ACHIEVEMENT THROUGH ELECTRONICS

nri

TRAINING KIT MANUAL

1T

NATIONAL RADIO INSTITUTE • WASHINGTON, D. C.

TRAINING KIT MANUAL 1T

PRACTICAL DEMONSTRATIONS
IN BASIC ELECTRONICS

A Plan For Studying The Experiments

As you know, these Experimental Kits are intended to come to you on a definite schedule. This arrangement is so that you will study the necessary theory in your regular lessons before you carry out any corresponding experiments. This permits you to adopt either of the following plans of study:

1. You may wish to complete one or two experiments in a kit, do a lesson, and then return to the kit for one or two more experiments. This plan permits the experiments in one kit to be finished about the time the next kit is due. Thus, the lessons and experiments run along together, and provide you with a varied program of study.

2. You may prefer to break away from your lessons and to complete all the experiments in a kit at one time before going back to your lessons. This plan has the advantage that you do not waste any time getting out and putting away materials, but it can be followed only if you can leave your equipment set up long enough to finish.

Whichever plan you follow, you can begin NOW with the experiments in this kit. However, be sure to read the preliminary information on pages one through sixteen before you begin, so you will know just how the experiments are to be carried out. In a similar manner, begin on future kits as soon as you receive them.

NOTICE

NRI has set up the CONAR Division of the National Radio Institute to handle the sale of professional test equipment and other electronic equipment. NRI has had unsurpassed experience in the design of quality kits. All CONAR kits are designed and produced by the National Radio Institute. The transistorized volt-ohmmeter you will build as part of your training is the CONAR Model 212. This is the same professional tvom you will see advertised nationwide. Several of the parts you received in this kit, including the meter, will be used in the assembly of your tvom.

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INSTRUCTIONS FOR PERFORMING EXPERIMENTS 1 THROUGH 10

LECTURE-ROOM DEMONSTRATIONS YOU PERFORM IN YOUR OWN HOME

How many times have you heard the expression, "Seeing is believing"? Probably many times, because it is human nature to doubt something you cannot see or touch.

Although you can learn how a piece of equipment works from pictures and words, the average person understands better if he can actually set up equipment and make tests himself to see how it works.

You must have a knowledge of theory before you can work successfully in the radio-TV-electronics field. However, unless you know how to apply theory and make tests, your knowledge is useless. Theory and practical application must go hand-in-hand.

The NRI Course of training is a well-balanced combination of theory and practical instruction. Practical demonstrations and experiments are given in this manual and the following manuals.

Doing these experiments will give you actual experience in handling parts and making measurements, and will help you understand explanations of more advanced circuit actions. This type of experience is more valuable to you than class or lecture-room demonstrations by an instructor in which you take no active part, and you can do the experiments at your own convenience.

This practical work with experimental equipment will help you develop confidence in your own ability and will provide what you need to become a practical technician.

The experiments will help you to solve technical problems you will encounter in your work. You will see for yourself what happens when a particular part is defective, and you will learn how to detect and correct errors and how to adjust circuits.

Every experiment in every manual is important, because it is an actual working demonstration. Do not pass over any of them hurriedly, even though you may feel that you already know the results.

If you look underneath the chassis of any modern piece of electronic equipment, you will see that the connections are soldered. A soldered connection is the most reliable type of connection to make in commercial production because it will not deteriorate much during the entire life of the electronic equipment.

When you repair defective equipment, you must be able to find the defective stage and then the defective part. However, the ability to find what is wrong is of little use unless you also know how to take out the defective part and how to solder the connections for a new part. Furthermore, you may often have to unsolder one or more connections during your tests in order to find the defective part.

In the first section of this manual, you will study the fundamentals of soldering and learn how to make a good soldered connection using actual electronic parts. You will make these connections in ex-

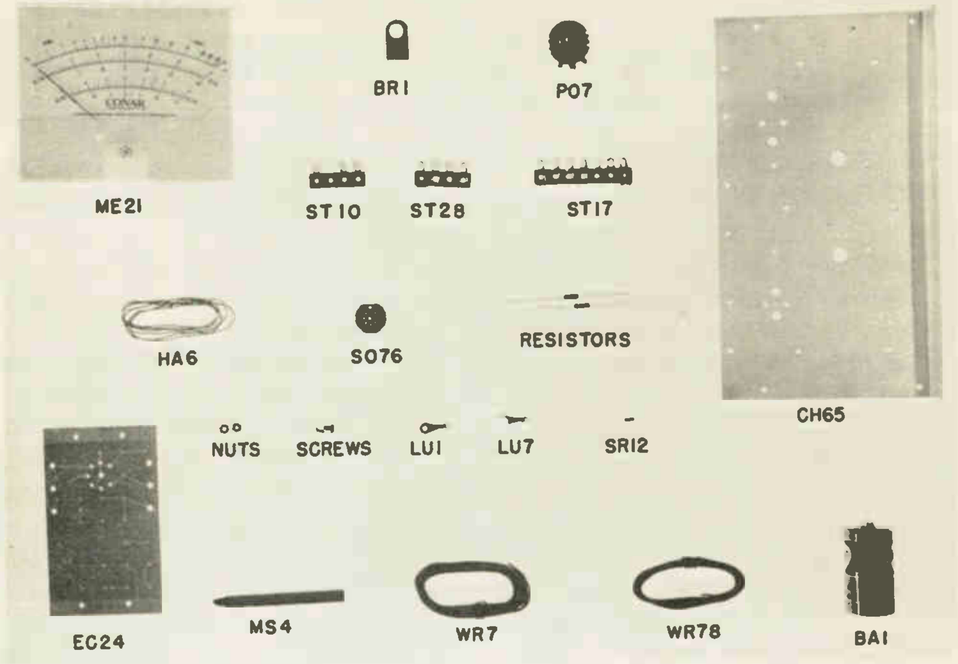


Fig. 1. Parts used in this Experimental Manual are shown here and listed below.

Quan.	Part No.	Description	Price Each
2	BA1	Size D flashlight cell	.20
1	BR1	Pot mounting bracket	.05
1	CH65	Chassis plate	.93
1	EC24	Etched circuit board	1.10
1	HA6	Solder	.41
1	LU1	Solder lug, small	12/.15
2	LU7	Solder lug, large	12/.15
1	ME21	Meter	10.92
1	MS4	Marking crayon	.05
6	NU1	6-32 hex nut	12/.15
2	NU5	4-40 hex nut	12/.15
1	PO7	1000-ohm pot w/lockwasher/nut	.75
1	RE28*	470-ohm resistor	.15
2	RE29	4700-ohm resistor	.15
3	RE30	1000-ohm resistor	.15
2	RE33	22,000-ohm resistor	.15
2	RE36	100,000-ohm resistor	.15
1	RE50	6800-ohm resistor	.15
1	RE52	82,000-ohm resistor	.15
2	RE56	680-ohm resistor	.15
1	RE165	15,000-ohm, 5% resistor	.24
6	SC1	1/4" X 6-32 machine screw	12/.15
2	SC6	1/4" X 4-40 machine screw	12/.15
1	SO76	7-pin tube socket	.12
2	SR12	Silicon diode	.67
1	ST10	3-lug terminal strip	.05
1	ST17	7-lug terminal strip	.12
1	ST28	4-lug terminal strip	.10
1	WR7	25' red hookup wire	.50
1	WR78	6' black hookup wire	.12

*All resistors are 1/2-watt, 10% tolerance unless otherwise specified.

actly the same way that you would in working on commercial equipment. The solder, hookup wire, and other parts that are included in this kit are standard items, just like those that you might use in working on any piece of electronic equipment. In later experiments, you will have practice in working from schematic diagrams. You will also assemble a number of simple circuits to demonstrate some basic electrical laws.

HOW THE MANUALS ARE ARRANGED

The manual for each kit in your Practical Demonstration Course contains the instructions for performing ten experiments. These experiments are numbered consecutively throughout the whole series; Experiments 1-10 are in the first manual, 11-20 in the second, etc. At the end of each experiment is a Statement that you are to complete, so that you can check your work as you go along. When the ten statements have been answered, be sure to submit the training Kit Report to NRI for grading.

In each manual, the figures are numbered to correspond to each experiment. Each figure number has two parts. The first part is the number of the experiment in which it appears, and the second part is the number of the figure within the experiment. For example, Fig. 1-3 would be the third figure in Experiment 1; Fig. 6-2 would be the second figure in Experiment 6. If there are any figures that do not apply to one particular experiment, they will be numbered consecutively in each manual, starting with Fig. 1.

CONTENTS OF THIS KIT

The parts included in your first kit are pictured in Fig. 1 and listed below. Each part that you receive in your kits is assigned a part number. The part number and description appears below Fig. 1. When you need a part for the experiments, you will be given the part value, a description, and in some cases the part number.

Now check the parts that you receive against this list to make certain that you have all of the parts. *Do not lose or discard any of these parts because you will use many of them again in later experiments.*

For your convenience, most of the parts are packed on cardboard under a clear plastic film. This protects the parts during shipment and also makes it easy to inventory your parts. To remove the parts, cut around them with a sharp knife or a razor blade.

IMPORTANT: If any part of this kit is obviously defective or has been damaged during shipment, please return the defective part to NRI for replacement, following the procedure given on the "Packing and Returned Material Slip" enclosed in this kit.

Preparing For The Experiments

Before you start the experiments, there are several things you will need to do. You will need a place to work and tools to work with.

You do not need an elaborate workbench. A folding card table set up near an electrical outlet will be satisfactory. Do not use a metal-top table, because it could cause short circuits that might damage the equipment. If you have to use a metal-top table, cover the top with a nonconductor, such as cardboard or linoleum.

TOOLS YOU WILL NEED

The tools you need to do these experiments are the same as those you will use in all kinds of electronic work. They are pictured in Fig. 2, and listed under the figure. None of these tools are supplied with this kit. Probably you already have some of these tools, since the average home usually does have a few tools for simple repair work.

You can get those tools you do not have from hardware stores, radio-supply

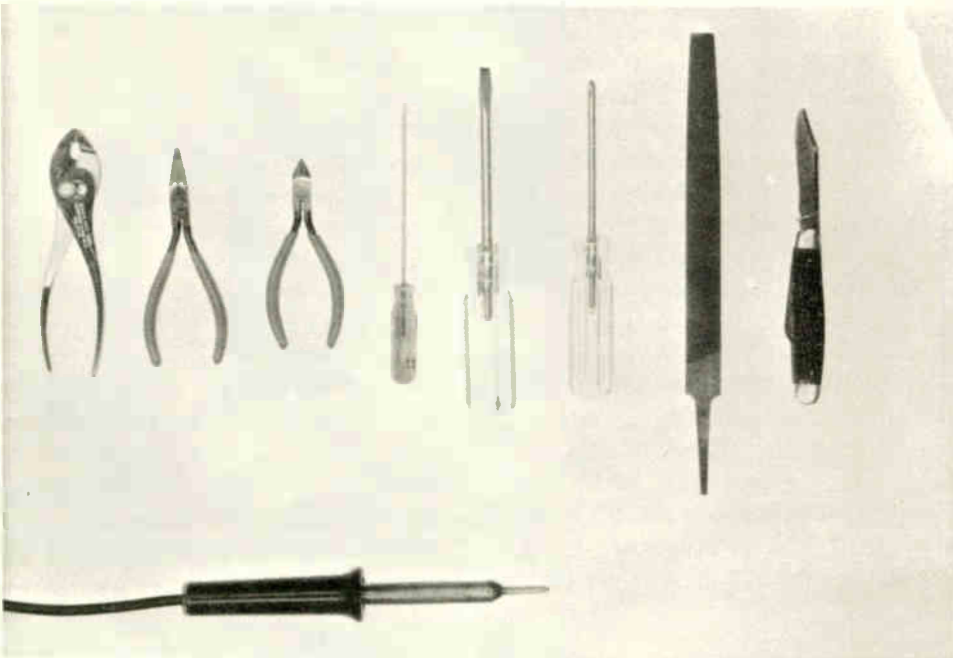


Fig. 2. These are the tools you will need to do these experiments. You probably already have many of them. Get the best ones you can afford; you will be using them throughout your course as well as when you do service work. These tools are not supplied with your kits. From left to right, all-purpose pliers, longnose pliers, diagonal cutters, small screwdriver, medium size screwdriver, Phillips screwdriver, metal-cutting file, and pocket knife. Below the tools is a soldering iron.

houses, or mail-order firms. Since you will use the tools in all of your electronic work, they are a worthwhile investment. Select good quality tools that "feel right" in your hand.

Pliers. The technician needs three types of pliers: longnose pliers, diagonal cutters, and ordinary slip-joint pliers. Each type has its own purpose and should be used for that purpose only. Pliers are designed primarily for holding, bending, and cutting. Many people use them for other purposes so they often ruin them or mar the material on which they are working.

Perhaps the pliers most often used in electronics are the longnose type. Although you may use longnose pliers to hold a nut in position so that it can be started on a screw, you should never use them to tighten nuts. You may spring the jaws so the points will not meet or you could actually break one of the jaws. Use your longnose pliers to hold wires in position for soldering, to remove wires, or for hard-to-reach places.

Diagonal cutting pliers, or "side cutters" as they are often called, are used for most cutting operations. Because the cutting jaws are at an angle, these pliers are ideal for cutting wires close to terminals.

Combination slip-joint pliers, often called "combination pliers," are also in common use. Because of the slip joint, the jaws can be opened wider at the hinge pin so that larger diameters can be gripped. These pliers come in 5, 6, 8, and 10-inch sizes. The thin-type, 6-inch size is best for electronics work.

Screwdrivers. Practically everyone is familiar with the standard screwdriver. The screwdriver is intended for one principal purpose - to loosen or tighten screws. Because the average person uses a screwdriver as a can opener, a pry or pinch bar, and even as a chisel, the screwdriver is one of the most abused tools.

The technician needs three screwdrivers - one with a small blade for loosening setscrews in dial and control knobs and one with a medium blade for general purpose work. He also needs a Phillips screwdriver because screws with a special head known as a "Phillips head" are often used in electronic equipment. Screwdrivers with plastic handles are best because the plastic is a good insulator. Later on you will need a special type of screwdriver, known as an "alignment tool." This is a non-metallic tool for special uses, but you won't need it now.

Files. There are more than twenty types of files. Each type comes in sizes from three to eighteen inches. They may be either single or double cut and are classified according to the different grades of coarseness or fineness, depending upon the size and spacing of the teeth.

The type most often used in electronics is a 10-inch second-cut mill file. It is used to keep the tip of the soldering iron in good condition by removing small amounts of metal, leaving the filed surface smooth. This type of file is also useful in brightening lugs for easier soldering.

Knife. A good knife is useful when preparing wires for connection to other parts; a sturdy pocket knife is fine.

Soldering Iron. The soldering iron is used more often by servicemen than any other tool. Since you will use it often and it is so important, you should choose it carefully. A number of soldering irons suitable for electronics work are shown in

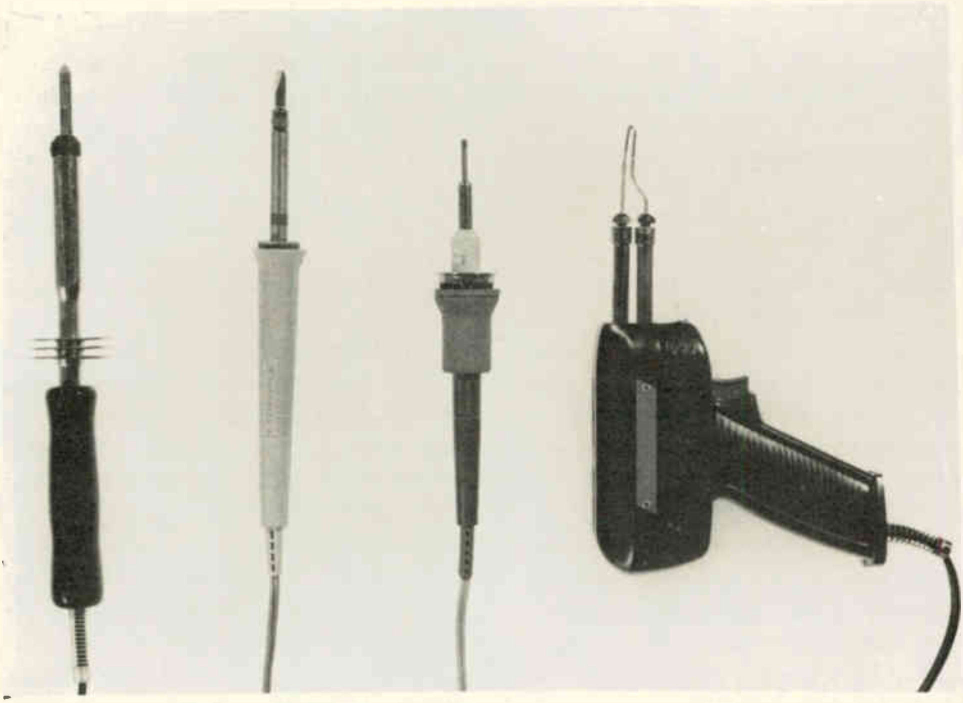


Fig. 3. Several soldering irons suitable for electronics work.

Fig. 3. It is best to buy a soldering iron from a firm that specializes in electronics parts. You should obtain your iron from your local wholesaler, from a mail-order wholesaler, or from the CONAR Instruments Division of NRI.

Hardware stores sometimes carry soldering irons in stock, but they may have only the large type that is used for heavy work, such as automobile radiator repair or roofing work. These irons are too heavy for easy handling and too big to be used where small parts are crowded together.

From left to right in Fig. 3, the first iron is called a medium duty iron. This type of iron generally has a rating of from 50 to 150 watts and is used where a relatively large amount of heat is needed, such as when soldering to the chassis.

The two irons in the center are "pencil" type irons. These types have replaceable heating elements and tips. They are available with various wattage ratings, usually 25 to 40 watts, suitable for general electronic soldering, and 40 to 50 watts, for heavier duty work. These "pencil" irons are the types most suitable for the beginner as they are lightweight and easy to handle. Perhaps the most suitable iron for the beginner would be one like the third iron from the left in Fig. 3. A 37-1/2 element and a chisel-shaped tip make an ideal choice of element and tip.

At the right in the photo is a soldering gun. A gun of this type has the advantage over the iron in that it heats and cools very quickly. Thus, it is excellent for a serviceman making house calls or a technician working on equipment in a plant. He plugs the gun in when he arrives at the job and it is ready for use immediately. Everyone going into electronics, whether on a part-time or full-time basis, will find a gun useful. However, it is not quite as easy to turn out well-soldered connections with a gun as it is with an iron. Therefore, the beginner should start with a conventional soldering iron and learn to use it correctly and later, if he so desires, he can use a soldering gun.

As mentioned previously, the most suitable single iron for general service work and for use in your kits is an electric iron with a tip about an inch long and 1/8" to 1/4" in diameter. The tip should be of the chisel type with two flat surfaces. The wattage rating should not be more than 50 watts, because a high-wattage iron is bulky, and if its barrel touches parts, it may damage them.

When you buy an iron, be sure you get a soldering iron stand with it, to rest the hot iron on when it is not in use. Or get an iron that is designed so that the handle is heavier than the tip end. Then the iron will balance when it is laid down with the tip off the bench.

The average electric soldering iron will operate on ac or dc at 117 volts. Power-line voltages may vary between 110 and 120 volts; an iron designed for 117-volt operation may be used on any voltage between 105 volts and 130 volts.

Although the modern soldering iron is a rugged tool, it should never be abused. Do not use it as a hammer, drop it, or attempt to cool it quickly by plunging it into water. When properly cared for, an iron will last for years.

Although some irons have pre-tinned tips, most tips must be tinned before use. If your iron has a bright, shiny tip or a dull gray tip, it has been pre-tinned, and it is ready for use. If the tip is a natural copper color, you must tin it before using it.

TINNING A SOLDERING IRON

You cannot solder properly unless your soldering iron is properly tinned. Therefore, your first step in learning how to solder is to learn how to tin a soldering iron.

The tip of the soldering iron is made of copper. When an untinned soldering iron is heated, the copper combines with the oxygen in the air, forming a dark coating of copper oxide on the tip of the iron. If you try to use an untinned iron, the copper oxide coating will act as a heat insulator and keep the heat of the iron from the parts you are trying to solder. It will be practically impossible to heat the part sufficiently to melt the solder properly.

You can prevent this by covering the tip of the iron with solder. This is called "tinning" the iron. The solder will form a protective layer over the copper tip so that the oxygen cannot get at the copper and corrode it. The tinned tip will be a good conductor of heat, and you will be able to heat the parts enough to solder them properly.

Preparing the Tip. The first step in tinning a soldering iron is to examine the tip. A photograph of the tip of a new soldering iron that has not been tinned is shown in Fig. 4A, and a photograph of a soldering iron that has been used and needs re-tinning is shown in Fig. 4B. Notice that the tip of the new iron is reasonably smooth, whereas the tip of the iron that has been used is pitted, dirty, and uneven.

If your soldering iron is in good condi-

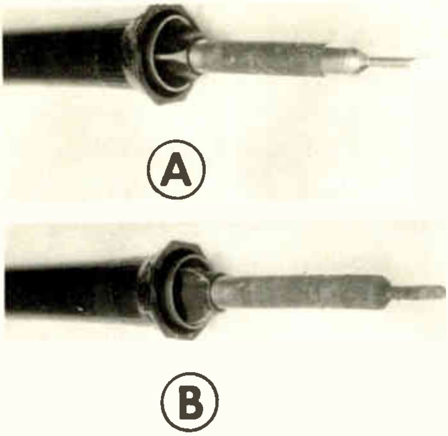


Fig. 4. If your soldering iron is new and has not been tinned as at (A), or if it has been used and is pitted as at (B), it will need tinning.

tion, like the one shown in Fig. 4A, you can plug it into an electrical outlet and start heating it. On the other hand, if you have an iron that has been used and looks like Fig. 4B, you should file the tip smooth before you start to heat it. Even though your iron may be in good condition, read the following instructions carefully, because after your iron has been used for some time, it will become pitted like the one shown in Fig. 4B. You will have to go through this procedure to re-tin it.

To file the tip of the iron, rest the iron on a vise or a similar metal support, as shown in Fig. 5. Grasp the iron in one hand and proceed to file one of the surfaces flat as shown. Try to file the surface at approximately the same angle as that of the original tip. Do not remove any more metal than is necessary, but make sure that you file the surface until all of the dark spots and holes in the surface are gone. When you have completed the operation, the tip of the iron should look as it does in Fig. 6.

After you have filed one surface of the tip, turn the iron over. In other words, rotate the iron 180°, and file the surface flat on the opposite side of the tip. Again, remove no more metal than is necessary, but make sure you file the surface until it is clean. Try to file at the same angle as the first surface, as shown in Fig. 7.

If your iron has a pyramid-shaped tip, turn the iron a quarter turn and file one of the other surfaces. Then turn the iron over and file the last surface. When you

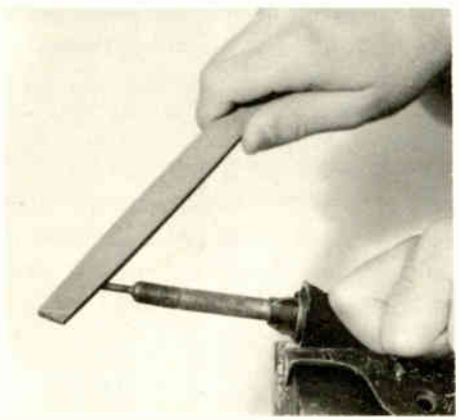


Fig. 5. To file the tip of your iron, hold it against a vise as shown here.

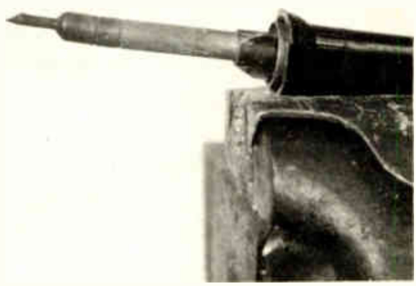


Fig. 6. When you have filed one surface, your iron should look like this.

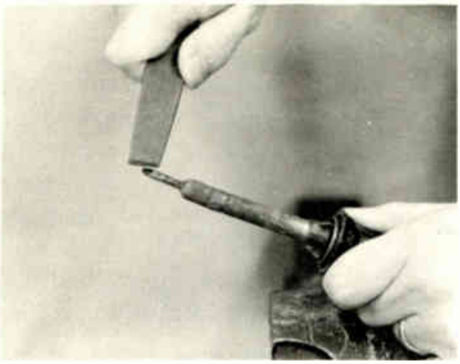


Fig. 7. File the opposite surface at the same angle as the first surface, as shown.

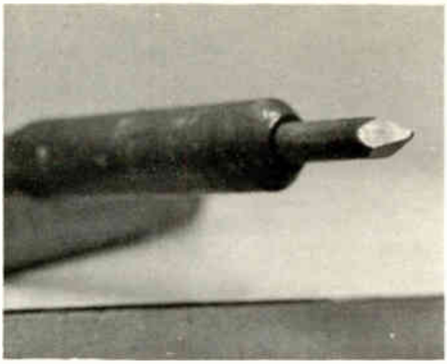


Fig. 8. Your iron should look like this after filing all four surfaces on its tip.

have filed all tip surfaces, the tip of the iron should look like the one shown in Fig. 8. Notice that the sides are approximately even.

Before you start to heat the iron, examine the edges of the flat surfaces on the tip. If the edges are rough, smooth them by careful rubbing with a piece of sandpaper.

Tinning the Iron. After you have prepared the surface for tinning, or if you are tinning a new iron that is in good condition, plug the iron in and wait for it to heat. As the iron heats, periodically touch the end of the solder to the tip so you will know when the iron is hot enough to melt the solder. You should tin it as soon as it reaches a high enough temperature, because the longer an untinned iron is heated, the more copper oxide will form on the tip.

When the iron has reached operating temperature, again rest it on a vise and lightly file one surface as shown in Fig. 5. Once you have filed the surface lightly so that it is shiny, quickly set the file down, pick up the roll of solder, and touch the end of the solder to the tip of the iron. Move the solder around the tip until the entire surface is tinned, as shown in Fig. 9. After you have tinned one surface of the tip, turn the iron and go through the same procedure of lightly filing the other surfaces, and then applying solder.

After you have tinned the surfaces of the tip, use a clean cloth to wipe off any excess solder. Hold the cloth loosely as shown in Fig. 10 to avoid burning your hand. When you have your iron tinned, it is ready for use. Unplug it, and set it aside until you are ready to start soldering.

Fig. 9. How to apply solder to tin the tip of the iron.

Fig. 10. Wiping excess solder from the iron with a piece of cloth.

Notice that the solder you received in this kit contains a rosin core that acts as a cleaning agent and prepares the metal surface to receive the solder. It is difficult to make a good soldered connection using plain solder alone; another material called flux must be applied along with the solder. Rosin flux is used in this case. Only rosin core solder should be used in soldering electronic equipment.

Hardware and other stores sell some solder with an acid core. Acid flux in any form should never be used in electronic equipment. The acid will corrode the leads and terminals and may damage some of the parts. Use only rosin core solder in electronics work; do not use liquid or paste flux. Solder similar to that which we have supplied in this kit should be used in all your electronics work.

> **IMPORTANT NOTICE**
>
> In checking students' problems, NRI has found that poor soldering is more frequently the cause of failure to get proper results than all other troubles combined. Therefore, be sure to perform every step in each experiment to learn all you can about soldering.
>
> DO NOT SKIP ANY STEPS

MOUNTING THE PARTS

Most of your experiments will be carried out on your experimental chassis plate which is shown in the parts photo, Fig. 1. You will mount several parts on the chassis plate before you begin the experiments.

The parts supplied with this kit are shown in Fig. 1 and identified in the list below the photograph.

Gather the following parts and place them on your worktable. Then they will be handy when you are ready to use them:

1 Chassis plate (CH65)
1 7-lug terminal strip (ST17)
1 3-lug terminal strip (ST10)
1 4-lug terminal strip (ST28)
1 Potentiometer mounting bracket (BR1)
1 1K-ohm potentiometer (PO7)
1 Solder lug (LU1)
6 1/4" X 6-32 screws (SC1)
6 6-32 hex nuts (NU1)
1 Marking crayon (MS4)

Notice that we have supplied two sizes of screws and nuts. The size of a machine screw is given by its diameter and the number of threads per inch. The first number is the diameter. Thus, the 6-32 screws (SC1) are larger in diameter than the 4-40 screws (SC6), but the 4-40 screws have a finer thread. The length of a screw is given in fractions of an inch.

Follow the instructions as you mount the parts on your chassis and do not attach any parts until instructed to do so.

Place the chassis upright on your worktable so that the holes are positioned as shown in Fig. 11. The bent lip should be away from you and pointing upward. To

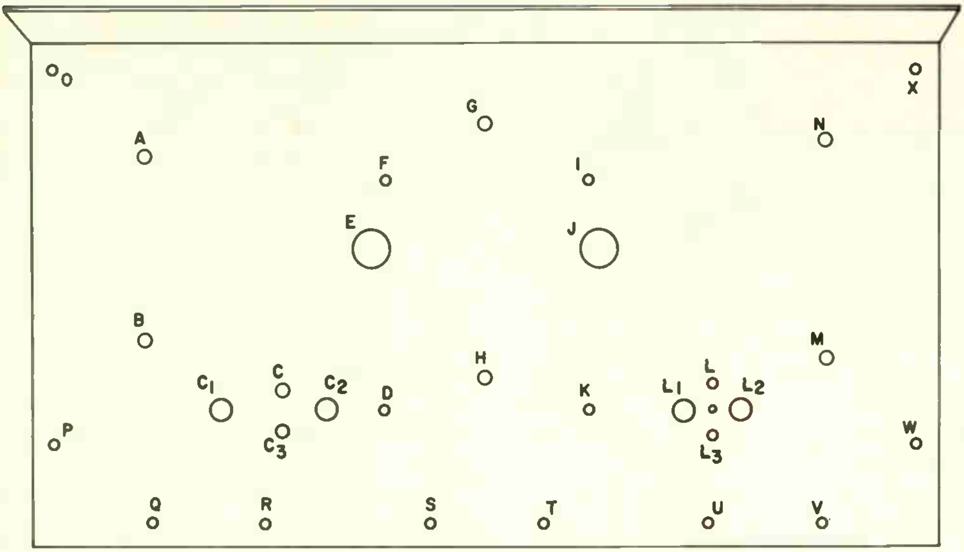


Fig. 11. Chassis hole identification.

help you locate the parts correctly, we have given the holes identifying letters. You can use the marking crayon to label these holes on the chassis. If you prefer, you can put small pieces of tape near these holes and mark on the tape with a pen.

Fig. 12 shows the chassis with the parts

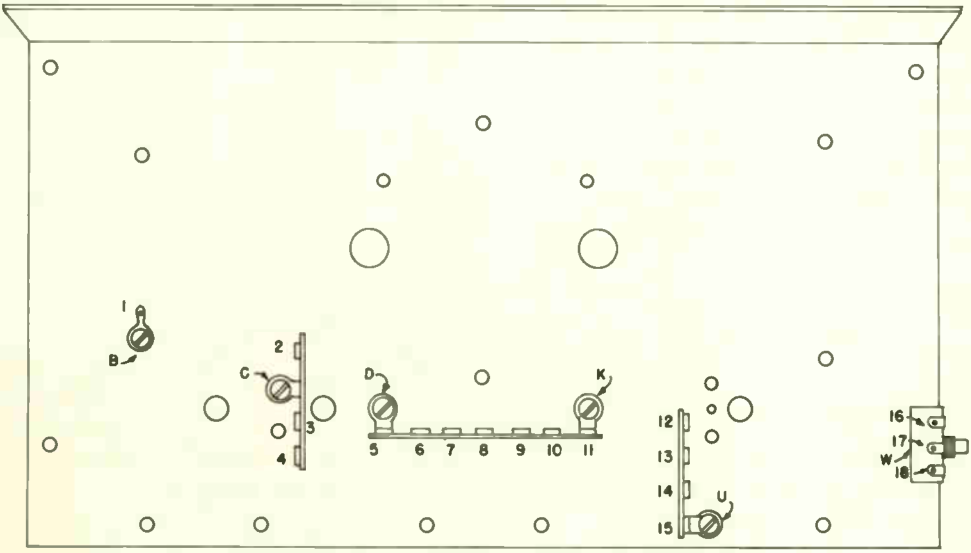
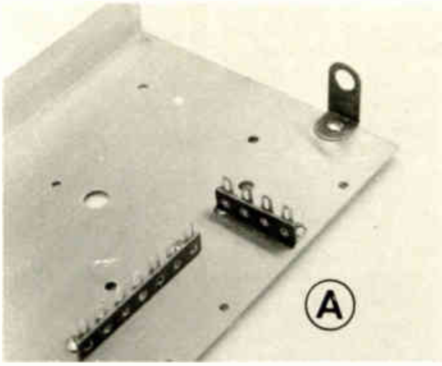


Fig. 12. Parts mounted on the chassis and the terminal identification number.



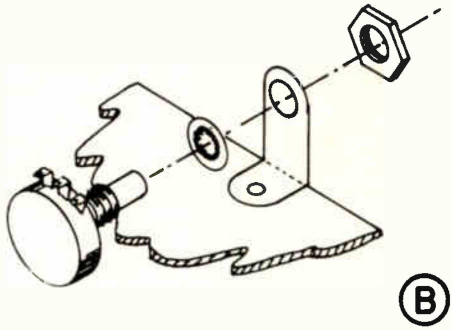


Fig. 13. (A) Mounting the potentiometer bracket; (B) mounting the potentiometer.

mounted on it. Be sure to mount the parts at the correct location and position them as shown in the drawing.

Mount the 3-lug terminal strip at hole C, as shown in Fig. 12. Pass a 1/4" X 6-32 screw down through the mounting foot in the terminal strip and through hole C in the chassis. Attach a 6-32 hex nut. Position the terminal strip as shown and tighten the screw. Hold the nut with pliers as you tighten the screw.

Install the 7-lug terminal strip at holes D and K. Use 1/4" X 6-32 screws and nuts. Position the strip exactly as shown in Fig. 12. Pass a screw down through the left mounting foot and hole D and attach a nut. Pass a screw through the other mounting foot and through hole K. Attach a nut and tighten both screws.

Mount the 4-lug terminal strip at hole U. Use a 1/4" X 6-32 screw and nut. Position the terminal strip as shown in Fig. 12 and tighten the screw.

Install the potentiometer mounting bracket at hole W. See Fig. 13A. Use a 1/4" X 6-32 screw and nut. Pass the screw down through the small mounting hole in the bracket and through hole W in the chassis. Attach the nut and tighten the screw.

Install the potentiometer in the potentiometer mounting bracket. As shown in Fig. 13B, slip the large lockwasher over the shaft and bushing of the potentiometer and slip the bushing through the hole in the bracket mounted on the chassis. Attach the large control nut, turn the potentiometer so its terminals are upward; then tighten the control nut.

Bend the solder lug at about a 45° angle, as shown in Fig. 14. Mount the solder lug at hole B, using a 1/4" X 6-32 screw and nut. Tighten the screw.

The numbers appearing in Fig. 12 are the terminal identification numbers. They will be used throughout this kit for identifying the terminals when making connections.

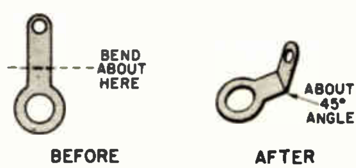


Fig. 14. Before you mount the solder lug, bend it as shown here.

Learning To Solder

Our experience in teaching students has shown that over 75% of the troubles encountered by students and technicians is due to poor soldering! You might think from this that good soldering is difficult, but this is not true. If you watch an experienced man work with a soldering iron, it looks quite simple. The experienced technician follows the two basic rules given below to make good soldering easy.

