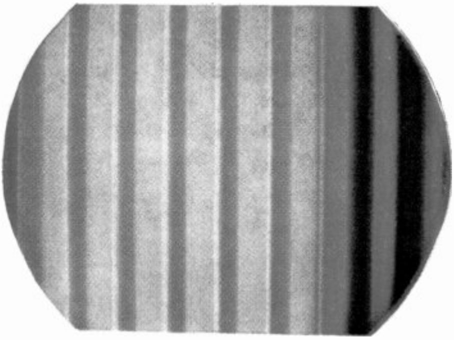


FIG. 23A. I signal missing.

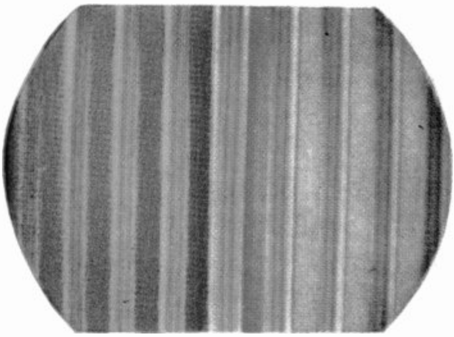


FIG. 23B. Q signal missing.

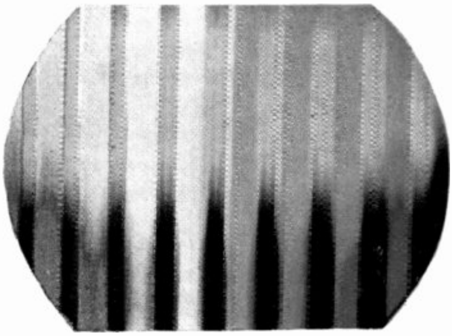


FIG. 24A. Hum in the Q channel.

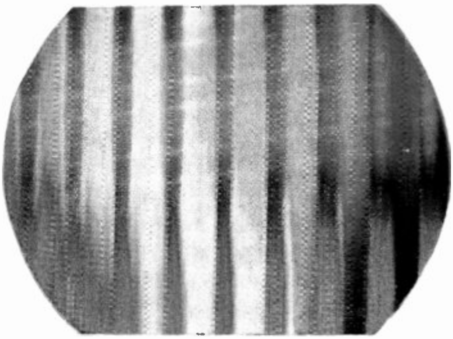


Fig. 24B. Hum in the I channel.

An oscilloscope is useful in locating defects in the color channels. By attaching the oscilloscope to the individual grids of the demodulator stages, you can quickly locate the points at which the chrominance signals or the subcarrier sine waves are missing.

When there is a defect in either the I (or R-Y) channel or the Q channel, the reproduced image is colored. This coloring is stationary, but there is an improper rendition of the hues. In a receiver that demodulates on the I and Q axes, the color images would appear as shown in Fig. 23. With the I signal missing (Fig. 23A), the dominant colors are in the green to purple range, while with the Q signal missing (Fig. 23B), the dominant colors are in the orange to blue-green range. By observing the image reproduced on the picture tube, you can quickly isolate the defect to the I or Q channel. Hum in the Q channel appears as green and magenta horizontal bars as shown in Fig. 24A. Hum in the I channel appears as orange and cyan horizontal bars as shown in Fig. 24B. Again this defect demonstrates how each channel emphasizes the range of hues that it is to pass.

The color-bar generator is also helpful in locating misadjustments and circuit defects in the three channels of the matrix unit. By observing the presence or absence of certain colors, you can quickly determine the defective section. For example, with the red signal removed, the color of the bars will range from blue to green as shown in Fig. 25A. Figs. 25B and 25C illustrate the resultant bar patterns when the green and blue signals are absent. Thus, improper adjustments as well as circuit defects can be located quickly by using this test instrument and observing the reproduced colors in the pattern.

As you gain experience in servicing color receivers, you will find that many of the trouble-shooting techniques used in locating defects in monochrome receivers can be used effectively in corresponding sections of the color receiver. Color receiver adjustments must be made more accurately than those in the black-and-white receiver because slight misadjustments will be more noticeable in the reproduced color picture. A customer who may disregard slight inaccuracies in the adjustment of a monochrome receiver will insist upon a faithful color rendition on his color

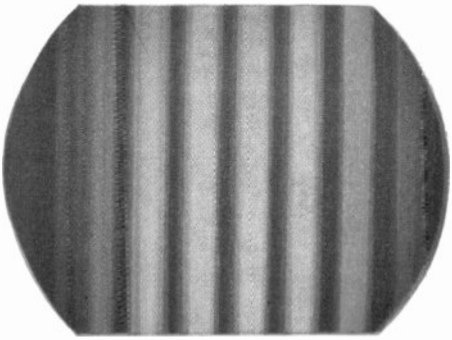


FIG. 25A. Red missing.

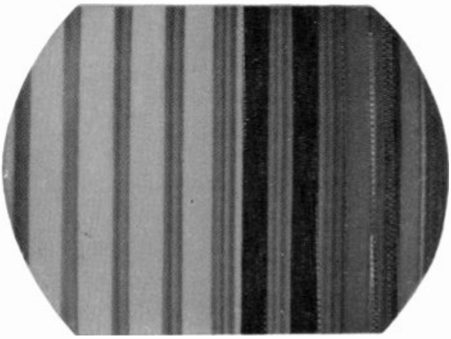


FIG. 25C. Blue missing.

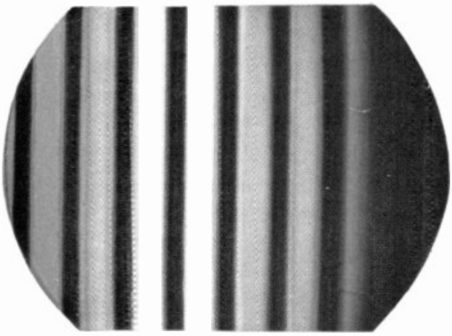


FIG. 25B. Green missing.

receiver. Remember, the more experience you have in receiver adjustments, the more rapidly and expertly you will be able to make them.

As you have noticed in this and in other lessons, the circuits used in color receivers and the adjustments vary considerably. Therefore, while you are learning to service and adjust receivers, obtain the service information on each model and follow the manufacturers' recommendations

Lesson Questions

Be sure to number your Answer Sheet 61B.

Place your Student Number on every Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time, or you may run out of lessons before new ones can reach you.

1. When you are installing a color receiver, when you turn it on for the first time to check its performance, which type of transmission should you try to tune in, a monochrome or a color transmission?

2. Why must the fine-tuning control on a color receiver be adjusted more carefully than the fine-tuning control on a monochrome receiver?

3. When adjusting a color receiver for best color using a color program transmission, what color should you adjust for best reproduction?

4. What adjustments are used to make the beams strike the center of their respective phosphor dots on the screen?

5. If the black and white pictures obtained on a color receiver during a monochrome transmission are outlined in color, what is the most likely trouble?

6. What is the purpose of the field-neutralizing assembly?

7. If the black and white picture on a color receiver during a monochrome transmission has a blue tint, which one of the following adjustments should be checked: purity, balance, convergence?

8. When making convergence adjustments, which would you use: a sweep signal generator, a dot generator, or a color-bar generator?

9. Will a defect in the video detector of a color receiver affect the performance of the receiver on color programs only, on monochrome programs only, or on both color and monochrome programs?

10. Will a defect in the I detector of an I and Q color receiver affect the performance of the receiver on color programs only, monochrome programs only, or on both color and monochrome programs?

TEN SUGGESTIONS

I. Accept and welcome fair criticism.

II. Don't be a chronic grouch or petty complainer.

III. Develop a "we" and "our" attitude toward your company. Realize that what hurts company business hurts you also.

IV. Hard work brings success just as fast today as ever. Remember this—if you never do more than you're paid to do, you'll never get paid for more than you do.

V. Prepare yourself to handle the work of men above you. A good understudy is valuable.

VI. Always be ready to do new tasks.

VII. Develop confidence in your abilities, but avoid over-confidence.

VIII. Keep your head when the routine of work is varied or when an emergency arises.

IX. Don't bury your nose in the details of your job. Assign routine duties to your assistants, so you will have time for more important things.

X. Devote a few minutes each day to clear thinking about your job, your future and your company's future.

J. E. Smith.

MULTIPLE OUTLET AND COMMUNITY TV ANTENNAS

REFERENCE TEXT 61BX

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WASHINGTON, D. C.
ESTABLISHED 1914

STUDY SCHEDULE

For each study step, read the assigned pages first at your usual speed, then re-read slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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1960 EDITION

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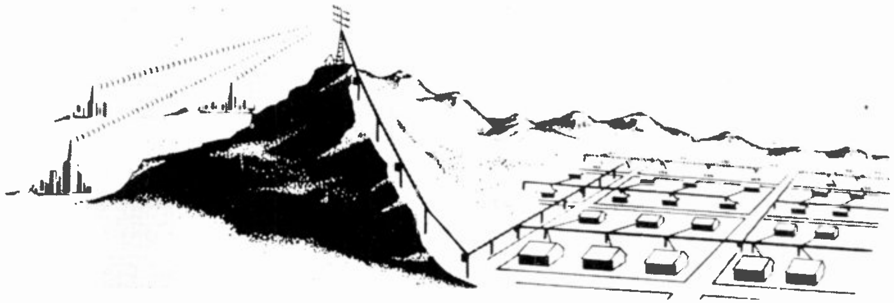
MULTIPLE-OUTLET AND COMMUNITY TV ANTENNAS



A MAJORITY of the television signal distribution systems that you will meet in your service work will consist merely of an indoor or an outdoor antenna, used to supply TV signals to a *single* receiver. However, in some localities it is not practical to erect a separate antenna for each receiver; this is particularly true in a large apartment house.

There are areas in which it is practically impossible to receive any television signals of sufficient strength to operate a receiver and obtain a satisfactory picture. For example, a community may be situated in a valley or in a location where there is a high mountain between it and the transmitter. In order to get TV signals to these isolated areas (isolated as far as TV signals are concerned), the community itself, or a private company, can erect a large antenna on the summit of the nearby mountain where television signal reception is possible. The antenna intercepts the television signals, amplifying equipment increases the signal strengths, and a system of coaxial cable and other accessories distribute the signals throughout the community. Usually the residents subscribe to the television service, and pay a small monthly fee.

The television signal distribution system in a large apartment house, on the other hand, is usually installed and maintained by the owner of the apartment building. He realizes that it is to his advantage to eliminate a "forest" of antennas on the roof. By installing a TV signal distribution system, only one antenna is required to supply adequate TV signals to all the apartments.

Signal distribution systems, however, are not confined to large apartment buildings or entire communities. The term "distribution system" can be applied to an installation that supplies signals to two receivers in a private home. The primary purpose of any distribution system, whether small or large, is to provide at each receiver outlet, a signal that will produce a high quality picture with a minimum of noise and interference.

This signal standard is set at the antenna. The remainder of the system, consisting of the coaxial cable, the amplifiers, and the other accessories, cannot improve the picture quality; however, the components that are used must be able to *maintain* the quality of the signal throughout the system.

The purpose of this lesson is to acquaint you with the various types of signal distribution systems, and to explain how they operate. In the following section, we will briefly describe each of the major types, from a simple two-receiver system for a private home to an elaborate system that sérves thousands of sets in an entire community or small city.

Later, we will describe in detail the equipment that is used in distribution systems. After you are acquainted with the components, we will discuss the systems again in more detail, and point out some of the problems that are encountered in planning installations of this kind. Although you may never encounter a signal distribution system in your service work, you should know of their existence, and know how they operate.

Types of Distribution Systems

Each type of distribution system, whether simple or complex, must be planned and installed carefully. Nothing can be left to chance—this applies particularly to the elaborate community distribution systems. An oversight or error in installing the system can greatly affect its operation.

Now, let us briefly describe each type of distribution system that you may encounter.

BASIC DISTRIBUTION SYSTEMS

The simplest distribution system is the two-receiver arrangement shown in Fig. 1. The signals that are picked up by the antenna in Fig. 1A are fed to an outlet unit which divides them into two paths, and transfers them to both sets without causing serious losses in the signal level. In addition, to prevent interaction between the sets, the impedance of the outlet units must match the input impedance of the receivers. Interaction upsets the loading and impedance characteristics between the receivers so that the adjustment of one influences the performance of the other. The outlet unit also must isolate the receivers from each other to prevent exchange of local oscillator signal components.

The outlet units will be discussed in detail later in this lesson. However, let us briefly describe the basic types, because they are used in all distribution systems, regardless of the size. The simplest outlet unit consists of either a resistor or inductor network that divides the signal and feeds it into two separate lines. Although this type of unit provides satisfactory isolation, it does appreciably decrease the signal strength. However, if the signal strength in the area is high, the resistor or inductor network will operate satisfactorily.

In locations where the signals picked up by the antenna are weak, outlet amplifier units employing one or two vacuum tubes can be used to provide isolation between receivers and still provide little or no loss in signal levels. Still more elaborate outlet units with several vacuum tubes can be designed to provide small gains in addition to effective isolation between receivers.