First: Have the materials to be joined and the tip of the iron clean and free from grease. If the terminals or wires are not bright, scrape them with a knife or with a piece of fine sandpaper until they are clean and bright.

Second: Have the sections to be joined hot enough to melt the solder so that it will run freely to all parts of the connection and form a good bond.

If you follow these two basic rules, you will never have soldering trouble. If you ignore them, you may spend hours looking for defective parts when the trouble is simply a poorly soldered connection.

SOLDERING TECHNIQUES

Perhaps the most important step in making a good soldered connection is to make sure that the parts you are attempting to solder together are clean. For example, if you try to solder a capacitor lead to a terminal strip, and the capacitor lead is not clean, you will find it practically impossible to get the solder to stick to the lead.

All leads, whether they are resistor or capacitor leads or merely wires to be soldered, should be tinned before you attempt to solder them. Most of the resistors and capacitors that you will receive in your kits have been tinned by the manufacturer. However, in the manufacturing processes, the tinned surface sometimes becomes covered with wax or other impurities. These leads should be cleaned and retinned whenever necessary.

You can use approximately the same procedure to tin a lead as you used to tin the tip of your soldering iron. The first step is to clean the lead. You can either scrape the lead carefully with a knife, as

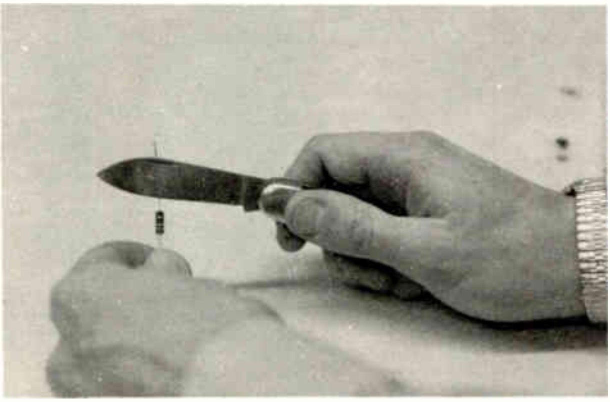


Fig. 15. How to use a knife to clean a resistor lead.

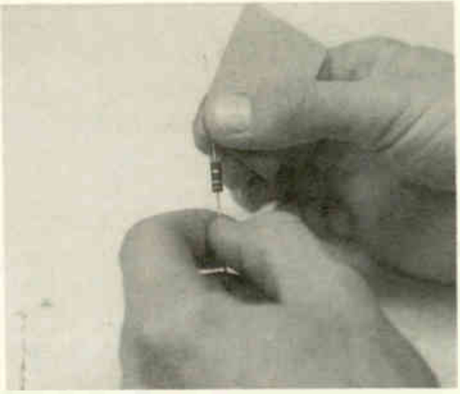


Fig. 16. Using sandpaper to clean a lead.

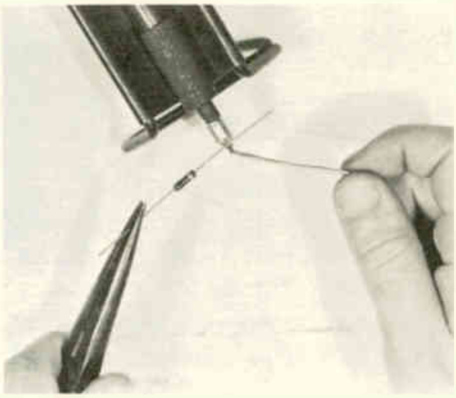


Fig. 17. How to tin a resistor lead.

shown in Fig. 15, or you can use a small piece of fine sandpaper. Hold the lead in the sandpaper, as shown in Fig. 16, and draw the sandpaper over the lead several times.

After you have cleaned the lead, hold the part with your longnose pliers and touch it to the tip of your soldering iron, as shown in Fig. 17. Then touch the solder to the lead. Allow a small amount of solder to melt onto the lead and onto the tip of the iron. Move the lead back and forth through the solder to tin the entire lead. If you apply enough heat to melt the solder thoroughly, the solder will flow smoothly over the lead, as shown in Fig. 18. Tin the other lead in the same way.

Lugs on terminal strips also should be cleaned and tinned before you attempt to solder a wire or a lead to the lug. Usually, brushing over the terminal quickly with a piece of sandpaper will remove any dirt or grease that may be on the terminal. Sometimes it will be necessary to scrape the terminal with a knife or file.

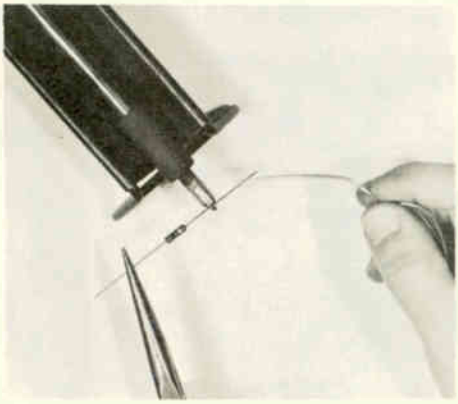


Fig. 18. A tinned resistor lead.

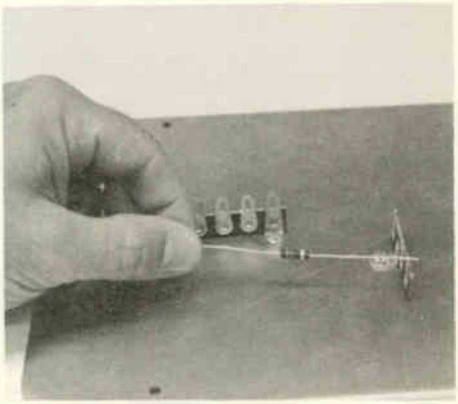


Fig. 19. Making a connection to terminal.

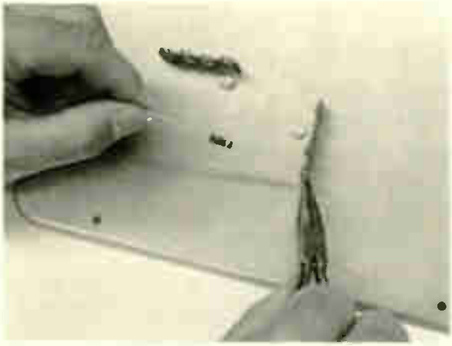


Fig. 20. Bending the lead.

Fig. 21. Soldering a connection.

The tube socket pins and lugs on the terminal strips that you will receive in your kits have been tinned. You should have no trouble in soldering to these terminals. However, before soldering to them, carefully examine them to be sure they are clean. If they are not, clean and tin them to avoid soldering difficulties later.

To solder a lead to a terminal strip or solder lug, place the lead through the opening in the terminal lug, as shown in Fig. 19. Bend the end of the lead slightly as in Fig. 20 so that the lead can be placed in contact with the metal part of the lug. Do not wrap the lead around the terminal strip lug unless you are told to do so. This type of connection is too difficult to remove. Later, when you begin wiring equipment that you will leave assembled permanently, you will wrap the leads around the various terminals in order to insure strong mechanical and electrical connections.

When you have the lead in place, hold your soldering iron against the terminal and against the lead, as shown in Fig. 21, to heat both of them to the solder-melting point. Unless you heat them both, you will not make a good connection.

After they are hot enough, touch the end of the solder to the terminal and lead, so that the solder will flow freely over the resistor lead and the terminal. Do not use too much solder. You want only enough to cover the resistor lead and hold it to the terminal. If you use too much, the solder will flow down the terminal strip and may short to the chassis. A properly soldered connection showing the correct amount of solder is shown in Fig. 22, and a connection with an excessive amount of solder is shown in Fig. 23.

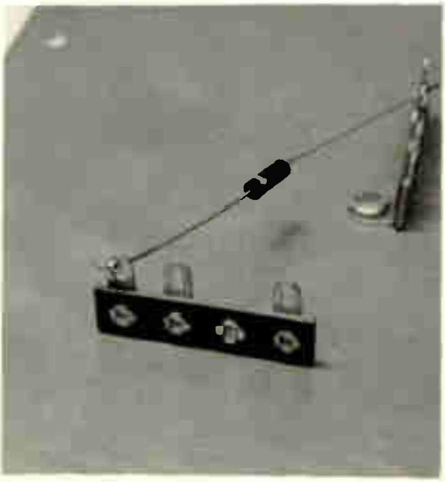


Fig. 22. Good solder connection.

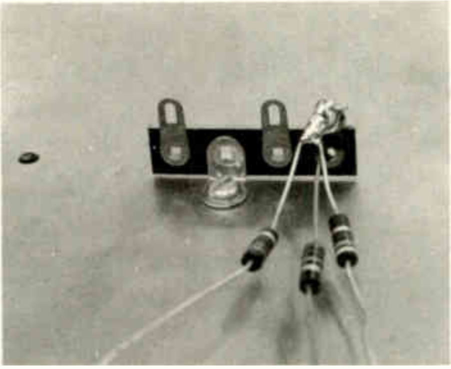


Fig. 23. Poor solder connection (too much solder).

When soldering a connection, do not be in a hurry to get the soldering iron off the connection. In most cases, it is better to hold the iron on the connection a little too long than it is not to hold the iron on long enough. When you are starting to solder, watch each connection carefully. Hold the iron on the connection long enough to allow the solder to flow freely. Solder should melt and flow in, around, and over all the leads you are attempting to solder to a terminal. The solder should also flow freely over the terminal. If you hold the iron on the terminal only long enough to melt the solder and have it start to flow, you will find that you have a rough-looking joint, and the chances are that if you apply pressure to the leads, they will pull loose. On the other hand, if you hold the iron on the joint long enough to allow the solder to melt completely and flow freely over the joint, you will have a smooth-looking connection that will be mechanically strong. This is extremely important - make sure that the solder flows freely over each connection you make.

Using Too Much Solder. Avoid using too much solder. It takes very little solder to make a good electrical connection. Usually, if you heat the terminal and lead sufficiently, you will find that a drop of solder will be all that is needed. Do not hold the soldering iron in place and simply melt more and more solder onto the joint. Once you have one drop of solder flowing around the joint, lift the solder off the terminal, but continue to heat the connection so that the solder that you have on the terminal flows around the leads and over the terminal. This may be all the solder you need. If not, add more solder and allow it to flow into the joint. If you use too much, the solder will flow between the pins and the chassis, and between the chassis and terminal strip lugs.

It is particularly important that you heat large wires thoroughly. You will often find in your radio, TV, or electronics work that you must solder transformer leads in place. Usually the leads from a transformer, particularly the leads from the filament winding on a TV replacement power transformer, will be of a fairly large size. In addition, they are made of copper, which is a good heat conductor. As a result, they can carry away a substantial amount of heat. You will have to be sure that you have the iron in good contact with the lead when making this type of connection.

Etched Circuit Wiring. Etched or "printed" circuit boards are used in many radio and TV receivers as well as in other types of electronic equipment. You can expect to have to wire and to repair circuit boards. Therefore, you should know how to do so.

Examine the etched circuit board included in your kit (NRI part EC24). This is fairly typical of the boards used in commercial equipment. The board consists of a sheet of phenolic, which is an insulating material, with a pattern of copper foil strips bonded to one side. Notice that the copper foil connects together holes in the circuit board. When parts are mounted on the board with their leads extending through these holes and soldered to the copper, the copper foil provides the electrical paths which connect the parts together to form circuitry.

We call them "etched" circuit boards because of the way the boards are made. Each board is cut from a large sheet of phenolic to which a sheet of copper foil has been bonded. The desired copper foil pattern is transferred to the board by a photographic process. The board is then placed in a highly corrosive solution which etches away the unwanted copper foil, leaving the desired foil pattern.

After the etching is completed, the board is cleaned and the holes are drilled or punched and the lettering and other markings are printed on the phenolic.

Parts are usually mounted on the phenolic side of the board and they are supported by their leads, as shown in Fig. 24. The leads are passed through the holes in the board and soldered to the foil. When you install a part, bend the lead outward slightly to hold the part until you can solder the leads. Place the tip of your iron in contact with the lead and the foil and apply solder. Allow a small amount of solder to melt and flow into and around the joint. After the solder cools, cut off the lead flush with the top of the soldered connection. Fig. 25 shows an etched circuit board with good soldered connections.

As you go through these experiments, pay particular attention to each soldered connection you make. Tin the part leads before attempting to solder them; heat each connection thoroughly; inspect each connection and wiggle the leads after it is soldered to make sure that it is a good solid connection. Try to develop sound soldering habits; they will save you a great deal of time and difficulty, not only in your experiments, but all through your electronics career.

Performing the Experiments. To get the most benefit from the experimental course, you should follow a logical, planned procedure in each experiment. When you start a new manual, always study first the introduction at the beginning of the book. Then perform the experiments one at a time, in the correct order, by observing the following procedures:

1. Read through the instructions and discussions for the entire experiment once very slowly, and study any parts that are not immediately clear to you. Do not touch a single tool or part until you make this preliminary study.

2. Lay out on your worktable the

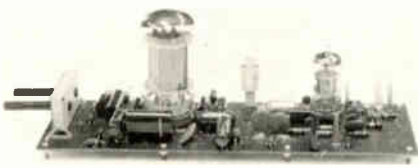


Fig. 24. Phenolic side of an etched circuit board with the parts installed.

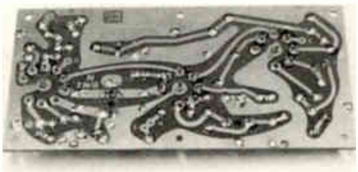


Fig. 25. Foil side of an etched circuit board, showing the parts installed.

parts and tools needed for the experiment to be performed.

3. Carry out the experiments one step at a time. Record your results whenever spaces are provided in the manual for this purpose. Additional observations and comments can be written in the margins of the pages for future reference.

4. Study the discussion at the end of the experiment very carefully, and analyze your results. After finishing an experiment, you should be able to tell in your own words exactly what you proved and how you did it.

5. Complete the Report Statement by writing the Statement Number on your Training Kit Report sheet in the space provided. Then enter the number of your choice for completing the Statement in the next column. Use the additional columns to the right for Statements that have more than one part.

6. When you have completed all ten experiments in the manual and have answered all of the statements, send in your Report Sheet for grading. Do not send in the manual.

EXPERIMENT 1

Purpose: To mount parts in a circuit; and to make soldered connections to these parts.

Introductory Discussion: Solder will hold parts together mechanically and fuse parts together so that they are, in effect, a single unit. A good soldered joint has little or no resistance and protects the surfaces of the parts from oxidation. Good soldered connections are a clue to the technician's ability. A man with an average knowledge of theory who can make good soldered connections will have less trouble than an expert on theory who cannot solder! In this experiment, you will mount parts and make several soldered connections. This experiment may seem simple, but do not pass over it quickly. The points that will be brought out are all very important.

Soldering ability is not hard to acquire and you should make this your first goal.

Experimental Procedure: Before you start the experiment, make sure your workbench is cleared so you will not lose any parts or have anything in your way. Gather your tools and the parts you will need in the experiment. At this time you should have a potentiometer, a solder lug and three terminal strips mounted on the chassis.

In the experiment, you will need the chassis with the parts mounted on it and the following parts:

3 1000-ohm resistors (RE30; brown-black-red-silver)
Rosin-core solder

Step 1: To prepare the parts to be soldered.

If you have the parts mounted on the chassis correctly, you are ready to wire the circuit by soldering resistors to various terminals. Plug in your soldering iron so that it can be heating.

Tin each lead of the three resistors until they are bright and shiny.

As you were instructed previously, you can use a knife or a small piece of sandpaper folded and held between the thumb and forefinger to clean the leads if they will not tin easily.

Test the iron by touching the end of the solder to the tinned tip of the iron. If the solder melts readily, the iron is ready for use.

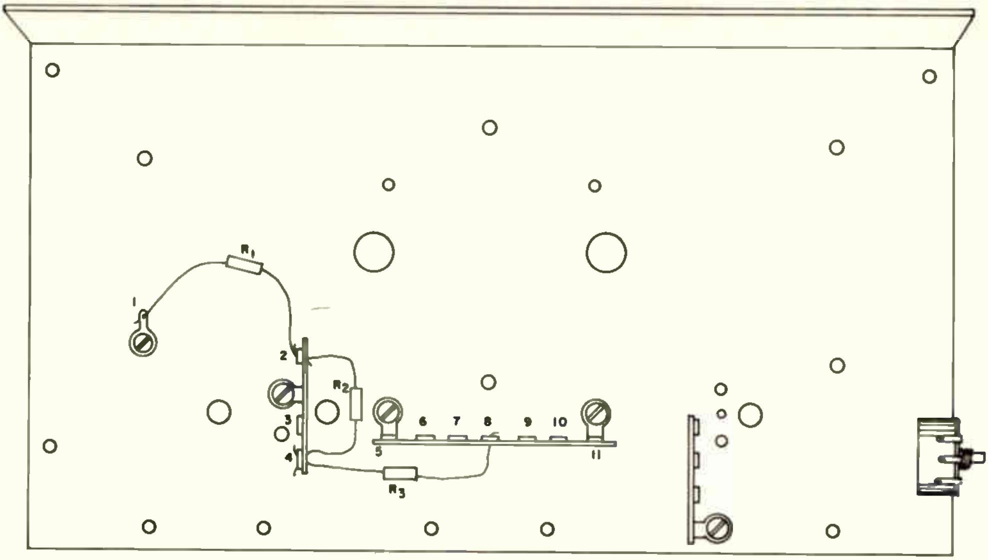


Fig. 1-1. Top view of the chassis, showing the resistors you will install in this experiment.

IMPORTANT: Do not cut the leads of any parts you received in this kit unless you are instructed to do so in the experiment. You will use most of the parts again in future experiments.

Fig. 1-1 shows you where you are to connect the resistors. The resistors are to be mounted so that the resistors and the leads are to be at least 1/2″ above the chassis. As we mentioned earlier, we have given each terminal an identifying number. We will use these terminal numbers in this kit to indicate where the connections are to be made so as to simplify the instructions.

Connect the lead of one of the resistors to terminal 1, which is the solder lug mounted at hole B. Push the end of the lead through the hole in the solder lug and solder, as shown in Fig. 1-2.

Bring the tip of your soldering iron into contact with both the solder lug and the resistor lead, as in Fig. 1-2. Position the iron so that one flat surface of the tip is against the terminal. This permits maximum transfer of heat from the tip of the iron to the connection.

Touch the solder to the point where the terminal and the lead meet, and allow the solder to melt. Notice that the rosin flux flows out of the solder as the solder

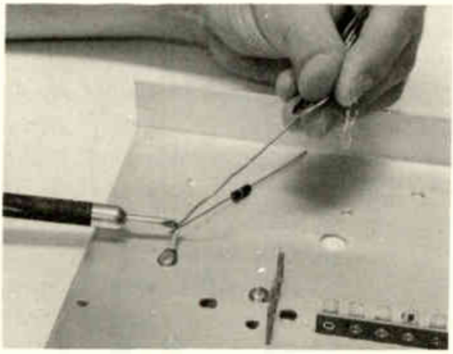


Fig. 1-2. Soldering the resistor lead to the terminal.

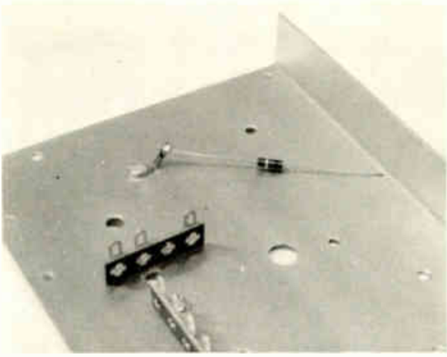


Fig. 1-3. Resistor R_1 soldered to terminal 1.

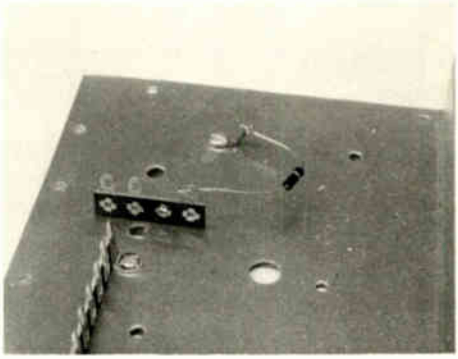


Fig. 1-4. Resistor R_1 in place on chassis.

melts. Remove the roll of solder and continue to heat the joint.

After the solder flows into the connection and coats the terminal and lead, remove the heat and allow the joint to cool and harden. Do not disturb the connection until the solder hardens.

If your solder joint is made correctly, the lead will be covered with solder where it touches the terminal and the solder should have a clean smooth appearance. Fig. 1-3 shows a good solder connection. The space between the resistor lead and the terminal is filled with solder and the solder also seals the connection.

It is a good idea to test each connection after it has cooled. To do this, grasp the resistor lead you have just soldered between the connection and the resistor body with your longnose pliers. Twist the lead gently and move it back and forth. If the lead does not move, you probably have a good soldered connection. If the lead breaks loose, or if the connection has a brown crust on it, re-melt the solder with your iron and let it cool again.

If you did make a poor solder connection, it may have been due to insufficient heat or to dirt on the lead or terminal. A poor joint can also result from your moving the lead before the joint has cooled.

Another problem which you might encounter is the "rosin" joint. This is a connection having a layer of rosin between the wire and the terminal. A rosin joint is indicated by a brown crusty appearance on the connection. You can correct a rosin joint by reheating the connection and allowing the rosin to boil out. As you heat the joint, you will see the vapor from the rosin rising from it.

With your longnose pliers, grasp the free lead of the resistor and slip it through the slot in terminal 2. Position the resistor as shown in Fig. 1-1. Twist the resistor slightly so the lead stays near the top of the slot in the terminal. Bend the end of the lead passing through the terminal so the lead touches the terminal, as shown in Fig. 1-4. Do not solder the connection at this time.

Step 2: To mount resistor R_2.

Now take another resistor and push the end of one lead about 1/8″ through the slot in terminal 2. Bend the end slightly to bring it into contact with the terminal. Solder both leads to terminal 2. Place the tip of your soldering iron in contact with both leads and the terminal, with a flat surface against the terminal. Touch your solder to the connection and allow a small amount of the solder to melt. Remove the roll of solder and allow the molten solder to flow into the connection. Remove the heat and let the joint cool.

Test each connection by twisting and trying to move each lead. If the joint does not break loose, and the solder looks smooth, you probably have an acceptable connection. If not, reheat the connection, remelt the solder and allow it to cool and test the connections again.

Bend the leads of resistor R_2 at a right angle about 1/2" from the body of the resistor and position the resistor as shown in Fig. 1-1. Connect the free lead of resistor R_2 to terminal 4. Do not solder it at this time, since another lead will be connected to the same terminal.

Step 3: To mount resistor R_3.

Connect another resistor, R_3, from terminal 4 to terminal 8. This time make the connection without detailed instructions. Bend the leads as required and position the resistor as shown in Fig. 1-1. Note that the body of the resistor should be about 1/2" to 3/4" from the 7-lug terminal strip. Solder and test both connections.

If you have done your work correctly, your chassis should look like Fig. 1-1. You should have a total of three resistors and four temporary soldered connections. We call them "temporary" because they can be disconnected easily, as you will see later. The solder provides both the mechanical strength and the electrical path between the leads and the terminals.

By contrast, a permanent connection does not rely on the solder for physical strength. Usually the wire is twisted or wrapped around the terminal for physical strength before the connection is soldered.

You will make only temporary soldered connections in the experiments in this manual. However, you will make permanent connections in later experiments. The instructions on how to make them will be given at that time.

Look over the connections you have made and examine them critically. Check to see if any solder has run down the terminal where it may make contact with the chassis and cause a short circuit. This condition is illustrated in Fig. 1-5. Also, look at each connection to see if solder has flowed to all parts of the joints. Look for big lumps of solder on the terminal. They indicate too little heat or too much solder.

Excess solder will do no harm, provided it does not short terminals together, short a terminal to the chassis, or contain excessive rosin. However, it looks messy and is a waste of solder. Too little heat means a poor connection; the cure is to hold the lead in position and reheat the joint.

Next you will unsolder the connections in order to learn the proper techniques for doing this.

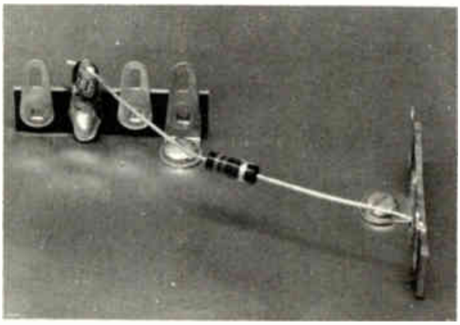


Fig. 1-5. A terminal shorted to the chassis by excessive solder.

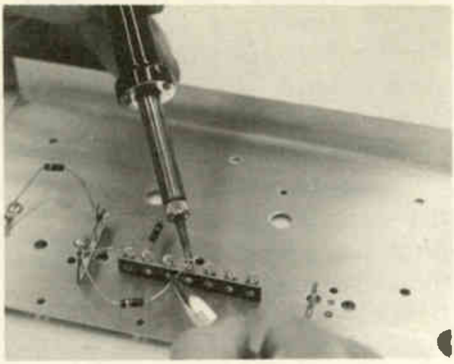


Fig. 1-6. Removing R_3 from terminal 8.

Step 4: To learn to unsolder connections.

Grasp the lead of R_3 connected to terminal 8 with your longnose pliers. See Fig. 1-6. Then touch the tip of your soldering iron to the connection. As soon as the solder melts, pull the lead out of the terminal. Wipe the tip of your iron with a cloth to remove the excess solder, and then touch the tip of the iron to the connections to terminal 4. Grasp the lead of resistor R_3 with your longnose pliers and, as soon as the solder melts, pull that lead free. Lay the resistor on your workbench. Grasp the lead of resistor R_2 connected to terminal 4. Apply heat to the terminal, and when the solder melts, pull the lead free. Wipe the excess solder from your iron with a cloth and then apply heat to the second lead of resistor R_2 which is connected to terminal 2. Remove the resistor and lay it on your work surface.

Use the procedure which we have outlined to unsolder the remaining connections and to remove resistor R_1.

Step 5: To clean parts so they will be ready for reuse.

Whenever you remove parts, clean the leads, lugs, and terminals so that you can use the parts again and connect other parts to the same lugs and terminals.

To practice this technique, first use your longnose pliers to straighten the resistor leads. Then, wipe any excess solder from the tip of your iron with a piece of cloth, and place the iron on the holder so that you can get to the tip easily. In one hand, hold a piece of cloth so that there are several thicknesses between your thumb and forefinger. With your longnose pliers in your other hand, grasp a resistor lead close to the body of the resistor. Hold the end of the lead against the tip of the iron until the solder on the lead melts, and quickly pull the hot lead through the cloth, as shown in Fig. 1-7. This will remove all excess solder and leave the lead surface clean and bright. Do this on all resistor leads that have been used in this experiment.

There are several methods of removing the solder from terminal and solder lugs. Probably the easiest and most efficient method to use on small pieces of elec-

Fig. 1-7. Removing the excessive solder from a resistor lead.

tronic equipment, such as the experimental chassis you received in this kit, is to turn the chassis upside down so that the terminals are pointing downward. Apply the tip of the iron to the end of the terminal, and when the solder melts most of it will run onto the tinned surface of the iron. Wipe the excess solder from the tip and repeat the procedure on the other lugs on the terminal strip. If a thin film of solder remains in the terminal holes, wipe the excess solder from the tip of the iron and reheat the lug. Push a resistor lead through the hole to remove the solder.

In addition to removing the solder from the terminals, this method will remove any excess solder that may be on the terminal strip lugs near the chassis.

Removing excess solder from terminals, tube socket pins and other types of solder lugs in large pieces of electronic equipment that you cannot pick up and turn upside down requires a slightly different procedure. In this case, with the terminals pointing upward, wipe the excess solder from the tip of your iron and keep the cloth in one hand while you work. Touch the tip of the iron to the side of the lug; when the solder melts, some of it will run onto the tinned surface of the iron. Wipe off the solder and keep repeating the process until all surplus solder has been removed. If you have trouble getting the solder out of the hole in a lug, heat the lug and push a resistor lead through the hole. The solder that accumulates on the resistor lead can then be easily removed.

The same procedure should be used to remove solder from tube socket pins and terminal strip lugs.

Discussion: In this first experiment, you began acquiring one of the most important skills a technician must have -- the ability to make good soldered connections. You have had practice in mounting actual electronics parts and soldering them into place. You have been able to see how solder looks as it cools and hardens. You should not expect to be an expert at soldering at this time; it takes considerable practice. However, if you carefully follow the procedures discussed in this experiment, you should have no trouble making good soldered connections and you will soon become an expert with a soldering iron.

You have also had practice in the equally important task of unsoldering, and you have learned how to clean the parts so they will be ready for reuse. This is important because often the serviceman must disconnect one part in order to check another. When you disconnect a part or lead, you should carefully prepare it and the terminal from which you removed it before resoldering the lead back into position.

Instructions for Statement No. 1: In this statement, there are two sentences to be completed, each having several choices preceded by numbers. Only one of the choices in each group correctly completes a sentence in the statement. Read the first sentence, and put a circle around the number preceding the choice that completes it. Do the same for the second sentence.

Statement No. 1: In this experiment, I used

(1) temporary
(2) permanent

connections; and I found that as molten solder becomes hard, its appearance is

(1) a copper color.
(2) a shiny gray color.
(3) a dull black color.

SOLDERING TIPS

Always use a clean, hot, well-tinned iron.	Never try to solder dirty or untinned leads or terminals.
Always heat the junction to be soldered enough to melt the solder.	Never melt solder on the iron tip and carry it to the junction.
Always use a rosin-core solder.	Never use acid-core solder or pastes for radio and electronic work.
Always tin part leads to be soldered.	Never drip solder off iron on to joint.
Always test all leads in each joint after solder cools.	Never let leads move while solder is setting.
Always keep iron on joint until the rosin has boiled out of the joint.	

Turn now to the enclosed Training Kit Report sheet. Fill in the top part with your name, address, student number and Kit number, 1T. Write the number 1 in the first box of the column with the heading, "Statement No." This statement is in two parts. Therefore, place the number of your choice for the first part in the second column and place the number of your choice for the second part of the statement in the third column. As an example, assume that the first statement was:

San Francisco is located in the

(1) East
(2) South
(3) West

And it is in the state of

(1) Nebraska.
(2) California.
(3) New York.

The correct answers are (3) for the first part and (2) for the second part. Therefore, you would place the Statement number in the first column, the number 3 as your answer for the first part is the second column, and the number 2 in the third column.

EXPERIMENT 2

Purpose: To learn how to wire and repair etched circuit boards.

Introductory Discussion: Etched circuit boards are often used where compactness, ease of wiring or freedom from circuit variations are important. The vast majority of radio and TV receivers use etched circuit boards. Thus, it is likely that when you repair a receiver you will have to make repairs on etched circuit boards.

Etched circuit boards are fragile. They can be damaged by rough handling or poor workmanship. The phenolic will crack or break when subjected to excessive pressure. This results in breaks in the copper foil strips and produces open circuits.

The copper foil is glued to the circuit board. When overheated, the glue will weaken and the copper foil strips will pull loose from the board. However, the board will withstand a surprisingly large amount of heat before either the phenolic or the foil becomes damaged.

In performing this experiment, you will develop skill in working on etched circuit boards. This will prepare you for work on your future experimental kits and for practical work as a technician.

Experimental Procedure: In this experiment, in addition to your chassis, soldering iron and solder, you will need the following:

1 Etched circuit board (EC24)
2 22,000-ohm resistors (RE33; red-red-orange-silver)
1 7-pin tube socket (SO76)
Red hookup wire
Solder

Plug in your soldering iron so that it can be heating. Inspect the tip. If the tip is not clean, wipe it with a cloth and apply a thin coating of solder. If you wipe the tip frequently, it will last longer. Also, you will seldom have to file and retin the tip.

In this experiment, you will practice soldering to the etched circuit board and you will make repairs on the copper foil. The foil near holes A through H is for practice only. Do not be concerned if you damage it in performing this experiment. However, the remainder of the board will be used in later experiments. Therefore, you should exercise reasonable care in working on the board.

Step 1: To wire a circuit on the etched circuit board.

In order to become proficient at working on circuit boards, you will have to develop a feel for soldering to the copper foil. Before mounting any parts, you will determine how much heat the foil can withstand.

Place your etched board on your work-table with the foil side up. Touch the tip of your soldering iron to the foil near hole B. Hold the soldering iron nearly

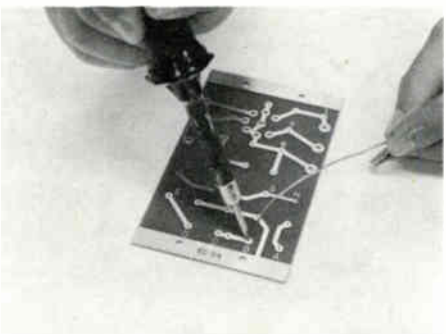


Fig. 2-1. Applying heat and solder to the foil.

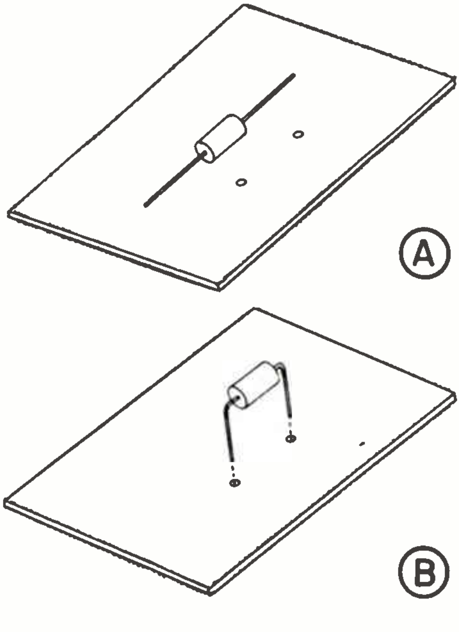


Fig. 2-2. (A) Measuring the resistor against the mounting holes; (B) resistor leads bent to correct spacing.

straight up with the tip at the edge of the hole, as shown in Fig. 2-1. Touch the end of your solder to a point where the tip touches the foil. Allow about 1/4" of solder to melt and flow onto the foil. When the solder spreads out smoothly on the foil, remove the heat and allow the foil to cool. Do not be concerned if the hole is covered with solder.

In a similar manner, apply heat to the foil surrounding hole A. Touch your solder to the iron and the foil and melt about 1/4" of the solder. Continue to heat the foil until the foil begins to loosen. This may take up to 15 seconds, depending upon the wattage rating of your iron and the condition of the tip. Remove the heat from the foil.

Notice that the phenolic around the overheated foil is charred slightly. Use a knife or your longnose pliers to peel the damaged foil off the board.

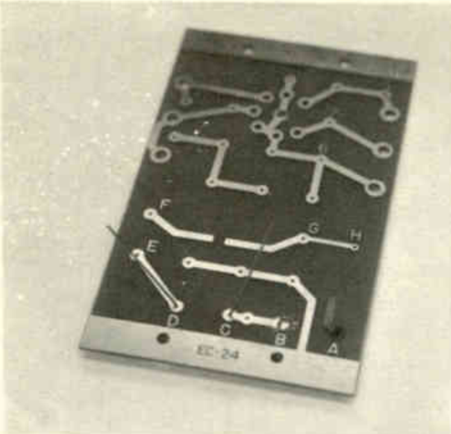


Fig. 2-3. Leads are bent outward to hold the resistor in place.

The brief experience which you have gained will give you some idea of how long it takes to make a connection and how long it takes to damage the circuit board. Next, you will mount and solder parts to the circuit board.