In a weak signal area, an amplifier unit called a wide-band amplifier can be placed between the antenna and the outlet unit, as shown in Fig. 1B, to boost the signal level and to compen-

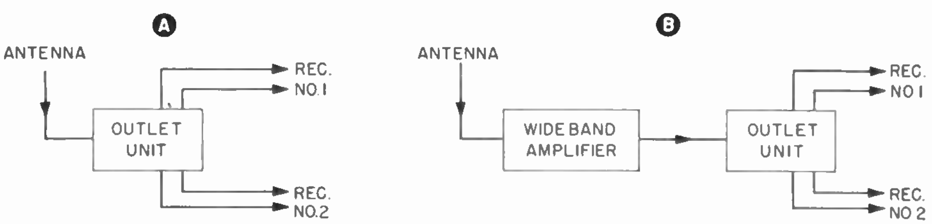


FIG. 1. Basic two-receiver plans.

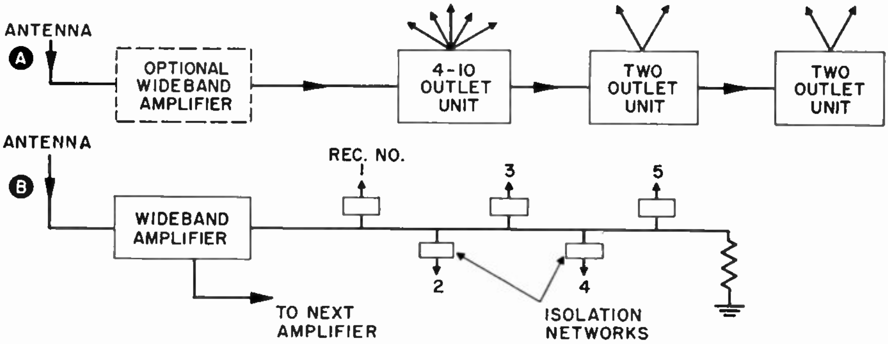


FIG. 2. Small apartment building methods.

sate for the loss encountered in the simpler type outlet units. The wide-band amplifier, as its name suggests, uniformly amplifies a wide range of frequencies. It can be designed to amplify either the high or low-band VHF signals, or the entire range from channels 2 through 13.

MULTIPLE OUTLET SYSTEMS

The distribution system can be designed to provide from four to ten individual outputs for feeding multiple receiver outlets in a small apartment house, a dwelling, a school, or a service shop and store. The outlet unit may be a resistance or an inductance network, or a more elaborate unit employing vacuum tubes.

The distribution system need not be elaborate. If the installation is in a strong signal area, the system can consist of a good antenna and a number of small vacuum tube outlet units. A dozen or more receivers can be supplied with signals using this arrangement, as shown in Fig. 2A. If the signal levels are weak, a wide-band amplifier can be added ahead of the distribution outlet amplifiers.

Instead of using individual vacuum tube outlet units, a single high gain wide-band amplifier may be used to supply a very strong signal to a single distribution cable, as shown in Fig. 2B. At each receiver, an attenuator pad of some type, either a resistor or an inductor network, is inserted to attenuate the signal and provide effective isolation between the receivers. The amount of attenuation presented by each pad progressively decreases toward the far end of the line, so that the signals delivered to each receiver are approximately equal. The signal loss at each receiver is compensated for by the initial amplification of the signal.

LARGE APARTMENT DISTRIBUTION SYSTEMS

The preceding distribution methods are effective where there are no reflection or interference problems, and where only a limited number of receivers are to be supplied with signals.

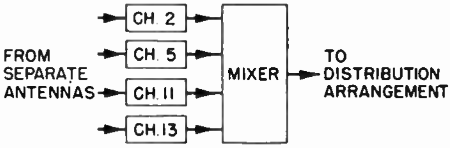


FIG. 3. Channel-strip amplifier plans.

However, in larger installations or in locations where there are reception problems, the distribution system must be more elaborate. The basic arrangement of the components is similar to the methods described earlier, except that individual channel amplifiers may be used, as shown in Fig. 3, instead of a single wide-band amplifier unit.

Each channel-strip amplifier is designed to amplify the signals of one channel only. It will reject the frequencies of the adjacent channels as well as all other signal frequencies. This arrangement reduces interference in the distribution system because the unit is sensitive over the desired signal ranges only, and no others.

It is not always possible to orient a single antenna and obtain the best reception on a number of channels; by using individual antennas, each can be oriented for peak performance on the channel it is to receive. The signal can then be fed to its corresponding channel-strip amplifier. The outputs of the strip amplifiers are fed into a mixer unit which combines the signals so that they can be supplied over a single distribution line.

In an installation which supplies signals to a large number of receivers, additional amplifiers must be inserted properly at spaced intervals to compensate for the attenuation of the signals as they pass along the distribution cables. A typical distribution system used in a large apartment building or hotel is shown in Fig. 4.

The signals from a single antenna or from four separate antennas are fed to the channel-strip amplifier and mixer sections. From the output of the mixer, the boosted signals are distributed to a multiple outlet unit which divides the signals into a number of lines, and feeds them to outlet units located on the various floors of the building. From the outlet unit, the signals are distributed to the receiver outlets. As the signals pass through the chain of outlet units, they are gradually attenuated. Therefore, after a specified number of outlets and a specified length of cable, an additional wide-band amplifier must be inserted to restore the signals to their original level. Another group of outlet units can then be supplied with the signals.

Usually, the signals are conveyed through main feeder cables to the several floors of the building. On each floor, the signal is supplied to a wideband amplifier, and then into the

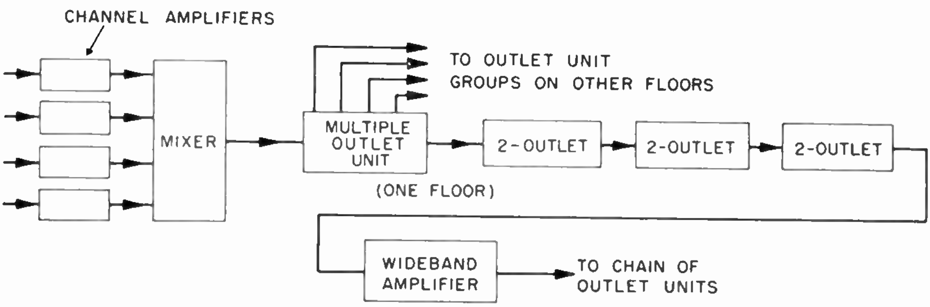


FIG. 4. General plan of large apartment installation.

distribution lines to the apartments. Thus, it is possible to supply signals to hundreds of receivers in an apartment building or hotel by using a single antenna installation and a properly designed distribution system.

COMMUNITY DISTRIBUTION SYSTEMS

A community distribution system contains the same basic units employed in a large apartment installation, except that the spacing between outlets is greater and the antenna is generally on a mountain top some distance from the community.

The signals are amplified at the antenna location, and then supplied over cables to the community. The cables are run on private poles or space is rented on local telephone or power poles. Since the signals are attenuated as they are conveyed over long lengths of cable, wide-band amplifiers must be inserted into the lines at spaced locations to boost and restore signal levels to the original amplitudes.

After the signal reaches the town, it is again amplified and divided so that it can be supplied to the main feeder lines that fan out into a community. In a small community system, as shown in Fig. 5, the house connections can be made from these main arteries. However, in a more elaborate system, the main arteries just convey the signals about the area and retain proper signal levels. Secondary feeder lines branch off the main trunk lines for feeding the receiver outlet sections.

In a community system, additional components are required to compensate for the miles of cable needed to convey the signal throughout the area. In carrying signals over long spans of cable, high frequency signals are attenuated more than low frequency signals. Thus, at various locations in the distribution system, it is necessary to insert line-loss equalizers to intentionally attenuate the lower frequencies more than the higher frequencies, and thus maintain uniform signal levels on the line.

Each of these distribution techniques will be discussed in more detail later. By understanding the operation of the various types, you should be

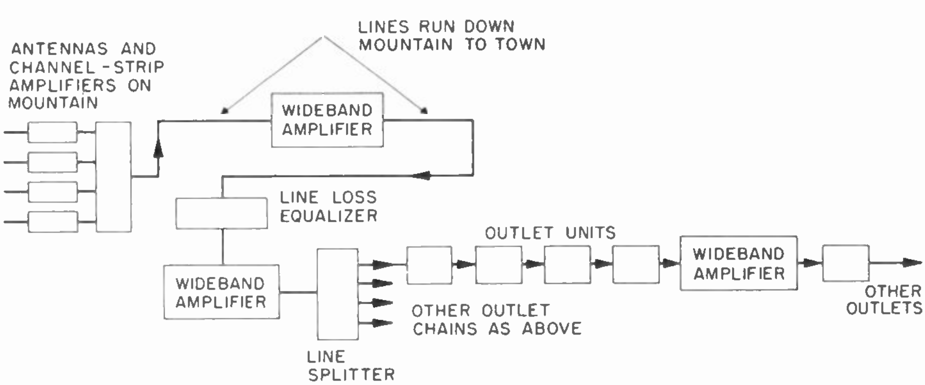


FIG. 5. General plan of a community system.

able to correct many of the distribution problems you may encounter in your service work. Remember, the objective of any distribution system is to obtain uniform and reliable performance over the entire system.

Component Units And Accessories

In the preceding section, we learned the fundamental arrangements of the various types of signal distributions systems. Next, let us discuss the individual components, from the antenna to the receiver outlets, that make up the systems. By studying the function and operation of each unit, it will be easier to understand the operation of any distribution system.

ANTENNAS

The type of antenna that is used in a distribution system depends upon the signal strength, the number of channels to be received, and the reflection problems at the antenna location. In a metropolitan area where the signal strength is high, a simple dipole and reflector type antenna is often all that is needed. If the installation is some distance from the transmitting antenna, high-band and low-band dipoles and reflectors also can be used to feed separate amplifiers. One amplifier can boost the strength of the signals from channels 2 through 6, while a second amplifier can boost the strength of the signals from channels 7 through 13.

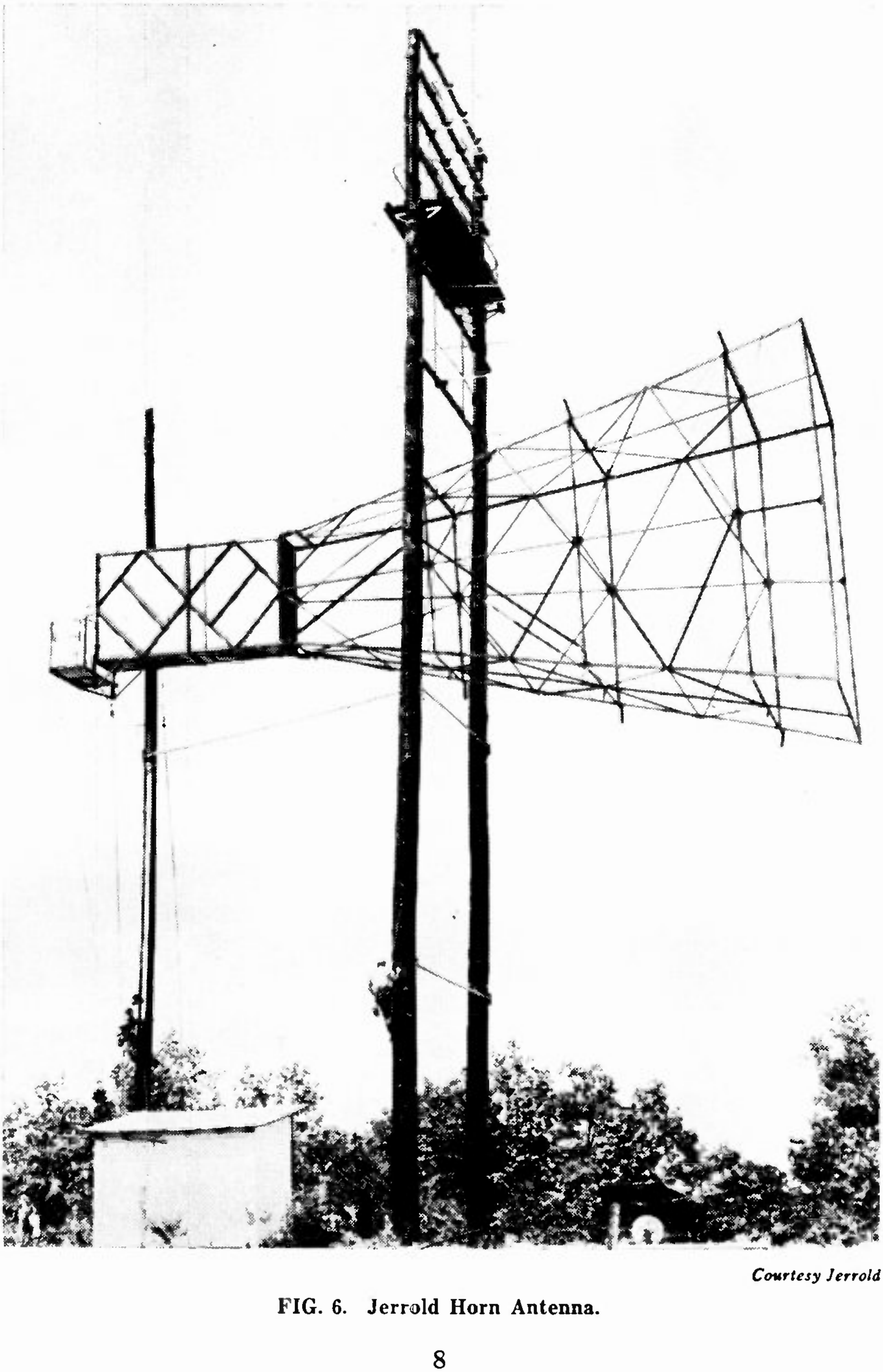
If the antenna site is surrounded by tall buildings, there may be reflection problems (ghosts). Reflections usually can be eliminated by using a separate antenna for each channel and feeding the signal from each antenna into an individual channel-strip amplifier. Each antenna can be rotated to receive the best signal with the least reflection pickup.