Install one of the 22,000-ohm resistors (red-red-orange-silver) on the phenolic side of the circuit board at holes C and D. Use the following procedure: First, "measure" the resistor against the spacing between the holes, as shown in Fig. 2-2A. In this case, the spacing between the holes is about 1/4″ greater than the length of the body of the resistor, so bend both leads at right angles about 1/8″ from the body of the resistor. Fig. 2-2B shows the leads ready for insertion in the holes.

Next, slip the leads through holes C and D and push the resistor down against the board. Bend the leads outward slightly, as shown in Fig. 2-3, to hold the resistor in place.

Turn the foil side of the circuit board up to solder the connections. Position the soldering iron so that the tip is in contact with both the foil and the lead. Touch the end of your solder to the point where the tip, lead and foil meet and allow about 1/4″ of the solder to melt. Continue to heat the connection until the solder flows smoothly and completely surrounds the lead. Then, remove the iron and allow the connection to cool.

Finally, use your diagonal cutters to cut off the lead flush with the top of the solder connection.

Use the procedure outlined here to solder the other resistor lead to the foil.

Fig. 2-4 shows typical poorly soldered

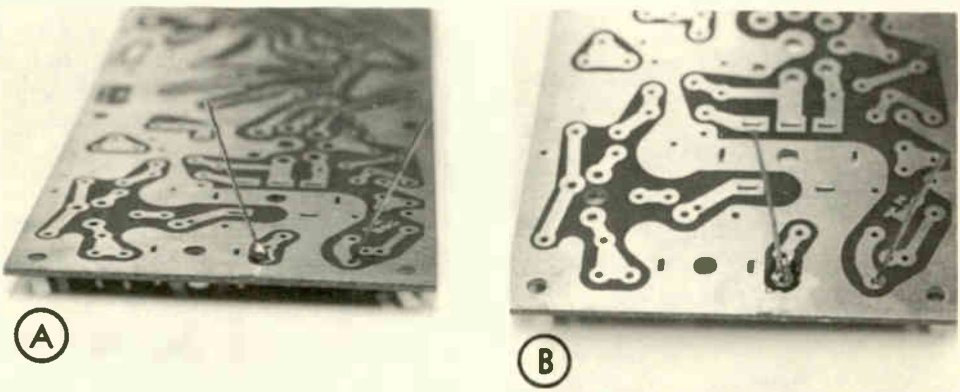


Fig. 2-4. Typical examples of poorly soldered connections.

connections. At A, too little heat was used; the solder adheres to the lead, but not to the foil. This connection could be improved by simply applying more heat. In Fig. 2-4B, too little solder was used, resulting in a minimum of strength and reliability. To improve this connection, you would apply both heat and solder.

Step 2: To demonstrate methods for removing components from etched circuit boards.

Wedge the blade of your small screwdriver between the board and the body of the resistor near hole C. (If the resistor is flat against the board, slip the screwdriver blade under the lead at hole C.) Heat the solder at hole C and lift the resistor enough to pull the lead from the hole.

Stand the circuit board on edge on your worktable. On the phenolic side of the board, grasp the lead of the resistor connected at hole D. With your forefinger and thumb pressing against the board, apply a lifting pressure to the resistor lead. Heat the connection at hole D on the foil side and when the solder melts, pull the resistor from the board and discard it.

Now you should clean the holes so that a new resistor can be installed. Heat the solder at one of the holes. While the solder is molten, insert a toothpick into the hole from the foil side of the board. Remove the soldering iron and let the foil and solder cool. When you remove the toothpick, the hole will be left clear.

Step 3: To demonstrate techniques for repairing etched circuit boards.

Cut through the foil between holes D and E to simulate a crack in the foil. You

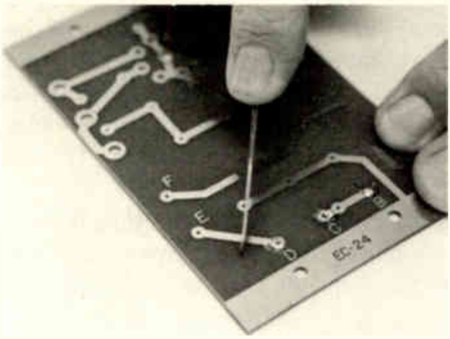


Fig. 2-5. Cutting the foil to simulate a crack in the board.

can use your pocket knife. Fig. 2-5 shows how to make a clean cut safely.

Heat the foil near the cut and melt a small amount of solder onto the foil. Use the tip of your iron to "run" the solder across the crack. The solder should adhere to the foil on both sides and bridge the narrow gap. If necessary, apply a little more solder to make a reliable repair.

A wider break, such as the one between holes F and G, requires a slightly different repair. You solder a short piece of bare wire across the break in the foil.

Remove about 2" of insulation from a length of red hookup wire. There are several ways of removing the insulation. You can peel the insulation off with a knife, or you can cut the insulation with your diagonal cutters, knife or wire strippers and simply pull off the unwanted piece. Another technique is to crush the insulation with pliers and then peel off the pieces. When stripping the insulation off wire, it is important to avoid nicking or cutting the wire because this will weaken the wire and make it break easily.

As you did previously for the narrow break, heat the foil on both sides of the break and tin the foil with solder. Lay the bare wire across the break in the foil and solder the wire to the foil. Run solder along the wire and foil for about 1/2" on each side of the break. Using your diagonal cutters, cut off the wire beyond the solder. This should leave about 1" of wire bridging the break in the foil.

Step 4: To install parts on the foil side of the circuit board.

Bend the leads of a 22,000-ohm resistor (red-red-orange-silver) at right angles close to the body of the resistor, and insert the leads through holes C and D from the foil side of the board. Position the resistor about 1/16" to 1/8" from the board. This will leave room for soldering the connections. Bend the leads outward slightly to hold the resistor in place.

Solder one lead of the resistor to the foil. Apply heat to both the foil and the lead and apply solder. Allow the solder to flow freely over the connection. Remove the heat and let the joint cool. In a similar manner, solder the other resistor lead to the foil. You will use this resistor in later experiments, so do not cut off the leads! (Normally, after installing a part from the foil side as you have just done, you would clip off the excess lead length on the other side of the board.)

Locate the 7-pin tube socket. The socket has 7 pin connections and a center locating pin. You will install the tube socket on the *foil* side of the circuit board instead of from the phenolic side. Align the pins over the holes on the circuit board. Notice that there is an open space between the pins. Install the socket on the board by pushing firmly. When the socket is properly installed, the pins project about 1/16" on the phenolic side of the board.

With the socket in position, you are ready to solder. Since the tube socket pins on the phenolic side of the board will become quite hot as you solder them to the board, it would be a good idea to lay the board on a newspaper to protect your worktable. Hold the soldering iron so the tip is at the junction of the foil and a pin of the tube socket.

The flat surface of the soldering iron tip should be turned toward the pin. Apply solder to the foil and to the pin. Melt about 1/4" of solder and let it flow around the pin. Solder should adhere to one half or more of the perimeter of the pin and to the foil. Remove the heat and let the solder cool. In the same manner, solder the six remaining pins of the tube socket. Do not try to solder the center locating pin. Fig. 2-6 shows the socket soldered in place.

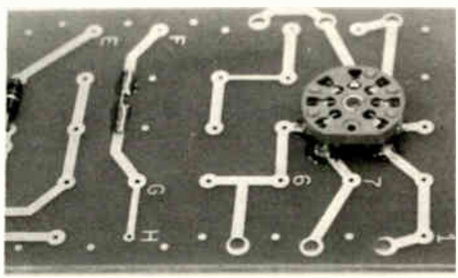


Fig. 2-6. Tube socket mounted on the etched circuit board.

Discussion: In this experiment, you have experienced working on a typical etched circuit board. You learned that you can solder to the circuit board with a moderate amount of heat. If the iron is clean and tinned, a connection can be soldered in a matter of seconds; it takes a considerable length of time to overheat and damage the circuit board.

In Step 2, you learned how to install components on the circuit board. First, you determined the lead spacing and bent the leads so you could insert the leads in the holes; then you pushed the part down against the circuit board and bent the lead to hold the part in place. Then you soldered the connection, allowed it to cool, and cut off the excess lead length, close to the soldered connection. In a good solder connection, the solder adheres to both the lead and to the foil and the solder has a smooth appearance.

You also learned how to remove parts from the etched circuit board. This is important because frequently you will have to disconnect a part to make tests and when you determine which part is bad, you will have to replace it. Before replacing a lead, clean the hole in the board. Otherwise, you may break the foil loose when you try to insert the lead.

In Step 4, you learned how to install parts on the foil side of the board. This is useful because you will sometimes find it easier to replace a part on the foil side of the board. Also, interconnecting jumper wires are sometimes connected on the foil side of the board in some pieces of equipment.

The circuit board with the tube socket attached will be used in later experiments.

Instructions for Statement No. 2: In order to answer the Report Statement for this experiment, you will have to make a few connections on your etched circuit board and trace the connections. You will need your red hookup wire.

Cut a 2" length of hookup wire and remove about 1/4" of insulation from each end. Push one end through hole E from the phenolic side of your circuit board. The holes are identified on the foil side of the board. Bend the wire and push the other end through hole F from the same side of the board. Solder both connections.

Cut a 3" length of hookup wire and remove about 1/4" insulation from each end. Push one end of the wire through hole G and push the other end through the hole identified by the number 7 from the phenolic side of the board. Solder both connections.

Trace the connections on the circuit board and answer the Report Statement. After you have completed the Report Statement, unsolder and remove the resistor and the pieces of hookup wire. Clean the holes which you used on your circuit board and clean and straighten the resistor leads.

Statement No. 2: When I traced the wiring, I found that the resistor

(1) was
(2) was not

electrically connected to the tube socket.

Using Schematic Diagrams

To service any type of electronic equipment, the technician must know how the parts are connected in the circuit.

The electrical connections in a circuit can be shown by means of a schematic diagram. In a schematic diagram, symbols are used to indicate the various parts, and the connections between the parts are shown by lines.

You have already seen many of the symbols used in schematic diagrams in your lesson texts. You have also seen some simple schematic diagrams. It is extremely important for you to become familiar with the various symbols used, and also to learn how to read schematic diagrams. You will have to use this type of diagram throughout your career, because manufacturers of electronic equipment seldom supply pictorial wiring diagrams. Even if you have a pictorial diagram, it is far easier to work from a schematic once you learn how to use it.

In your experiments, you will start first with simple schematics, and gradually work up to more complex ones. In time, you will be as much at ease reading a complex schematic diagram as you are reading your evening newspaper. You will soon learn the value of this type of diagram and see how much easier it is to use than the pictorial type.

SYMBOLS USED

Before you can read schematic diagrams, you must be able to recognize the symbols used in them. Fig. 26 shows the symbols commonly used to represent resistors, capacitors, and ground connec-

Fig. 26. Symbols often used in schematics.

tions. Study these symbols so that you will be sure to recognize them the next time you see them. You will use them in these experiments.

Connections and Crossovers. Often in a schematic diagram, one lead crosses over another. In some cases, there will be a connection between the two leads; in other cases, there will be no connection. There are three different systems in use to indicate whether or not there is a connection; the one that is used in any particular diagram depends on the preferences of the person making the diagram. You might think that this would be confusing, but it is usually very simple to see which system has been used.

Fig. 27 shows the three systems. Notice that in System 1 when there is a dot used on some crossovers and no dot used on the others, the dot indicates a connection, and the crossover without the dot indicates that there is no connection.

In System 2, a straight crossover is used to show a connection, and a loop is used to show no connection. You can easily tell when this system has been used. If you notice some crossovers with the loop, and some without the loop, you know that the straight crossovers represent connections, and the crossovers with the loop indicate no connection. Similarly, if you see some crossovers with dots and others without, you will know that System 1 has been used.

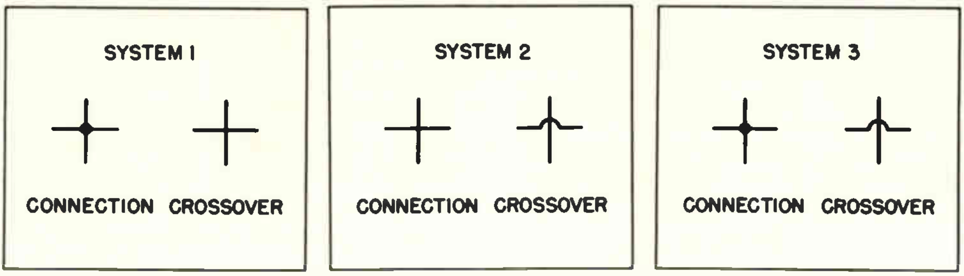


Fig. 27. Three systems used on schematics to show connections and crossovers on wires.

System 3 is a combination of the first two. We will use this system in the drawings in the experiments. The cross-over with a dot indicates a connection. The crossover with a loop indicates no connection. Study these three systems - become familiar with them now, and you will have no trouble later.

Tubes. The various symbols used to represent the elements in a tube are shown in Fig. 28. The symbol for the heater is shown at A, the symbol for the cathode at B, for the grid at C, for the plate at D, and for the whole tube at E. This tube is called a triode - it has three elements plus a heater. Notice the little numbers beside each of the elements. These tell you which pin each element is connected to inside the tube. The tube we have shown is a 6C4. In this particular tube, the plate is connected to pins 5 and 1; the grid to pin 6, the cathode to pin 7, and the heater to pins 3 and 4. Nothing is connected to pin 2.

Diodes. The symbol for a semi-conductor diode is shown in Fig. 29. The two elements of a diode are the cathode and the anode. The "arrow" in the symbol points toward the cathode terminal.

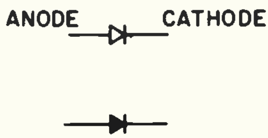


Fig. 29. Schematic symbols for a semi-conductor diode.

Transistors. There are several types of transistors in wide usage. The symbols for two types are shown in Fig. 30. At A and B, we have bipolar transistors. As you can see, the only difference between the NPN and PNP symbols is the direction of the arrow. The e, b, and c labels identify the emitter, base and collector of both transistors.

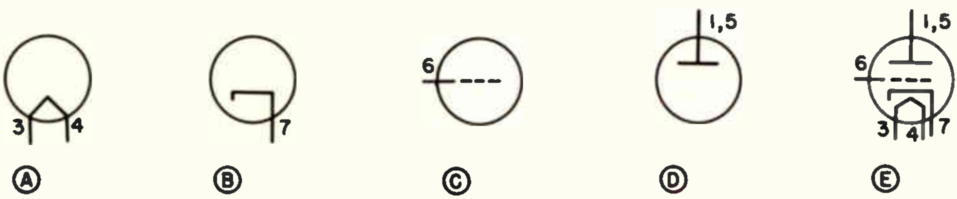


Fig. 28. Symbols used to represent the elements in a tube. Shown is tube type 6C4.

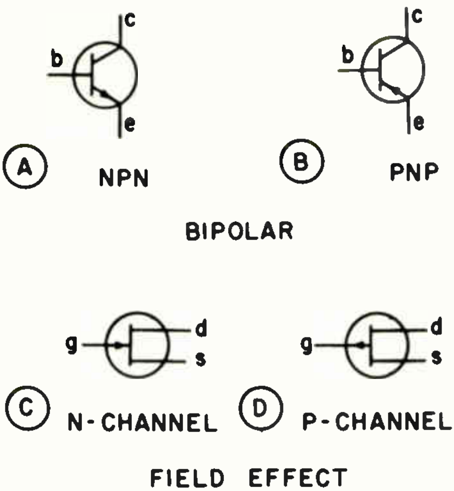


Fig. 30. Schematic symbols for transistors.

The symbols for junction field-effect transistors (FET's) are shown in Figs. 30C and 30D. You can see that the direction of the arrow is toward the junction for the N-channel and away from the junction for the P-channel FET's. In both cases, the s, g and d represent the source, gate and drain terminals. You will learn other transistor symbols later in your course.

Meters. Fig. 31 shows symbols used to represent meters on schematic diagrams. In the symbols in Fig. 31A, the letters inside the circle indicate the type of meter: V for voltmeter, μa for microammeter, ma for milliammeter, and ohm for ohmmeter. Fig. 31B shows semi-pictorial symbols that are sometimes used.

READING A SCHEMATIC

When working with schematic diagrams, you must remember that the schematic diagram shows the electrical connections, not the actual physical connections. An example of this can be seen in Fig. 32A. The schematic diagram shows the capacitor C_1 connected on the left to resistor R_1. From the junction of these two components there is a line going to the plate of the tube V_1.

In your work you will be interested only in the electrical connections. It will be unimportant to know whether the capacitor and resistor are first connected together and a lead run from the junction of the two to the tube socket, or whether the two are connected directly to the tube socket. Electrically both connections are the same.

The other side of capacitor C_1 is connected to the grid of the tube marked V_2. The schematic diagram shows C_1 connected to R_2 and then a line going from the junction over to the grid. The pictorial wiring diagram shows that both the capacitor and the resistor are connected directly to the grid terminal on the socket.

Notice on the schematic diagram that the lower end of resistor R_2 is connected to ground. In the wiring diagram, we see

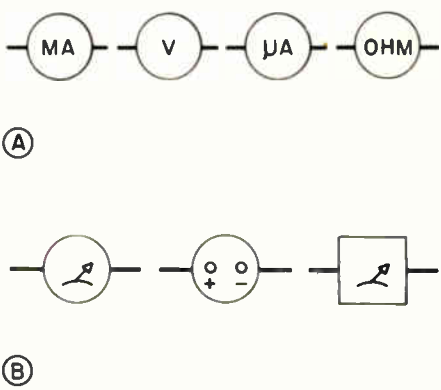
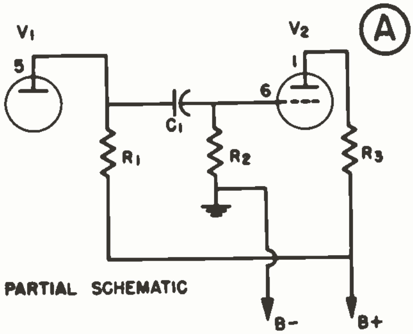


Fig. 31. Symbols used on schematics to represent meters.



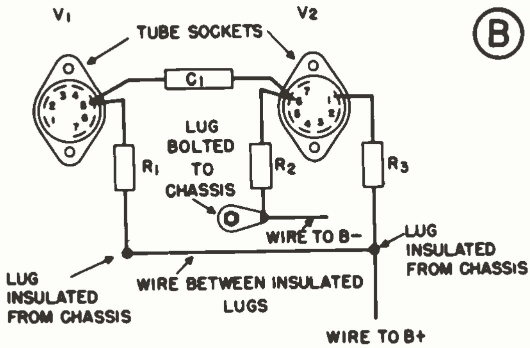


Fig. 32. (A) A schematic diagram; (B), actual wiring diagram of the same circuit.

that R_2 connects to a lug that is bolted to the chassis. Any number of ground connections can be made in this way to the chassis. When this is done, the chassis is used as part of the circuit; the chassis connects directly to B-. In some equipment the chassis is not used as part of the circuit. You will see later how to tell from a schematic diagram whether or not the chassis is part of the circuit. This information will be given to you on the schematic diagram.

Study Fig. 32 carefully. Find an electrical circuit on the schematic diagram, and then trace out the circuit on the pictorial wiring diagram. This will be valuable practical experience for you and will help you to become familiar with schematic diagrams.

EXPERIMENT 3

Purpose: To obtain practical experience in wiring from a schematic diagram.

Introductory Discussion: Fig. 3-1 is a pictorial diagram showing the actual physical location of the parts in the circuit you will wire in this experiment.

Fig. 3-2 shows the same circuit in schematic form. The circuit is that of a simple power supply. If an ac voltage were connected between terminals 1 and 2, a variable positive dc voltage would be available between terminals 17 and 15.

In a simple circuit of this type a pictorial diagram may seem easier to follow than a schematic diagram. However, a glance under the chassis of any electronic device will show how complex the pictorial diagram would become. In fact, it would be practically impossible to show how the parts are connected with a photograph or pictorial drawing. On the other hand, it is easy to show the connections with a schematic diagram.

Experimental Procedure: In this experiment, in addition to the chassis with the terminal strips and potentiometer mounted on it, you will need:

- 3 **1000-ohm resistors (RE30; brown-black-red-silver)**
- 1 **Silicon diode (SR12)**
- **Hookup wire**
- **Solder**

As you can see in Fig. 3-1, the diode appears similar to a resistor and is somewhat smaller. The diode is a semiconductor device which passes current in one direction only. Current can pass from cathode to anode but not from anode to

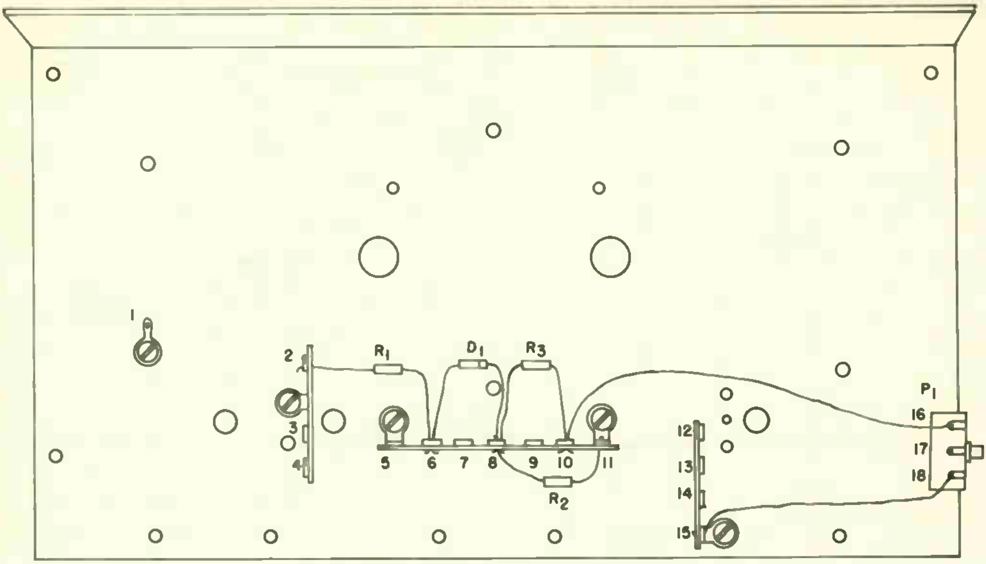


Fig. 3-1. Pictorial diagram of the circuit used in Step 1.

cathode. Thus, the diode is capable of rectifying an ac voltage.

The cathode and anode terminals of a diode are identified in one of several ways. You will usually find colored bands or a plus sign near one end of the diode, or one end of the diode may be tapered. The band, taper or other markings indicate the cathode lead of the diode as shown in Fig. 3-3.

Step 1: To determine what connections are to be made.

First, carefully study Fig. 3-2. Resistor R_1 is connected between terminal 2, which is the "input" terminal, or the terminal to which the ac voltage would be applied, and the diode D_1. The cathode lead of diode D_1 is connected to resistors R_2 and R_3. One lead of R_2 is grounded.

Resistor R_3 is connected between the junction of diode D_1 and resistor R_2 and the potentiometer, P_1. Potentiometer P_1 is connected between R_3 and ground.

Notice the ground symbols on the diagram. The metal chassis forms the common connection between the ground points.

Where possible, leads of the parts which are wired together are connected to a common terminal. For example, the cathode lead of D_1, one lead of R_2 and one lead of R_3 can all be soldered to the same terminal.

When instructed to use hookup wire, cut a length of your red wire and remove about 1/4" of insulation from each end before making the connection. See that the insulation is about 1/16" back from the actual solder connection. Never try to solder to the insulation.

When we instruct you to use a short length of bare wire, use your wire strippers, diagonal cutters or longnose pliers to remove the insulation from a short length of hookup wire.

In the next step, you will perform the actual wiring.

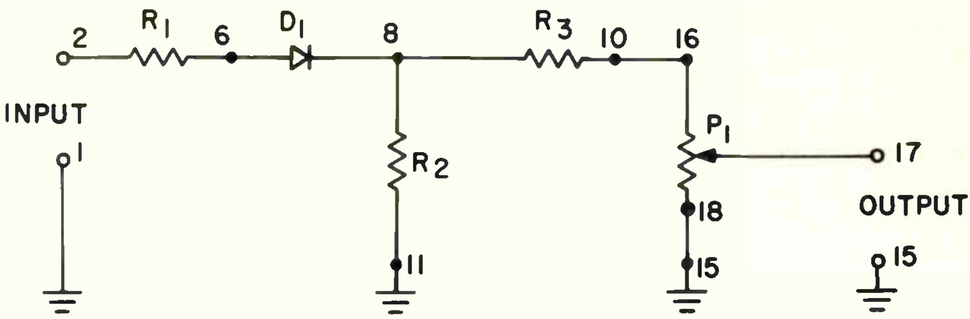


Fig. 3-2. Circuit used in Experiment 3.

Step 2: To wire the circuits from the schematic diagram.

In this step, you will mount the parts and connect wires between them to form the circuit shown in the schematic diagram in Fig. 3-2.

Connect resistor R_1 to terminals 2 and 6 as shown in Fig. 3-2. You can choose any of the three resistors since they are all the same value. Bend the leads so that the ends are spaced properly to slip through the slots in terminals 2 and 6. Slip the leads through the terminals and solder terminal 2.

Connect the diode to terminals 6 and 8 with the proper polarity. The cathode and anode leads are identified in Fig. 3-3. The cathode lead of each diode is on the right. Connect the cathode lead to terminal 8 and connect the anode lead to terminal 6. Solder terminal 6.

On the schematic diagram, notice that the cathode lead of the diode and one lead of resistor R_2 are connected together. Also, R_2 is connected from the junction with the diode lead to ground. Therefore, connect R_2 between terminals 8 and 11 as shown in Fig. 3-1. Solder terminal 11.

Next connect resistor R_3. On the schematic, this resistor is connected between the junction of diode D_1 and resistor R_2 and terminal 16 of the potentiometer. For convenience, we connect the resistor between terminals 8 and 10 and use hookup wire to complete the connection.

Install the resistor and solder terminal 8. Connect a length of hookup wire from

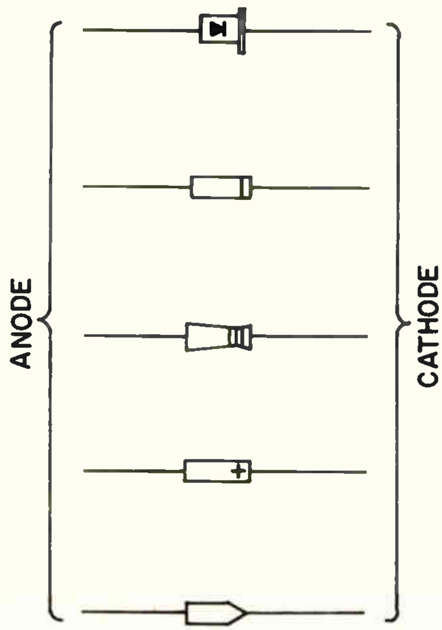


Fig. 3-3. Methods used to identify the leads of semiconductor diodes.

terminal 10 to terminal 16 and solder both connections.

The potentiometer is connected between resistor R_3 and ground. Thus, we must ground terminal 18. Again, we choose a convenient grounded terminal, which is terminal 15. Connect a length of hookup wire from terminal 18 to terminal 15 to complete the wiring. The center terminal of the potentiometer, terminal 17, is the "output" terminal.

This completes your wiring. You should have made all of the connections shown in Fig. 3-1. To make certain, check your wiring as follows:

1. There should be a resistor, R_1, between terminals 2 and 6.
2. Diode D_1 should be connected between terminals 6 and 8, with the cathode lead to terminal 8.
3. Resistor R_2 should be connected between terminals 8 and 11.
4. Resistor R_3 should be connected between terminals 8 and 10.
5. There should be hookup wire from terminal 10 to terminal 16 on the potentiometer.
6. There should be a length of hookup wire from terminal 18 on the potentiometer to terminal 15.

You should make a habit of checking your connections in this way each time you finish wiring a circuit. By checking your work, you may find and correct errors that could be serious or difficult to find later. When you check your work, pay particular attention to the soldered connections. Be sure that all connections are soldered properly. If not, resolder them.

When you are satisfied with your work, unsolder all of the connections and remove the parts. Straighten the resistor and diode leads and remove the excess solder from all terminals. Use the techniques you learned in Experiment 1.

Remove the 1000-ohm potentiometer from the mounting bracket and carefully clean the terminals. Remove the potentiometer mounting bracket and put it with the potentiometer. You will use these in a later Training Kit.

Discussion: In this experiment, we have taken you step-by-step through the wiring of a circuit from a schematic diagram. You have checked your work by comparing the actual parts layout with a list of the connections and with a pictorial diagram. This layout is not the only one that could be made from the schematic of Fig. 3-1. The same electrical circuit could have been made with the leads routed along different paths.

You should practice drawing schematic diagrams because such practice will help you to become more familiar with schematic symbols and will aid you later in tracing circuits. You need not start with elaborate diagrams; simple circuits like those shown in this experiment will be satisfactory.

The schematic diagram shows electrical connections only. Therefore, additional information is needed in order to wire more complex circuits. Experienced technicians usually sketch a layout before wiring. However, once a circuit is wired, it is easy to trace the circuit by following the schematic diagram.

Instructions for Statement No. 3: This statement is a test of your ability to relate a physical parts layout to a schematic diagram of that layout. Fig. 3-4 shows a circuit wired on your experimental chassis using resistors, a diode and a potentiometer.

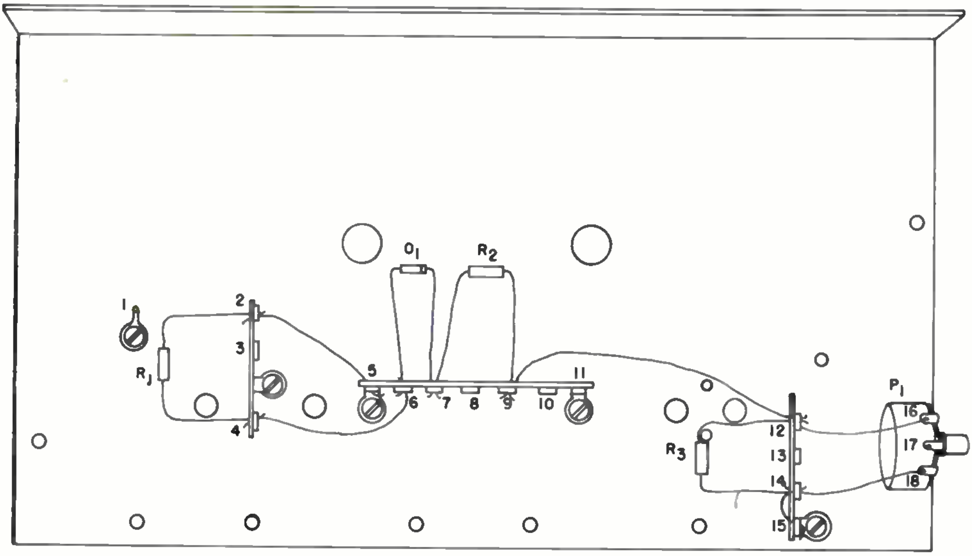


Fig. 3-4. Pictorial diagram of the circuit shown in Statement 3.

Study this circuit carefully and compare the arrangement with the four schematics in Fig. 3-5. When you are certain you have the schematic which corresponds to the circuit of Fig. 3-4, complete the statement here and on your Report Sheet.

Statement No. 3: The schematic diagram of the circuit in Fig. 3-4 is Fig. 3-5:

(1) A
(2) B
(3) C
(4) D

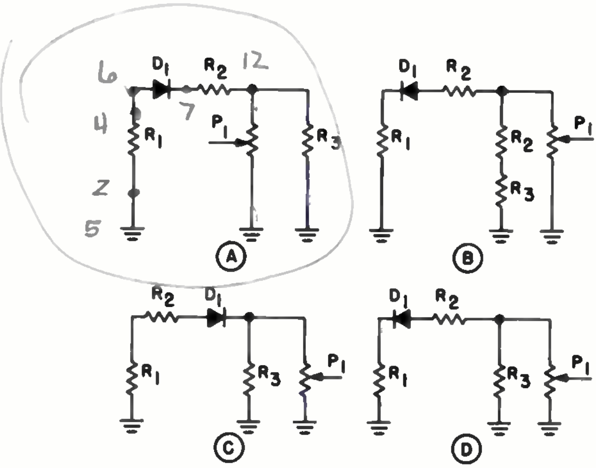


Fig. 3-5. Schematics for use with Statement No. 3.

IDENTIFYING RESISTORS

As you go ahead with your experiments, and when you work on your own, you will need to be able to identify the value of resistors.

Although the value is stamped on some resistors, on most 1/2-watt, 1-watt, and 2-watt resistors the value is indicated by means of colored bands on the resistor. You should learn to read this color code so that you can identify resistors quickly.

The colored bands on the resistor usually are nearer to one end than the other. Thus, to read the color code, turn the resistor so that the colored bands are toward the left end of the resistor as shown in Fig. 33.

Each color represents a number. These are given in Fig. 33. The first band, labeled A, gives the first figure in the value; the second band, labeled B, gives the second figure in the value; the third band, labeled C, gives the number of zeros after the second figure in the value, and the fourth band gives the tolerance of the resistor (silver for ±10% tolerance, gold for ±5% tolerance). If the tolerance is ±10%, it means that the actual value of the resistor may be as much as 10% higher or lower than the value indicated. If it is ±5%, the actual value may be up to 5% higher or lower than the value indicated.

Some resistors may have a fifth color band. This band will follow the tolerance band (to the right) and is used to indicate a military reliability level. The fifth band will be Brown, Red, Orange or Yellow which indicate increasing percent of reliability. In your work you can simply ignore the fifth band.

To find the value, you need to look only at the first three bands. For example, suppose you have a resistor color-coded red, red, and black. Referring to the chart, you see that red represents 2. Therefore, the first two figures in the value are both 2. As we have said, the third band indicates the number of zeros in the value. Since black represents 0, when the third band is black, there are no zeros in the value. So the value of the resistor is 22 ohms.

If the resistor had been color-coded red, red, and brown, the first two figures would again be 2. Brown represents 1, so there would be one zero, and the value would be 220 ohms. Red, red, and red would indicate a value of 2200 ohms (often written 2.2K ohms, where the K stands for 1000); red-red-orange, a value of 22,000 ohms (often written 22K-ohms); red-red-yellow, a value of 220,000 ohms (or 220K ohms or .22 meg; a megohm is 1,000,000 ohms); red-red-green, a value of 2,200,000 ohms (or 2.2 megohms); and red-red-blue, a value of 22,000,000 ohms (or 22 megohms).

Look over the resistors you have re-

COLOR	FIGURE
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9

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%

Fig. 33. Standard resistor color code.

ceived, and practice reading the color codes on them. You can check the values by referring to the parts list given in Fig. 1. In the next experiment you will have some practice in picking out resistors of different values.

EXPERIMENT 4

Purpose: To construct a circuit using only a schematic diagram for guidance.

Introductory Discussion: If you read construction articles in any of the radio-TV-electronics magazines, you will see that step-by-step wiring instructions are rarely given; you work from a schematic diagram. Thus, if you wanted to build some of this equipment, you would have to work out the placement of the parts and other details for yourself.

We want you to become so familiar with schematic diagrams that you can look at one and picture the arrangement of the parts. That is not hard if you start with simple circuits like those you have built so far, and gradually work up to more complex circuits. The manufacturer's servicing information on any equipment usually has a complete schematic diagram and the parts values. If you are servicing the equipment, you will have to find the defective part, determine its value, and make the replacement.

Usually connections between parts are shown by a line that follows the shortest path between the two parts. However, this is not always true. The only sure way to find the part is to trace the circuit. Often it is more convenient to run a lead over a somewhat longer path to avoid crowding a section of the diagram. An example of this is given in Fig. 4-1. We could have drawn a horizontal line directly from pin 4 of V_1 to pin 3 of V_2 to show that they are connected. However, the line would have had to cross a number of other lines, thus crowding the diagram, and perhaps causing some confusion. Drawing the line as in Fig. 4-1 avoids confusion.