The most common antenna type for community antenna systems is the five or six element Yagi. This antenna has a high gain and a good unidirectional pattern to minimize off-channel interference pickup. A separate Yagi antenna is often used for each channel to be received.

For reception over a great distance and to prevent interference from other TV stations operating on the same channel frequencies (co-channel interference), massive horn antennas of the type shown in Fig. 6 are often used. This design is of particular benefit in minimizing co-channel interference because the antenna has peak sensitivity (highest gain) in the desired direction and a much weaker sensitivity in all other directions.

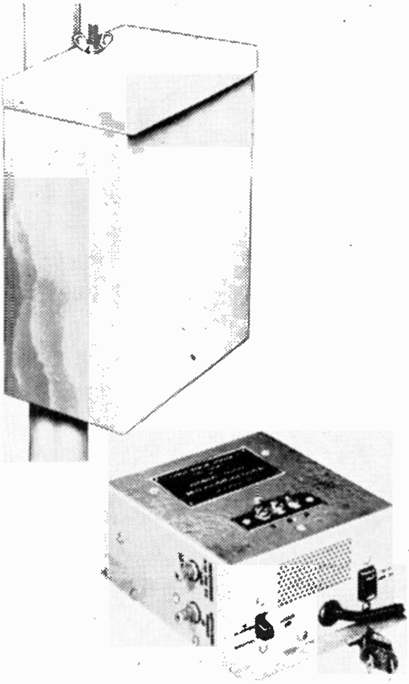
ANTENNA AMPLIFIERS

In all distribution systems, with the exception of the simplest types, amplifiers are used to boost the signal strength before the signals are supplied to the transmission line. In community systems, the antenna am-



Courtesy Jerrold

FIG. 6. Jerrold Horn Antenna.



Courtesy Jerrold
Antenna-mounted amplifier and control box.

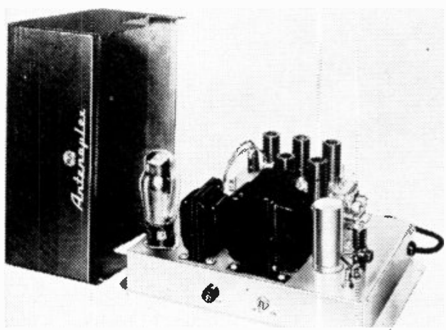
plifiers can be mounted either on the antenna mast or at the base of the antenna tower. For an apartment installation, a location should be chosen that is convenient to the antenna. In any system, the antenna amplifier should be mounted as close to the antenna as possible to obtain higher signal-to-noise ratios, and to prevent transmission line attenuation.

There are several basic amplifier methods in common use. The method to be used depends upon the needs of the system. It may consist of a single wide-band amplifier that boosts the entire frequency range from channel 2 through channel 13, separate high- and low-band amplifiers, or individual channel-strip amplifiers—one for each channel to be received.

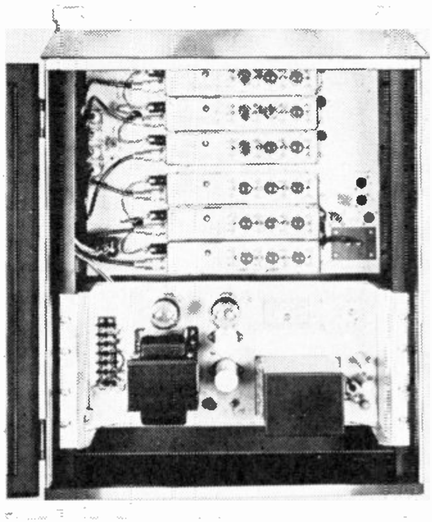
A high signal-to-noise ratio can be obtained (and interference eliminated) by fastening an additional strip amplifier to the antenna mast a short distance from the antenna so that the signal is amplified before any significant signal attenuation is introduced. Thus, strength of the noise signals picked up by the transmission line between the amplifiers on the mast and those at the base of the antenna tower is much lower than the signal strength.

The amplifier-mixer units consist of four 2-tube channel strip amplifiers and a mixer circuit that is able to mix and distribute four TV signals. Strip amplifiers are available for any one of the twelve VHF channels, and UHF converter strips also can be inserted for any of the UHF channels. For additional channels, two or more amplifier-mixer units can be cascaded.

Channel Strip Amplifier. A schematic diagram of a channel strip amplifier is shown in Fig. 7. It consists of a grounded grid input stage and a pentode output amplifier. The



Courtesy RCA
RCA broadband amplifier.



Courtesy RCA

RCA strip amplifiers and power supply.

input stage, using a 6AB4 triode, presents a low impedance to match either a 300-ohm or a 75-ohm antenna system.

The plate of the triode is coupled through a band-pass circuit to the grid of the pentode amplifier. A band-pass circuit consisting of inductors L15, L16, L17, and L18, the output capacity of the triode (increased by capacitor C25), and the input capacity of the pentode stage are chosen to pass only the frequency range of the channel to be amplified. The values of these components present minimum gain to the adjacent channel frequencies, and thus reduce the possibility of adjacent channel interference. To improve the stability of the strip and maintain a constant input impedance with a high signal-to-noise ratio, a proper amount of neutralization is supplied through the feedback link consisting of inductor L15 and capacitor C30.

The output of the pentode stage is coupled through the plug of the strip

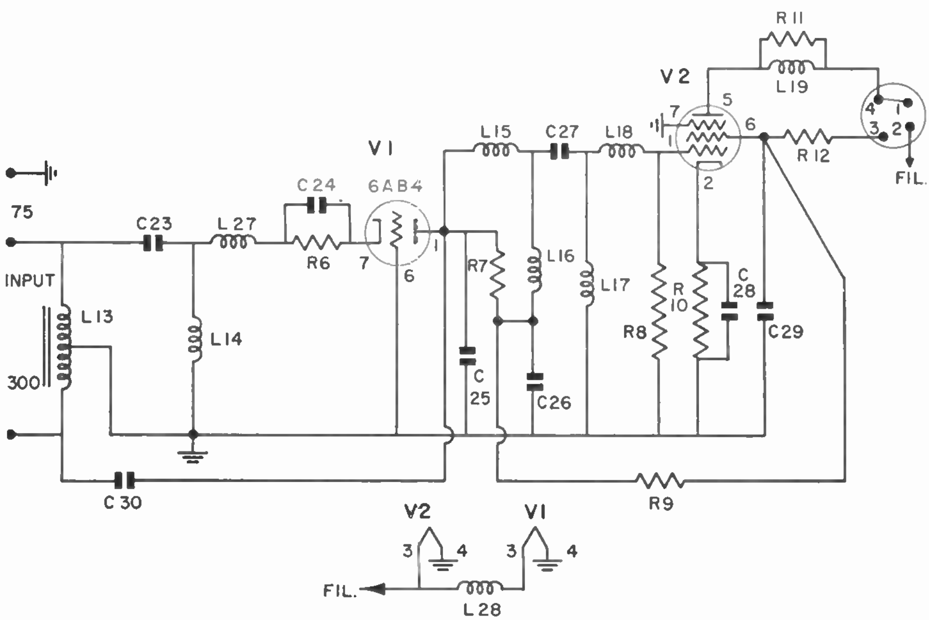


FIG. 7. Channel strip amplifier.

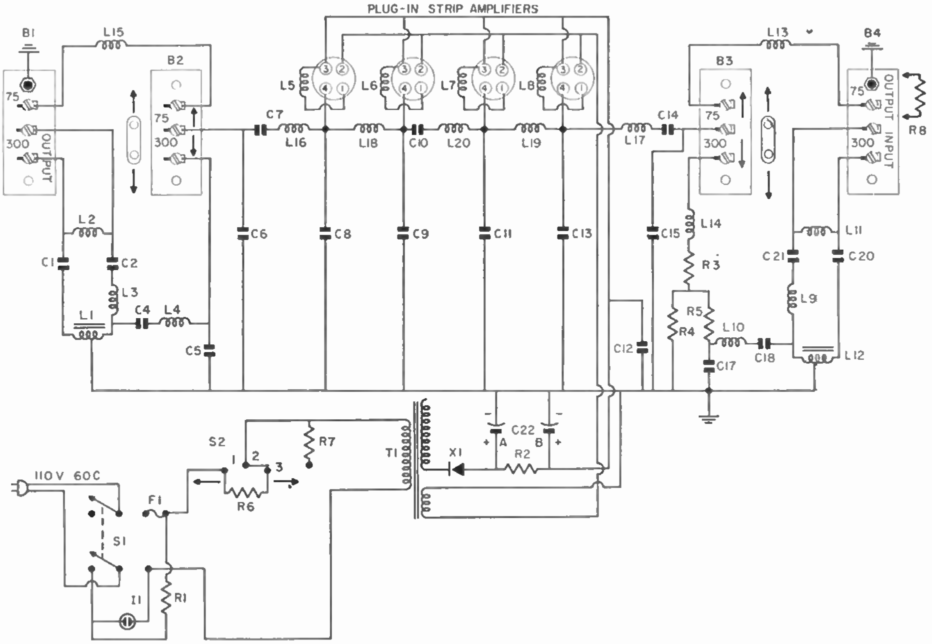


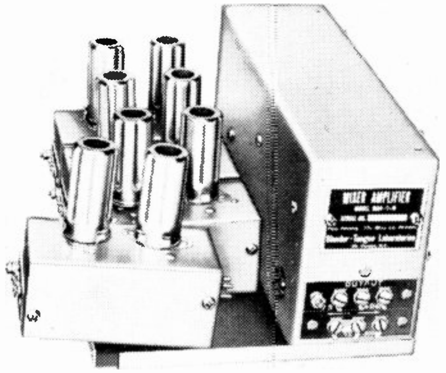
FIG. 8. Mixer section.

to the socket at the input to the mixer. All supply voltage and filament lines are adequately filtered by inductors or resistor-capacitor combinations.

Mixer Units. The mixer section shown in Fig. 8 combines the four outputs of the individual strip amplifiers so that they can be applied to a single transmission line. The actual mixing occurs in the inductor-capacitor sections. By using this type of circuit, which acts as an artificial transmission line, there is a minimum of interaction between the four channels. The inductor-capacitor sections also serve as a transmission line feed-through from the input to the output of the mixer, consequently additional mixer units can be connected in cascade to introduce other signals into the distribution system.

The inductor-capacitor mixing section is an unbalanced arrangement, and it is possible to obtain a 75-ohm output directly from this section by making certain that the link on the second terminal board from the left (B2), as shown in Fig. 8, is connected between the top and middle screws. When a 300-ohm output is desired, the same link is moved to connect the middle and lower screws on the same terminal board. Thus, the output of the artificial line passes through an unbalance-to-balance transformer, consisting of inductors and capacitors, to the 300-ohm output on the terminal board, B1.

Terminal board B4 on the right contains another 300-ohm input so that an additional strong local signal can be introduced into the distribution



Courtesy Blonder-Tongue

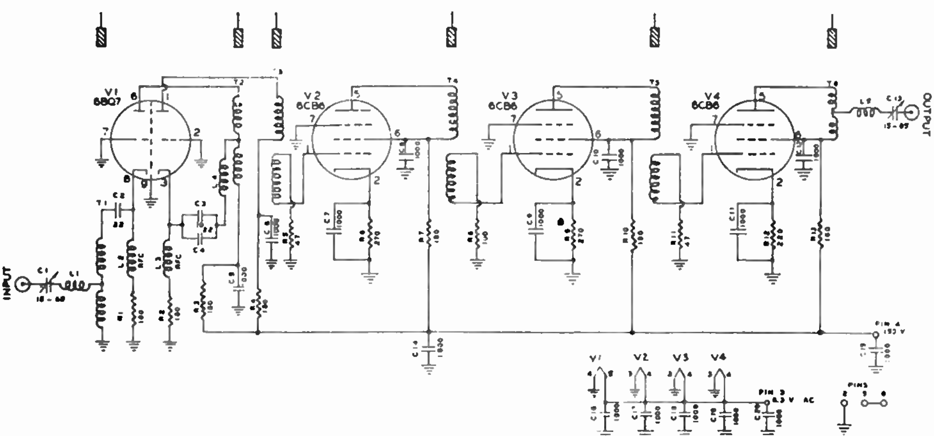
Blonder-Tongue channel strips and amplifier-mixer.

system. The stronger signal is attenuated by the balance-to-balance transformer to equalize all the signal levels at the output of the mixer. To introduce this signal, however, the link on terminal board B3 must be connected between the middle and lower screws.

A second 75-ohm output can be obtained at terminal board B4 by connecting the link between the top and middle screws on terminal board B3. This arrangement permits the mixer unit to serve also as a two-receiver outlet, or as a single receiver outlet plus a line output into a distribution system.

Although it is possible to transmit the actual channel frequencies over the distribution system, the losses in the coaxial cable would cause the high-band frequencies to be attenuated more than the low-band frequencies. Therefore, in a typical community system, all the signals, regardless of the channel frequencies, are converted to the frequencies of channels 2, 4, and 6. This method will be discussed in more detail later in this lesson.

Wide-band Amplifier. In smaller distribution systems for hotels and apartments in stronger signal areas, multiple-channel reception can be obtained by using two wide-band amplifiers—one to cover channels 2 to 6 and a second for channels 7 to 13. A typical low-band channel amplifier is shown in Fig. 9. Notice that the input stages are two grounded-grid triodes connected in cascade. They present



Courtesy Jerrold

FIG. 9. Schematic diagram of Jerrold low-band amplifier.

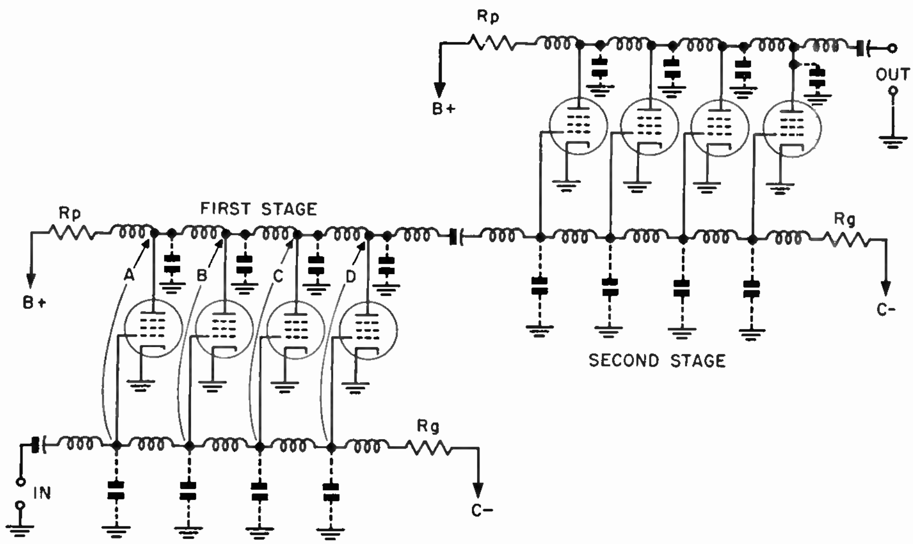


FIG. 10. Plan of chain amplifier.

the proper low impedance for matching the antenna circuit and establishing a low noise level. The output of the low-noise stage is transformer-coupled to the first pentode amplifier. The three pentode amplifiers, containing stagger-tuned resonant circuits, increase the level of the low-band signals. In addition, the tuned circuits are close-coupled to obtain the necessary band width.

The high-band amplifier strip is of similar design; however, an additional stage of amplification is needed because it is more difficult to obtain as much gain per stage and maintain the broad band width in the frequency range from channels 7 to 13.

Chain Amplifier. It is also possible to design an amplifier to cover the entire range of frequencies from channels 2 through 13. It differs from the conventional type and is often referred to as a *chain amplifier,* because it is a multiple-tube arrangement connected into transmission line segments, as shown in Fig. 10. The chain amplifier is a method of cascading a number of tubes so their plate current changes become additive, while their tube capacities remain isolated.

In a conventional vacuum tube stage, the greater the band width required, the lower the gain that can be obtained from a particular tube type. This relationship exists because the greater the band width, the more the output circuits must be loaded to obtain a uniform impedance over the wide range of frequencies. This results in a lower output impedance and a lower stage gain. Also, a vacuum tube has both input and output capacities; the higher the signal frequency that must be passed by the stage, the lower the effective reactance presented by these capacities. Consequently, the obtainable output impedance becomes less and less with higher frequencies.

It may seem possible to obtain sufficient gain by connecting two or more tubes in parallel. However, while this arrangement will increase the current output, it will also increase the total capacity in the amplifier. Consequently, the output impedance for a given band width will be much lower (greater charge and discharge currents because of the lower capacitive reactance), and the output voltage will increase very little.

The problem, then, is to make the currents of the tubes additive without causing their capacities to add. This can be done by employing the chain-amplifier technique. Notice in the circuit in Fig. 10 that the cascaded tubes are isolated by small inductors. The combination of these inductors and the shunt capacities of each tube forms an artificial transmission line section. Like a transmission line, the impedance remains essentially constant along the line, and therefore, many sections can be added without altering the impedance and band width.

With the plates of the tubes connected to a similar line, we have a method of plate current addition without the resulting addition of tube capacities. However, as in any transmission line, the charge and discharge of the inductor-capacitor chain require a definite time, causing a transmission delay. If the delay time presented by each tube is the same, however, phase distortion will not occur in the output.

To set up proper conditions on each delay section, the lines must be properly terminated as in any transmission line system. The terminations are the grid and plate resistors of the chain amplifier stage.

Let us list some of the advantages and disadvantages of the two types of amplifiers. The chain amplifier reduces standing waves and matching problems because it is, in effect, a continuation of the transmission line. Since each stage is composed of a number of tubes, a change in tube characteristics or a failure of one tube will not result in a complete loss of service in the distribution system.

With a conventional wide-band amplifier which amplifies only the signals of three to five channels, less equipment is required because there can be a wider spacing between the units. In addition, the gains of the individual strip amplifiers can be regulated to obtain uniform signal levels on all channels. Because of the narrower band width, as compared to the chain amplifier, there is a minimum of adjacent channel interference from strong local signals and from off-channel frequencies.

TRANSMISSION LINES

The type of transmission line used in a distribution system depends upon the distance between the antenna and the outlets, the size of the system, and the interference problems in the locality. If there is a great distance between the antenna and the first section of the distribution system, as in a community installation, open wire lines are usually employed because they attenuate the signals less than any other type. When the transmission line enters the community, coaxial cable is used to convey the signal to the subscriber's home. Using coaxial cable decreases the chance of radiation from the lines, which would introduce interference into the system.

FIG. 11. Double-shielded cable.

In a large city distribution system where the signals in some of the cables are at high voltage levels, there may be a strong radiation from the lines. In this case, it is possible to erect an antenna, orient it toward the lines, and pick up a weak but usable signal. This is unfair, of course, to those who subscribe to the distribution system. In other locations, the radiated signals may introduce ghosts into the pictures received by those who have put up their own elaborate antenna systems. Therefore, line radiation must be kept to a minimum.

Line radiation can be eliminated by using a type of coaxial cable that has an additional outer braid. This type, illustrated in Fig. 11, is called a double-shielded cable. When the outer shield is grounded, signals cannot be radiated from the line. Double-shielded cable also is less subject to variations due to weather conditions, and it has a longer useful life than the conventional single-shielded type.

Ribbon lines are used primarily in small systems or in connecting the receiver to the outlet box in the home. This type of transmission line, like the open wire type, is not satisfactory for signal distribution purposes because it is subject to interference pick-up, and it produces strong radiated signals. Ribbon lines also cause a higher signal loss. Therefore, as stated previously, coaxial cables are generally used to distribute the signals throughout the community. The larger

TV TRANSMISSION LINES

db. LOSS PER 100 FEET

Type	Nominal Impedance (Ohms)	50 MC.	100 MC.	200 MC.	500 MC.	1000 MC.
		VHF	VHF	VHF	UHF	UHF
RG 11/u	75	1.4	2.0	3.1	5.1	8.0
RG 59/u	73	2.7	3.8	5.7	9.4	14.2
Ribbon	300	.8	1.2	1.8	3.2	5.0
Tubular	300	.7	1.2	2.0	3.1	4.6
Open Wire	375	.5	.8	1.2	2.0	3.0
Open Wire	450	.3	.4	.5	.8	1.2
JEL 101	75	1.3	1.75	2.8	—	—
JEL 102	73	2.5	3.3	4.9	—	—

FIG. 12. Transmission line losses.

diameter and lower loss RG11/U cable is used as the trunk or main artery line, while the smaller RG59/U is used between the take-off point on the line and the receiver outlet in the subscriber's home.

The amount of signal loss in the distribution system depends upon the type of transmission line used and the frequency of the signal to be conveyed. Fig. 12 is a table showing the amount of attenuation in various types of lines. Notice that the open wire lines have less attenuation than the coaxial and ribbon types. Therefore for long distances, open wire lines should be used because fewer line amplifiers are required to maintain an adequate signal level.

In planning a distribution system, the amount of cable attenuation not only determines the spacing between the amplifiers, but it also governs the number of receivers that can be connected to a specific cable. For example, let us assume that we wish to extend a distribution system a distance of 200 ft. to a new receiver outlet. Also suppose that the signal level at the take-off point on the original distribution system is 1600 microvolts, and that we must have at least 1000 microvolts available at the new outlet. If RG59/U cable is used to carry a low-band channel signal to the new point, it will present a loss of approximately 3 db per 100 ft. The attenuation over the 200-ft. span, then, will be 6db. If we compute it mathematically ($db=20 \log E1/E2$), we will find that the signal voltage level at the far end of the cable will be cut in half, and the original 1600-microvolt signal will be reduced to 800 microvolts. Thus, the signal level will have dropped 200 microvolts below the desired strength.

To establish the 1000-microvolt level, we can arrange the system so that a 2000-microvolt signal is available, or insert an additional amplifier at the input of the 200-ft. section of the line.

Most TV sets will produce a snow free picture if the signal level at the receiver input is 1000 microvolts. Therefore, distribution systems are planned to maintain this signal level at each outlet. Of course, every attempt must be made to retain the same quality picture that exists at the antenna receiving site.

LINE AMPLIFIERS

The amplitude of the signals leaving the antenna amplifier is much higher than that normally required by TV receivers. You learned that as the signals progress along the transmission line they are attenuated, and become lower and lower in intensity. Just before the signals decline to too low a value, an additional amplifier must be inserted to restore the high amplitude levels. Therefore, in a distribution system, it is a continuous process of amplification to hold the signals between prescribed levels. They must not be so strong that they will overload the amplifiers and cause excessive radiation, nor must they become so weak that noise components are added and cause the reproduced pictures to be of poor quality.

Like the antenna amplifiers, the line amplifiers are of three basic types—

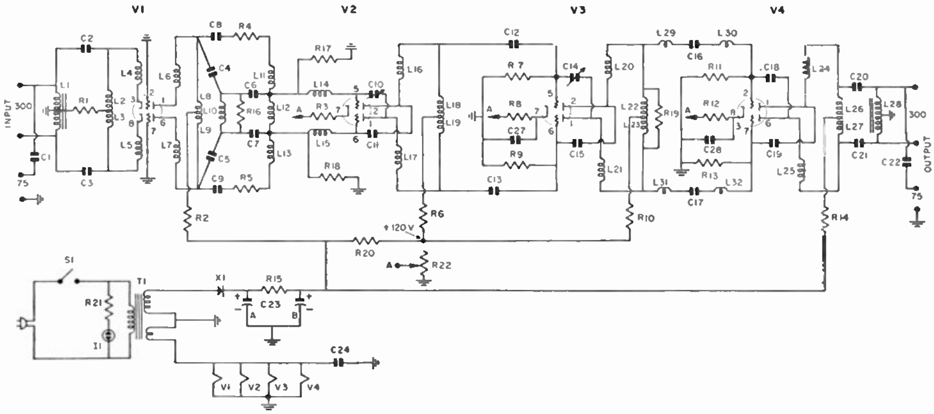


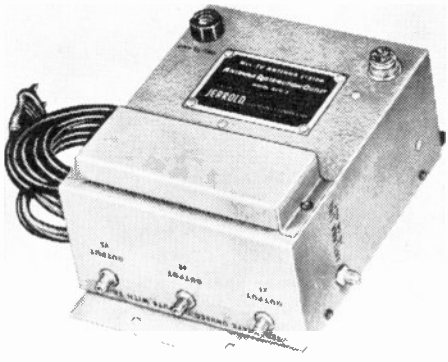
FIG. 13. Blonder-Tongue high-gain wide-band amplifier.

wide-band amplifiers (channels 3 through 13), high and low-band amplifiers (which are essentially the same as the wide-band amplifiers), and channel strip amplifiers. A typical wide-band amplifier is shown in Fig. 13. Notice that the amplifier contains four push-pull triode stages. The input circuit can be matched to either a 300-ohm or a 75-ohm line. The first stage is a grounded-grid push-pull amplifier with the input signal applied to the cathodes. The outputs of this stage are coupled to the grids of a conventional grounded-cathode push-pull amplifier. Two more grounded-cathode push-pull stages follow, with the final stage matched to a 300-ohm or a 75-ohm output line.

Because the cathodes of tubes V2, V3, and V4 are grounded, these stages must be neutralized. Neutralization is accomplished in tube V2 by a feedback path through capacitors C10 and C11. Similar circuits are employed in the last two stages.

The interstage coupling circuits are arranged to give uniform gain over the frequency range from channels 2 through 6 and channels 7 through 13. The gain of the amplifier over these ranges is approximately 27 db. This can be adjusted with the common-cathode bias gain control associated with the final amplifier stages.

Line amplifiers of the channel strip type are particularly versatile because the gain of each channel can be adjusted individually. Thus, the signal levels can be equalized or adjusted in proper relation to each other. Another advantage of the channel strip amplifier is that automatic gain control can be employed to hold the signal levels uniform with changes in signal intensity and with the changes in operating conditions along the distribution line. An agc installation in the distribution system automatically increases the amplification when signal levels are low, and automatically holds down signal intensities to a level where they will not cause overload when amplitudes are high. In addition, agc compensates for cable variation due to weather and temperature conditions. In the more elaborate com-



Courtesy Jerrold
Jerrold antenna distribution outlet.

munity systems, every third line amplifier should be agc controlled.