Tracing circuits on a schematic diagram is in many ways like tracing a road between your home and another city on a

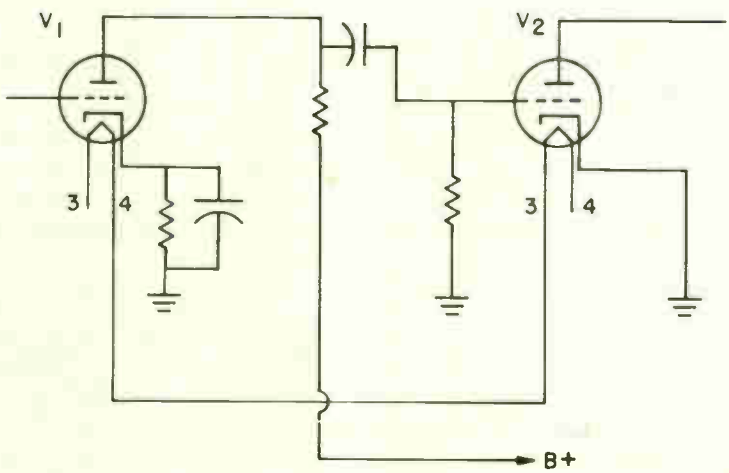


Fig. 4-1. Typical schematic diagram showing a two-stage tube circuit.

road map. You will seldom find a road that goes in a straight line from one place to another. Instead, the road will turn time and time again; you may have to go a certain distance on one road and then turn onto another. So it is in tracing the circuit on a schematic diagram. You start at one point in the circuit and trace toward another point. You may find a direct circuit between the two points, but more often you will find the circuits are connected by something other than a direct connection. In addition, you may find that to get from one point to the other you have to trace the circuit to some intermediate point, and then from that point on through an additional circuit to the point that you are interested in reaching.

Frequently in service work you will have to trace out the actual wiring in a receiver and compare the wiring with a schematic diagram. We cannot stress too strongly how important it is for you to learn to use this type of diagram. This is why we will concentrate on learning how to use diagrams.

When you work from a schematic diagram in the experiments, there may be several ways in which the various leads can be run. In general, try to use the shortest possible route. When we work on the more complicated circuits, we will give detailed instructions on exactly where to place each important lead; but during these early experiments, we will leave you on your own as much as possible to give you all the practical experience we can.

When you build equipment from a schematic diagram, you should carefully check each circuit you wire to make sure it is wired correctly. Also make sure that each connection is properly soldered. Even if you learn to work from a schematic, the equipment you build will not work properly unless all connections are properly soldered. Many people waste a great deal of time because of careless wiring and poorly soldered connections, which could easily have been spotted if a little extra time had been taken to check the work. Start right now by checking each circuit you wire against the schematic diagram and by checking each soldered connection you make. These are good habits, and the sooner you acquire them the better.

Experimental Procedure: For this experiment, in addition to the chassis with the solder lug and terminal strips, you will need the following:

- 1 1000-ohm resistor
- 1 22,000-ohm resistor
- 1 100,000-ohm resistor
- 2 1/4" X 4-40 screws
- 2 4-40 hex nuts
- 1 Etched circuit board (EC24)
- Hookup wire
- Solder

Use the resistor color code chart shown in Fig. 33 to help identify the three resistors used in this experiment.

Check your experimental chassis and make certain that the terminals are clean and all excess solder has been removed. At the same time, check the tip of your soldering iron to be sure it is clean and well-tinned.

For this experiment, you will use the tube socket on your circuit board and the terminals on your chassis. You will mount the circuit board along the edge of the chassis and connect "jumper" wires from the tube socket terminals in the copper foil to the 7-lug terminal strip on the chassis.

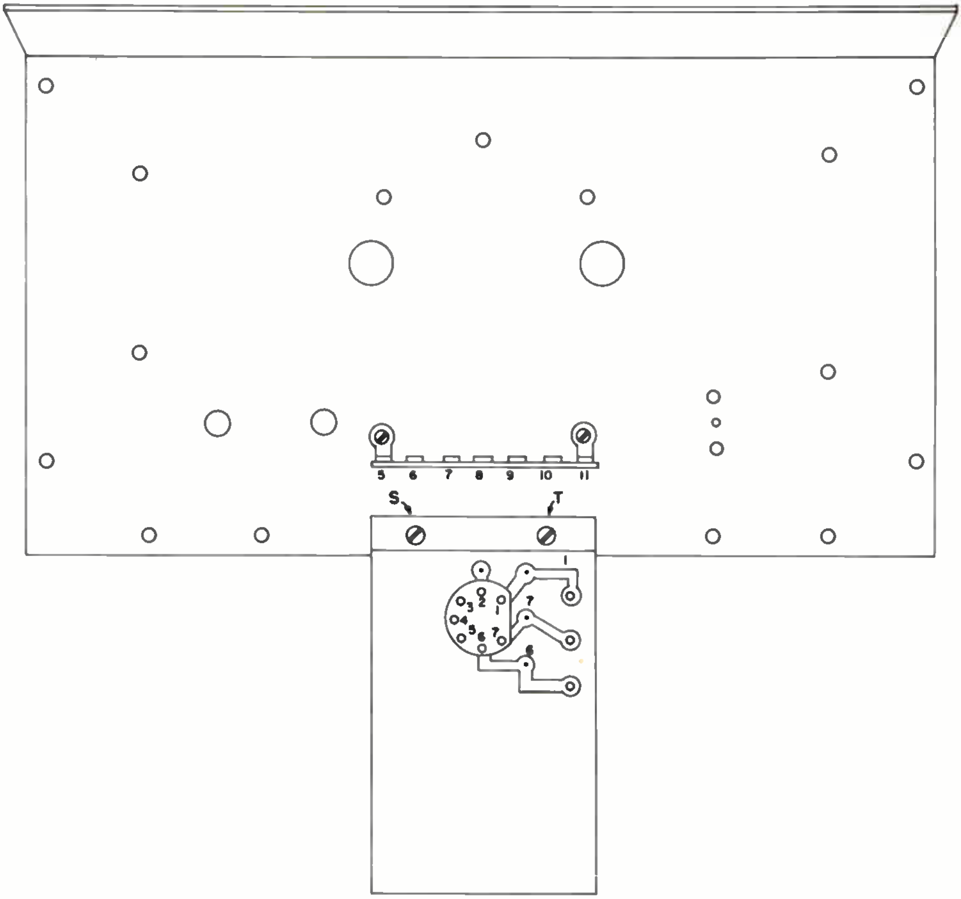


Fig. 4-2. Mounting the circuit board on the experimental chassis.

Mount the circuit board over holes S and T in the chassis (the holes are identified in Fig. 11 and Fig. 4-2). Position the circuit board over the edge of the chassis as shown in Fig. 4-2. Note that the tube socket is toward the chassis and the foil side of the board is turned upward. Attach the board with 1/4" X 4-40 screws through the mounting holes in the circuit board and chassis. Attach two 4-40 nuts and tighten.

The pins on the tube socket or tube are numbered from the blank space in a counterclockwise direction when viewed from the top. As shown in Fig. 4-3, pin 1 is at the right of the blank space, pin 2 is next, and so on. Pin 7 is to the left of the blank space. The pin in the center of the socket is not numbered. We will be primarily interested in pins 1, 6, and 7 of the socket. Connections to these holes are labeled on the foil side of EC24.

Refer to Fig. 4-4 as you make the following connections. Connect a short length of hookup wire from the hole in the foil which connects to pin 1 of the tube socket to terminal 8 on the 7-lug terminal strip. Remove about 1/4" insula-

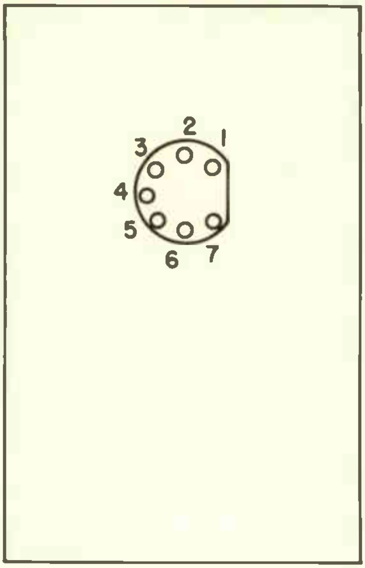


Fig. 4-3. Identifying the tube socket pins on the etched circuit board.

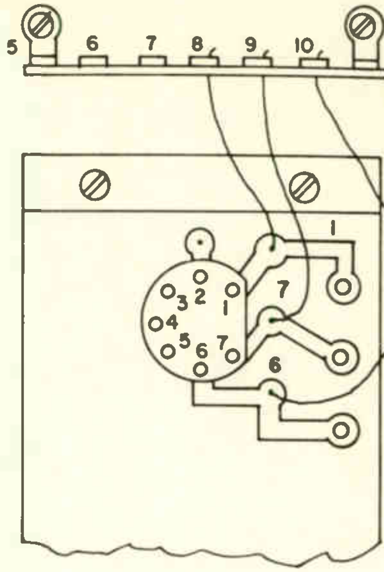


Fig. 4-4. Wiring connecting the tube socket to the terminal strip.

tion from each end of the wire. Slip the end of the wire through the hole in the circuit board from the foil side and solder to the foil.

Similarly, connect a short length of hookup wire from the hole in the foil at pin 7 to terminal 9.

In the same manner, connect a short length of hookup wire from the hole in the foil at pin 6 to terminal 10.

We often refer to a terminal or a conductor connected to a tube socket pin by the tube pin number or even by the element of the tube connected to that pin when a tube is inserted in the socket. Thus, the terminals on the chassis may be identified by the tube socket pin numbers, or as the grid, cathode and plate terminal of the 6C4 tube.

When working from schematic diagrams, remember that ground symbols indicate connections to the common return point (the chassis in this case) and that these connections can be made to anything that is connected to the chassis electrically. As your chassis is presently set up, you can use terminals 1, 5, 11, and 15 as ground connections.

If you are connecting two or more leads to a given point, do not solder until all leads are in position.

In this experiment, you are to wire a circuit directly from a schematic diagram. The diagram you are to use is shown in Fig. 4-5. The tube socket pins are indicated by the open circles nearest the tube symbol. All of the other terminals, which are shown by black dots, represent terminals on the terminal strip.

Before mounting a part, make a trial fit to determine where the part should be located. Sometimes this technique is used by experienced technicians in order to get a neat layout and prevent undue crowding of parts.

Step 1: To mount resistor R_1.

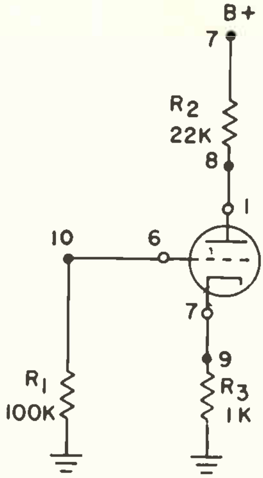


Fig. 4-5. Circuit used in Step 1.

First, find R_1 on the schematic diagram in Fig. 4-5. Notice that it is a 100,000-ohm resistor. Select a 100,000-ohm resistor from among the parts you have collected for this experiment.

From the schematic, you can see that R_1 is connected between pin 6 of the tube socket and ground. Because these connections will be made on the terminal strip, the connection will be made to terminal 10 and a ground terminal.

As stated earlier, there are four places where you can make your ground connection. The solder lug, terminal 1, and the mounting feet of the terminal strips, terminals 5, 11 and 15, are bolted directly to the chassis. Thus, they make electrical contact with the chassis and can be used for ground connections.

Connect one end of the 100,000-ohm resistor to terminal 10 and connect the other end to whichever ground point you find to be most convenient. Bend the resistor leads so that they do not touch the chassis. Also, they should not make contact with any other terminals. Solder terminal 10. Do not solder the ground terminal because you may want to make other connections to it.

Step 2: To mount resistor R_2.

Find resistor R_2 on the schematic diagram. You will see that it is a 22,000-ohm resistor (indicated by 22K on the diagram). You can also see that R_2 is connected from pin 1 of the tube socket, which is the same as terminal 8 on the terminal strip to terminal 7. Terminal 7 is marked "B+" on the schematic. Connect one lead of the 22,000-ohm resistor and solder these connections.

Step 3: To mount resistor R_3.

R_3 is a 1000-ohm resistor. On the schematic, R_3 is between pin 7 of the tube socket and ground.

Install the resistor between terminal 9 on the terminal strip (which is electrically the same as pin 7) and ground. You will have to choose a ground terminal. There are no more connections to be made. Thus, you can solder all connections which you have not yet soldered.

Step 4: To check your work.

After all wiring is in place, check your work against the schematic diagram. This check should now show:

1. A 100,000-ohm resistor between tube socket pin 6 and a ground terminal.
2. A 22,000-ohm resistor between tube socket pin 1 and terminal 7.
3. A 1000-ohm resistor between pin 7 of the tube socket and ground.

Discussion: In this experiment, you have gained experience in working from a schematic diagram. You have practiced reading resistor color codes, and you have again practiced making solder connections. You will use each of these skills every time you work on any electronic equipment.

After you have looked over your work to be sure that it is electrically equivalent to the circuit shown in Fig. 4-5, turn to the back of this manual. On page 77 you will see Fig. 4-6. This shows two ways in which you might have arranged your parts. However, these are not the only possible ways to mount the parts. As long as your arrangement is electrically the same as Fig. 4-5, you have done the experiment correctly.

Instructions For Statement No. 4: After carefully checking your work, answer the statement here and on your Report Sheet. Then unsolder the connections and remove the resistors. Disconnect the three jumper wires from the terminal strip and from the circuit board. Remove the circuit board from the chassis, clean the holes, and put the board aside. Finally, clean the resistor leads and terminals so that they will be ready for use in later experiments.

Statement No. 4: When I wired the circuit used in this experiment, I connected the 22,000-ohm resistor to the:

(1) plate
(2) cathode
(3) grid

terminal of the tube socket.

Learning to Use A Meter

An electric current is invisible, odorless and tasteless. In other words, we cannot tell that a wire is carrying current unless we use some special means of detecting it.

Although a bell or light bulb can be used to show the presence of current, neither of these devices will indicate how much current is flowing. The current in the circuit must be at a certain level before the bell will ring or the bulb will light. For example, the light bulb will light to full brilliance when its greatest current is flowing through it. As the current is decreased, the light will grow dimmer. Finally, it will reach a point where the light will give no visual indication of current, even though current may still be present in the circuit. Something is needed that will show not only whether there is current flowing, but also how much current is flowing. A meter will do both of these jobs.

MEASURING CURRENT

A meter that is used to measure current is known as an ammeter. An ammeter indicates current in amperes. The ampere, however, is much too large a unit for most measurements in electronics, so we use a meter that indicates either milliamperes (ma) or microamperes (μa). A milliampere equals one-thousandth of an ampere and a microampere equals one-millionth of an ampere. Such meters are called milliammeters and microammeters. They are made the same and operate in the same manner as an ammeter. The only difference is that the milliammeter and microammeter are much more sensitive and will respond to much smaller currents.

The meter you will use in your experiments has a range of 0 to 200 microamperes. This means that a full scale reading on the meter indicates that 200 microamperes are flowing through the meter. When the meter pointer is at half scale, half of 200 microamperes or 100 microamperes are flowing through the meter. When the meter pointer is at 1/10th scale, 20 microamperes are flowing through the meter.

PREPARING THE METER

The meter supplied in this kit is an extremely delicate instrument. It contains a jewel movement similar to that of a fine watch. Therefore, the meter must be handled with care at all times. We cannot replace any meter that has been damaged through careless handling or improper usage. If you follow carefully the instructions given, you will have no trouble with the meter. However, if you fail to follow the instructions, you may damage your meter and have to replace it.

The meter case is plastic. It can easily be scratched with a screwdriver or similar tool, or by scraping it across your workbench. Also, the plastic can be permanently damaged by heat. Be sure that you do not accidentally touch the soldering iron to the meter case.

While you are performing these experiments, the meter will be left in its box. You will connect wires to the meter terminals so that you will have easy access to the meter.

You will need the following:

- 2 Large solder lugs (LU7)
- 1 Meter (ME21)
- 2 Diodes (SR12)
- Hookup wire
- Solder

Your meter is supplied with mounting hardware and two large nuts for each terminal. These parts are in an envelope in the meter box. Save all of the hardware as you will have need for it later.

To prepare the meter, place a soft pad or towel on your workbench. Next, remove the meter from the box and place the meter carefully on the pad or towel, face down, and with the top of the meter away from you.

Remove the wire from the meter terminals. The terminals were shorted together to prevent damage to the meter during shipment. If the meter is shaken or dropped, the physical movement will cause the meter pointer to move. A voltage is generated in the coil attached to the pointer. The short circuit across the meter terminals permits the current to flow through the terminals and back through the coil. This cancels the tendency of the coil to move and protects the meter from violent pointer swing.

You will now attach the large solder lugs to the meter terminals. First, attach a large nut to one of the terminals and run it all the way down. Then slip a large solder lug over the terminal and secure it with another nut. Position the solder lug so it points toward the bottom of the meter case and tighten the nut. Hold the lower nut with a small wrench or pliers and tighten the outer nut. Do not allow the terminal to turn, since this could damage the connection inside the meter case.

In a similar manner, attach two nuts and a solder lug to the other meter terminal and tighten the nuts.

Now you will identify the lugs on the back of the meter. The one on the left as you face the back of the meter is the positive, or plus terminal of the meter; the one on the right is the negative or minus terminal. The terminals may be further identified by plus or minus signs stamped on the plastic or on the ends of the screws or "POS" and "NEG" printed near the terminals.

Examine the two diodes supplied with this kit. Refer to Fig. 3-3 to help you identify the cathode leads.

Connect the lead at the cathode end of one diode to the positive terminal of the meter. This is diode D_1 in Fig. 34. Slip the end of the lead through the lug attached to the terminal. Do not solder at this time. Slip the anode lead of D_1 through the negative terminal lug.

Connect the second diode, D_2, to the meter terminals also, but with the opposite polarity. Slip the cathode lead through the negative terminal lug and the anode lead through the positive terminal lug. Do not solder at this time.

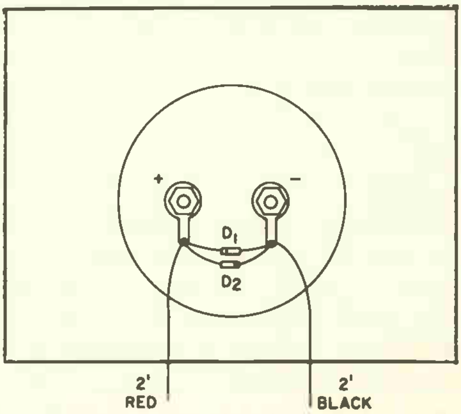


Fig. 34. Connections to the meter movement.

Prepare 2-foot lengths of red and black hookup wire. Remove about 1/4" of insulation from each end of each wire.

Connect the 2-foot length of red hookup wire to the positive meter terminal lug. Check to see that all three leads are through the hole in the terminal; then solder the connection. Be sure all three leads are soldered. After the solder cools, test the connection.

In a similar manner, connect and solder the length of black hookup wire to the negative meter terminal lug. Compare your wiring with Fig. 34 to see that you have done the work correctly.

Next, you will connect the meter leads to terminals on your chassis. Refer to Fig. 35. Connect the red lead from the meter to terminal 14. Connect the black lead from the meter to terminal 12.

Connect a 6" length of hookup wire from terminal 14 to terminal 10. Solder terminal 14.

In order to simplify the instructions, we will call terminal 10 the "positive meter terminal" and we will call terminal 12 the "negative meter terminal."

Put the meter in its box, face up. Do not attempt to make any measurements with your meter until instructed to do so.

The diodes, which you connected to the meter, are used to help protect the meter movement from excessive current. When a voltage of about .6 volt is present, one of the diodes will conduct and provide a low resistance path around the meter movement. We use two diodes connected with the opposite polarities to provide protection regardless of the polarity of the excessive voltage.

In normal operation, the voltage across the meter terminals will not exceed .15 volt. Therefore, the diodes have no significant effect on the operation of the meter unless excessive voltage is applied.

SETTING THE METER POINTER TO ZERO

The meter pointer should rest directly

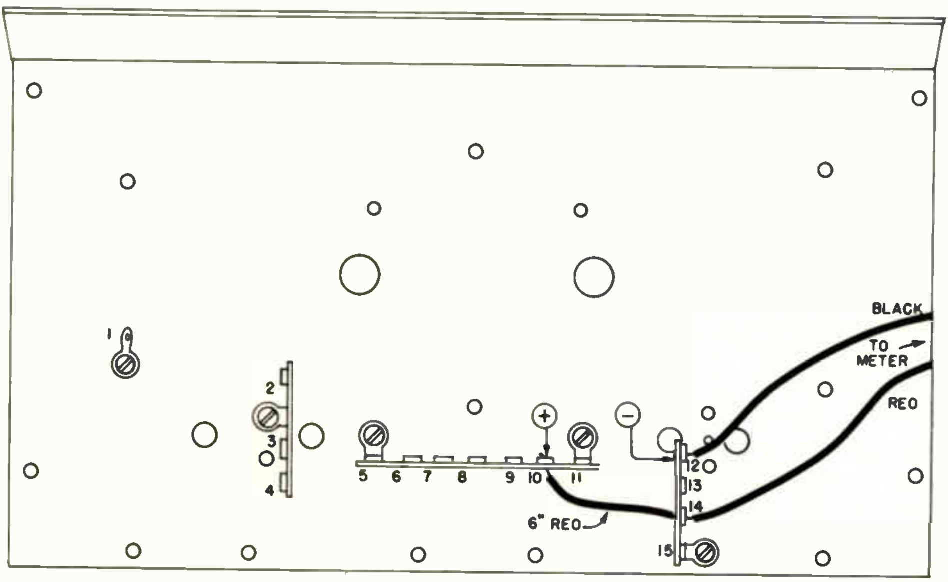


Fig. 35. The meter leads connected to terminals 12 and 14 with a jumper from 10 to 14.

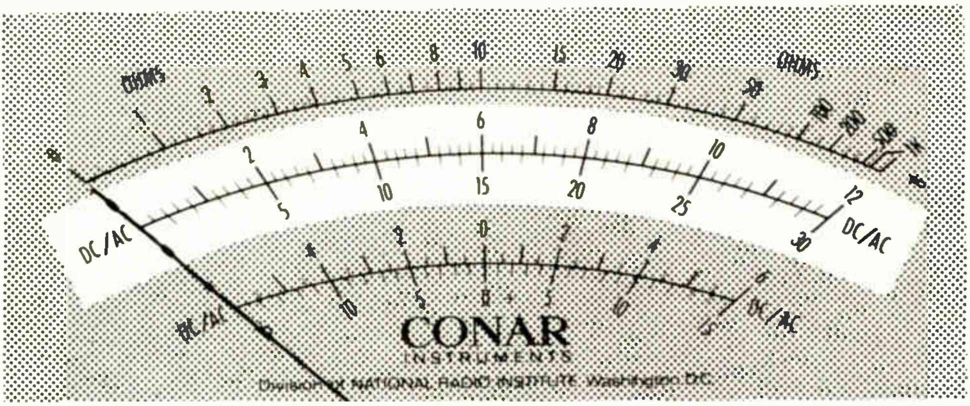


Fig. 36. The 0-12 and 0-30 volt scales on your meter.

over zero as shown in Fig. 36 when the meter is not in use. To set the pointer to zero, use a screwdriver blade that fits in the plastic screw slot on the meter face. Too small or too large a blade can damage the screw. Turn this screw, and notice that the meter pointer can be placed to the right or to the left of zero. Leave the screw adjusted so the meter pointer is over the zero mark. It is unlikely that you will have to make this adjustment again.

READING THE METER

The first time you look at the face of the meter you received in this kit, you may think that the meter is complicated and that it will be difficult to read. As a matter of fact, it is no more difficult to read a meter than it is to tell time on a clock. Of course, a meter may be something new to you, and it will take some practice to learn how to read it quickly. However, it will not be long before you will be able to read it at a glance.

At this time we will concentrate on the 0 to 12 and 0 to 30 volt scales. As you will see, the two scales may often be used together to help you obtain precise readings. These two scales are shown in white in Fig. 36. The 0 to 12 volt scale is the upper scale and has the numbers 0, 2, 4, 6, 8, 10 and 12 printed in black. The 0 to 30 volt scale is the lower scale and has the

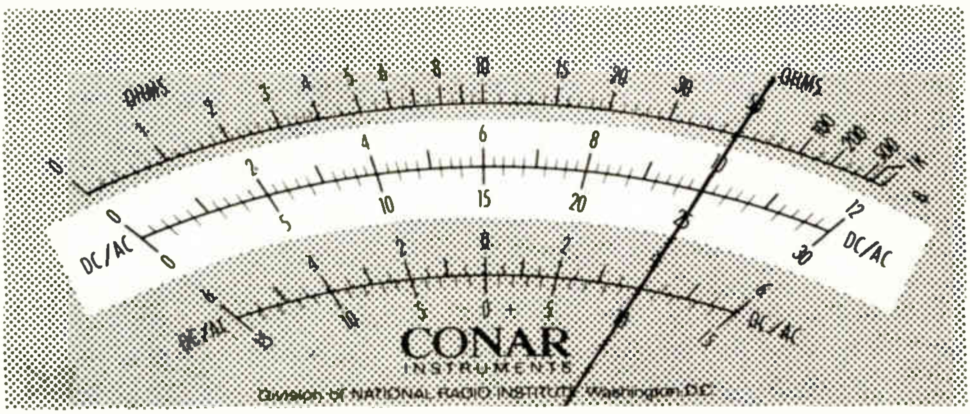


Fig. 37. A meter reading of 25 or 10.

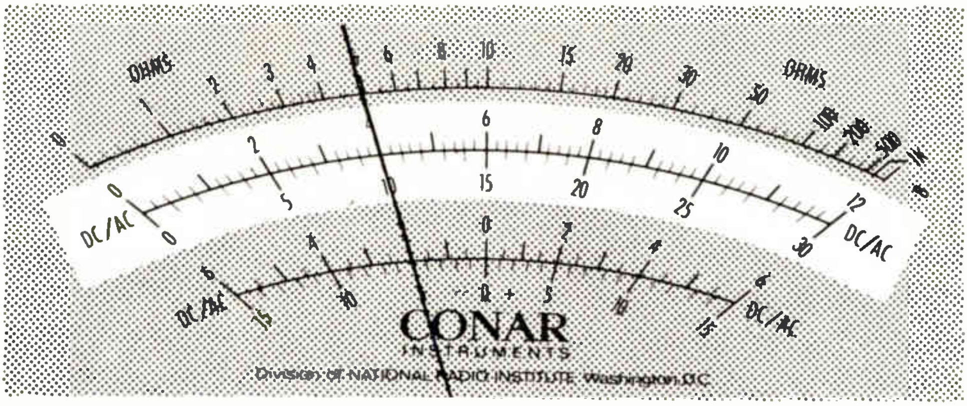


Fig. 38. A meter reading of 10 or 4.

numbers 0, 5, 10, 15, 20, 25 and 30 printed in black. Notice that the 0 to 12 volt scale has several short marks as well as some longer unnumbered marks. The 0 to 30 volt scale has four short unnumbered marks between each number.

Now look at the meter shown in Fig. 37. In this case the pointer is indicating 10 on the 0 to 12 volt scale and shows 25 on the 0 to 30 volt scale. If the pointer is as shown in Fig. 38, the reading would be 10 on the 0 to 30 volt scale and 4 on the 0 to 12 volt scale. These readings are quite easy to determine, as you can see, but what happens if the pointer is somewhere between the numbers on the scale?

Look at the scale shown in Fig. 39. Now the pointer is over one of the short marks of the 0 to 12 volt scale, but is between two short marks on the 0 to 30 volt scale! To read this value, note that on the 0 to 12 volt scale there are nine marks (or ten spaces) between 6 and 8; eight short marks and one long mark. The long mark represents 7 volts, and each short mark represents 0.2V. The pointer in Fig. 39 is on the third short mark following the 6 volt mark. Since each short mark is 0.2V, the pointer shows a reading of 6.6 volts.

Now, what is the reading of Fig. 39 on the 0 to 30 volt scale? First, notice that

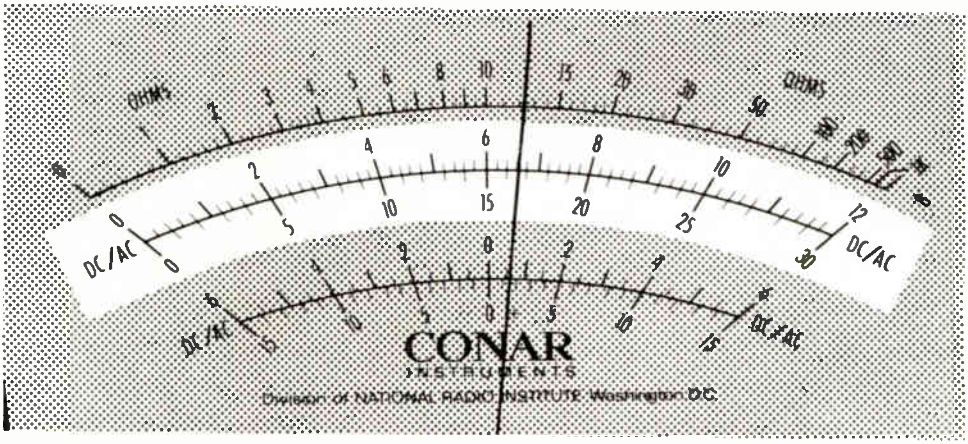


Fig. 39. Another sample meter reading.

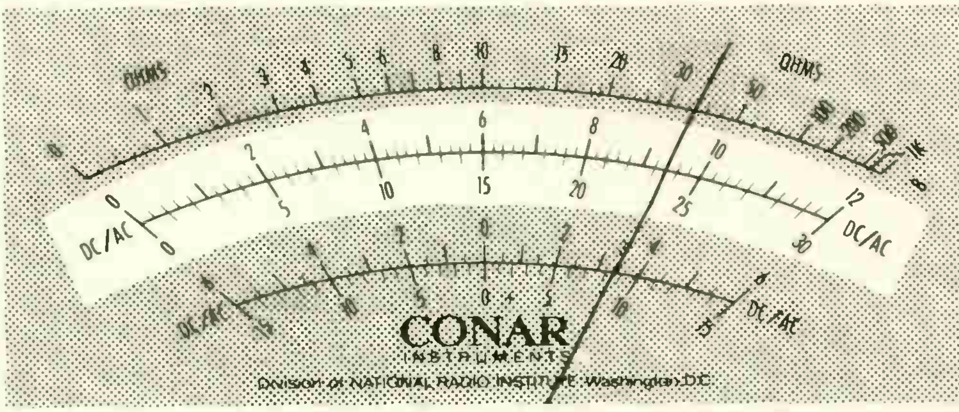


Fig. 40. Study this meter reading and see if you can tell what it is.

between 15 and 20 there are four short marks. Each mark, therefore, represents one volt. The pointer is halfway between the first and second marks following 15 so the reading is 16.5 volts. You can tell that the pointer is exactly halfway between the two marks by looking at the upper (0 to 12 volt) scale. On this scale, every other mark falls exactly halfway between the one volt marks on the 0 to 30 volt scale. This means that while the 0 to 30 volt scale is marked in one volt steps, you can determine readings to one half a volt by looking at the divisions on the 0 to 12 volt scale.

Let's look at another example. Take a look at the scale shown in Fig. 40. Using the reasoning that we applied in the previous examples, can you tell what the reading would be on the 0 to 12 and 0 to 30 volt scales? If you have trouble, go back and reread the material in the previous paragraphs. After careful study you should have no difficulty in seeing that the readings are 9.4 volts and 23.5 volts respectively on the 0 to 12 and 0 to 30 volt scales.

There is always the possibility that the pointer will not fall precisely on one of the short marks of the 0 to 12 volt scale. How are these values read? Take a look at Fig. 41. Notice here that the pointer is halfway between the second and third short marks after 4 on the 0 to 12 volt

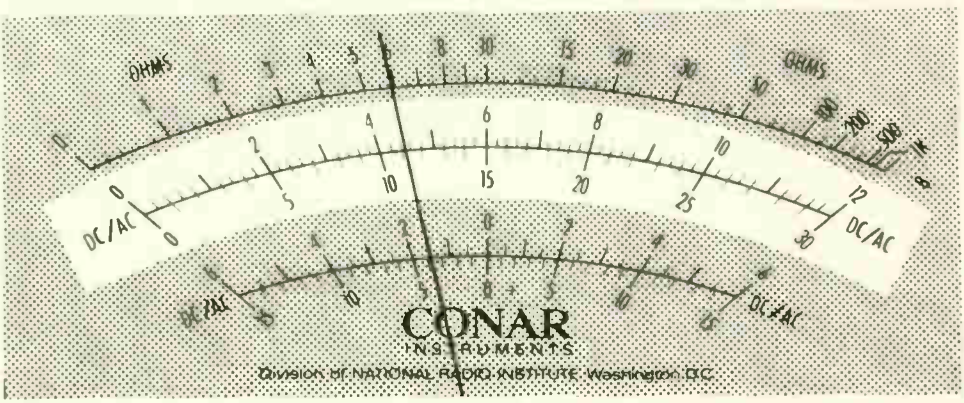


Fig. 41. Here is another meter reading for you to practice on.

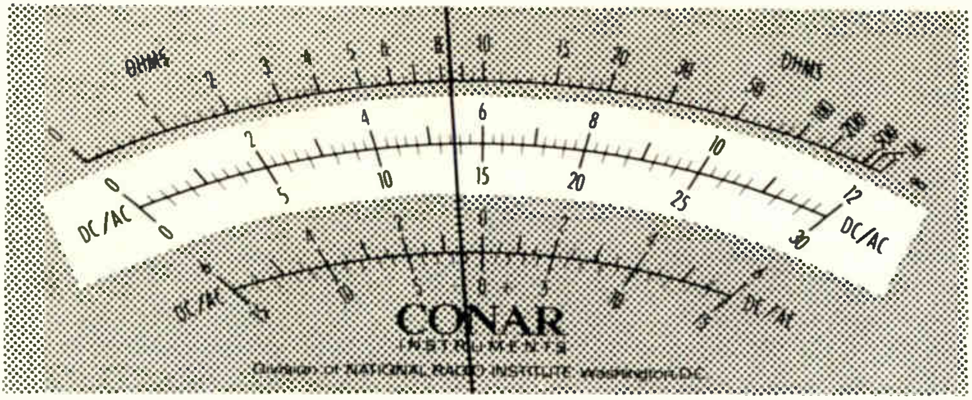


Fig. 42. What is the indication on this meter?

scale. This would be a reading of 4.5 volts. On the 0 to 30 volt scale it is just as easy. The pointer falls one fourth of the way between the first and second mark after 10, so the reading is 11.25 volts.

As a final example, try your hand at reading the two values indicated in Fig. 42. Again, the pointer does not fall on any of the scale marks of either scale. Let us see how close we can come to reading the meter by applying what we have already learned. On the 0 to 12 volt scale, the pointer is between 5 and 6. We can be more exact than that; it appears to be halfway between the second and third marks following the (unmarked) 5 volt mark. The first mark is 5.2 volts, the second mark is 5.4 volts and the third mark is 5.6 volts. Therefore the reading is between 5.4 and 5.6 volts. How much, is the question. The pointer falls about halfway between 5.4 and 5.6 volts so we would call it 5.5 volts. There is, of course, some uncertainty in this reading. For the purposes of your experiments, you would read it as 5.5 volts.

What reading does Fig. 42 represent on the 0 to 30 volt scale? Well, it is somewhere between 10 and 15 volts. Each short mark represents one volt, so the reading would be between 13 and 14 volts. Remember that the short mark on the *upper* scale (0 to 12 volts) is exactly halfway between the 13 and 14 volt marks, or in other words represents 13.5 volts. The pointer falls to the right of this mark so the reading must be between 13.5 and 14.0 volts. We would probably call this 13.75 volts; any value from 13.7 to 13.8 volts would be sufficient.

Building A Simple Series Circuit

You have already studied Ohm's Law and you know that there is a definite relationship between the voltage, current and resistance in a circuit. In Experiment 5, you will see just what happens to the current when you change either the resistance in the circuit or the voltage applied to the circuit. Before you begin Experiment 5 you will prepare the chassis by installing some parts on it. Then, when you begin Experiment 5 you will add some more parts and perform the Experiment.

In addition to your meter and chassis, you will need:

2 4.7K-ohm resistors (yellow-violet-red-silver)
1 6.8K-ohm resistor (blue-gray-red-silver)
1 1.5-volt flashlight cell
Black hookup wire
Red hookup wire
Solder

Inspect the tip of your soldering iron. If necessary, file and retin the tip.

You will connect the three resistors to terminals 7, 8, 9 and 10 on your chassis. The chassis with the resistors in place is shown in Fig. 43. Begin by connecting one lead of a 4.7K-ohm resistor to terminal 10. (There should already be a red wire connected to terminal 10.) Temporarily solder the lead and the red wire to terminal 10. Bend the resistor leads near the body of the resistor and push the free lead through the slot in terminal 9. Connect one lead of another 4.7K-ohm resistor to terminal 9. Solder terminal 9. Connect the other lead of this resistor to terminal 8. Connect one lead of the 6.8K-ohm resistor from terminal 8 to terminal 7 as shown in Fig. 43. Solder terminal 8.

Remove 1/4" of insulation from each end of a 10" length of red hookup wire. Connect and solder one end to terminal 7. Leave the other end free.

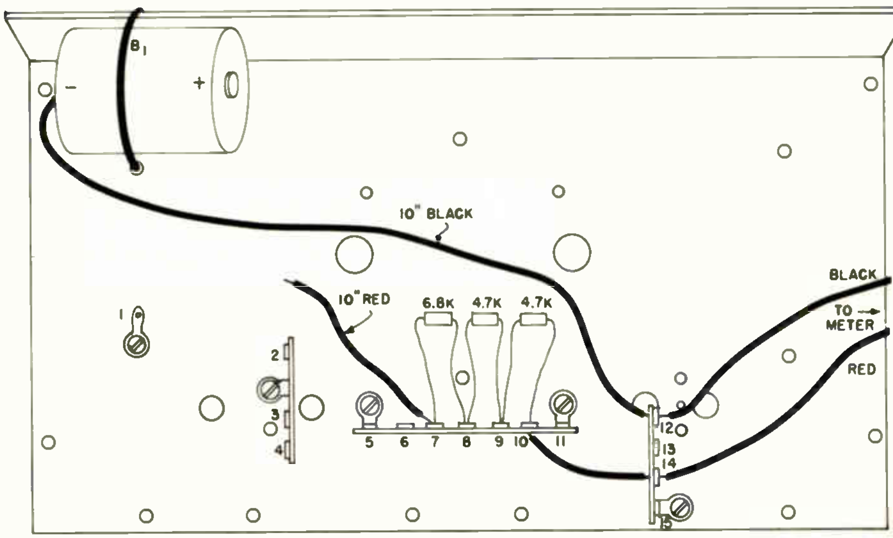


Fig. 43. Experimental chassis wired for Experiment 5.

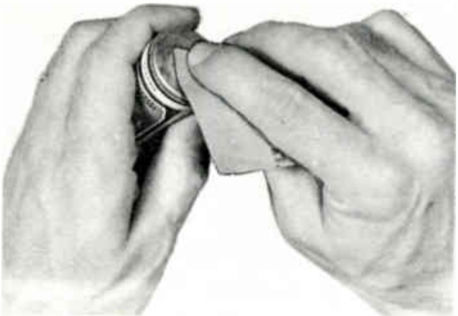


Fig. 44. How to clean the center of the bottom of a flashlight cell with a piece of sandpaper.

You should now have three series-connected resistors going from the positive meter terminal (terminal 10) to terminal 7. The total resistance between terminal 7 and the positive meter terminal is the sum of the values of the three resistors; a total of about 16,000 ohms.

You now have a 0-200 microampere meter with approximately 16,000 ohms in series with it.

In order to measure current, your meter must be connected to a source of voltage with the proper polarity. The positive terminal of the voltage source must always be connected to the lead or circuit point that goes to the positive meter terminal.

At first, we will use a flashlight cell which produces 1.5 volts dc as a source of voltage. To do this, you are to connect a wire from the negative meter terminal, terminal 12, to the negative battery terminal. Notice that one end of your flashlight cell has a raised portion while the other end is flat. The negative battery terminal is the end with no raised section. Clean a spot in the middle of the bottom of the cell with a piece of fine sandpaper, as shown in Fig. 44.

Be sure that your soldering iron tip is clean and hot. Then, hold the end of your roll of solder on the negative terminal of the cell and touch your soldering iron to the solder. Rub the iron around so that the terminal becomes well-tinned.

Now cut a 10" length of black hookup wire and remove 1/4" of insulation from each end. Place one end of the 10" length black hookup wire on the tinned area of the negative terminal of the cell. Touch the tip of your soldering iron to the wire and the tinned portion of the cell. The solder should melt and run over the wire. Remove the heat and allow the joint to cool. If the solder does not flow smoothly over the wire, add a little more solder as you heat the connection.

If you like, you can use a piece of hookup wire to secure the cell in place along the bend in the chassis as shown in Fig. 43. Note that the negative terminal is toward the left side of the chassis.

Fig. 45. Schematic symbol for a battery.

The symbol we use on schematic diagrams to represent a battery is shown in Fig. 45. Each pair of lines represents one cell of the battery. The short wide line represents the negative terminal and the longer thin line represents the positive terminal. To represent one cell, we use only one pair of lines; but to represent several cells, we do not try to show the exact number, as two or more pairs are sufficient.

EXPERIMENT 5

Purpose: To show that current flowing in a series circuit will change when the

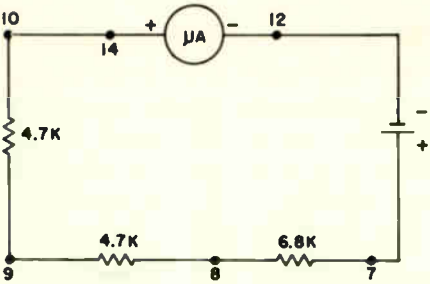


Fig. 5-1. The circuit you will use in Step 1 of Experiment 5.

resistance in the circuit or the voltage applied to the circuit is changed.

Introductory Discussion: Although the circuit you will use in this experiment is a simple circuit, it will act in the same way that a more complex circuit would act when either the resistance or voltage is changed.

This experiment will demonstrate Ohm's Law, which is one of the most important laws you will study. Do each step of the experiment carefully and make sure you understand exactly what you are doing and what the changes in current that you observe mean.

Experimental Procedure: In this experiment, in addition to the meter, chassis and the circuit you have just wired, you will need the following:

1 1.5-volt flashlight cell
Hookup wire

The first circuit you will use is shown in Fig. 5-1. When you read the meter, use the 30-volt scale which you practiced reading previously.

Step 1: To connect 1.5 volts across the meter and series resistor combination.

Touch the red wire from terminal 7 to the positive terminal of the flashlight cell. This closes the circuit and causes current to flow.

Observe the pointer on your meter. It should be slightly below one-half scale. If you get no reading, look for a bad connection or a short circuit. Check to be sure that your circuit is wired as shown in Fig. 5-1. Trace the wiring from terminals 12 and 10 back to the terminals on the meter. Also check for a short circuit between the meter terminals or leads.

The meter scale which you are using in this experiment (Fig. 5-2) is the 0 to 30 volt scale. However, in this experiment you are using this scale only as a relative indication of the amount of current in the circuit. The meter indicates a current of about 100 microamperes, since you know that a full scale reading (30) repre-

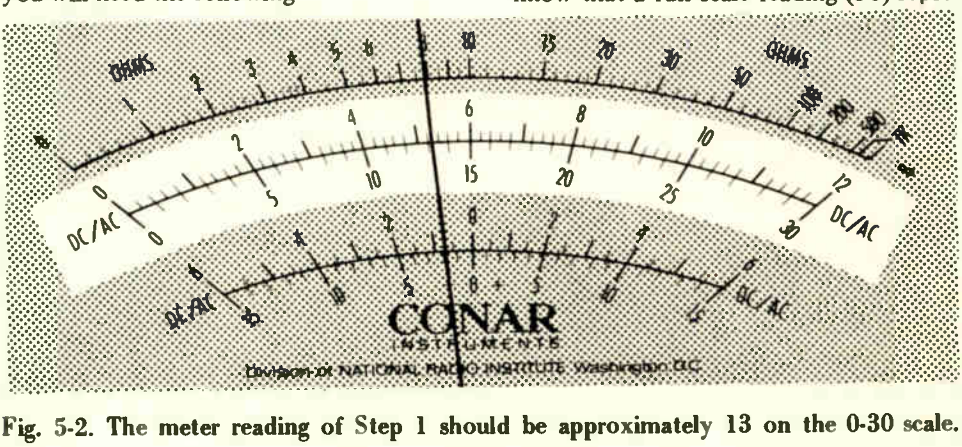


Fig. 5-2. The meter reading of Step 1 should be approximately 13 on the 0-30 scale.

STEP	READING
1	13.5
2	27.5
3	23.2

Fig. 5-3. Record your reading for Experiment 5 here.

sents a current of 200 microamperes.

In later experiments you will learn that the 0 to 30 volt scale will also be used to indicate 0 to 3 volts, and 0 to 300 volts. The 0 to 12 volt scale will also be used to indicate ranges of 0 to 1.2 volts, 0 to 120 volts and 0 to 1200 volts. For the time being, however, you need only be concerned with relative scale indications on the 0 to 30 volt scale. Read the meter carefully and write the reading of the meter in the space provided for Step 1 in Fig. 5-3. Remove the red wire from the positive terminal of the flashlight cell to open the circuit.

Step 2: To determine the effect of increasing the voltage in a series circuit.

To do this, you will connect another flashlight cell in series with the cell you used in Step 1. This is shown in the schematic diagram in Fig. 5-4.

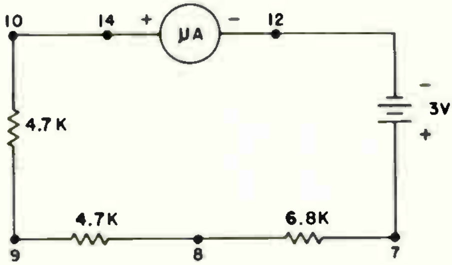


Fig. 5-4. Circuit to use for Step 2.

Clean the positive terminal of the second flashlight cell with a piece of fine sandpaper. Hold your soldering iron on the terminal and apply solder. Melt

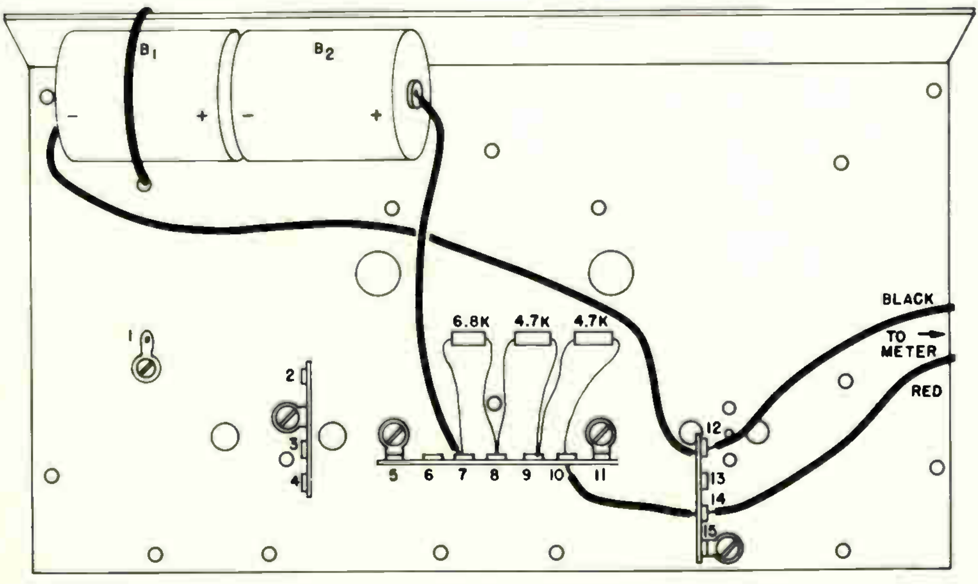


Fig. 5-5. Series resistor with 3-volt battery.

enough solder on the terminal to tin it. Rub the tip of the iron around so that the terminal is well-tinned.

Place the free end of the red wire connected to terminal 7 on the tinned area of the positive terminal of this flashlight cell and apply heat to solder the wire to the terminal. Use additional solder if necessary.

Now, to complete the circuit, hold the positive end of the first flashlight cell against the negative terminal of the second flashlight cell, as shown in Fig. 5-5. This places the two 1.5-volt cells in series, thus forming a 3-volt battery.

The meter pointer should swing to the right to just under 30 on the 30-volt scale. Look at the meter carefully, read the value as closely as you can, and write the reading in the space reserved in Fig. 5-3.

Step 3: To show that the amount of current will change when the resistance is changed.

The circuit you will use is shown in Fig. 5-6. Unsolder the red wire from the positive terminal of the second flashlight cell and from terminal 7 and set the cell to one side. Solder one end of the red wire you just removed to terminal 8.

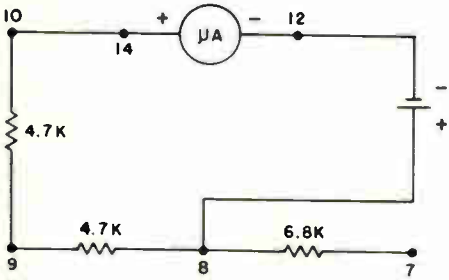


Fig. 5-6. Circuit you use for Step 3.

Touch the free end of the red wire to the positive terminal of the flashlight cell on the chassis. You now have a total of about 9,400 ohms in the circuit with a source voltage of 1.5 volts. Read the meter and record your readings in the space for Step 3 in Fig. 5-3.

Discussion: In this experiment, you have seen what happens in a series circuit when the voltage or resistance is changed. You should have a reading of something less than 15 for Step 1. When you doubled the voltage in the circuit by adding a second flashlight cell, you should have obtained a reading of about two times the original reading. In other words, when you double the voltage supplied to the circuit, the current in the circuit doubles. From this, you can see that there is a definite relationship between voltage and current in a series circuit.

In Step 3, when you reduced the resistance in the circuit, you should have found that the current was greater than in Step 1. This shows that if you reduce the resistance in a series circuit, the current will increase. We could have shown that increasing the resistance will cause the current to decrease, but this should have been obvious from the steps that you have already carried out in this experiment.

Instructions For Statement No. 5: In order to complete this statement you must obtain one additional reading. You will find the current through a resistance of approximately 7,500 ohms connected across a voltage of 1.5 volts. To get this reading, wire the circuit shown in the schematic in Fig. 5-7. Connect a short length of hookup wire from terminal 7 to terminal 9. Solder both connections. Fig.

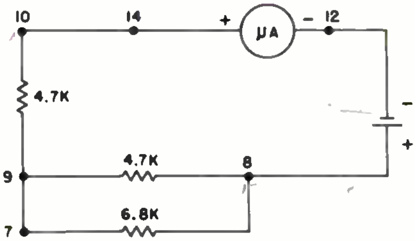


Fig. 5-7. Connect the free end of the resistors to the junction of the first and second resistors to get Statement answers.

5-8 shows the chassis wired according to Fig. 5-7. This places a 4,700-ohm resistor in parallel with the 6,800-ohm resistor. This combination is in series with the other 4,700-ohm resistor. Next, touch the red wire from terminal 8 to the positive terminal of the flashlight cell on the chassis.

Observe the meter reading on the 30-volt scale and answer the statement.

Remove the three resistors connected to terminals 7, 8, 9 and 10 and clean their leads so they will be ready for reuse. Also, disconnect and remove the short length of wire connecting terminals 7 and 9 and remove the 10″ length of red wire from terminal 8. Do not discard this wire as you can reuse it in later experiments. Do not remove any of the other wires.

Statement No. 5: When I touched the free end of the lead from terminal 8 to the 1.5-volt cell, I obtained a reading of approximately

(1) 15
(2) 30
(3) 10

EXPERIMENT 6

Purpose: To show how to connect resistors in parallel; and to show that the net resistance of a group of parallel-connected resistors is less than that of the smallest resistor in the group.

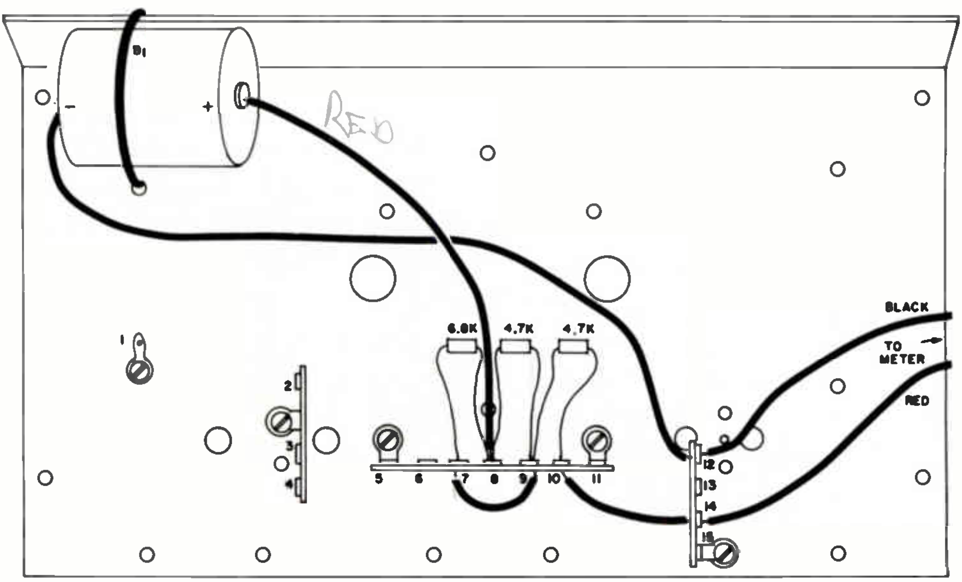


Fig. 5-8. Chassis arrangement for Statement 5.

Introductory Discussion: In the last experiment, you learned how to connect resistors in series with a source of voltage. When resistors or any other parts are connected across a voltage source, they are called a load. In a circuit of this type, each resistance, including that of the meter, can be considered as part of the total load resistance. Thus, the total load resistance is the sum of the individual resistances.

In this experiment we will show that loads can also be connected to the source voltage so that the entire source voltage is connected to each load. We will also show that when loads are connected in this manner, the net resistance of the combined load is less than the resistance of the smallest resistance in the group.

Experimental Procedure: In making these tests, you will use the following parts:

2 100,000-ohm resistors
1 82,000-ohm resistor
2 Flashlight cells
Red hookup wire

Since good connections will be required, we will solder leads to the batteries. To do this, clean the battery terminals (that you have not yet used) with a piece of sandpaper and tin them, as you learned to do in the last experiment.

Remove 1/2" of insulation from each end of an 8" length of red hookup wire. Place one end of one wire on the tinned area of the positive terminal of the cell connected to terminal 12. Touch the soldering iron to the junction. The solder on the tinned areas should melt and run over the wire. If necessary, add solder to get a good connection. Remove the heat, and let the joint cool. Solder the other end of the wire lead to the tinned area on

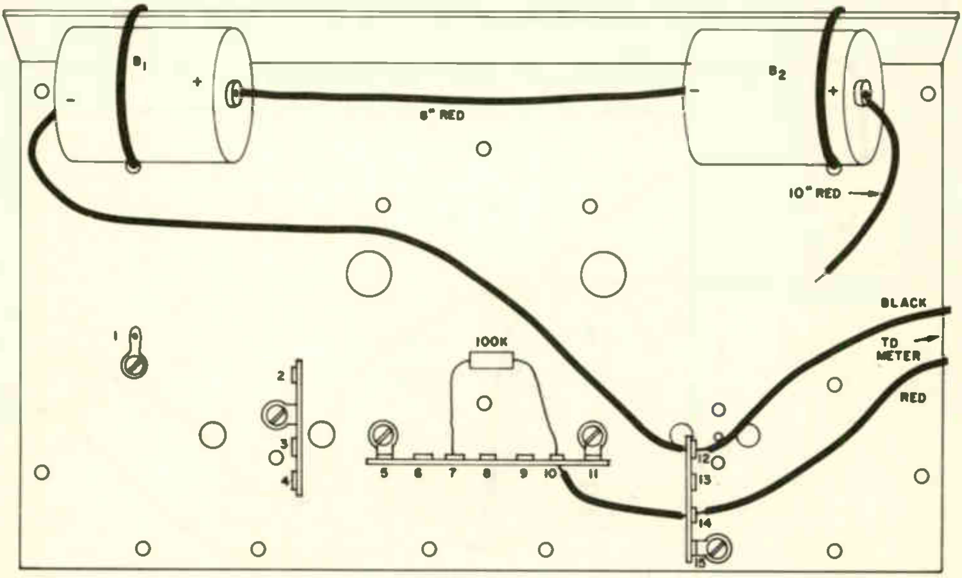


Fig. 6-1. Chassis wired for Step 1.

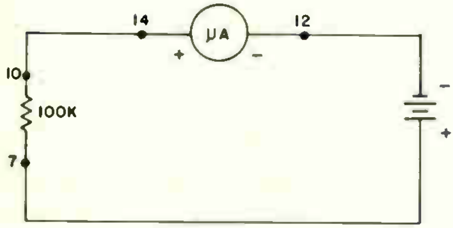


Fig. 6-2. Schematic diagram for Step 1.

the negative terminal of the second battery.

Secure the second battery to the right side of the chassis as shown in Fig. 6-1. You can pass a piece of string or hookup wire through the hole in the chassis and around the battery.

We will call the cell on the left side of the chassis B_1 and we will call the cell on the right B_2.

Locate the 10″ length of red hookup wire you used in the last experiment. Solder one end of this wire to the positive terminal of the flashlight cell, B_2. Leave the other end free.

You now have a 3-volt battery. The negative terminal of the 3-volt battery is the negative terminal of B_1 and is connected to terminal 12. The red wire connected to the positive terminal of B_2 is the "positive battery lead."

Complete the circuit shown in Figs. 6-1 and 6-2 by soldering a 100,000-ohm resistor between terminals 7 and 10.

Step 1: To get an indication of the current flowing with a 100,000-ohm resistor in the circuit.

Touch the free end of the positive battery lead, which is soldered to the positive terminal of B_2, to terminal 7. Read the meter indication on the 30-volt scale. The meter pointer should be in about the position shown in Fig. 6-3. Your reading may be somewhat higher or lower than the value shown in Fig. 6-3 because of normal tolerances in resistor values and the output voltages of different cells. Read the meter carefully and then remove the free end of the positive battery lead from terminal 7 to open the circuit. Record your reading in the space provided for Step 1 in Fig. 6-4.

Step 2: To connect a 100,000-ohm resistor in parallel with the resistor used in Step 1.

Clean the leads of the second 100,000-ohm resistor and connect it in parallel with the resistor used in the last

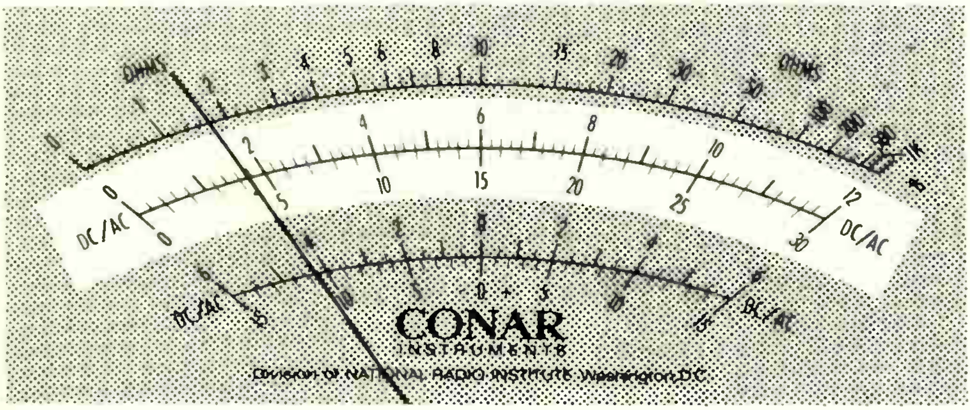


Fig. 6-3. Meter reading for Step 1.

STEP	READING
1	4.7
2	9.5
3	14.9

Fig. 6-4. Record your reading for Experiment 6 here.

step. You may solder the leads to terminal 7 and 10 or, if you prefer, you may solder the leads to the leads of the resistor already in the circuit. The circuit for this step is shown in Fig. 6-5.

Touch the positive battery lead to terminal 7 and read the meter on the 30-volt scale. Remove the positive battery lead after recording your reading in the chart in Fig. 6-4.

Step 3: To add an 82,000-ohm resistor to the parallel connected 100,000-ohm resistor.

Clean the leads of the 82,000-ohm resistor and solder it either to terminals 7 and 10 or to the leads of one of the resistors used in Step 2. The schematic diagram of the circuit for this step is shown in Fig. 6-6. Touch the positive battery lead to terminal 7 and note the reading on the meter. Open the connection after recording your reading in Fig. 6-4.

Discussion: In this experiment you have demonstrated what happens to the current in a circuit when resistors are connected in parallel. You should have discovered that as you added the second 100,000-ohm resistor to the circuit, your reading on the meter was about twice what it was with only one resistor in the circuit. When you added the third resistor, you should have found that the current increased still more.

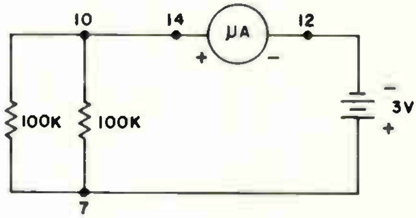


Fig. 6-5. Schematic diagram for Step 2.

You know from Ohm's Law that the amount of current that will flow in a circuit depends on the voltage applied to the circuit and the resistance in the circuit. In other words, $I = E \div R$. The value of E did not change; it was 3 volts throughout the entire experiment. Therefore, the change in current must have been entirely due to the change in resistance. In fact, the total resistance in the circuit decreased as you added more

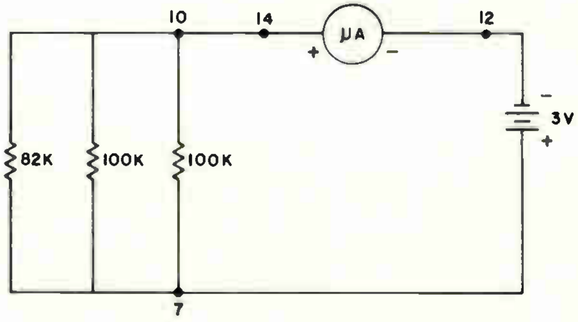


Fig. 6-6. Schematic diagram for Step 3.

resistors in parallel to produce the increase in the circuit current.

Of the three resistors used in this experiment, the 82,000-ohm resistor has the lowest resistance, and we will use this resistor by itself in the statement for this experiment.

Instructions for Statement No. 6: Remove all three resistors from terminals 7 and 10. Separate the resistors and reconnect the 82,000-ohm resistor to terminals 7 and 10.

Touch the positive battery lead to terminal 7 and note the reading on the meter. Open the circuit, and write the reading in the margin of this page. Answer the statement, and then disconnect the 82,000-ohm resistor. Clean and straighten its leads so that it will be ready for re-use. Leave all other connections alone as they will be used in the next experiment. Leave the two flashlight cells connected together and the lead from the negative terminal of the battery connected to terminal 12.

Statement No. 6: When I connected an 82,000-ohm resistor in place of the parallel group, the reading was:

(1) higher
(2) lower

5.7

than the reading obtained in Step 3.

This indicates that the resistance of the parallel group was:

(1) more than
(2) less than

that of the 82,000-ohm resistor by itself.

EXPERIMENT 7

Purpose: To show that the current is the same at every point in a series circuit.

Introductory Discussion: You already know that current in a circuit is the flow of electrons through the circuit. Electrons flow from the negative terminal of the voltage source, which is the battery in this experiment, through the load, and back to the positive terminal of the battery. Inside the battery, electrons flow from the positive terminal to the negative terminal.

In any series circuit, the current is the same throughout the entire circuit. In other words, if you connect a current-measuring instrument into the circuit to measure the current, it will not make any difference where you connect the instrument -- you will always get the same current reading. In this experiment you will demonstrate this. You will even show that the current flowing in the battery itself is the same as the current flowing in the external circuit.

Experimental Procedure: In this experiment, in addition to the meter, chassis and flashlight cells you will need the following parts:

1 100,000-ohm resistor
1 82,000-ohm resistor
1 22,000-ohm resistor
Hookup wire

Fig. 7-1 shows the circuit you will use for Step 1. This is the same setup used in

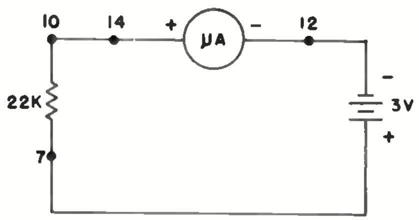


Fig. 7-1. Schematic of circuit for Step 1.

STEP	READING
1	20.5
2	20.5
3	20.5

Fig. 7-2. Record your reading for Experiment 7 here.

the last experiment. To construct the circuit, solder the leads of the 22,000-ohm resistor to terminals 7 and 10. When you have made these connections you should have:

(1) a wire from the negative battery terminal (negative terminal of B_1) to terminal 12,
(2) a wire connecting terminal 14 and terminal 10,
(3) a 22,000-ohm resistor connected from terminal 10 to terminal 7,
(4) a wire from the positive terminal of B_1 to the negative terminal of B_2, and
(5) a wire soldered to the positive battery terminal with the other end free. There should be no wire soldered to terminal 7.

If your circuit is properly wired, you may proceed with the first step.

Step 1: To measure the current leaving the battery.

Touch the free end of the positive battery lead to terminal 7. Read the meter on the 30-volt scale and record the reading in the space provided for Step 1 in Fig. 7-2. On the schematic in Fig. 7-1, you can see that the battery current flows from the negative battery terminal, through the meter to the resistor. It then flows through the resistor and back to the positive battery terminal.

Step 2: To measure the current returning to the battery.

Rewire the circuit as shown in Fig. 7-3. To do this, first unsolder and remove the red wire from terminal 10 to terminal 14. Unsolder the black negative battery lead from terminal 12. Solder the free end of the black wire to terminal 10. Connect and solder a length of hookup wire from terminal 7 to terminal 12.

Notice on the schematic in Fig. 7-3 that the meter is now between the resistor and the positive battery terminal.

Touch the free end of the positive battery lead to terminal 14 to complete the circuit. Read the meter on the 30-volt scale. Open the circuit after recording the reading for Step 2 in Fig. 7-2.

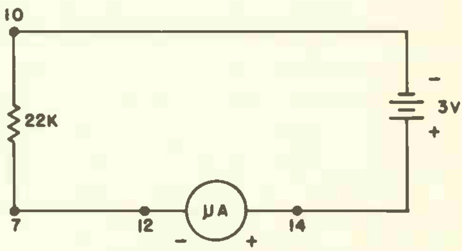


Fig. 7-3. Circuit for Step 2.

Step 3: To show that the current flowing inside the battery itself is the same as the current flowing in the external circuit.

The battery you are using in this experiment consists of two flashlight cells. Large batteries of the type used in earlier tube-type portable radios have voltages of 45 and 90 volts and are made up of groups of 1.5-volt cells, similar to flashlight cells. These are connected in series to get the required voltage. The more cells that are connected in series, the higher the voltage.

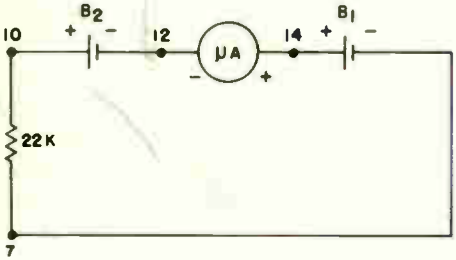


Fig. 7-4. Circuit for Step 3.

With an external circuit connected to the battery, you can measure the internal current in the battery by inserting a meter between any two adjacent cells.

To illustrate this in the experiment, wire the circuit shown in the schematic in Fig. 7-4. Fig. 7-5 shows a pictorial diagram of the wiring. Unsolder and remove the short length of hookup wire connected from terminal 7 to terminal 12.

Locate the wire connecting the two flashlight cells. Unsolder this wire from the positive terminal of B_1. Solder the free end of the wire to terminal 12.

Solder the negative battery lead to terminal 7.

Connect and solder a length of hookup wire from terminal 14 to the positive terminal of B_1. Check to see that your circuit is wired correctly.

Touch the positive battery lead (from B_2) to terminal 10 to complete the circuit. Read the meter carefully and open the circuit after recording your reading in the space provided for Step 3 in Fig. 7-2.

Discussion: In Step 3 of this experiment, the circuit is connected as shown in Fig. 7-4. Here the meter is actually placed between the two flashlight cells, and is measuring the current flowing from one cell into the second cell. Compare your readings for this step with your readings in Steps 1 and 2.

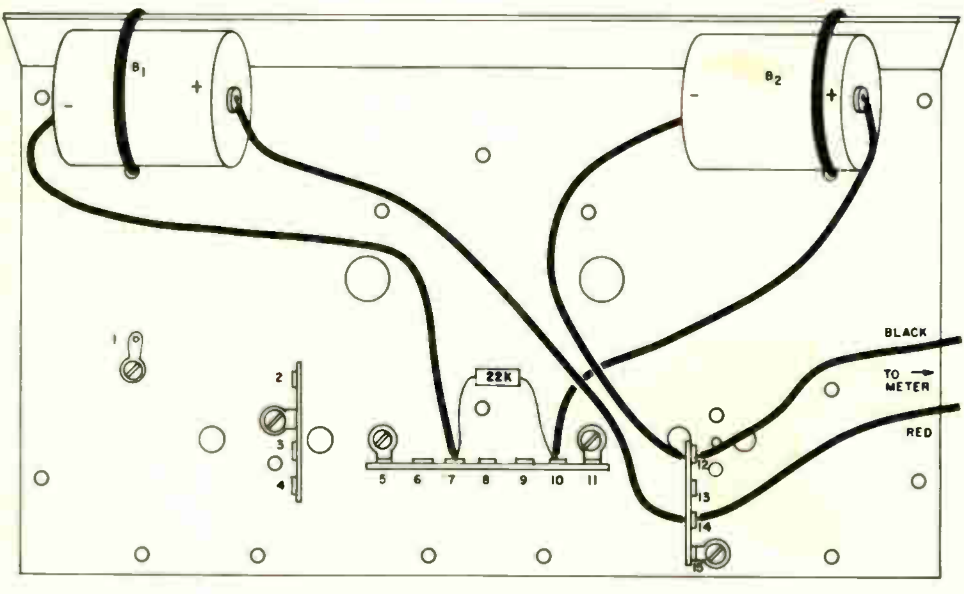


Fig. 7-5. Chassis wired for Step 3.

Notice that the readings are the same in all three steps. This demonstrates an extremely important fact. The value of the current is the same throughout the entire circuit. This means you can connect a meter at any point in a simple series circuit to measure the current; the reading will be the same regardless of where the meter is connected.