LINE SPLITTERS

In a distribution system, line splitters are inserted into the main lines at various points to divide the signal between two or more secondary lines. The secondary lines branch out and distribute the signal throughout the system. The line splitters, however, must be designed to establish a correct impedance match between the main line and the secondary lines. Otherwise, standing waves and reflections will be set up and cause ghosts and other picture disturbances.

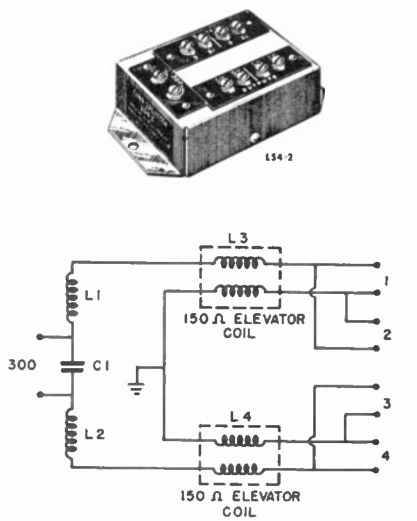
Line splitters are two basic types. One type, shown in Fig. 14, is a low-loss impedance matching unit that divides the signal into two parallel paths. Although this type does present minimum attenuation of the signal levels, it also offers very little isolation between the secondary lines. When this type is used, all outputs must be terminated in 300 ohm lines or resistors.

A second type of line splitter, which is composed of resistors, not only divides the signals into separate paths but also isolates one path from another. This type, however, presents a high insertion loss; the signal on each secondary line is substantially less than that at the input of the splitter.

The type of line splitter used in any distribution system, therefore, depends upon the needs of the system and the signal level at the location where it is inserted.

LINE-LOSS EQUALIZER

The high- and low-band signals, as they pass through the transmission lines, are not attenuated equally. For example, notice in Fig. 12 that the attenuation of a low-band VHF signal in RG59/U cable is approximately 3 db per 100 ft., while the attenuation on the high-band signal is more than 5 db. If a low-band signal and a high-band signal leave the antenna site at



Courtesy Blonder-Tongue
FIG. 14. Blonder-Tongue line splitter.

approximately the same amplitude levels, some distance away the low-band signal will be substantially stronger than the high-band signal, because of the greater transmission line attenuation of the higher frequencies. If this condition exists over many thousands of feet of cable and if the signal is amplified by a number of line amplifier units, the lower frequency signal will eventually become strong enough to overload some of the units in the distribution system, while the weaker high-band signal will be near the noise level.

To establish a proper uniformity in all the signal levels, special line-loss equalizers must be inserted at various points along the transmission line. The purpose of the line-loss equalizer is to attenuate the low-band, or low frequency signals more than the high-band signals. The equalizer units are designed so that their frequency attenuation characteristics are opposite to those of the transmission lines. Even in a system that is distributing low-band channels only, it is necessary to use an equalizer to compensate for the difference in attenuation between channels 2 and 6.

The equalizer circuit shown in Fig. 15 consists of an inductor-capacitor impedance path for low- and high-frequency signals. The values of the components are chosen so that the resonant frequencies of the series and parallel resonant circuits are near the high end of the frequency range. As you have learned, the output of a resonant circuit is highest at the resonant frequency. If we insert resistors R1 and R2 to broaden the response curve, the frequency attenuation will vary over the entire range, with the result that the low-band frequencies will be attenuated more than the high-band frequencies. Thus, the high- and low-band signals at the output of the equalizer circuit again will have approximately the same relative amplitudes as those at the antenna.

DISTRIBUTION OUTLET UNITS

Distribution outlet amplifiers are used to connect the distribution cable to the lines that run into the individual dwellings. These units are able to handle anywhere from two to twenty-five receivers, depending on the type of unit used and the available signal strength. Another function of the outlet unit is to isolate one receiver from another, and one outlet section from another section on the distribution cables. Some outlet units provide a small gain, while others are low-loss, one-way devices.

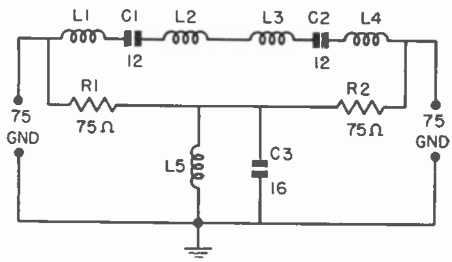


FIG. 15. Line-loss equalizer.

The circuit diagram of a two-outlet distribution amplifier is illustrated in Fig. 16. In a strong signal area, the antenna is connected to the input of this unit, and two receivers can be supplied from its output. Not only is there excellent isolation between the

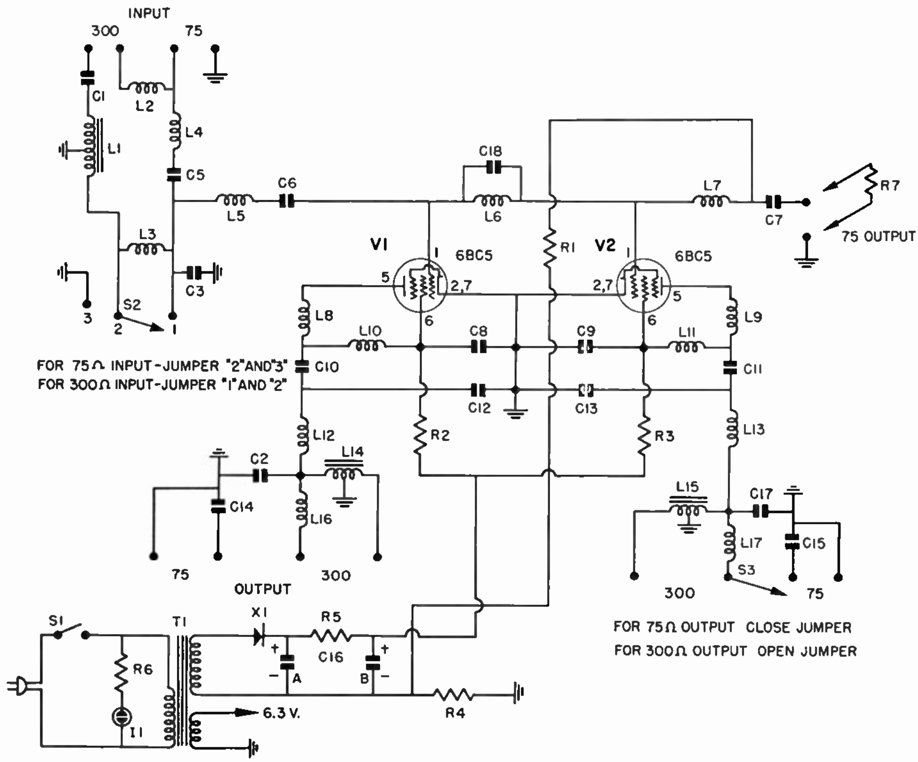
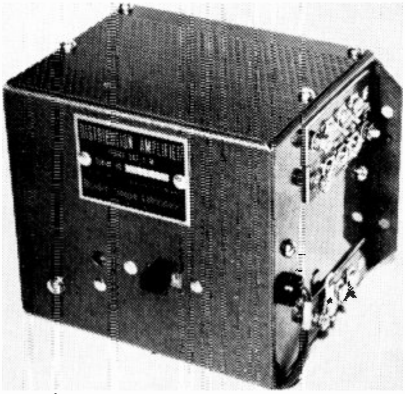


FIG. 16. Blonder-Tongue 2-outlet distribution amplifier.

two receivers, but there is also some small amplification of the applied signals. A feed-through connection is provided so that a number of units of this type can be connected in cascade to supply additional receivers. For example, two of these units can supply high level signals to four apartments in a duplex dwelling. Only one good antenna installation is required. In small community systems, the units are connected into the main feeder line; in larger systems they are connected into the secondary lines.

The output voltage of these amplifiers can be as high as 1 volt. Therefore, a single unit in a strong signal area can supply more than two receivers, if outlet pads of the type shown in Fig. 17 are used on the two receiver lines. At a fringe area location, a wide-band amplifier can be placed ahead of the outlet amplifier and, therefore, supply strong fringe signals to more than one receiver.

The distribution amplifier shown in Fig. 16 is a two-tube unit. The control grids of both tubes are supplied with signals from the impedance matching transformers through a segment of transmission line formed by inductors L5, L6, L7, and the tube capacities. This same section of line serves as the feed-through path for other outlet units. When a single outlet unit is employed, the output



Courtesy Blonder-Tongue

Blonder-Tongue distribution outlet amplifier.

must be terminated with resistor R7 to prevent setting up standing waves on the line. If other outlets units are used, a line is attached to this output to supply signals to the next unit. The final outlet unit on the chain, of course, must be terminated with a resistor (R7).

Tube V1 supplies one receiver output through the proper impedance transformer, while tube V2 supplies a second output. Each stage has a gain of approximately 1 db on the low band. The plate output components have been chosen to present a rising gain characteristic of the high band, with channel 13 having a gain of approximately 3 db. This arrangement compensates for the attenuation of the high-band .signals in the transmission line.

The outlet units for a very small distribution system that is located in a strong signal area need not be elaborate. A simple method for supplying signals to two receivers is the resistor pad outlet unit shown in Fig. 17A. This type of unit has an appreciable signal attenuation. Therefore, it must be used only in strong signal areas, if no additional preamplification is used. However, it does permit effective isolation between the receivers. Other types of two- or four-outlet units can be constructed of inductors, as in Fig. 17B, or small elevator transformers (Fig. 17C) simi-

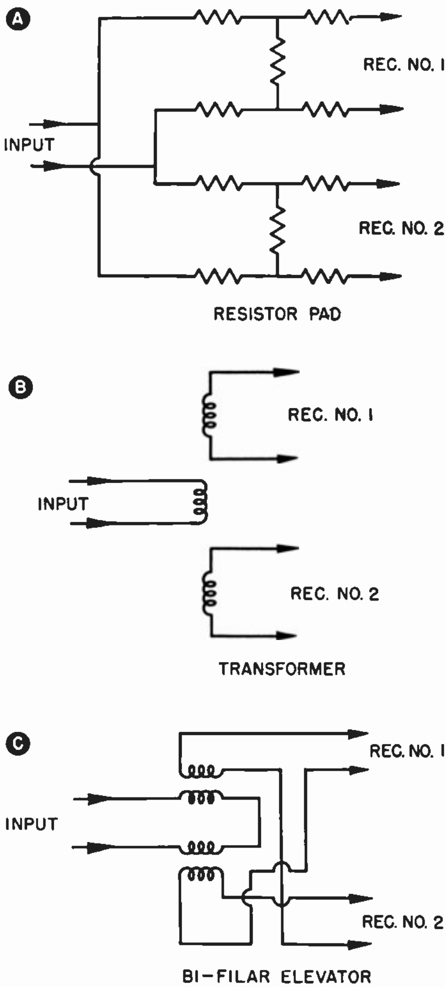
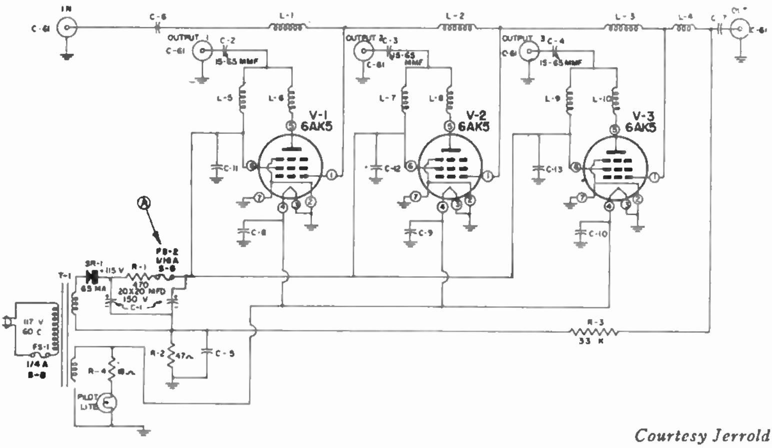


FIG. 17. Two-receiver outlet devices.



Courtesy Jerrold

FIG. 18. Schematic of distribution outlet.

lar to those used in the tuner circuits of modern receivers. Although these are generally more expensive, they do not attenuate the signals as much as the resistor pad.

A three-outlet, or bridging amplifier circuit is shown in Fig. 18. This type of unit is used in an apartment or a community antenna system to serve as an isolating link between the main feeder lines and the secondary cables, called riser cables, to which the individual receivers are attached. In an actual installation, the number of receivers to be attached to each of the three outlets depends upon the spacing between the receivers and the type of transmission line that is used. In a closely-spaced apartment installation, as many as sixty receivers can be supplied with signal from a single three-outlet distribution amplifier of this type.