It is easy to see why the current in a series circuit is the same throughout the entire circuit. When you close the circuit by touching the battery wire to the circuit, electrons begin to leave the negative terminal of the battery. They strike other electrons and cause them to move. These electrons, in turn, strike additional electrons, and so on throughout the entire circuit. This, of course, occurs instantaneously; as soon as the circuit is completed, electrons start moving through the entire circuit.

At the same instant that electrons begin to leave the negative terminal of the battery, pushing other electrons before them, other electrons begin entering the positive terminal of the battery, because the electrons are attracted by the positive potential. The number of electrons moving in one part of the series circuit is exactly equal to the number of electrons moving in any other part of the series circuit.

Instructions for Statement No. 7: In 7
the preceding experiment, you demonstrated that when resistors are connected in parallel, the total resistance of the combination is lowered. If the applied 4
voltage does not change, this results in an increase in current. For this Report Statement, you will connect a low resistance in series with a high resistance. Then you will shunt each resistance with an 82,000-ohm resistor and note the effect on the total circuit current.

To carry out the experiment for this statement, you will need one 100,000-ohm resistor and one 82,000-ohm resistor. Wire the circuit as shown in Fig. 7-6. Connect a 100,000-ohm resistor from terminal 10 to terminal 13. Solder both connections. Check your circuit to see that it is wired according to Fig. 7-6. Solder the positive battery wire to terminal 13.

Note the reading on the meter on the 30-volt scale. Bend the leads of the 82,000-ohm resistor so that you can conveniently bridge the resistor across either the 100,000-ohm or the 22,000-ohm resistor. Bridge the 82,000-ohm resistor first across the 100,000-ohm resistor and note the meter reading on the margin. Next move the 82,000-ohm resistor over and bridge the 22,000-ohm resistor. Again, read the meter and note the reading in the margin.

Compare the two meter readings and answer the Report Statement.

Unsolder the positive battery lead from terminal 13. Unsolder and remove the 100,000-ohm resistor connected between terminals 10 and 13 and the 22,000-ohm resistor connected between terminals 7 and 10. Unsolder and remove the short red wire between the positive terminal of B_1 and terminal 14. Unsolder the red wire from terminal 12. (The other end of

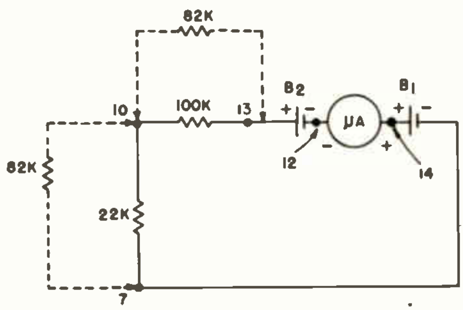


Fig. 7-6. Circuit for Statement 7.

this wire is soldered to the negative terminal of B_2.) Solder the free end of this wire to the positive terminal of B_1 to connect the two cells in series again. Clean and straighten the leads of the resistors you removed and clean all unused terminals.

Statement No. 7: When I shunted the 100K-ohm resistor with an 82K-ohm resistor, and then shunted the 22K-ohm resistor with the 82K-ohm resistor, I found that the effect on the current was:

(1) greater when the 22K-ohm resistor was shunted.
(2) greater when the 100K-ohm resistor was shunted.
(3) the same in both cases.

EXPERIMENT 8

Purpose: To show that the total current flowing in a parallel circuit is the sum of the currents flowing in the branches.

Introductory Discussion: In any piece of electronic equipment, there are usually several tubes or transistors connected across a single power supply. Each circuit, or stage, as they are usually called, generally draws a different current. The total current that the power supply must provide is equal to the sum of the currents drawn by the individual stages. Each stage acts as a separate load connected across the power supply. If a defect develops in one stage so that the stage draws more current than it should, not only will that stage be overloaded, but also the total current that the power supply must furnish will increase. As a result, the power supply may be overloaded. It is important for you to remember this when you start doing repair work. If a power transformer overheats, it does not necessarily indicate that the transformer is defective; it often indicates

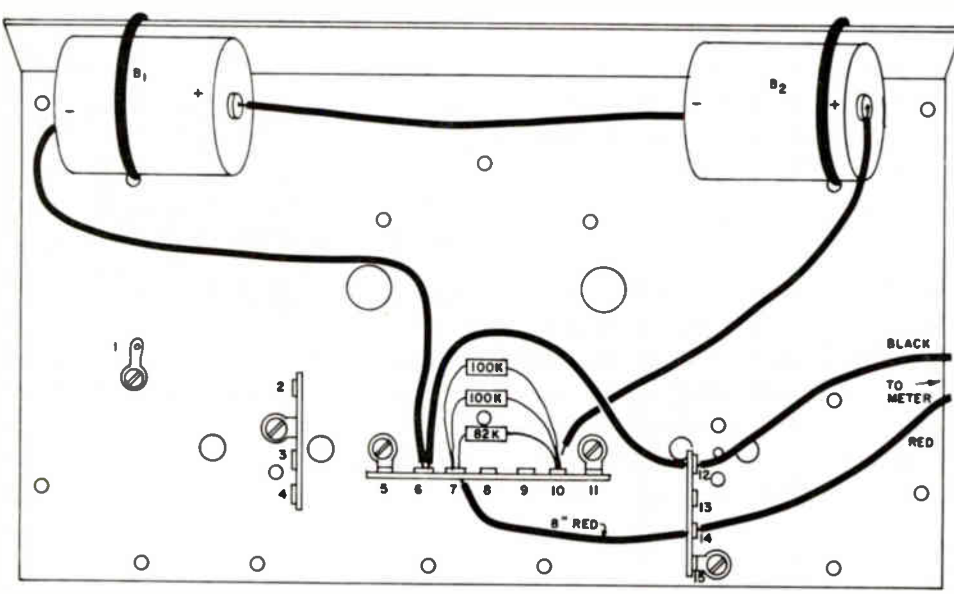


Fig. 8-1. Chassis for Step 1.

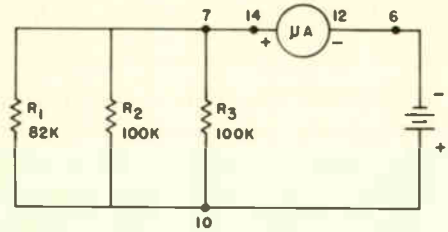


Fig. 8-2. Schematic of circuit for Step 1.

that a defect in some stage other than the power supply is causing the transformer to overheat.

In this experiment you will prove that the sum of the individual branch currents in a parallel circuit is equal to the total circuit current.

Experimental Procedure: In addition to the parts already on the experimental chassis you will need the following parts:

2 **100K-ohm resistors**
1 **82K-ohm resistor**
Hookup wire

1 9
4' 2/8

You should have the two flashlight cells connected to form a 3-volt battery on your chassis. For this experiment, you must wire your circuit as shown in Figs. 8-1 and 8-2.

Solder the two 100,000-ohm resistors and the 82,000-ohm resistor to terminals 10 and 7. You should then have two 100,000-ohm resistors and the 82,000-ohm resistor connected in parallel. Connect the black wire from the negative terminal of B_1 to terminal 6. Next strip 1/4" of insulation from each end of a 5" length of black hookup wire and solder this wire to terminals 6 and 12 as indicated in Fig. 8-1.

Remove about 1/4" of insulation from each end of an 8" length of red hookup wire. Solder one end to terminal 14 and solder the other end to terminal 7. Do not connect the positive battery lead at this time.

Before you go to Step 1, carefully check your work with the schematic of Fig. 8-2 and the pictorial drawing of Fig. 8-1. Make sure you have made all of the connections correctly.

Step 1: To measure the total current flow in a parallel circuit.

Touch the positive battery lead (connected to the positive terminal of B_2) to terminal 10. Observe the readings on the 30-volt scale on your meter. Remove the positive battery lead from terminal 10 after recording your reading in the space provided for Step 1 in Fig. 8-3.

STEP	READING
1	14.9
2	4.9
3	4.9
4	6

Fig. 8-3. Record your reading for Experiment 8 here.

With the arrangement shown in Fig. 8-2, the three resistors are in parallel and the current which you measured is the total current flowing in the circuit.

Step 2: To measure the current through a 100,000-ohm resistor.

You will use the circuit shown in the schematic diagram in Fig. 8-4. To change your wiring to make this circuit, unsolder the lead of the 82,000-ohm resistor and the lead of one 100,000-ohm resistor from terminal 7. Solder these two leads to terminal 6.

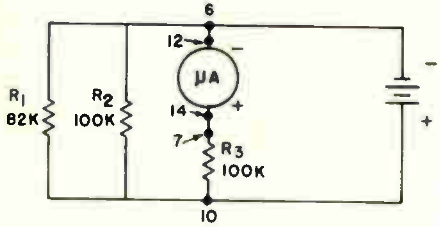


Fig. 8-4. Circuit for Step 2.

As you can see in the schematic, when the circuit is completed, current will flow through all three resistors. However, only the current through R_3 the 100,000-ohm resistor connected to terminal 7 will flow through the meter.

Touch the positive battery lead to terminal 10. Read the meter on the 30-volt scale and record your reading for Step 2 in Fig. 8-3.

Step 3: To measure the current through the second 100,000-ohm resistor, R_2.

Fig. 8-5 shows the circuit. To make the necessary changes, unsolder the 100,000-ohm resistor lead from terminal 7 and resolder it to terminal 6. Then unsolder the lead of the other 100,000-ohm resistor from terminal 6 and resolder it to terminal 7.

Touch the positive battery lead to

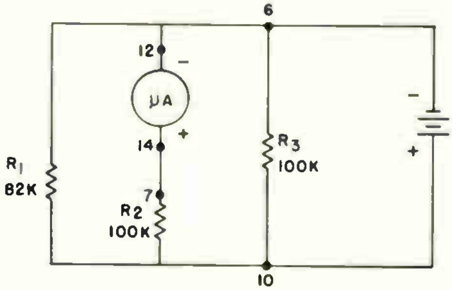


Fig. 8-5. Circuit for Step 3.

terminal 10 and observe the meter indication on the 30-volt scale. Remove the battery lead from terminal 10 after recording your reading in the space for Step 3 in Fig. 8-3.

Step 4: To measure the current through the 82,000-ohm resistor.

Modify the circuit as shown in the schematic in Fig. 8-6. Unsolder the 100,000-ohm resistor lead from terminal 7 and resolder it to terminal 6. Unsolder the lead of the 82,000-ohm resistor from terminal 6 and resolder it to terminal 7. This places the meter in the 82,000-ohm resistor circuit only.

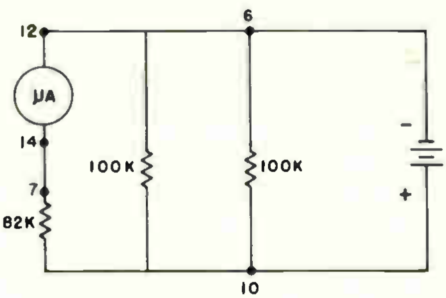


Fig. 8-6. Circuit for measuring the current through the 82K-ohm resistor.

Touch the positive battery lead to terminal 10. Read the meter on the 30-volt scale. Remove the positive battery lead from terminal 10 after recording your reading in the space provided for Step 4 in Fig. 8-3.

Discussion: In this experiment, you have measured the total current flowing in a circuit, and also the current flowing in the individual branch circuits. Since you used two 100,000-ohm resistors, you should have found that the current flowing through these resistors was the same.

In other words, the readings you obtained in Steps 2 and 3 should have been equal.

In actually taking this measurement, you may have found a slight variation because the resistors have a tolerance of 10%. Even though we call the resistor a 100K-ohm resistor, its actual resistance may be as much as 10,000 ohms more or less than 100,000 ohms. The resistance in series with the meter, therefore, may be any value between 90,000 and 110,000 ohms, which would account for the variation in your measurements. The 82,000-ohm resistor can have any value between 73,800 ohms and 90,200 ohms. Therefore, it is actually possible to have little or no difference in reading between the 82,000-ohm resistor and one or both of the 100,000-ohm resistors. In most electronics work, resistor values are not critical, and it is much more economical to use a resistor having a 10% tolerance, than it is to use a resistor having a 1% tolerance.

To show that the total current flowing in the circuit is equal to that in the individual branch circuits, add your readings for Steps 2, 3, and 4, and compare the result with the readings for Step 1. The sum of the readings recorded in Steps 2, 3, and 4 should be approximately equal to the reading you have recorded in Step 1.

Instructions for Statement No. 8: For this Statement, you do not need to take any additional measurements. You can use the readings you took in the experiment to answer the statement.

Answer the statement and unsolder and remove the two 100,000-ohm resistors and the 82,000-ohm resistor from terminals 6, 7, and 10. Remove the red wire from terminals 7 and 14 and remove the black wire from terminals 6 and 12.

Statement No. 8: When I measured the individual branch currents flowing in the circuit consisting of two 100K-ohm resistors and one 82K-ohm resistor, I found that the current was greatest

(1) through one of the 100K-ohm resistors.
(2) through the 82K-ohm resistor.

This shows that maximum current will flow through the branch in the parallel circuit having

(1) the lowest resistance.
(2) the highest resistance.

EXPERIMENT 9

Purpose: To show that a microammeter can be used as a voltmeter if a suitable resistor is placed in series with the meter.

Introductory Discussion: You have seen how a microammeter can be used to indicate the presence of current and to show if the current increases, decreases, or remains constant when circuit conditions are changed. We have not been able to measure the current in microamperes or milliamperes because the meter is not calibrated to read in microamperes. It would be possible to calculate the current from your scale readings, but since we are not interested in exact values, it is not necessary.

Your meter is a 0-200 microammeter. This means that a current of 200 microamperes must flow through the meter to give a full-scale deflection. In other words, when the pointer is at 30 on the 30-volt scale, the current flowing through the meter is 200 microamperes. (Microamperes is abbreviated μa.)

If your meter had a 200 microampere (200 μa) scale printed on it, and we inserted a resistance in series with the meter, and then connected the combination across a voltage source, you could read the current through the meter. The current would depend upon two things: the voltage of the source, and the resistance we placed in series with the meter. If we knew what the resistance was, we could read the current from the meter, and then calculate the voltage by using Ohm's Law. Ohm's Law states that $E = I \times R$. So we would multiply the current in amperes by the resistance in ohms to get the voltage of the source.

This arrangement has one drawback, however. It takes quite a bit of time to make the mathematical calculations. Actually, it is not necessary to do this, because as long as the resistance remains unchanged, the current will depend only on the voltage. Therefore, we can calibrate the meter to read directly in voltage. Now let us see how we can find out what resistor we need in order to use the 3-volt range on the meter.

To do this, we again turn to Ohm's Law. One form of Ohm's Law states that the resistance is equal to the amount of voltage divided by the amount of current. In other words, $R = E \div I$. We want the meter to read full scale when the voltage applied is 3 volts; therefore E will be equal to 3. We know that the meter is a 200 microampere meter; it takes 200 microamperes (200 μa) of current to make the meter read full scale. Converting this value to amperes, we get .0002 ampere. Now, to get the value of resistance needed, we divide 3 by .0002. This will give us 15,000. Therefore, the resistance value that should be added to the circuit is 15,000 ohms.

If we want to build an accurate meter, we will have to subtract the resistance of the meter itself from the resistance to be placed in series with the meter. However, the resistance of your microammeter is small compared to 15,000 ohms, so we will simply connect the 15,000-ohm resistor in series with the meter to give us a voltmeter that will read 3 volts on full scale. The error introduced by disregarding the meter resistance will be unimportant in this experiment.

As mentioned earlier, the scales on the meter are labeled 0 to 12 and 0 to 30. For the 3-volt scale, read the 0 to 30 volt scale but mentally divide the reading by 10, or place a decimal point before the last digit. For example, for a full scale reading, the pointer will point to 30. Dividing this by 10 gives us 3.0. Similarly, a reading of 20 is actually 2.0 on the 3-volt scale, just as 15 is 1.5 volts, 5 is 0.5 volts and so on.

Experimental Procedure: In this experiment, in addition to your meter and chassis with parts mounted, you will need the following parts:

1 15,000-ohm resistor
Hookup wire

Prepare 1′ lengths of red and black hookup wire. Remove about 1/2″ of insulation from each end of the wires.

Step 1: To convert your microammeter to a voltmeter.

Unsolder the red meter lead from terminal 14 and reconnect to terminal 13. Connect the 15,000-ohm resistor from terminal 13 to terminal 14. Solder terminal 13. Solder one end of the 1′ length of red wire to terminal 14. Leave the other end free.

Solder one end of the 1′ length of black hookup wire to terminal 12. The meter can now be used as a 0 to 3 volt voltmeter. The black wire connected to terminal 12 is your *negative voltmeter lead* and the red wire connected to terminal 14 is your *positive voltmeter lead.*

Step 2: To measure the voltage of the two flashlight cells connected in series.

The cells should still be connected in series as they were in the last experiment. Touch the negative meter lead (the black wire connected to terminal 12) to the negative terminal of the 3-volt battery, and touch the positive meter lead to the positive terminal of the 3-volt battery. Fig. 9-1 shows the circuit used in this step. Note the reading on the 3-volt scale on your meter. The reading should be approximately full scale, indicating a voltage of about 3 volts. The reading might be a little higher or lower than full scale, depending upon the tolerance of the 15,000-ohm resistor and the actual voltage of your battery. In general, new flashlight cells have a terminal voltage of 1.55 volts which drops to about 1.5 volts when the cells are heavily loaded (are supplying large current). In this circuit there is hardly any load so the battery voltage should be 2 times 1.55 volts or

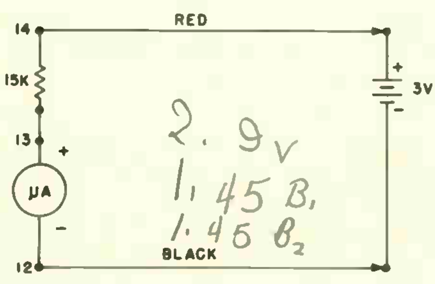


Fig. 9-1. Circuit to measure battery voltage.

about 3.1 volts which would make your meter read slightly above full scale.

Step 3: To measure the voltage of a single flashlight cell.

Touch the positive voltmeter lead to the positive terminal of one cell, and touch the negative meter lead to the negative terminal of the same flashlight cell. Note the reading on the meter. The reading should be about center scale, indicating a voltage of approximately 1.5 volts. Check the voltage of the other flashlight cell in the same way.

Discussion: The meter that you constructed in this experiment is often referred to as a 5,000-ohms per volt voltmeter. We usually write this as 5,000 ohms/volt. Notice that to convert the meter to a 3-volt voltmeter, we use a 15,000-ohm resistor. If we wanted to convert the meter to a 12-volt meter, we would have used a 60,000-ohm resistor. If we wanted to convert the meter to a 30-volt meter, we would have used a 150,000-ohm resistor. In all cases, to find the resistance needed, we multiply the required full scale voltage by 5,000.

In the early days of electronics, meters with sensitivities of 1,000 ohms/volt and 5000 ohms/volt were the only types available. Today most meters have sensitivities of 20,000 ohms/volt to 150,000 ohms/volt.

The sensitivity of the meter used in service work is important. If the meter has a sensitivity of only 5,000 ohms per volt, it is quite possible that you will not get an accurate indication of the voltage in a circuit. In the next experiment we will show you exactly how this can happen and why the sensitivity of the meter is important to the serviceman.

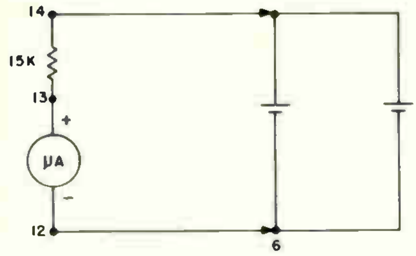


Fig. 9-2. Circuit for Statement 9.

Another type of meter, the vacuum tube voltmeter or the transistor voltmeter, has an even higher sensitivity than the meters previously discussed. For this reason most electronics technicians prefer this type to the simple voltmeter of the type you have just constructed. You will build a sensitive transistor voltmeter in the next Training Kit.

Instructions for Statement No. 9: In this statement, you are to measure the voltage of the two flashlight cells when they are connected in parallel. To do this, unsolder the red wire from the positive terminal of cell B_1 which is on the left side of your chassis. This wire should still be attached to the negative terminal of cell B_2. Solder the free end of this wire to terminal 6. Solder the free end of the positive battery lead (the wire soldered to the positive terminal of B_2) to the positive terminal of B_1. Check your work against Figs. 9-2 and 9-3.

Touch the positive voltmeter lead to the positive terminal of battery B_1 or B_2 and the negative meter lead to terminal 6. Note the reading on your meter, and answer the statement.

Unsolder the red wire from the positive terminal of battery B_1 and push the free end out of the way. Unsolder the red wire from terminal 6 and solder the free end to the positive terminal of flashlight cell B_1. Leave the 15,000-ohm resistor connected to terminals 13 and 14, and the

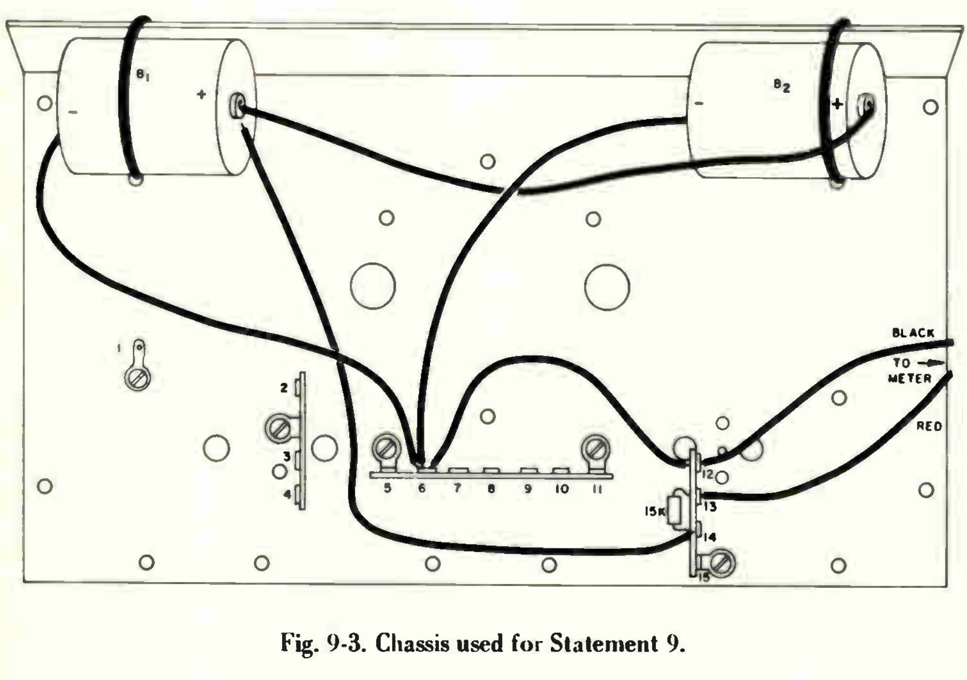


Fig. 9-3. Chassis used for Statement 9.

red and black voltmeter leads connected to terminals 12 and 13.

Statement No. 9: When I measured the voltage of the two parallel-connected flashlight cells, I found that it was approximately

(1) 3 volts.
(2) 1.5 volts.
(3) 0.

EXPERIMENT 10

Purpose: To show that in a series circuit, there is a voltage across each part, that the sum of the voltages is equal to the source voltage, and that a voltmeter can upset the voltage division.

Introductory Discussion: You already know that if you connect your voltmeter across the battery, you get an indication of the voltage produced by the battery.

When the battery is connected to a series circuit, the battery voltage drives electrons through the circuit. The electrons, in moving through each part of the circuit, set up a voltage across each part. If you accurately measure the voltage across each part and add these voltages, you will find that the sum of these voltages is equal to the source voltage.

In this experiment, you will construct a simple circuit and measure the voltage across each of the individual parts in the circuit to prove that the sum of the voltages is equal to the battery voltage.

Experimental Procedure: In this experiment, in addition to the meter and chassis, you will need:

1 470-ohm resistor
1 680-ohm resistor
1 1,000-ohm resistor
2 100,000-ohm resistors
1 82,000-ohm resistor
2 Flashlight cells

Your flashlight cells should still be connected in series to form a 3-volt battery.

Construct the circuit shown in Fig. 10-1. Solder one lead of a 1,000-ohm resistor to terminal 6. Push the free lead through the slot in terminal 4. Connect the 680-ohm resistor between terminals 3 and 4 and solder terminal 4. Connect the 470-ohm resistor between terminals 2 and 3. Solder terminal 3. Solder the resistor lead and the free end of the positive battery lead to terminal 2.

Step 1: To measure voltages in a low-resistance series circuit.

You will use your 3-volt meter to measure the voltages in the circuit shown in Fig. 10-1.

To measure the source voltage, hold the negative voltmeter lead on terminal 6, and touch the positive meter lead to terminal 2. Observe the meter on the 3-volt scale and place your reading in the space for the source voltage in Fig. 10-2.

Next, while holding the negative voltmeter lead on terminal 6, touch the positive lead to terminal 4 and measure

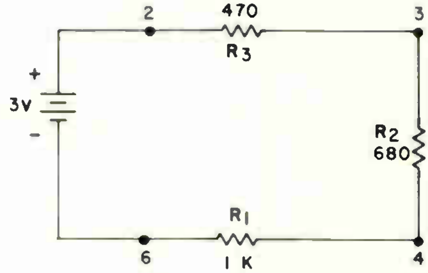


Fig. 10-1. Circuit for Experiment 10.

1.35
.85
2.20
.65
2.85

	READINGS
R_1	1.35
R_2	.85
R_3	.65
$R_1+R_2+R_3$	2.85
SOURCE	2.9

Fig. 10-2. Record your reading for Step 1 here.

the voltage across resistor R_1. Record this voltage in the space provided for R_1 in Fig. 10-2.

Move the positive meter lead to terminal 3 and the negative meter lead to terminal 4 and measure the voltage across resistor R_2. Record your reading in the space provided for R_2 in Fig. 10-2.

To measure the voltage across resistor R_3, touch the positive meter lead to terminal 2 and the negative meter lead to terminal 3. Read the voltage on the 3-volt scale on your meter and record your reading in the space provided for resistor R_3, in Fig. 10-2. Now add together the three voltages you recorded for R_1, R_2, and R_3 and put this value in place labeled $R_1 + R_2 + R_3$ in Fig. 10-2.

Unsolder the positive battery lead from terminal 2, to open the circuit. Unsolder and remove the 470-ohm, the 680-ohm and the 1,000-ohm resistors.

Step 2: To measure voltage in a higher resistance series circuit.

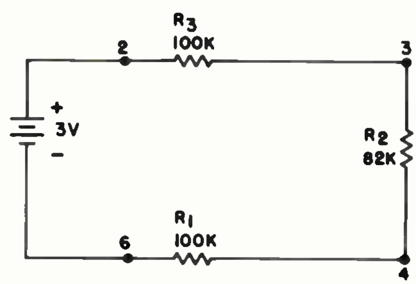


Fig. 10-3. Circuit used in Step 2.

Construct the circuit shown in Fig. 10-3. Solder one lead of a 100,000-ohm resistor, R_1, to terminal 6. Connect the other lead to terminal 4. Connect one lead of the 82,000-ohm resistor to terminal 4 and solder. Connect the other lead of this resistor to terminal 3. Connect and solder the other 100,000-ohm resistor, R_3, from terminal 3 to terminal 2. To complete the circuit, solder the positive battery lead to terminal 2.

Measure the voltage applied to the circuit by holding the positive voltmeter lead on terminal 2 and touching the negative voltmeter lead to terminal 6. Read your meter on the 3-volt scale and record your reading in the space reserved for the source voltage in Fig. 10-4.

	READINGS
R_1	.25
R_2	.2
R_3	.25
$R_1+R_2+R_3$	.75
SOURCE	2.9

Fig. 10-4. Record your readings for Step 2 here.

Using the same technique you used in Step 1, measure the voltages across each of the three resistors. Record these voltages in the spaces provided for it in Fig. 10-4. Now add together the three voltages you recorded for R_1, R_2, and R_3 and put this value in the place labeled $R_1 + R_2 + R_3$ in Fig. 10-4.

When you have made your readings, disconnect the positive battery lead from terminal 2.

Discussion: In Step 1, you measured the source voltage applied to the circuit and you measured the voltage across each resistor. You found that the source voltage was about 3 volts. This is the voltage across the three series-connected resistors.

The voltage drop across R_1 was about 1.4 volts, across R_2 it was about .95 volts and across R_3 about .7 volts. When you added the voltage drops across resistors R_1, R_2 and R_3, you should have found the sum to be approximately equal to the source voltage.

The voltage across a resistor is determined by the current in the resistor and the value or resistance of the resistor. As you would expect from Ohm's Law, the largest resistor has the largest voltage across it while the smallest resistor has the smallest voltage.

Another important point that you should learn from the experiment is how to connect the voltmeter to measure voltage. A voltmeter is always placed in parallel with or across the voltage you are interested in measuring.

To measure the battery voltage in the circuit in Fig. 10-1, you measure between terminals 2 and 6, which are directly across the battery. To measure the voltage across resistor R_1, you measure the voltage between terminals 4 and 6. In every case, the positive meter lead is connected to a more positive point than is the negative meter lead. The negative battery terminal is the most negative point in the circuit. In Fig. 10-1, the voltage at terminal 4 is more positive than the voltage at terminal 6. Similarly, the voltage at terminal 3 is more positive than the voltage at terminal 4 and the voltage at terminal 2 is more positive than the voltage at terminal 3.

You must always connect your voltmeter so the positive lead is connected to the more positive terminal. Otherwise, your meter will read backwards and may be damaged.

In Step 2, you also found that the supply voltage is about 3 volts. However, when you add the three readings taken for Step 2, you will find that the three voltage drops do not add up to 3 volts. At first glance, you might think that something is wrong.

Actually, the error is due to your meter resistance. The circuit you have when you connect the meter across R_1 is shown in Fig. 10-5.

Since the resistance of the voltmeter, which consists of the 15,000-ohm resistor and the resistance of the 0 to 200 microammeter, is only slightly more than

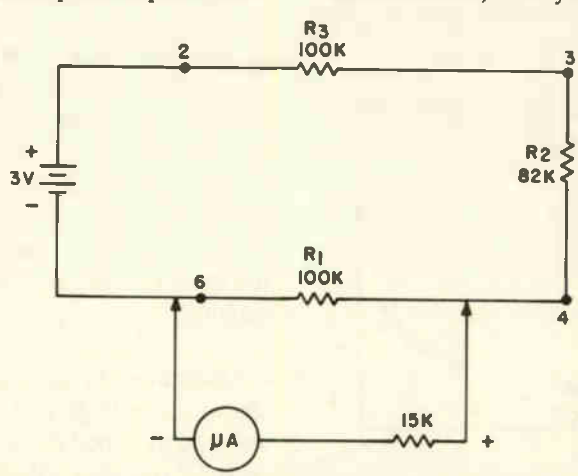


Fig. 10-5. Circuit for Experiment 10 with meter connected across R_1.

15,000 ohms, the total resistance of R_1 and the meter in parallel with it is much less than the 100,000-ohm value of R_1 alone. The resistance of the combination is very close to 15,000 ohms. Therefore, most of the voltage will be dropped across resistor R_2 and R_3, and very little will appear across the combination of R_1 and the meter circuit in parallel with it.

The same thing is true when you connect your meter across R_2 and R_3. Each time you connect the meter across a high resistance, the parallel combination of the meter and the resistor across which you are measuring voltage forms a resistance that is much lower than the original resistor value. The entire circuit, therefore, is upset and the voltage you measure is not the true voltage that is across the resistor when the meter is not connected to it.

To prevent such erroneous readings, you need a meter with a very high resistance. If your meter had a sensitivity of 100,000 ohms per volt on the 3-volt scale, you would have a total resistance of 300,000 ohms in the voltmeter circuit. Then, when you make your measurements, you would be placing 300,000 ohms in parallel with 100,000 ohms. Although the meter resistance is still low enough to upset the circuit you used in this experiment, it would not upset the circuit nearly as much as the 15,000-ohm resistance did.

The resistor values used in the first step were much less than the combined value of the meter and its series resistor. For this reason, the meter resistance has very little effect on the readings you made in the circuit in Step 1.

In your next set of experiments, you will build a transistorized voltmeter. This meter has a resistance of several megohms. Thus, when you use this meter to measure the voltage in high resistance circuits, you will get a more accurate voltage indication than you would using a simple voltmeter such as that which you used in this experiment.

Instructions for Statement 10: For this statement, you are to measure the voltage drop across two resistors. R_1 and R_2 in Fig. 10-3. Solder the positive battery lead to terminal 2. Touch your negative meter lead to terminal 6 and the positive meter lead to terminal 3. Observe your meter indication on the 3-volt scale and write the reading in the margin on this page.

Statement No. 10: When I measured the voltage across resistors R_1 and R_2, I found that the voltage was

(1) less than 1 volt.
(2) approximately 1.5 volts.
(3) approximately 3 volts.

After you have answered the statement, unsolder the positive battery lead from terminal 2 and push it out of the way. Unsolder and remove the red and black meter leads and all other parts and wires connected to terminals 12, 13, and 14. Straighten and clean the leads of the 15,000-ohm resistor and set it aside.

You should still have the two flashlight cells connected in series and attached to the chassis. You should also have the two 100K-ohm and one 82K-ohm resistors soldered to terminals 2, 3, 4 and 6. These resistors and the 3 volt battery will be used in the first experiment of the next training kit.

Looking Ahead

This completes the experiments in Kit 1T. One of the most important things you should have learned is how to solder correctly. As we pointed out, you will make soldered connections in all your electronics work, and one poorly soldered connection can cause you hours of unnecessary work.

In later kits you will have further experience in reading the meter. Of course, you will use the meter throughout your Practical Demonstration Course. You should have learned how to read the 0 to 30 volt and 0 to 12 volt scales in this group of experiments; in the next kit, you will learn how to read the ohmmeter scale. You also demonstrated a number of important basic circuit actions. It is much easier to study and understand the more advanced circuits that you will encounter later if you understand how the simple circuits work, and what changes in the circuit will do to voltage distribution and current flowing in the circuit.

In the next kit, you will build a transistorized voltmeter (tvom). You will find this work extremely interesting, and at the same time you will be building an instrument that will be useful to you in the rest of your experiments, and later when you start work in any branch of the electronics field. In addition to building the tvom you will continue with your studies of basic circuits.

Check to see that your training Kit Report sheet is completed and send it to NRI for grading.

While waiting for the return of this Report and for your next kit, prepare the parts you have left over for use in later kits. The parts left over are shown in Table I. *Remove the meter from its box and unsolder and remove the diodes and wires from the meter terminals.* Also, remove the solder lugs. Clean the meter terminals, and place the meter back in its box. Since the meter is a delicate instrument, be sure to put it in a safe place.

TABLE I

1	Pot mtg. bracket	2	4700-ohm resistors
1	Chassis plate	1	6800-ohm resistor
1	Etched circuit board with tube socket	1	15,000-ohm resistor
1	Marking crayon	1	22,000-ohm resistor
1	Meter	1	1/4" X 6-32 machine screw
1	6-32 hex nut	2	1/4" X 4-40 machine screws
2	4-40 hex nuts	2	Large solder lugs
1	1000-ohm potentiometer	2	Silicon diodes
1	470-ohm resistor		Hookup wire
1	680-phm resistor		Solder
3	1000-ohm resistors		

IMPORTANT: Be sure to save ALL PARTS from this Kit, including screws and nuts, because you will need them later. Keep small parts in individual envelopes or boxes.