TAP-OFFS AND OUTLET BOXES

After the signal leaves the distribution outlet amplifier, it passes down the feeder lines to various tap-off or isolation networks, as shown in Fig. 19. These units, which are either resistance or inductance networks, tap

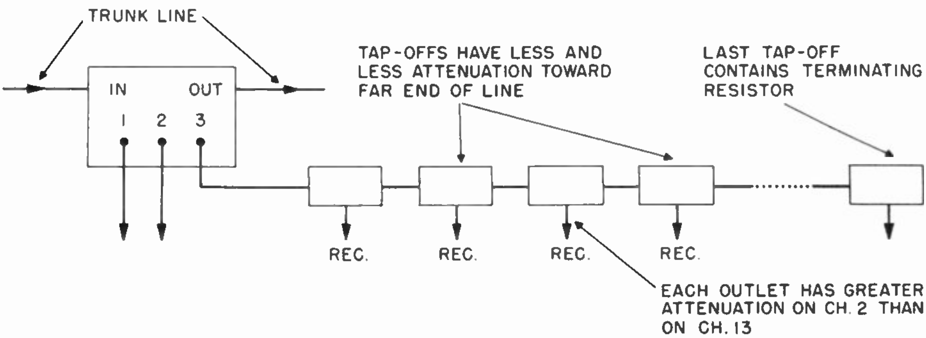
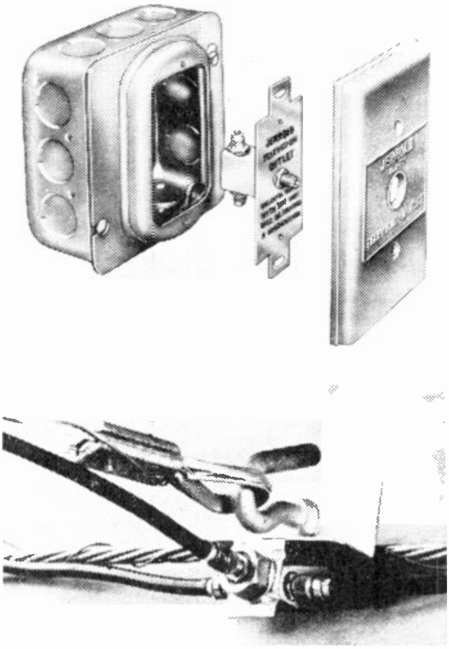


FIG. 19. Arrangement of outlet box and tap-offs.



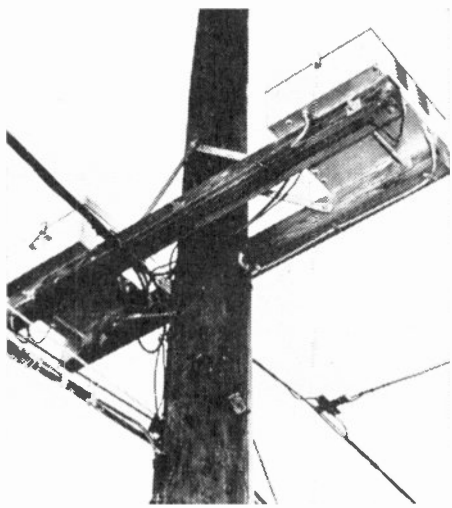
Courtesy Jerrold

FIG. 20. Indoor outlet box (above). Outdoor tap-off (below).

off the signals for the various receivers, and at the same time present sufficient backward attenuation to prevent interaction between the receivers. The first tap-off along the line has a higher attenuation than the last one, because of the rising attenuation of the cable toward its far end. With this method, the signal levels at the first receiver and the last receiver are approximately the same.

Another function of the tap-off network in some installations is to compensate for the non-linear frequency attenuation of the line. The network is designed, therefore, to offer higher attenuation to the low-band signals than to the high-band signals.

Typical indoor and outdoor tap-off arrangements are shown in Fig. 20. The indoor unit in Fig. 20 is a combination tap-off network and outlet box. The illustration shows the coaxial cable feed-through connectors as well as the outlet for the receiver. For an outdoor or community antenna system, the tap-off is made from coaxial cable that is attached to the power or telephone poles. Below in Fig. 20 is shown the coaxial cable feed-through and the connection for the service drop that is to run into the dwelling. Notice that heavy steel cable and messenger wires are used to support the main cable from one pole to another, and from the tap-off point to the house. The service drop terminates in the house in a small outlet box. Some outlet boxes contain small capacitors to isolate any dc components that might exist in the receiver.



Courtesy Jerrold

Distribution equipment mounted on utility pole.

Small Distribution Systems

Small distribution systems are similar in many respects to much larger installations, except that fewer and less expensive units are needed to supply signals to a number of receivers. We have discussed the various arrangements for the basic systems earlier in this lesson. Remember that the type of installation and the components used in the system are governed by the signal strength, the interference problems, and the number of receivers that are to be connected to the system.

Since these arrangements are fundamental to all types of distribution systems, let us briefly review them so that you will understand them clearly. Later in this section we will describe the systems used in specific installations, and some of the problems encountered in areas in which fringe signals as well as local signals are to be received.

BASIC TWO-RECEIVER METHODS

In a strong signal area where there are few interference or reflection problems, the distribution system can consist of an antenna and an outlet unit. The type of outlet unit used, of course, depends on how strong the signals are, and how much loss can be permitted in dividing the signals into separate paths. If the signal levels are low, a wide-band amplifier can be inserted between the antenna and the outlet unit.

If the installation is in a fringe area, the signal can be boosted and the system can be planned in any of the arrangements shown in Fig. 21. In Fig. 21A, an outlet unit and separate boosters (wide-band amplifiers) are used for each receiver. The boosters amplify the weak fringe signal and at the same time isolate one receiver from another. In the arrangement in Fig. 21B, a booster is mounted on the antenna mast or as near the antenna mast as possible to amplify the signals and establish a high signal-to-noise ratio before the signals are applied to the outlet unit. The transmission line is attached to the outlet unit (a no-loss type) and then through separate boosters, when necessary, to individual receivers.

Still another plan (Fig. 21C) is to use separate high- and low-band boosters and separate high- and low-band antennas. This is particularly desirable if the channels are received from different directions.

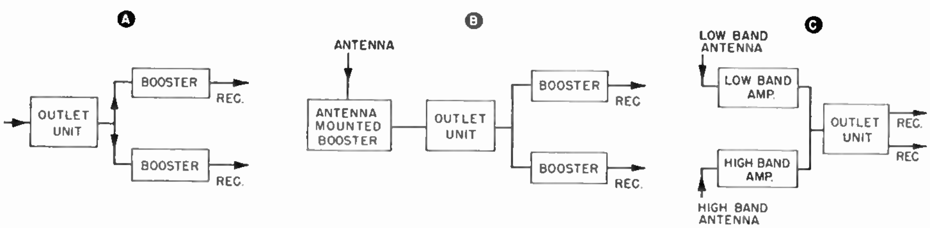


FIG. 21. Basic fringe area two-outlet plans.

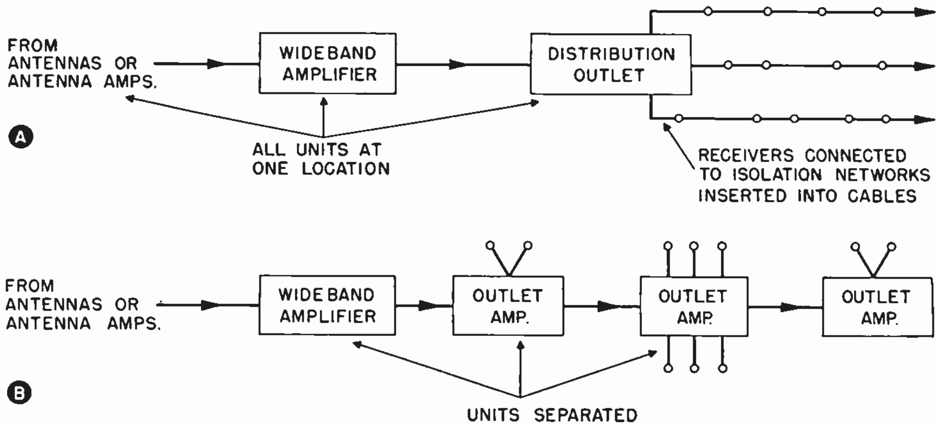


FIG. 22. Basic distribution methods.

MULTI-RECEIVER METHODS

Any of the basic distribution systems just described can be expanded to serve more receivers by adding additional amplifiers or additional no-loss outlet units. However, it should be emphasized that the antenna and the following unit, either an outlet unit or an amplifier unit, determine the picture quality. The remainder of the system cannot improve it. The primary purpose of the system from the output of this unit, therefore, is to maintain a constant 1000-microvolt signal level at each receiver outlet without any loss in quality.

The distribution methods shown in Fig. 22 illustrate how the system can be enlarged to serve a number of receivers. In the system shown in Fig. 22A, the signals are greatly increased in amplitude before they are applied to the distribution line. Then, these signals are tapped off through networks at various locations along the line. Of course, the signal strength decreases because of the attenuation in the isolation networks and in the transmission line. However, with sufficient signal strength at the input of the line, the individual receivers along the line will receive sufficient signal to reproduce a good quality picture. With this arrangement, all the units can be in one location.

Another type of multi-receiver distribution system is illustrated in Fig. 22B. Notice that the signals from the antennas or the antenna amplifiers are fed to a wide-band amplifier and then over cables to the various outlet units. The outlet units are of the no-loss type containing several vacuum tubes. While this method provides a no-loss distribution system, the vacuum tube units must be located some distance apart. Either of the methods shown in Fig. 22 is satisfactory for a distribution system in a small hotel or apartment building.

If the distribution system is to serve twenty or more receivers, it will probably contain the following major units: An antenna-mounted amplifier, a wide-band amplifier, a line splitter to divide the wide-band amplifier output into four separate lines, and the required receiver outlet units. An ex-

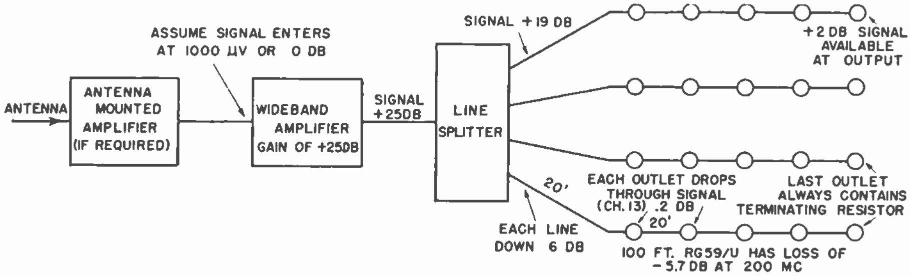


FIG. 23. Jerrold block plan distribution system.

ample of a system of this type is shown in block form in Fig. 23. With a 1000-microvolt input signal applied to the wide-band amplifier, twenty receivers can be supplied with TV signals. Additional receiver outlets can be employed if the signal level is above 0 db (or 1000 microvolts) reference level. It is customary to represent a 1000-microvolt signal as a 0 db reference signal in antenna distribution systems. The 1000-microvolt choice has been made because it assures a snow-free picture on most modern receivers.

Now, let us see how the system can be planned to supply a signal greater than the 1000-microvolt reference level to the receivers on the distribution line. With 0 db applied to the input, the wide-band amplifier increases the level to 25 db. However, the line splitter in providing the proper isolation between the four lines introduces a 6 db loss so that a +19 db signal is available at the input to each of the lines. Of course, the signal will be weakest at the last outlet unit because of the line attenuation. Also, the highest frequency (channel 13) will encounter the greatest attenuation in the line. Therefore, the cable attenuation for channel 13 will amount to approximately 5.7 db per 100 ft. between the input and last outlet box. The four preceding outlet boxes have an insertion loss of 0.2 db, or a total of 0.8 db. As a result, the +19 db level at the input of the line is reduced to 12.5 db at the last outlet box. The outlet attenuation on channel 13 is 10.5 db. Therefore, the signal available at the last outlet is + 2 db. This 2 db level is higher than the necessary 0 db level to obtain a noise-free picture.

Since the signal level at the last outlet is higher than 0 db, we can feed additional outlets on each line. However, if the signal applied to the input of the wide-band amplifier were lower than 1000 microvolts (0 db), we would have to increase the signal level at the input of the wide-band amplifier. We could increase the signal by placing a high gain antenna in a higher or better location, or by mounting an amplifier on the antenna mast to increase the signal strength before the signals are applied to the transmission line.

TYPICAL PROBLEMS

In some locations, the television signals in the distribution system may

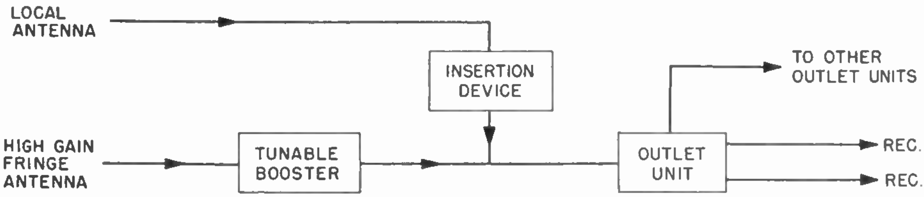


FIG. 24. Local reception plus addition of single fringe station to distribution system.

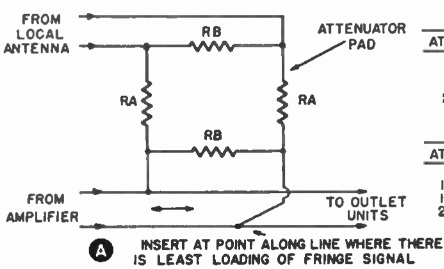
not originate in the same area. For example, one or more locally transmitted signals may have to be distributed along with one or more weak fringe signals. There are various methods that can be used to distribute all the signals over the one system.

Suppose you wish to distribute a single weak fringe signal and several strong local signals. The best procedure is to amplify the weak channel and then insert the local signals into the distribution system at the output of the amplifier. Of course, the local signal must be adjusted so that it will not overload the following amplifiers and outlet units and cause cross-modulation interference.

A system of this type is shown in Fig. 24. A tunable booster is used to receive the weak channel signal, while the local signals are inserted into the system at some convenient point between the booster and the outlet unit. The insertion device can be a commercial line splitter, a resistor pad, an adjustable attenuator, or an outlet box. Probably the simplest insertion device is the matched attenuator pad shown in Fig. 25A. The local signal can be inserted into the line without attenuating the fringe signal. In this arrangement, some experimental work is often required to find the proper insertion point on the transmission line that runs between the booster and the outlet unit. This spot should be located where there is the least attenuation of the weak fringe signal.

The chart in Fig. 25B gives the values of the resistor networks for either 300-ohm to 300-ohm, or 75-ohm to 75-ohm pads. Notice that the values of the networks vary with the amount of attenuation required to prevent the strong local signal from overloading the distribution system.

Now, let us see how a distribution system can be arranged to receive a

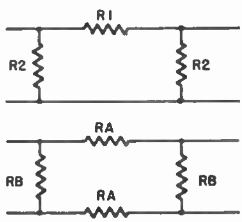


FOR 75 OHM

ATT(DB)	R1	R2
6	55	220
12	140	125
18	290	95
24	585	85

FOR 300 OHM

ATT(DB)	RA	RB
6	110	890
12	275	495
18	575	380
24	1170	335



B

FIG. 25. (A) Attenuator pad insertion device. (B) Table showing values of the components.

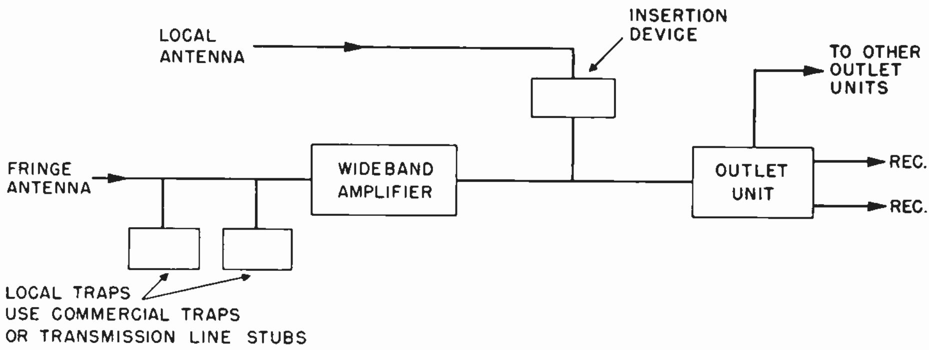


FIG. 26. Insertion of local and fringe signals into distribution line.

number of weak fringe signals as well as several strong local ones. Again, the local channels must be inserted into the system through an insertion device, as shown in Fig. 26. The weak fringe signals are picked up by a separate antenna and are increased in strength by a wide-band amplifier. The insertion technique is the same as described previously.

The antenna that is used to pick up the fringe signal should have a low sensitivity to the local channels, and, if possible, it should be oriented away from the local stations. However, these conditions cannot always be met in a practical installation. If the strong local signals are present at the input of the wide-band amplifier, they will probably overload the unit and cause cross-modulation interference.

Therefore, it is usually necessary to insert a filter trap in the line to the input of the wide-band amplifier and tune it so as to reduce the strength of the local channel or channels. The filter trap can be a commercial unit, or in the form of a stub constructed from a section of 300-ohm line. A piece of aluminum foil wrapped around the line can be used to peak the stub for minimum strength of the local signals.

There is another problem that you may encounter in a distribution system. Let us assume that there is adjacent channel interference between the strong local signals and the weak fringe signals. To eliminate this type of disturbance, check the antenna system and also be certain that the traps are properly adjusted in the receiver. The antenna used for the weak fringe signals should be of a type that will offer peak sensitivity to the desired channels and be as insensitive as possible to the interfering local stations. The channel strip amplifier arrangement shown in Fig. 27 is particularly useful in minimizing adjacent channel troubles. The channel strip frequency can be chosen to amplify only the desired fringe signals. Separate antennas can be used for the various fringe stations with each antenna oriented for best signal-to-interference ratio.

As an example, in Fig. 27 we will assume that the local signals are on channels 3 and 10 and that the fringe

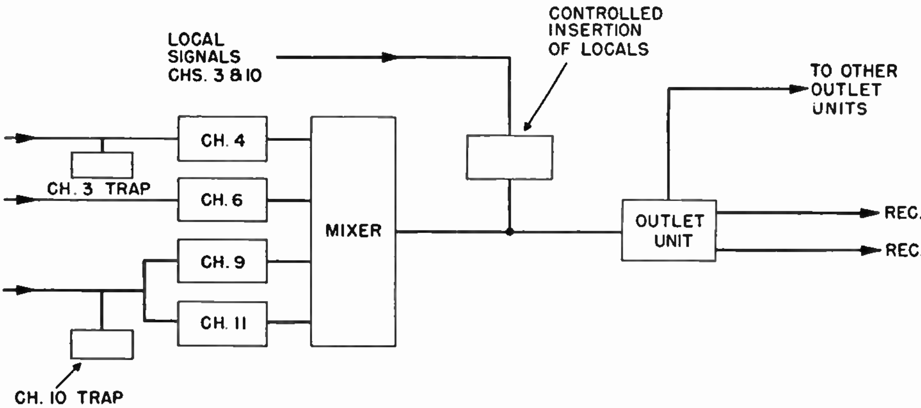


FIG. 27. Insertion of local signals into a channel strip distribution plan.

signals are on channels 4, 6, 9, and 11. We can use filter traps at the input of the channel strip amplifiers to eliminate the signals from channels 3 and 10. Therefore, these signals receive no amplification in the amplifier-mixer section. Instead, they are picked up by a separate antenna and inserted between the mixer and the outlet unit. In an installation of this type, it is best to supply only enough local signal to keep the pictures from these stations free from interference and background noise.

UHF can be added to the distribution system by using a UHF converter and a separate UHF antenna, as shown in Fig. 28. If a single UHF channel is to be added, the converter can be either a pre-tuned or a tunable type, set to the exact channel. The converter automatically converts the UHF signal to an unused VHF channel so that it can be distributed to the various receiver outlets. Therefore, the signal at the output of the UHF converter, which is often in the channel 5 or channel 6 range, can be supplied to the mixer section and on to the distribution line.

If more than one UHF channel is to be added, pre-tuned converters can be used to supply signals to the mixer for each UHF channel. In this arrangement, the output of the UHF converters must be tuned to different VHF channels.

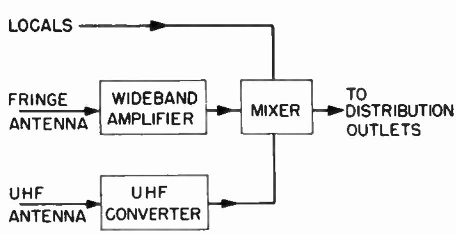


FIG. 28. Insertion of a UHF signal into a distribution line.

Large Apartment And Community Systems

The antenna distribution systems required in large apartments or community installations are more elaborate than the smaller systems discussed in the previous section. Of course, since more receivers are supplied with signals in the larger systems, more equipment is needed to maintain the signal levels throughout the distribution area. However, you will notice as you study the arrangements of the various pieces of equipment that basically the systems are the same.

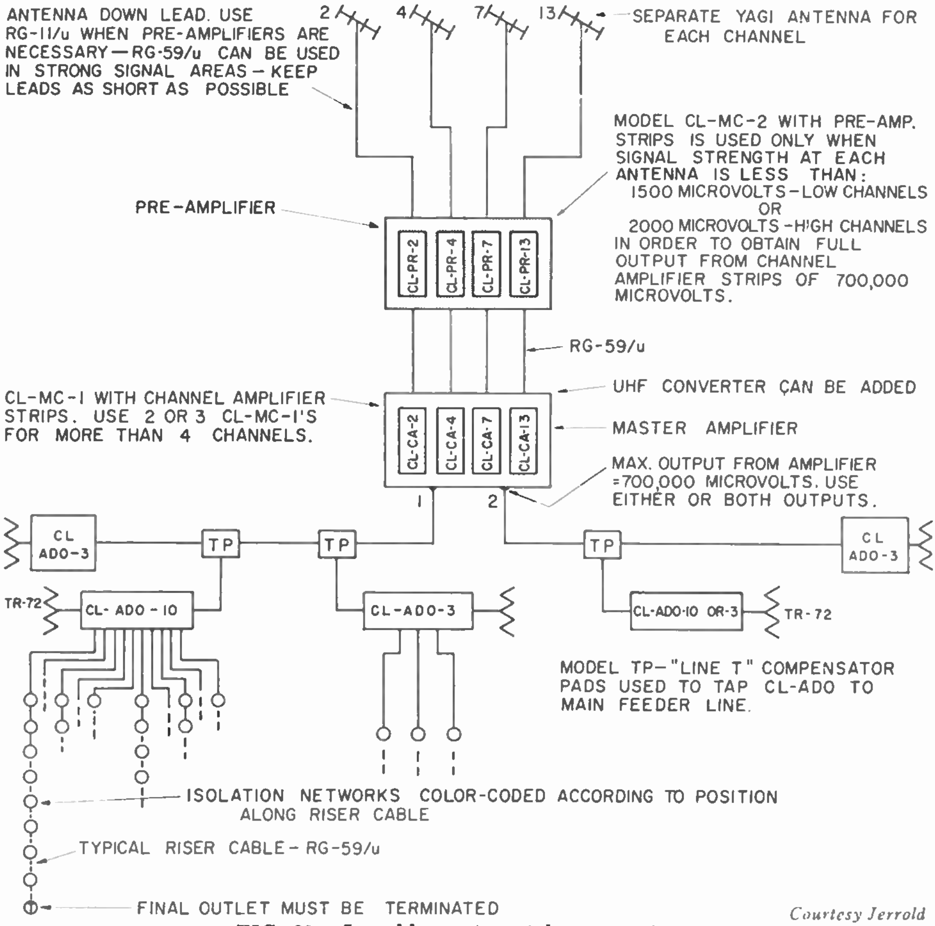
LARGE APARTMENT SYSTEMS

A typical plan for a large apartment installation is shown in the diagram in Fig. 29. Let us assume that channels 2, 4, 7, and 13 can be received in the area. Notice that separate antennas are used for each of the four channels.

In a strong signal area, the antennas can be connected directly to a strip-type master antenna amplifier unit. The cable that connects the antennas to the strip amplifiers can be RG59/U coaxial cables. Where the antenna signals on the high channels are less than 2000 microvolts (or 1500 microvolts on the low channels), special channel pre-amplifiers generally are used, as shown in the shaded block. To prevent as much signal attenuation as possible, the lower-loss RG11/U cable is connected between the antenna and the pre-amplifier strips. It is possible, of course, to distribute more than four channels by using additional strip amplifier-mixer units. UHF also can be distributed over the system by connecting the special UHF converter into the channel strip amplifier. The channel strip amplifiers can be adjusted individually so that the signal is the same strength for each channel.

In this system, the output of the amplifier-mixer unit should be 700,000 microvolts on each channel. Two main feeder lines supply signals to the compensator pads (TP) at various points along each line. The compensator pads, which supply signals to the distribution outlet units, provide impedance matching and equalize the signal levels throughout the main feeder lines.

The distribution outlet units can be either the three-outlet or ten-outlet types. Riser cables come off the distribution outlet amplifiers to supply signals to the various receivers. As many as twenty individual isolation network units can be connected to each riser cable. Therefore, a large number of receivers can be supplied with signals from this basic distribution plan. The attenuation presented by the isolation networks, as discussed earlier in this lesson, varies with their location along the riser cable so that equal signal levels are available for each receiver outlet.