The following parts are attached to the chassis plate:

- 2 Flashlight cells
- 1 3-lug terminal strip
- 1 4-lug terminal strip
- 1 7-lug terminal strip
- 1 Small solder lug
- 5 1/4" X 6-32 machine screws
- 5 6-32 hex nuts
- 2 100,000-ohm resistors
- 1 82,000-ohm resistor

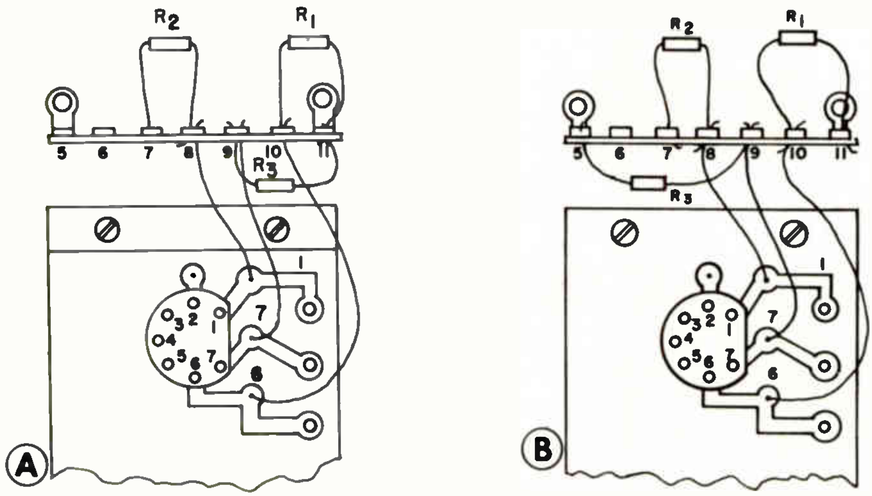


Fig. 4-6. Examples of how you could have wired the circuit used in Experiment 4.

Important Notice

As you use your soldering iron, a scale will accumulate on it. Eventually this scale will keep the iron from heating properly, and you will have to remove it. To do so, remove the tip from the barrel. Remove the scale from the tip and tap the end of the barrel against the workbench to loosen and remove the scale in the barrel. Refile the tip, if necessary, and put it back in the barrel.

If you have a soldering gun, poor contact may develop between the tip and the metal terminals of the gun. This can be eliminated by loosening and then tightening the nuts holding the tip in place. Make sure the nuts are tightened securely. Clean and re-tin the tip when it gets dirty, and replace it when it gets pitted.

Warning

You are expected to make a grade of A, B, C, or D for each group of ten experiments in this Practical Demonstration Course. If any of your reports come back to you marked "Low," you are to repeat the experiments and report statements marked "X" and then send in a complete new set of answers, using the new report blank we will send you. Since this procedure may mean that you will have to dismantle equipment that is to be used as a unit in succeeding experiments, do not begin work on the next Kit until you have received a grade of A, B, C, or D.

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.

Innovation in learning
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ACHIEVEMENT THROUGH ELECTRONICS

nri

TRAINING KIT MANUAL

1T

NATIONAL RADIO INSTITUTE • WASHINGTON, D. C.

TRAINING KIT MANUAL 1T

PRACTICAL DEMONSTRATIONS IN BASIC ELECTRONICS

A Plan For Studying The Experiments

As you know, these Experimental Kits are intended to come to you on a definite schedule. This arrangement is so that you will study the necessary theory in your regular lessons before you carry out any corresponding experiments. This permits you to adopt either of the following plans of study:

1. You may wish to complete one or two experiments in a kit, do a lesson, and then return to the kit for one or two more experiments. This plan permits the experiments in one kit to be finished about the time the next kit is due. Thus, the lessons and experiments run along together, and provide you with a varied program of study.

2. You may prefer to break away from your lessons and to complete all the experiments in a kit at one time before going back to your lessons. This plan has the advantage that you do not waste any time getting out and putting away materials, but it can be followed only if you can leave your equipment set up long enough to finish.

Whichever plan you follow, you can begin NOW with the experiments in this kit. However, be sure to read the preliminary information on pages one through sixteen before you begin, so you will know just how the experiments are to be carried out. In a similar manner, begin on future kits as soon as you receive them.

NOTICE

NRI has set up the CONAR Division of the National Radio Institute to handle the sale of professional test equipment and other electronic equipment. NRI has had unsurpassed experience in the design of quality kits. All CONAR kits are designed and produced by the National Radio Institute. The transistorized volt-ohmmeter you will build as part of your training is the CONAR Model 212. This is the same professional tvom you will see advertised nationwide. Several of the parts you received in this kit, including the meter, will be used in the assembly of your tvom.

KL10M671 1973 EDITION Litho in U.S.A.

INSTRUCTIONS FOR PERFORMING EXPERIMENTS 1 THROUGH 10

LECTURE-ROOM DEMONSTRATIONS YOU PERFORM IN YOUR OWN HOME

How many times have you heard the expression, "Seeing is believing"? Probably many times, because it is human nature to doubt something you cannot see or touch.

Although you can learn how a piece of equipment works from pictures and words, the average person understands better if he can actually set up equipment and make tests himself to see how it works.

You must have a knowledge of theory before you can work successfully in the radio-TV-electronics field. However, unless you know how to apply theory and make tests, your knowledge is useless. Theory and practical application must go hand-in-hand.

The NRI Course of training is a well-balanced combination of theory and practical instruction. Practical demonstrations and experiments are given in this manual and the following manuals.

Doing these experiments will give you actual experience in handling parts and making measurements, and will help you understand explanations of more advanced circuit actions. This type of experience is more valuable to you than class or lecture-room demonstrations by an instructor in which you take no active part, and you can do the experiments at your own convenience.

This practical work with experimental equipment will help you develop confidence in your own ability and will provide what you need to become a practical technician.

The experiments will help you to solve technical problems you will encounter in your work. You will see for yourself what happens when a particular part is defective, and you will learn how to detect and correct errors and how to adjust circuits.

Every experiment in every manual is important, because it is an actual working demonstration. Do not pass over any of them hurriedly, even though you may feel that you already know the results.

If you look underneath the chassis of any modern piece of electronic equipment, you will see that the connections are soldered. A soldered connection is the most reliable type of connection to make in commercial production because it will not deteriorate much during the entire life of the electronic equipment.

When you repair defective equipment, you must be able to find the defective stage and then the defective part. However, the ability to find what is wrong is of little use unless you also know how to take out the defective part and how to solder the connections for a new part. Furthermore, you may often have to unsolder one or more connections during your tests in order to find the defective part.

In the first section of this manual, you will study the fundamentals of soldering and learn how to make a good soldered connection using actual electronic parts. You will make these connections in ex-

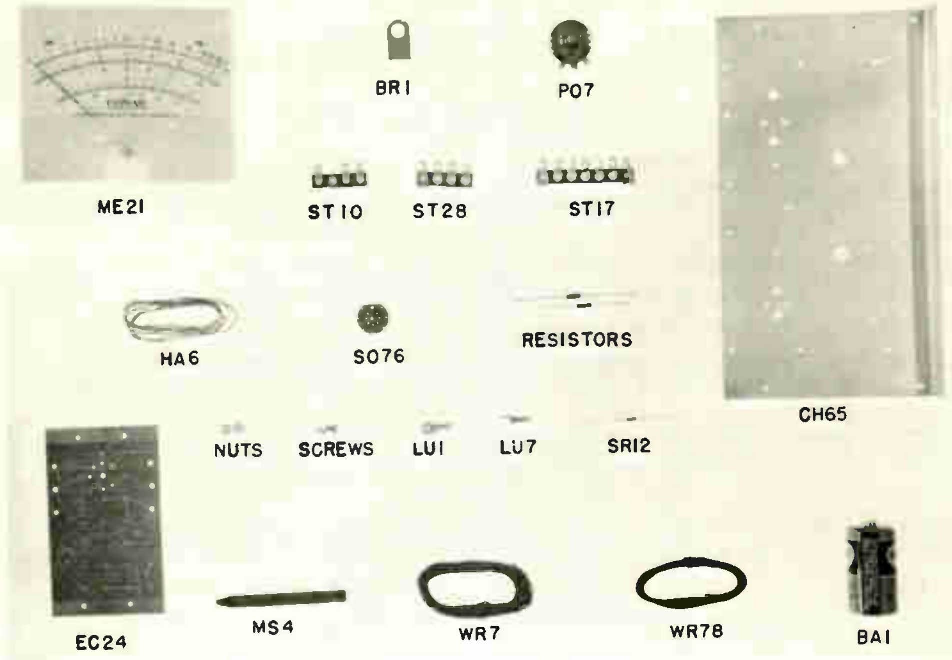


Fig. 1. Parts used in this Experimental Manual are shown here and listed below.

Quan.	Part No.	Description	Price Each
2	BA1	Size D flashlight cell	.20
1	BR1	Pot mounting bracket	.05
1	CH65	Chassis plate	.93
1	EC24	Etched circuit board	1.10
1	HA6	Solder	.41
1	LU1	Solder lug, small	12/.15
2	LU7	Solder lug, large	12/.15
1	ME21	Meter	10.92
1	MS4	Marking crayon	.05
6	NU1	6-32 hex nut	12/.15
2	NU5	4-40 hex nut	12/.15
1	PO7	1000-ohm pot w/lockwasher/nut	.75
1	RE28*	470-ohm resistor	.15
2	RE29	4700-ohm resistor	.15
3	RE30	1000-ohm resistor	.15
2	RE33	22,000-ohm resistor	.15
2	RE36	100,000-ohm resistor	.15
1	RE50	6800-ohm resistor	.15
1	RE52	82,000-ohm resistor	.15
2	RE56	680-ohm resistor	.15
1	RE165	15,000-ohm, 5% resistor	.24
6	SC1	1/4" X 6-32 machine screw	12/.15
2	SC6	1/4" X 4-40 machine screw	12/.15
1	SO76	7-pin tube socket	.12
2	SR12	Silicon diode	.67
1	ST10	3-lug terminal strip	.05
1	ST17	7-lug terminal strip	.12
1	ST28	4-lug terminal strip	.10
1	WR7	25' red hookup wire	.50
1	WR78	6' black hookup wire	.12

*All resistors are 1/2-watt, 10% tolerance unless otherwise specified.

actly the same way that you would in working on commercial equipment. The solder, hookup wire, and other parts that are included in this kit are standard items, just like those that you might use in working on any piece of electronic equipment. In later experiments, you will have practice in working from schematic diagrams. You will also assemble a number of simple circuits to demonstrate some basic electrical laws.

HOW THE MANUALS ARE ARRANGED

The manual for each kit in your Practical Demonstration Course contains the instructions for performing ten experiments. These experiments are numbered consecutively throughout the whole series; Experiments 1-10 are in the first manual, 11-20 in the second, etc. At the end of each experiment is a Statement that you are to complete, so that you can check your work as you go along. When the ten statements have been answered, be sure to submit the training Kit Report to NRI for grading.

In each manual, the figures are numbered to correspond to each experiment. Each figure number has two parts. The first part is the number of the experiment in which it appears, and the second part is the number of the figure within the experiment. For example, Fig. 1-3 would be the third figure in Experiment 1; Fig. 6-2 would be the second figure in Experiment 6. If there are any figures that do not apply to one particular experiment, they will be numbered consecutively in each manual, starting with Fig. 1.

CONTENTS OF THIS KIT

The parts included in your first kit are pictured in Fig. 1 and listed below. Each part that you receive in your kits is assigned a part number. The part number and description appears below Fig. 1. When you need a part for the experiments, you will be given the part value, a description, and in some cases the part number.

Now check the parts that you receive against this list to make certain that you have all of the parts. *Do not lose or discard any of these parts because you will use many of them again in later experiments.*

For your convenience, most of the parts are packed on cardboard under a clear plastic film. This protects the parts during shipment and also makes it easy to inventory your parts. To remove the parts, cut around them with a sharp knife or a razor blade.

IMPORTANT: If any part of this kit is obviously defective or has been damaged during shipment, please return the defective part to NRI for replacement, following the procedure given on the "Packing and Returned Material Slip" enclosed in this kit.

Preparing For The Experiments

Before you start the experiments, there are several things you will need to do. You will need a place to work and tools to work with.

You do not need an elaborate workbench. A folding card table set up near an electrical outlet will be satisfactory. Do not use a metal-top table, because it could cause short circuits that might damage the equipment. If you have to use a metal-top table, cover the top with a nonconductor, such as cardboard or linoleum.

TOOLS YOU WILL NEED

The tools you need to do these experiments are the same as those you will use in all kinds of electronic work. They are pictured in Fig. 2, and listed under the figure. None of these tools are supplied with this kit. Probably you already have some of these tools, since the average home usually does have a few tools for simple repair work.

You can get those tools you do not have from hardware stores, radio-supply

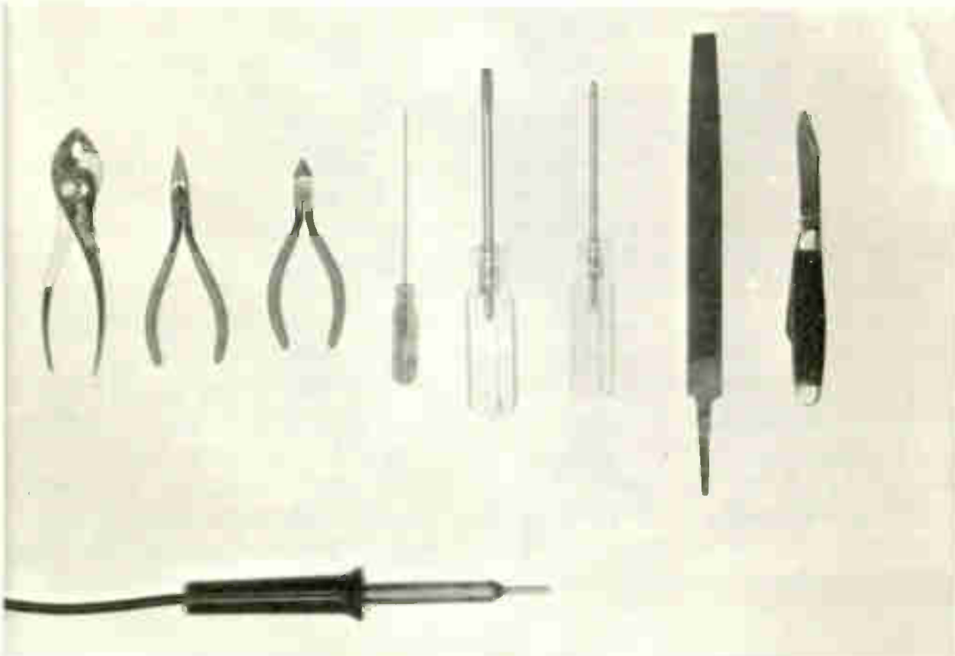


Fig. 2. These are the tools you will need to do these experiments. You probably already have many of them. Get the best ones you can afford; you will be using them throughout your course as well as when you do service work. These tools are not supplied with your kits. From left to right, all-purpose pliers, longnose pliers, diagonal cutters, small screwdriver, medium size screwdriver, Phillips screwdriver, metal-cutting file, and pocket knife. Below the tools is a soldering iron.

houses, or mail-order firms. Since you will use the tools in all of your electronic work, they are a worthwhile investment. Select good quality tools that "feel right" in your hand.

Pliers. The technician needs three types of pliers: longnose pliers, diagonal cutters, and ordinary slip-joint pliers. Each type has its own purpose and should be used for that purpose only. Pliers are designed primarily for holding, bending, and cutting. Many people use them for other purposes so they often ruin them or mar the material on which they are working.

Perhaps the pliers most often used in electronics are the longnose type. Although you may use longnose pliers to hold a nut in position so that it can be started on a screw, you should never use them to tighten nuts. You may spring the jaws so the points will not meet or you could actually break one of the jaws. Use your longnose pliers to hold wires in position for soldering, to remove wires, or for hard-to-reach places.

Diagonal cutting pliers, or "side cutters" as they are often called, are used for most cutting operations. Because the cutting jaws are at an angle, these pliers are ideal for cutting wires close to terminals.

Combination slip-joint pliers, often called "combination pliers," are also in common use. Because of the slip joint, the jaws can be opened wider at the hinge pin so that larger diameters can be gripped. These pliers come in 5, 6, 8, and 10-inch sizes. The thin-type, 6-inch size is best for electronics work.

Screwdrivers. Practically everyone is familiar with the standard screwdriver. The screwdriver is intended for one principal purpose - to loosen or tighten screws. Because the average person uses a screwdriver as a can opener, a pry or pinch bar, and even as a chisel, the screwdriver is one of the most abused tools.

The technician needs three screwdrivers - one with a small blade for loosening setscrews in dial and control knobs and one with a medium blade for general purpose work. He also needs a Phillips screwdriver because screws with a special head known as a "Phillips head" are often used in electronic equipment. Screwdrivers with plastic handles are best because the plastic is a good insulator. Later on you will need a special type of screwdriver, known as an "alignment tool." This is a non-metallic tool for special uses, but you won't need it now.

Files. There are more than twenty types of files. Each type comes in sizes from three to eighteen inches. They may be either single or double cut and are classified according to the different grades of coarseness or fineness, depending upon the size and spacing of the teeth.

The type most often used in electronics is a 10-inch second-cut mill file. It is used to keep the tip of the soldering iron in good condition by removing small amounts of metal, leaving the filed surface smooth. This type of file is also useful in brightening lugs for easier soldering.

Knife. A good knife is useful when preparing wires for connection to other parts; a sturdy pocket knife is fine.

Soldering Iron. The soldering iron is used more often by servicemen than any other tool. Since you will use it often and it is so important, you should choose it carefully. A number of soldering irons suitable for electronics work are shown in

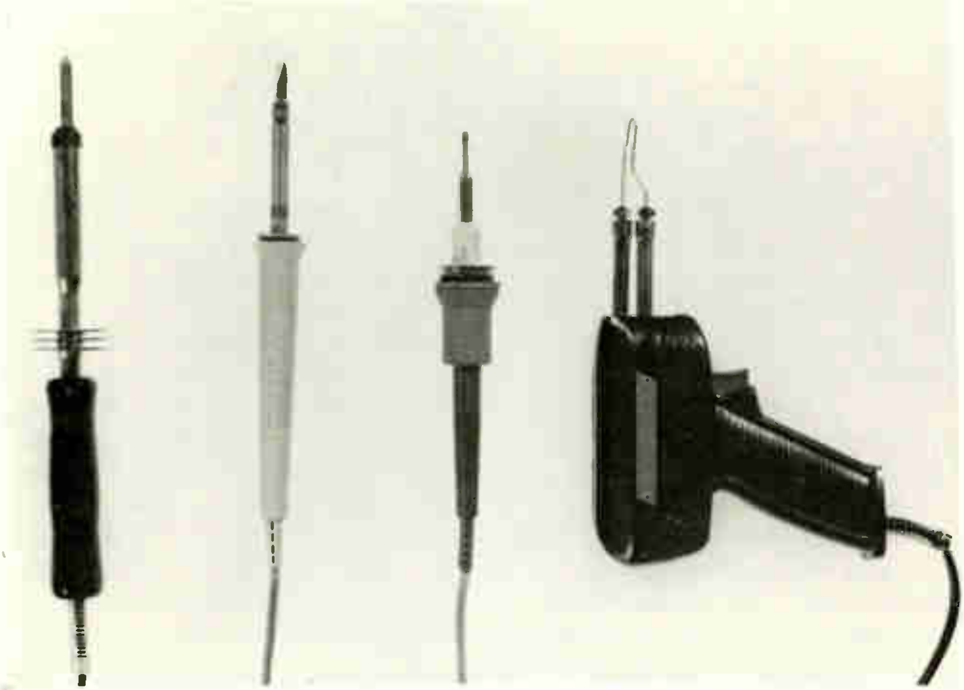


Fig. 3. Several soldering irons suitable for electronics work.

Fig. 3. It is best to buy a soldering iron from a firm that specializes in electronics parts. You should obtain your iron from your local wholesaler, from a mail-order wholesaler, or from the CONAR Instruments Division of NRI.

Hardware stores sometimes carry soldering irons in stock, but they may have only the large type that is used for heavy work, such as automobile radiator repair or roofing work. These irons are too heavy for easy handling and too big to be used where small parts are crowded together.

From left to right in Fig. 3, the first iron is called a medium duty iron. This type of iron generally has a rating of from 50 to 150 watts and is used where a relatively large amount of heat is needed, such as when soldering to the chassis.

The two irons in the center are "pencil" type irons. These types have replaceable heating elements and tips. They are available with various wattage ratings, usually 25 to 40 watts, suitable for general electronic soldering, and 40 to 50 watts, for heavier duty work. These "pencil" irons are the types most suitable for the beginner as they are lightweight and easy to handle. Perhaps the most suitable iron for the beginner would be one like the third iron from the left in Fig. 3. A 37-1/2 element and a chisel-shaped tip make an ideal choice of element and tip.

At the right in the photo is a soldering gun. A gun of this type has the advantage over the iron in that it heats and cools very quickly. Thus, it is excellent for a serviceman making house calls or a technician working on equipment in a plant. He plugs the gun in when he arrives at the job and it is ready for use immediately. Everyone going into electronics, whether on a part-time or full-time basis, will find a gun useful. However, it is not quite as easy to turn out well-soldered connections with a gun as it is with an iron. Therefore, the beginner should start with a conventional soldering iron and learn to use it correctly and later, if he so desires, he can use a soldering gun.

As mentioned previously, the most suitable single iron for general service work and for use in your kits is an electric iron with a tip about an inch long and 1/8" to 1/4" in diameter. The tip should be of the chisel type with two flat surfaces. The wattage rating should not be more than 50 watts, because a high-wattage iron is bulky, and if its barrel touches parts, it may damage them.

When you buy an iron, be sure you get a soldering iron stand with it, to rest the hot iron on when it is not in use. Or get an iron that is designed so that the handle is heavier than the tip end. Then the iron will balance when it is laid down with the tip off the bench.

The average electric soldering iron will operate on ac or dc at 117 volts. Power-line voltages may vary between 110 and 120 volts; an iron designed for 117-volt operation may be used on any voltage between 105 volts and 130 volts.

Although the modern soldering iron is a rugged tool, it should never be abused. Do not use it as a hammer, drop it, or attempt to cool it quickly by plunging it into water. When properly cared for, an iron will last for years.

Although some irons have pre-tinned tips, most tips must be tinned before use. If your iron has a bright, shiny tip or a dull gray tip, it has been pre-tinned, and it is ready for use. If the tip is a natural copper color, you must tin it before using it.

TINNING A SOLDERING IRON

You cannot solder properly unless your soldering iron is properly tinned. Therefore, your first step in learning how to solder is to learn how to tin a soldering iron.

The tip of the soldering iron is made of copper. When an untinned soldering iron is heated, the copper combines with the oxygen in the air, forming a dark coating of copper oxide on the tip of the iron. If you try to use an untinned iron, the copper oxide coating will act as a heat insulator and keep the heat of the iron from the parts you are trying to solder. It will be practically impossible to heat the part sufficiently to melt the solder properly.

You can prevent this by covering the tip of the iron with solder. This is called "tinning" the iron. The solder will form a protective layer over the copper tip so that the oxygen cannot get at the copper and corrode it. The tinned tip will be a good conductor of heat, and you will be able to heat the parts enough to solder them properly.

Preparing the Tip. The first step in tinning a soldering iron is to examine the tip. A photograph of the tip of a new soldering iron that has not been tinned is shown in Fig. 4A, and a photograph of a soldering iron that has been used and needs re-tinning is shown in Fig. 4B. Notice that the tip of the new iron is reasonably smooth, whereas the tip of the iron that has been used is pitted, dirty, and uneven.

If your soldering iron is in good condi-

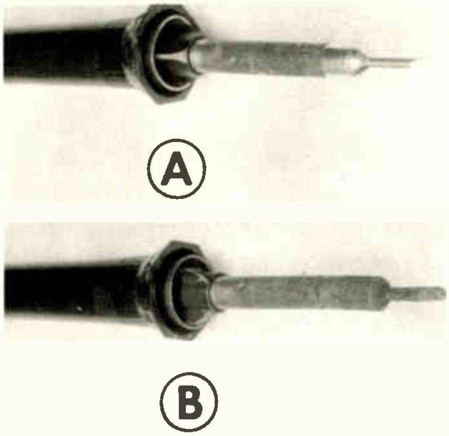


Fig. 4. If your soldering iron is new and has not been tinned as at (A), or if it has been used and is pitted as at (B), it will need tinning.

tion, like the one shown in Fig. 4A, you can plug it into an electrical outlet and start heating it. On the other hand, if you have an iron that has been used and looks like Fig. 4B, you should file the tip smooth before you start to heat it. Even though your iron may be in good condition, read the following instructions carefully, because after your iron has been used for some time, it will become pitted like the one shown in Fig. 4B. You will have to go through this procedure to re-tin it.

To file the tip of the iron, rest the iron on a vise or a similar metal support, as shown in Fig. 5. Grasp the iron in one hand and proceed to file one of the surfaces flat as shown. Try to file the surface at approximately the same angle as that of the original tip. Do not remove any more metal than is necessary, but make sure that you file the surface until all of the dark spots and holes in the surface are gone. When you have completed the operation, the tip of the iron should look as it does in Fig. 6.

After you have filed one surface of the tip, turn the iron over. In other words, rotate the iron 180°, and file the surface flat on the opposite side of the tip. Again, remove no more metal than is necessary, but make sure you file the surface until it is clean. Try to file at the same angle as the first surface, as shown in Fig. 7.

If your iron has a pyramid-shaped tip, turn the iron a quarter turn and file one of the other surfaces. Then turn the iron over and file the last surface. When you

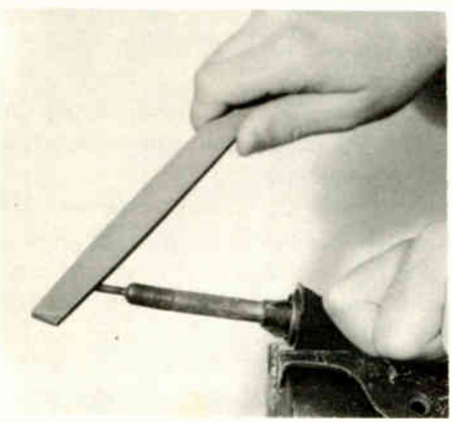


Fig. 5. To file the tip of your iron, hold it against a vise as shown here.

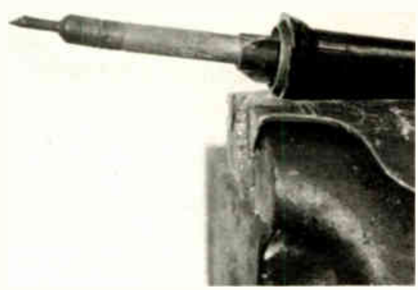


Fig. 6. When you have filed one surface, your iron should look like this.

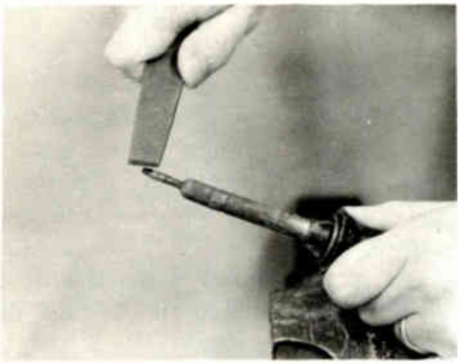


Fig. 7. File the opposite surface at the same angle as the first surface, as shown.

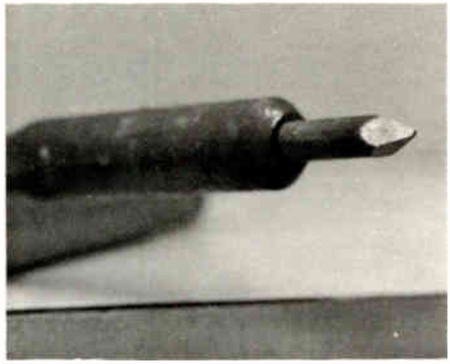


Fig. 8. Your iron should look like this after filing all four surfaces on its tip.

have filed all tip surfaces, the tip of the iron should look like the one shown in Fig. 8. Notice that the sides are approximately even.

Before you start to heat the iron, examine the edges of the flat surfaces on the tip. If the edges are rough, smooth them by careful rubbing with a piece of sandpaper.

Tinning the Iron. After you have prepared the surface for tinning, or if you are tinning a new iron that is in good condition, plug the iron in and wait for it to heat. As the iron heats, periodically touch the end of the solder to the tip so you will know when the iron is hot enough to melt the solder. You should tin it as soon as it reaches a high enough temperature, because the longer an untinned iron is heated, the more copper oxide will form on the tip.

When the iron has reached operating temperature, again rest it on a vise and lightly file one surface as shown in Fig. 5. Once you have filed the surface lightly so that it is shiny, quickly set the file down, pick up the roll of solder, and touch the end of the solder to the tip of the iron. Move the solder around the tip until the entire surface is tinned, as shown in Fig. 9. After you have tinned one surface of the tip, turn the iron and go through the same procedure of lightly filing the other surfaces, and then applying solder.

After you have tinned the surfaces of the tip, use a clean cloth to wipe off any excess solder. Hold the cloth loosely as shown in Fig. 10 to avoid burning your hand. When you have your iron tinned, it is ready for use. Unplug it, and set it aside until you are ready to start soldering.

Fig. 9. How to apply solder to tin the tip of the iron.

Fig. 10. Wiping excess solder from the iron with a piece of cloth.

Notice that the solder you received in this kit contains a rosin core that acts as a cleaning agent and prepares the metal surface to receive the solder. It is difficult to make a good soldered connection using plain solder alone; another material called flux must be applied along with the solder. Rosin flux is used in this case. Only rosin core solder should be used in soldering electronic equipment.

Hardware and other stores sell some solder with an acid core. Acid flux in any form should never be used in electronic equipment. The acid will corrode the leads and terminals and may damage some of the parts. Use only rosin core solder in electronics work; do not use liquid or paste flux. Solder similar to that which we have supplied in this kit should be used in all your electronics work.

> **IMPORTANT NOTICE**
>
> In checking students' problems, NRI has found that poor soldering is more frequently the cause of failure to get proper results than all other troubles combined. Therefore, be sure to perform every step in each experiment to learn all you can about soldering.
>
> DO NOT SKIP ANY STEPS

MOUNTING THE PARTS

Most of your experiments will be carried out on your experimental chassis plate which is shown in the parts photo, Fig. 1. You will mount several parts on the chassis plate before you begin the experiments.

The parts supplied with this kit are shown in Fig. 1 and identified in the list below the photograph.

Gather the following parts and place them on your worktable. Then they will be handy when you are ready to use them:

1	**Chassis plate (CH65)**
1	**7-lug terminal strip (ST17)**
1	**3-lug terminal strip (ST10)**
1	**4-lug terminal strip (ST28)**
1	**Potentiometer mounting bracket (BR1)**
1	**1K-ohm potentiometer (PO7)**
1	**Solder lug (LU1)**
6	**1/4" X 6-32 screws (SC1)**
6	**6-32 hex nuts (NU1)**
1	**Marking crayon (MS4)**

Notice that we have supplied two sizes of screws and nuts. The size of a machine screw is given by its diameter and the number of threads per inch. The first number is the diameter. Thus, the 6-32 screws (SC1) are larger in diameter than the 4-40 screws (SC6), but the 4-40 screws have a finer thread. The length of a screw is given in fractions of an inch.

Follow the instructions as you mount the parts on your chassis and do not attach any parts until instructed to do so.

Place the chassis upright on your worktable so that the holes are positioned as shown in Fig. 11. The bent lip should be away from you and pointing upward. To

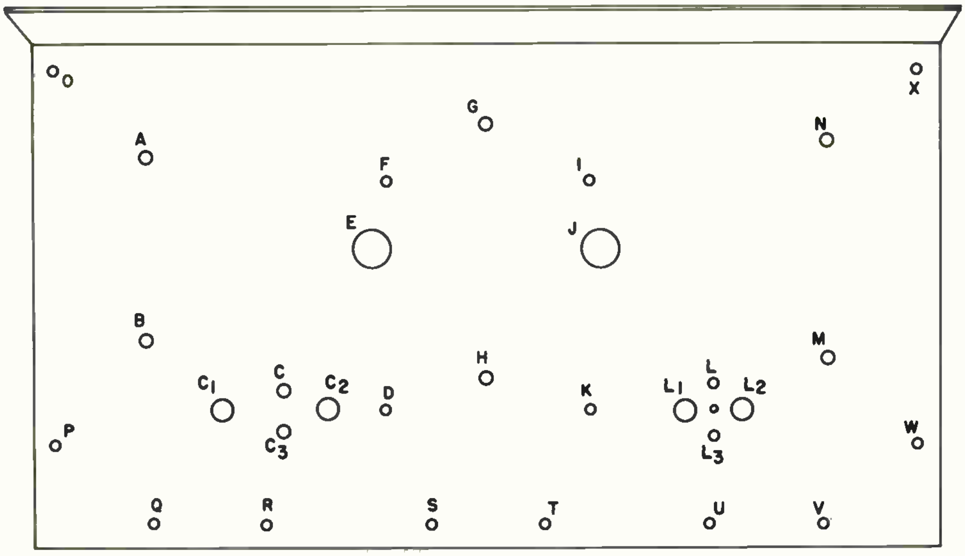


Fig. 11. Chassis hole identification.

help you locate the parts correctly, we have given the holes identifying letters. You can use the marking crayon to label these holes on the chassis. If you prefer, you can put small pieces of tape near these holes and mark on the tape with a pen.

Fig. 12 shows the chassis with the parts

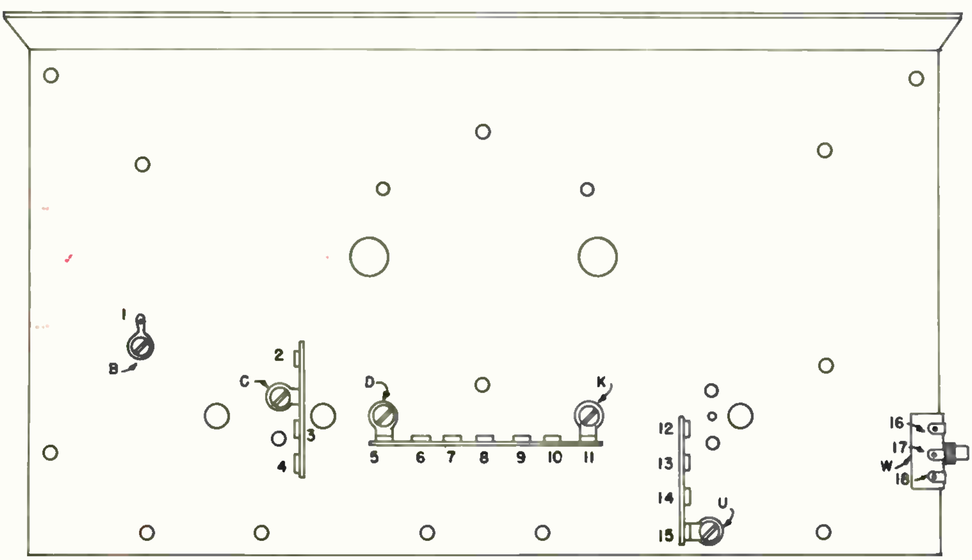
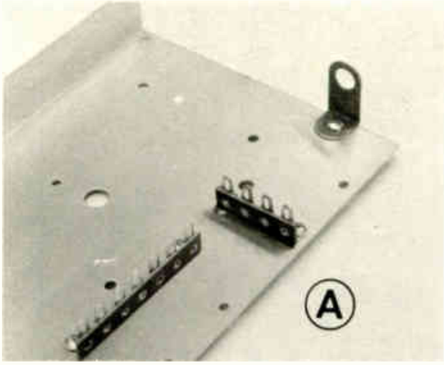


Fig. 12. Parts mounted on the chassis and the terminal identification number.