Courtesy Jerrold

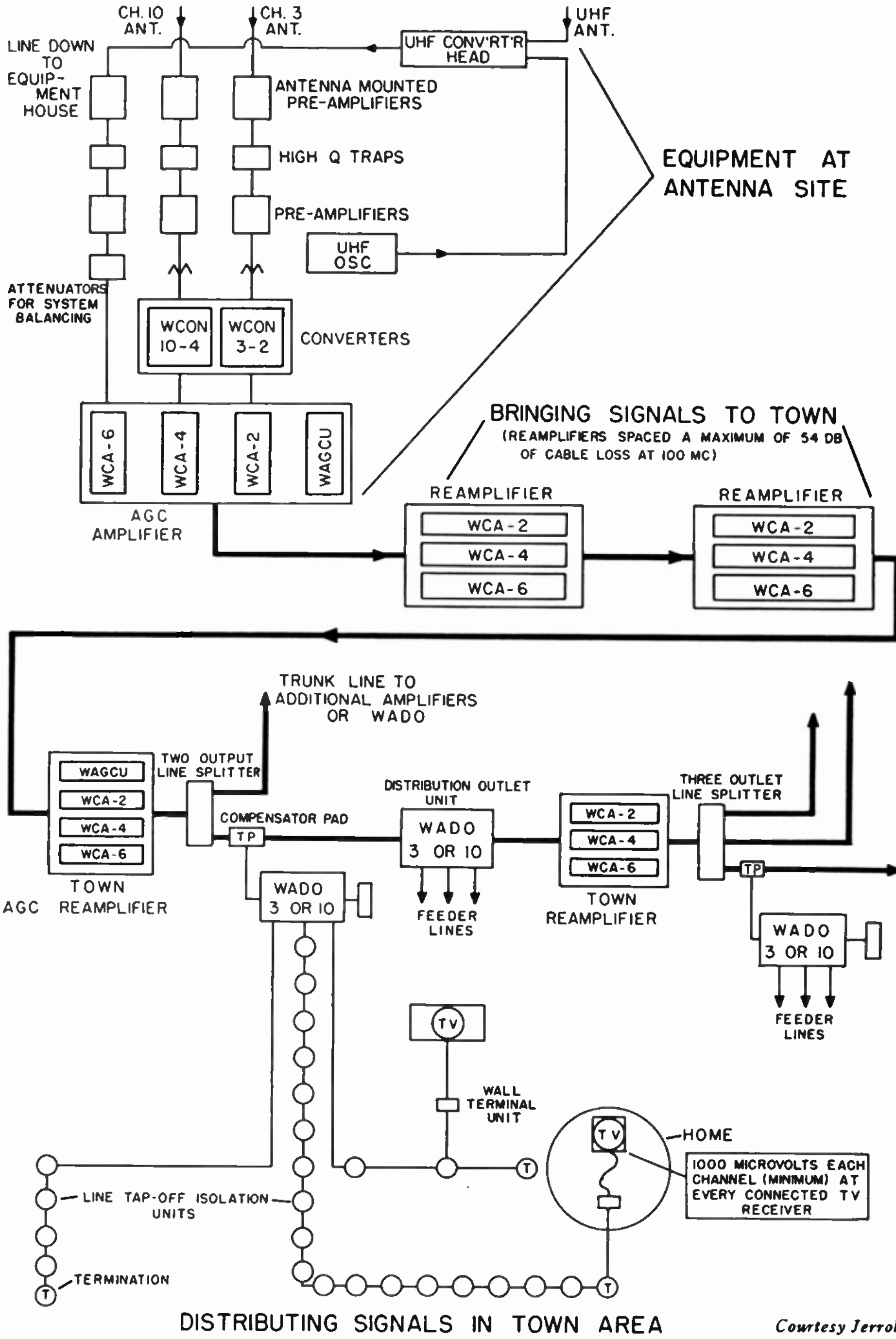
FIG. 29. Jerrold apartment house system.

COMMUNITY ANTENNA SYSTEMS

A community antenna system that supplies television signals to hundreds or thousands of receivers is a complex installation. The typical plan shown in Fig. 30 can best be understood by tracing the signals from the antenna to a receiver outlet.

The antenna site is generally located on a mountain top as near the city to be served as possible. However, the antenna location is not always a matter of convenience. Only after exhaustive tests have been made in the area, is the site chosen that delivers the strongest and most consistent signals.

The antenna used in a community distribution system is usually very elaborate. The installation illustrated in Fig. 31 employs high gain Yagi-type antennas to obtain the best signal-to-noise ratio in the fringe area. The height of the antenna may be from 70 to 200 ft. Therefore, antenna-



Courtesy Jerrold

FIG. 30. Jerrold community antenna system.

mounted pre-amplifiers, which are similar to the wide-band amplifiers discussed previously, are used to amplify the signal before it is applied to the transmission lines to the equipment house below the tower.

UHF signals also can be conveyed over the distribution system by using a special UHF antenna-mounted converter to heterodyne with the UHF signal and reduce it to the VHF range. The UHF oscillator for the converter head is located in the equipment house. To provide the necessary stability, this oscillator is usually crystal-controlled. The output signal from the UHF converter head is applied to the input of a VHF pre-amplifier before it is applied to the transmission line which runs to the equipment house at the base of the tower.

In the equipment house, a considerable amount of amplifying, converting, and monitoring equipment is required. Each signal from the antenna pre-amplifiers is passed through a trapping circuit to attenuate all off-channel frequencies and FM interference. The signals are again amplified and applied to the conversion system.

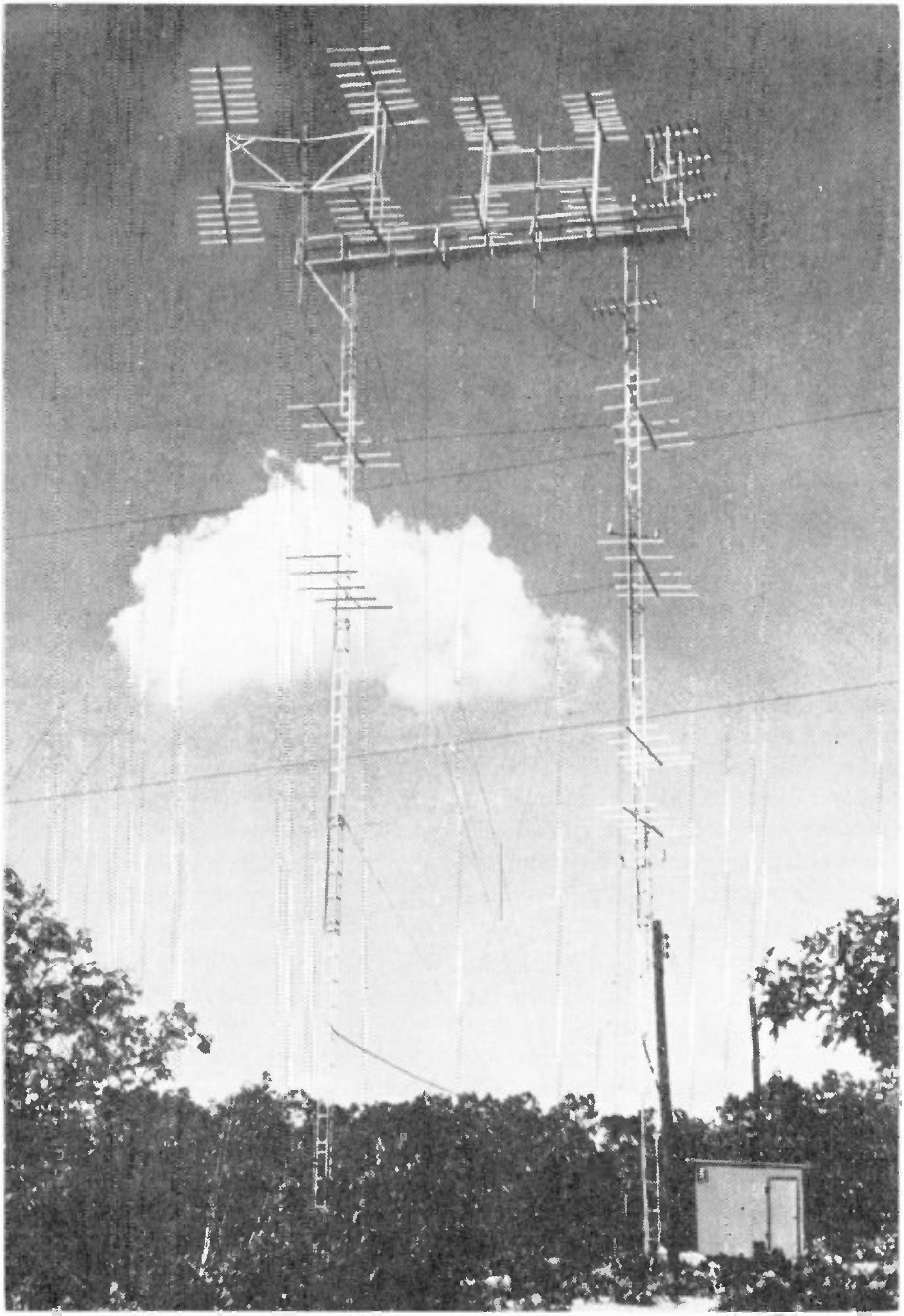
Frequency Conversion Methods. As explained earlier in this lesson, the channel frequencies supplied over most large distribution systems are in the low-band range from channels 2 through 6. In the three-channel arrangement, shown in Fig. 30, all incoming signals are converted to channels 2, 4, and 6. The choice of these low-band, spaced frequencies is made to minimize adjacent channel interference problems and to provide the least cable attenuation.

After reaching the equipment house, the frequency of channel 10 is converted to the channel 4 frequency by a high-low converter (WCON). The UHF signal is converted to channel 6 at the antenna top, and therefore, it does not require further conversion. The channel 3 signal is converted to channel 2 by the low-low converter. Thus, all three signals to be conveyed by the distribution system have been converted to low-band frequencies.

Notice that an agc unit (WAGCU) is associated with the three channel strips. Although the strip amplifiers contain individual gain controls, an agc unit is desirable to maintain equal signal strengths with small variations in the receiver signal levels.

It is possible to add two more channels (3 and 5) to the distribution system by converting the signals to sub-TV frequencies between 24 and 30 megacycles and 40 and 46 megacycles. These new bands and the amplifiers that are used to convey them are designated as 03 and 05. This plan, shown in Fig. 32, is called "K," while the three-channel arrangement is called "W."

In the K plan, the two new channels are converted first to the 03 and 05 frequencies at the antenna site. Five channel frequencies leave the conversion sections and are conveyed over the distribution lines into the city. Additional strips, of course, must be added at each line amplifier to amplify the 03 and 05 frequencies. These sub-TV frequencies were chosen to minimize adjacent channel interference problems through the amplifier and distribution systems, and to per-



Courtesy Jerrold

FIG. 31. Antennas and equipment house for a typical community antenna system.

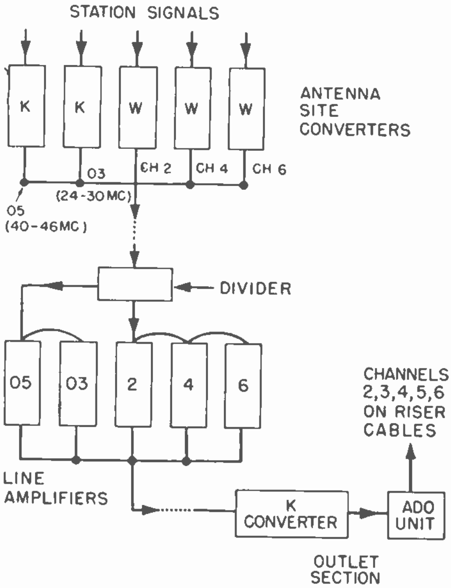


FIG. 32. K-plan addition of two channels to a three-channel distribution system.

mit low-loss distribution of these low frequencies.

At each distribution outlet, a converter must be installed to change the 03 and 05 frequencies to VHF channels 3 and 5. Therefore, the five channels (2, 3, 4, 5, and 6) are distributed over the remainder of the system and into the riser cables so that the receiver is able to pick up all the channels with no changes made in the set itself.

Now, let us refer again to Fig. 30 and trace the distribution system on into the community. After the signals leave the equipment house, they are fed to either open-wire lines or coaxial cable. The distance between the antenna and the city may be a few thousand feet up to many miles. Therefore, line amplifiers must be inserted along the line to maintain the signals at the proper levels. In an actual installation, an amplifier should be inserted every 54 db of cable loss (at 100 megacycles). In addition, every third line amplifier should be agc-controlled to improve the signal stability and uniformity.

The output of the final amplifier usually is applied to a line splitter from which the main trunk lines spread out into the city. Additional line amplifiers and, if needed, line splitters, can be added to supply more receivers.

The section of the distribution system from the line splitter to the individual receiver outlet is similar to the systems used in large apartment house installations. However, the number of receivers connected to each riser cable depends on the separation between the dwellings and the overall length of the riser cable. The attenuation caused by these components must be considered in planning the system so that each receiver outlet will receive an adequate signal.

Notice in particular, that all cables must be properly terminated. Thus, the final outlet unit in any distribution system contains a terminating resistor. In a simple antenna-receiver installation, the line can be improperly terminated and still not cause serious interference and reflection problems. However, when there are thousands of feet or many miles of cable, improper terminations cause the signals to race back and forth along the lines and set up multiple reflections and unstable conditions in the system. Therefore, it is very important that a terminating resistor be inserted at the end of each distribution line.

You have learned in this lesson that the size and type of distribution system that is installed in any location depends upon the number of receivers to be supplied with signals, the interference problems in the area, and the signal strength. The most important requirement of any system is to supply good quality pictures to *all* the receivers. Therefore, any system, whether small or large, must be planned carefully to meet this requirement.

You may not be called upon to service or install an elaborate signal distribution system. However, you should know how they operate and be familiar with the difficulties you may encounter in repairing a receiver that is connected to one of these systems. First you will have to decide whether the defect is actually in the receiver or in the distribution system. If you find that the receiver is at fault, you can repair it in the usual manner. However, if the receiver is operating normally, but there is no signal at the receiver outlet, you may have to locate and repair the defect in the distribution system. With the knowledge you have gained from this lesson, this should not be too difficult a task.

YOU HAVE TWO KINDS OF KNOWLEDGE

Almost two hundred years ago, Samuel Johnson made a statement which applies to you today — as you approach the end of your NRI Course.

Johnson wrote:

> "Knowledge is of *two kinds:*
> You know a subject yourself — OR you know *where* you can find information about it."

As an NRI graduate, you will know the answers to radio and television problems — *or* you will know *where and how to find the answers* to your problems as they arise.

In fact, one of the important and valuable features of the NRI Home Study Course is the fact that you have built up a complete reference library. And you know where to look for more information on subjects when you need additional information.

J. E. Smith