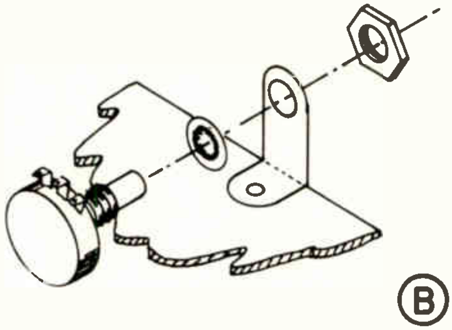


Fig. 13. (A) Mounting the potentiometer bracket; (B) mounting the potentiometer.

mounted on it. Be sure to mount the parts at the correct location and position them as shown in the drawing.

Mount the 3-lug terminal strip at hole C, as shown in Fig. 12. Pass a 1/4" X 6-32 screw down through the mounting foot in the terminal strip and through hole C in the chassis. Attach a 6-32 hex nut. Position the terminal strip as shown and tighten the screw. Hold the nut with pliers as you tighten the screw.

Install the 7-lug terminal strip at holes D and K. Use 1/4" X 6-32 screws and nuts. Position the strip exactly as shown in Fig. 12. Pass a screw down through the left mounting foot and hole D and attach a nut. Pass a screw through the other mounting foot and through hole K. Attach a nut and tighten both screws.

Mount the 4-lug terminal strip at hole U. Use a 1/4" X 6-32 screw and nut. Position the terminal strip as shown in Fig. 12 and tighten the screw.

Install the potentiometer mounting bracket at hole W. See Fig. 13A. Use a 1/4" X 6-32 screw and nut. Pass the screw down through the small mounting hole in the bracket and through hole W in the chassis. Attach the nut and tighten the screw.

Install the potentiometer in the potentiometer mounting bracket. As shown in Fig. 13B, slip the large lockwasher over the shaft and bushing of the potentiometer and slip the bushing through the hole in the bracket mounted on the chassis. Attach the large control nut, turn the potentiometer so its terminals are upward; then tighten the control nut.

Bend the solder lug at about a 45° angle, as shown in Fig. 14. Mount the solder lug at hole B, using a 1/4" X 6-32 screw and nut. Tighten the screw.

The numbers appearing in Fig. 12 are the terminal identification numbers. They will be used throughout this kit for identifying the terminals when making connections.

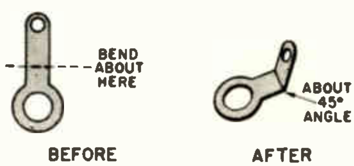


Fig. 14. Before you mount the solder lug, bend it as shown here.

Learning To Solder

Our experience in teaching students has shown that over 75% of the troubles encountered by students and technicians is due to poor soldering! You might think from this that good soldering is difficult, but this is not true. If you watch an experienced man work with a soldering iron, it looks quite simple. The experienced technician follows the two basic rules given below to make good soldering easy.

First: Have the materials to be joined and the tip of the iron clean and free from grease. If the terminals or wires are not bright, scrape them with a knife or with a piece of fine sandpaper until they are clean and bright.

Second: Have the sections to be joined hot enough to melt the solder so that it will run freely to all parts of the connection and form a good bond.

If you follow these two basic rules, you will never have soldering trouble. If you ignore them, you may spend hours looking for defective parts when the trouble is simply a poorly soldered connection.

SOLDERING TECHNIQUES

Perhaps the most important step in making a good soldered connection is to make sure that the parts you are attempting to solder together are clean. For example, if you try to solder a capacitor lead to a terminal strip, and the capacitor lead is not clean, you will find it practically impossible to get the solder to stick to the lead.

All leads, whether they are resistor or capacitor leads or merely wires to be soldered, should be tinned before you attempt to solder them. Most of the resistors and capacitors that you will receive in your kits have been tinned by the manufacturer. However, in the manufacturing processes, the tinned surface sometimes becomes covered with wax or other impurities. These leads should be cleaned and retinned whenever necessary.

You can use approximately the same procedure to tin a lead as you used to tin the tip of your soldering iron. The first step is to clean the lead. You can either scrape the lead carefully with a knife, as

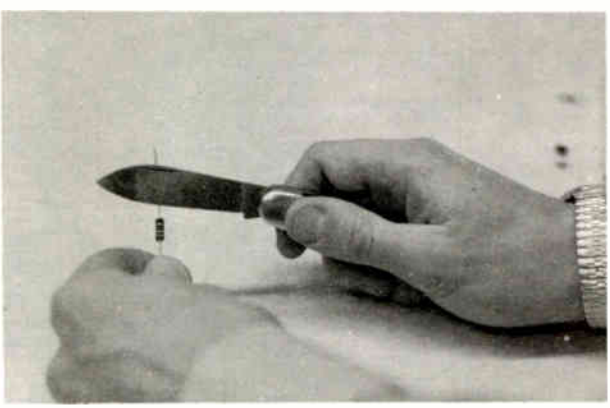


Fig. 15. How to use a knife to clean a resistor lead.

Fig. 16. Using sandpaper to clean a lead.

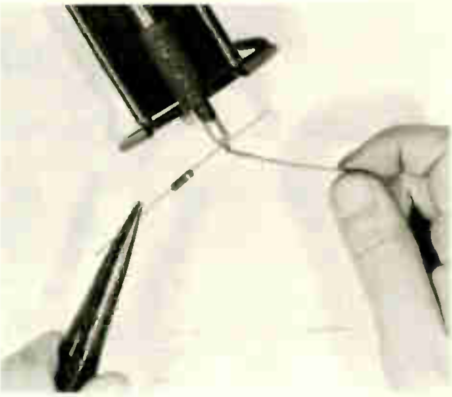


Fig. 17. How to tin a resistor lead.

shown in Fig. 15, or you can use a small piece of fine sandpaper. Hold the lead in the sandpaper, as shown in Fig. 16, and draw the sandpaper over the lead several times.

After you have cleaned the lead, hold the part with your longnose pliers and touch it to the tip of your soldering iron, as shown in Fig. 17. Then touch the solder to the lead. Allow a small amount of solder to melt onto the lead and onto the tip of the iron. Move the lead back and forth through the solder to tin the entire lead. If you apply enough heat to melt the solder thoroughly, the solder will flow smoothly over the lead, as shown in Fig. 18. Tin the other lead in the same way.

Lugs on terminal strips also should be cleaned and tinned before you attempt to solder a wire or a lead to the lug. Usually, brushing over the terminal quickly with a piece of sandpaper will remove any dirt or grease that may be on the terminal. Sometimes it will be necessary to scrape the terminal with a knife or file.

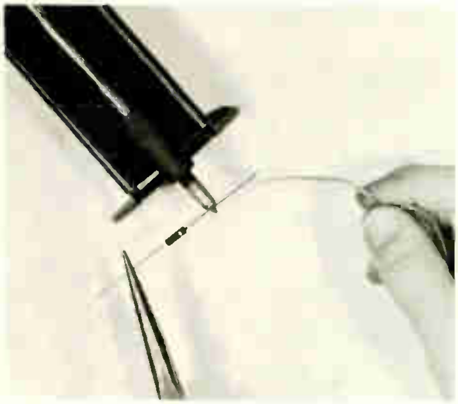


Fig. 18. A tinned resistor lead.

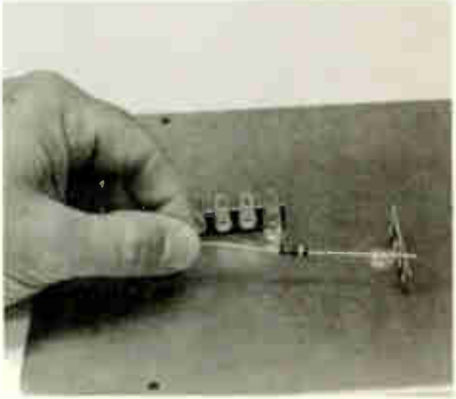


Fig. 19. Making a connection to terminal.

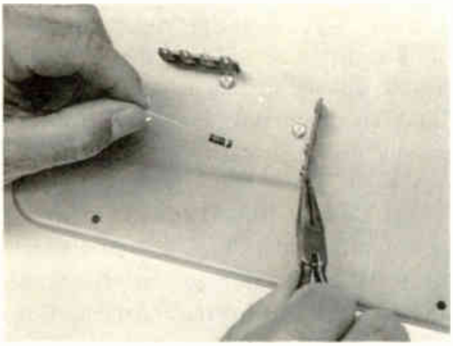


Fig. 20. Bending the lead.

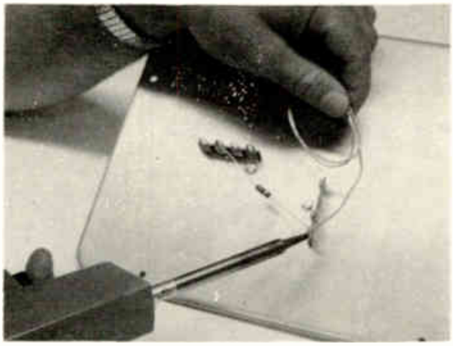


Fig. 21. Soldering a connection.

The tube socket pins and lugs on the terminal strips that you will receive in your kits have been tinned. You should have no trouble in soldering to these terminals. However, before soldering to them, carefully examine them to be sure they are clean. If they are not, clean and tin them to avoid soldering difficulties later.

To solder a lead to a terminal strip or solder lug, place the lead through the opening in the terminal lug, as shown in Fig. 19. Bend the end of the lead slightly as in Fig. 20 so that the lead can be placed in contact with the metal part of the lug. Do not wrap the lead around the terminal strip lug unless you are told to do so. This type of connection is too difficult to remove. Later, when you begin wiring equipment that you will leave assembled permanently, you will wrap the leads around the various terminals in order to insure strong mechanical and electrical connections.

When you have the lead in place, hold your soldering iron against the terminal and against the lead, as shown in Fig. 21, to heat both of them to the solder-melting point. Unless you heat them both, you will not make a good connection.

After they are hot enough, touch the end of the solder to the terminal and lead, so that the solder will flow freely over the resistor lead and the terminal. Do not use too much solder. You want only enough to cover the resistor lead and hold it to the terminal. If you use too much, the solder will flow down the terminal strip and may short to the chassis. A properly soldered connection showing the correct amount of solder is shown in Fig. 22, and a connection with an excessive amount of solder is shown in Fig. 23.

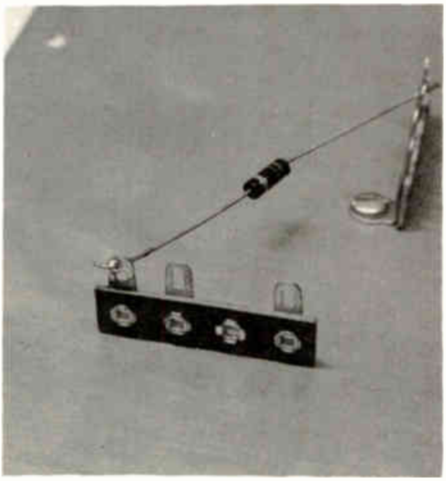


Fig. 22. Good solder connection.

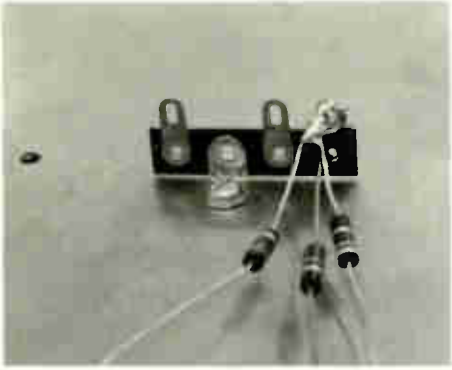


Fig. 23. Poor solder connection (too much solder).

When soldering a connection, do not be in a hurry to get the soldering iron off the connection. In most cases, it is better to hold the iron on the connection a little too long than it is not to hold the iron on long enough. When you are starting to solder, watch each connection carefully. Hold the iron on the connection long enough to allow the solder to flow freely. Solder should melt and flow in, around, and over all the leads you are attempting to solder to a terminal. The solder should also flow freely over the terminal. If you hold the iron on the terminal only long enough to melt the solder and have it start to flow, you will find that you have a rough-looking joint, and the chances are that if you apply pressure to the leads, they will pull loose. On the other hand, if you hold the iron on the joint long enough to allow the solder to melt completely and flow freely over the joint, you will have a smooth-looking connection that will be mechanically strong. This is extremely important - make sure that the solder flows freely over each connection you make.

Using Too Much Solder. Avoid using too much solder. It takes very little solder to make a good electrical connection. Usually, if you heat the terminal and lead sufficiently, you will find that a drop of solder will be all that is needed. Do not hold the soldering iron in place and simply melt more and more solder onto the joint. Once you have one drop of solder flowing around the joint, lift the solder off the terminal, but continue to heat the connection so that the solder that you have on the terminal flows around the leads and over the terminal. This may be all the solder you need. If not, add more solder and allow it to flow into the joint. If you use too much, the solder will flow between the pins and the chassis, and between the chassis and terminal strip lugs.

It is particularly important that you heat large wires thoroughly. You will often find in your radio, TV, or electronics work that you must solder transformer leads in place. Usually the leads from a transformer, particularly the leads from the filament winding on a TV replacement power transformer, will be of a fairly large size. In addition, they are made of copper, which is a good heat conductor. As a result, they can carry away a substantial amount of heat. You will have to be sure that you have the iron in good contact with the lead when making this type of connection.

Etched Circuit Wiring. Etched or "printed" circuit boards are used in many radio and TV receivers as well as in other types of electronic equipment. You can expect to have to wire and to repair circuit boards. Therefore, you should know how to do so.

Examine the etched circuit board included in your kit (NRI part EC24). This is fairly typical of the boards used in commercial equipment. The board consists of a sheet of phenolic, which is an insulating material, with a pattern of copper foil strips bonded to one side. Notice that the copper foil connects together holes in the circuit board. When parts are mounted on the board with their leads extending through these holes and soldered to the copper, the copper foil provides the electrical paths which connect the parts together to form circuitry.

We call them "etched" circuit boards because of the way the boards are made. Each board is cut from a large sheet of phenolic to which a sheet of copper foil has been bonded. The desired copper foil pattern is transferred to the board by a photographic process. The board is then placed in a highly corrosive solution which etches away the unwanted copper foil, leaving the desired foil pattern.

After the etching is completed, the board is cleaned and the holes are drilled or punched and the lettering and other markings are printed on the phenolic.

Parts are usually mounted on the phenolic side of the board and they are supported by their leads, as shown in Fig. 24. The leads are passed through the holes in the board and soldered to the foil. When you install a part, bend the lead outward slightly to hold the part until you can solder the leads. Place the tip of your iron in contact with the lead and the foil and apply solder. Allow a small amount of solder to melt and flow into and around the joint. After the solder cools, cut off the lead flush with the top of the soldered connection. Fig. 25 shows an etched circuit board with good soldered connections.

As you go through these experiments, pay particular attention to each soldered connection you make. Tin the part leads before attempting to solder them; heat each connection thoroughly; inspect each connection and wiggle the leads after it is soldered to make sure that it is a good solid connection. Try to develop sound soldering habits; they will save you a great deal of time and difficulty, not only in your experiments, but all through your electronics career.

Performing the Experiments. To get the most benefit from the experimental course, you should follow a logical, planned procedure in each experiment. When you start a new manual, always study first the introduction at the beginning of the book. Then perform the experiments one at a time, in the correct order, by observing the following procedures:

1. Read through the instructions and discussions for the entire experiment once very slowly, and study any parts that are not immediately clear to you. Do not touch a single tool or part until you make this preliminary study.

2. Lay out on your worktable the

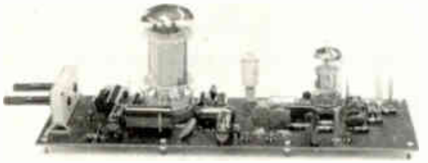


Fig. 24. Phenolic side of an etched circuit board with the parts installed.

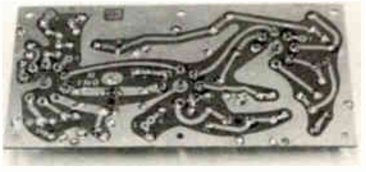


Fig. 25. Foil side of an etched circuit board, showing the parts installed.

parts and tools needed for the experiment to be performed.

3. Carry out the experiments one step at a time. Record your results whenever spaces are provided in the manual for this purpose. Additional observations and comments can be written in the margins of the pages for future reference.

4. Study the discussion at the end of the experiment very carefully, and analyze your results. After finishing an experiment, you should be able to tell in your own words exactly what you proved and how you did it.

5. Complete the Report Statement by writing the Statement Number on your Training Kit Report sheet in the space provided. Then enter the number of your choice for completing the Statement in the next column. Use the additional columns to the right for Statements that have more than one part.

6. When you have completed all ten experiments in the manual and have answered all of the statements, send in your Report Sheet for grading. Do not send in the manual.

EXPERIMENT 1

Purpose: To mount parts in a circuit; and to make soldered connections to these parts.

Introductory Discussion: Solder will hold parts together mechanically and fuse parts together so that they are, in effect, a single unit. A good soldered joint has little or no resistance and protects the surfaces of the parts from oxidation. Good soldered connections are a clue to the technician's ability. A man with an average knowledge of theory who can make good soldered connections will have less trouble than an expert on theory who cannot solder! In this experiment, you will mount parts and make several soldered connections. This experiment may seem simple, but do not pass over it quickly. The points that will be brought out are all very important.

Soldering ability is not hard to acquire and you should make this your first goal.

Experimental Procedure: Before you start the experiment, make sure your workbench is cleared so you will not lose any parts or have anything in your way. Gather your tools and the parts you will need in the experiment. At this time you should have a potentiometer, a solder lug and three terminal strips mounted on the chassis.

In the experiment, you will need the chassis with the parts mounted on it and the following parts:

3 **1000-ohm resistors (RE30; brown-black-red-silver)**
Rosin-core solder

Step 1: To prepare the parts to be soldered.

If you have the parts mounted on the chassis correctly, you are ready to wire the circuit by soldering resistors to various terminals. Plug in your soldering iron so that it can be heating.

Tin each lead of the three resistors until they are bright and shiny.

As you were instructed previously, you can use a knife or a small piece of sandpaper folded and held between the thumb and forefinger to clean the leads if they will not tin easily.

Test the iron by touching the end of the solder to the tinned tip of the iron. If the solder melts readily, the iron is ready for use.

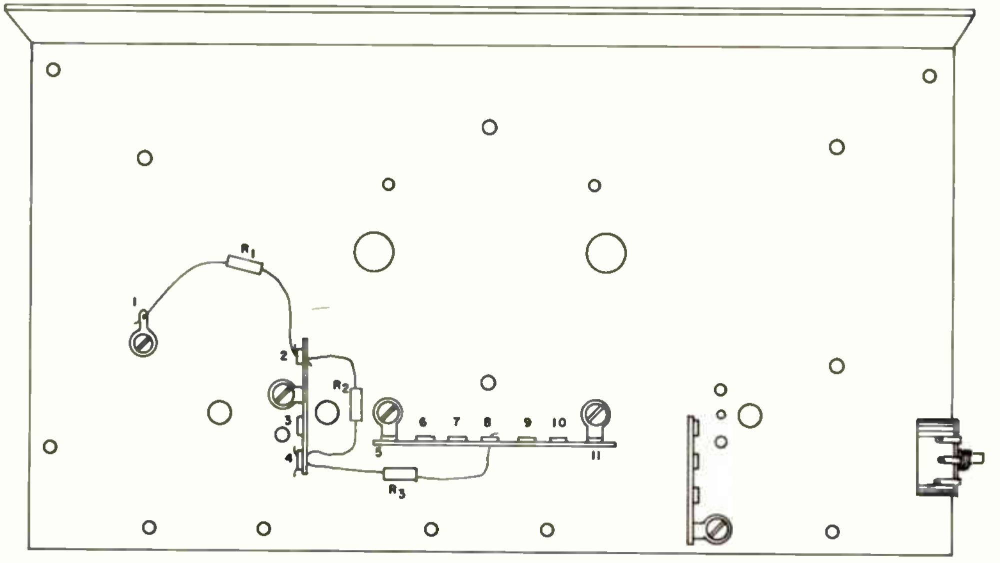


Fig. 1-1. Top view of the chassis, showing the resistors you will install in this experiment.

IMPORTANT: Do not cut the leads of any parts you received in this kit unless you are instructed to do so in the experiment. You will use most of the parts again in future experiments.

Fig. 1-1 shows you where you are to connect the resistors. The resistors are to be mounted so that the resistors and the leads are to be at least 1/2" above the chassis. As we mentioned earlier, we have given each terminal an identifying number. We will use these terminal numbers in this kit to indicate where the connections are to be made so as to simplify the instructions.

Connect the lead of one of the resistors to terminal 1, which is the solder lug mounted at hole B. Push the end of the lead through the hole in the solder lug and solder, as shown in Fig. 1-2.

Bring the tip of your soldering iron into contact with both the solder lug and the resistor lead, as in Fig. 1-2. Position the iron so that one flat surface of the tip is against the terminal. This permits maximum transfer of heat from the tip of the iron to the connection.

Touch the solder to the point where the terminal and the lead meet, and allow the solder to melt. Notice that the rosin flux flows out of the solder as the solder

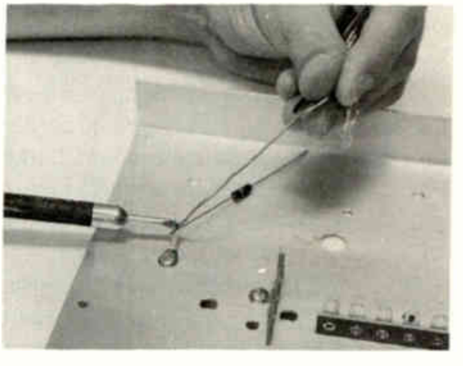


Fig. 1-2. Soldering the resistor lead to the terminal.

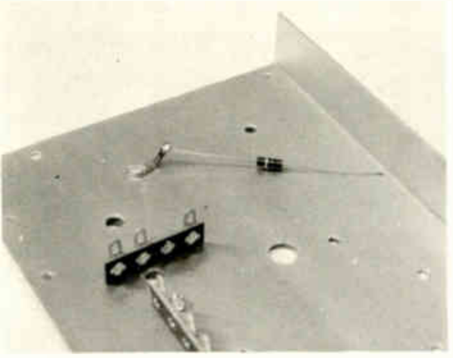


Fig. 1-3. Resistor R_1 soldered to terminal 1.

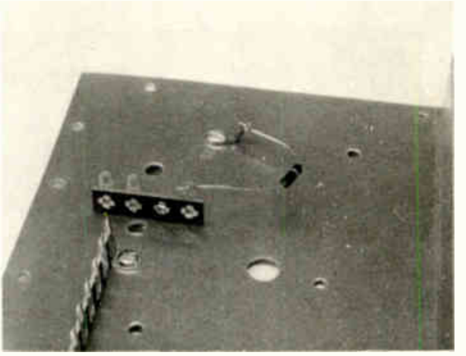


Fig. 1-4. Resistor R_1 in place on chassis.

melts. Remove the roll of solder and continue to heat the joint.

After the solder flows into the connection and coats the terminal and lead, remove the heat and allow the joint to cool and harden. Do not disturb the connection until the solder hardens.

If your solder joint is made correctly, the lead will be covered with solder where it touches the terminal and the solder should have a clean smooth appearance. Fig. 1-3 shows a good solder connection. The space between the resistor lead and the terminal is filled with solder and the solder also seals the connection.

It is a good idea to test each connection after it has cooled. To do this, grasp the resistor lead you have just soldered between the connection and the resistor body with your longnose pliers. Twist the lead gently and move it back and forth. If the lead does not move, you probably have a good soldered connection. If the lead breaks loose, or if the connection has a brown crust on it, re-melt the solder with your iron and let it cool again.

If you did make a poor solder connection, it may have been due to insufficient heat or to dirt on the lead or terminal. A poor joint can also result from your moving the lead before the joint has cooled.

Another problem which you might encounter is the "rosin" joint. This is a connection having a layer of rosin between the wire and the terminal. A rosin joint is indicated by a brown crusty appearance on the connection. You can correct a rosin joint by reheating the connection and allowing the rosin to boil out. As you heat the joint, you will see the vapor from the rosin rising from it.

With your longnose pliers, grasp the free lead of the resistor and slip it through the slot in terminal 2. Position the resistor as shown in Fig. 1-1. Twist the resistor slightly so the lead stays near the top of the slot in the terminal. Bend the end of the lead passing through the terminal so the lead touches the terminal, as shown in Fig. 1-4. Do not solder the connection at this time.

Step 2: To mount resistor R_2.

Now take another resistor and push the end of one lead about 1/8" through the slot in terminal 2. Bend the end slightly to bring it into contact with the terminal. Solder both leads to terminal 2. Place the tip of your soldering iron in contact with both leads and the terminal, with a flat surface against the terminal. Touch your solder to the connection and allow a small amount of the solder to melt. Remove the roll of solder and allow the molten solder to flow into the connection. Remove the heat and let the joint cool.

Test each connection by twisting and trying to move each lead. If the joint does not break loose, and the solder looks smooth, you probably have an acceptable connection. If not, reheat the connection, remelt the solder and allow it to cool and test the connections again.

Bend the leads of resistor R_2 at a right angle about 1/2" from the body of the resistor and position the resistor as shown in Fig. 1-1. Connect the free lead of resistor R_2 to terminal 4. Do not solder it at this time, since another lead will be connected to the same terminal.

Step 3: **To mount resistor R_3.**

Connect another resistor, R_3, from terminal 4 to terminal 8. This time make the connection without detailed instructions. Bend the leads as required and position the resistor as shown in Fig. 1-1. Note that the body of the resistor should be about 1/2" to 3/4" from the 7-lug terminal strip. Solder and test both connections.

If you have done your work correctly, your chassis should look like Fig. 1-1. You should have a total of three resistors and four temporary soldered connections. We call them "temporary" because they can be disconnected easily, as you will see later. The solder provides both the mechanical strength and the electrical path between the leads and the terminals.

By contrast, a permanent connection does not rely on the solder for physical strength. Usually the wire is twisted or wrapped around the terminal for physical strength before the connection is soldered.

You will make only temporary soldered connections in the experiments in this manual. However, you will make permanent connections in later experiments. The instructions on how to make them will be given at that time.

Look over the connections you have made and examine them critically. Check to see if any solder has run down the terminal where it may make contact with the chassis and cause a short circuit. This condition is illustrated in Fig. 1-5. Also, look at each connection to see if solder has flowed to all parts of the joints. Look for big lumps of solder on the terminal. They indicate too little heat or too much solder.

Excess solder will do no harm, provided it does not short terminals together, short a terminal to the chassis, or contain excessive rosin. However, it looks messy and is a waste of solder. Too little heat means a poor connection; the cure is to hold the lead in position and reheat the joint.

Next you will unsolder the connections in order to learn the proper techniques for doing this.

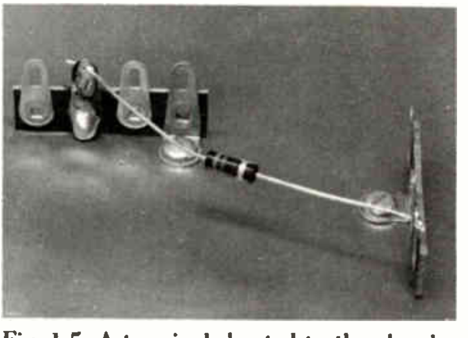


Fig. 1-5. A terminal shorted to the chassis by excessive solder.

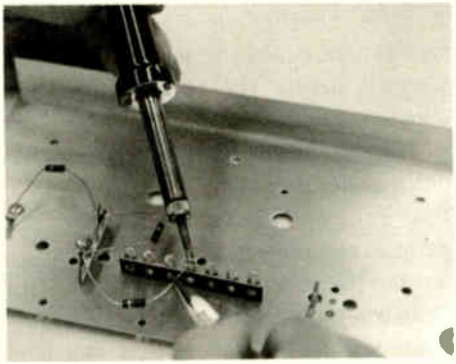


Fig. 1-6. Removing R_3 from terminal 8.

Step 4: To learn to unsolder connections.

Grasp the lead of R_3 connected to terminal 8 with your longnose pliers. See Fig. 1-6. Then touch the tip of your soldering iron to the connection. As soon as the solder melts, pull the lead out of the terminal. Wipe the tip of your iron with a cloth to remove the excess solder, and then touch the tip of the iron to the connections to terminal 4. Grasp the lead of resistor R_3 with your longnose pliers and, as soon as the solder melts, pull that lead free. Lay the resistor on your workbench. Grasp the lead of resistor R_2 connected to terminal 4. Apply heat to the terminal, and when the solder melts, pull the lead free. Wipe the excess solder from your iron with a cloth and then apply heat to the second lead of resistor R_2 which is connected to terminal 2. Remove the resistor and lay it on your work surface.

Use the procedure which we have outlined to unsolder the remaining connections and to remove resistor R_1.

Step 5: To clean parts so they will be ready for reuse.

Whenever you remove parts, clean the leads, lugs, and terminals so that you can use the parts again and connect other parts to the same lugs and terminals.

To practice this technique, first use your longnose pliers to straighten the resistor leads. Then, wipe any excess solder from the tip of your iron with a piece of cloth, and place the iron on the holder so that you can get to the tip easily. In one hand, hold a piece of cloth so that there are several thicknesses between your thumb and forefinger. With your longnose pliers in your other hand, grasp a resistor lead close to the body of the resistor. Hold the end of the lead against the tip of the iron until the solder on the lead melts, and quickly pull the hot lead through the cloth, as shown in Fig. 1-7. This will remove all excess solder and leave the lead surface clean and bright. Do this on all resistor leads that have been used in this experiment.

There are several methods of removing the solder from terminal and solder lugs. Probably the easiest and most efficient method to use on small pieces of elec-

Fig. 1-7. Removing the excessive solder from a resistor lead.

tronic equipment, such as the experimental chassis you received in this kit, is to turn the chassis upside down so that the terminals are pointing downward. Apply the tip of the iron to the end of the terminal, and when the solder melts most of it will run onto the tinned surface of the iron. Wipe the excess solder from the tip and repeat the procedure on the other lugs on the terminal strip. If a thin film of solder remains in the terminal holes, wipe the excess solder from the tip of the iron and reheat the lug. Push a resistor lead through the hole to remove the solder.

In addition to removing the solder from the terminals, this method will remove any excess solder that may be on the terminal strip lugs near the chassis.

Removing excess solder from terminals, tube socket pins and other types of solder lugs in large pieces of electronic equipment that you cannot pick up and turn upside down requires a slightly different procedure. In this case, with the terminals pointing upward, wipe the excess solder from the tip of your iron and keep the cloth in one hand while you work. Touch the tip of the iron to the side of the lug; when the solder melts, some of it will run onto the tinned surface of the iron. Wipe off the solder and keep repeating the process until all surplus solder has been removed. If you have trouble getting the solder out of the hole in a lug, heat the lug and push a resistor lead through the hole. The solder that accumulates on the resistor lead can then be easily removed.

The same procedure should be used to remove solder from tube socket pins and terminal strip lugs.

Discussion: In this first experiment, you began acquiring one of the most important skills a technician must have -- the ability to make good soldered connections. You have had practice in mounting actual electronics parts and soldering them into place. You have been able to see how solder looks as it cools and hardens. You should not expect to be an expert at soldering at this time; it takes considerable practice. However, if you carefully follow the procedures discussed in this experiment, you should have no trouble making good soldered connections and you will soon become an expert with a soldering iron.

You have also had practice in the equally important task of unsoldering, and you have learned how to clean the parts so they will be ready for reuse. This is important because often the serviceman must disconnect one part in order to check another. When you disconnect a part or lead, you should carefully prepare it and the terminal from which you removed it before resoldering the lead back into position.

Instructions for Statement No. 1: In this statement, there are two sentences to be completed, each having several choices preceded by numbers. Only one of the choices in each group correctly completes a sentence in the statement. Read the first sentence, and put a circle around the number preceding the choice that completes it. Do the same for the second sentence.

Statement No. 1: In this experiment, I used

(1) temporary
(2) permanent

connections; and I found that as molten solder becomes hard, its appearance is

(1) a copper color.
(2) a shiny gray color.
(3) a dull black color.

SOLDERING TIPS

Always use a clean, hot, well-tinned iron.
Always heat the junction to be soldered enough to melt the solder.
Always use a rosin-core solder.
Always tin part leads to be soldered.
Always test all leads in each joint after solder cools.
Always keep iron on joint until the rosin has boiled out of the joint.

Never try to solder dirty or untinned leads or terminals.
Never melt solder on the iron tip and carry it to the junction.
Never use acid-core solder or pastes for radio and electronic work.
Never drip solder off iron on to joint.
Never let leads move while solder is setting.

Turn now to the enclosed Training Kit Report sheet. Fill in the top part with your name, address, student number and Kit number, IT. Write the number 1 in the first box of the column with the heading, "Statement No." This statement is in two parts. Therefore, place the number of your choice for the first part in the second column and place the number of your choice for the second part of the statement in the third column. As an example, assume that the first statement was:

San Francisco is located in the

(1) East
(2) South
(3) West

And it is in the state of

(1) Nebraska.
(2) California.
(3) New York.

The correct answers are (3) for the first part and (2) for the second part. Therefore, you would place the Statement number in the first column, the number 3 as your answer for the first part is the second column, and the number 2 in the third column.

EXPERIMENT 2

Purpose: To learn how to wire and repair etched circuit boards.

Introductory Discussion: Etched circuit boards are often used where compactness, ease of wiring or freedom from circuit variations are important. The vast majority of radio and TV receivers use etched circuit boards. Thus, it is likely that when you repair a receiver you will have to make repairs on etched circuit boards.

Etched circuit boards are fragile. They can be damaged by rough handling or poor workmanship. The phenolic will crack or break when subjected to excessive pressure. This results in breaks in the copper foil strips and produces open circuits.

The copper foil is glued to the circuit board. When overheated, the glue will weaken and the copper foil strips will pull loose from the board. However, the board will withstand a surprisingly large amount of heat before either the phenolic or the foil becomes damaged.

In performing this experiment, you will develop skill in working on etched circuit boards. This will prepare you for work on your future experimental kits and for practical work as a technician.

Experimental Procedure: In this experiment, in addition to your chassis, soldering iron and solder, you will need the following:

1 Etched circuit board (EC24)
2 22,000-ohm resistors (RE33; red-red-orange-silver)
1 7-pin tube socket (SO76)
Red hookup wire
Solder

Plug in your soldering iron so that it can be heating. Inspect the tip. If the tip is not clean, wipe it with a cloth and apply a thin coating of solder. If you wipe the tip frequently, it will last longer. Also, you will seldom have to file and retin the tip.

In this experiment, you will practice soldering to the etched circuit board and you will make repairs on the copper foil. The foil near holes A through H is for practice only. Do not be concerned if you damage it in performing this experiment. However, the remainder of the board will be used in later experiments. Therefore, you should exercise reasonable care in working on the board.

Step 1: To wire a circuit on the etched circuit board.

In order to become proficient at working on circuit boards, you will have to develop a feel for soldering to the copper foil. Before mounting any parts, you will determine how much heat the foil can withstand.

Place your etched board on your work-table with the foil side up. Touch the tip of your soldering iron to the foil near hole B. Hold the soldering iron nearly

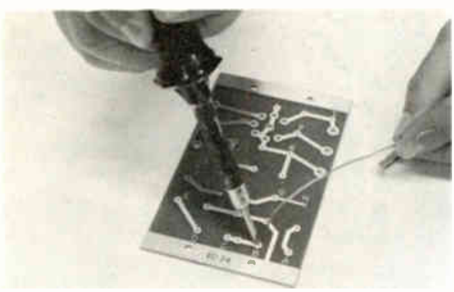


Fig. 2-1. Applying heat and solder to the foil.

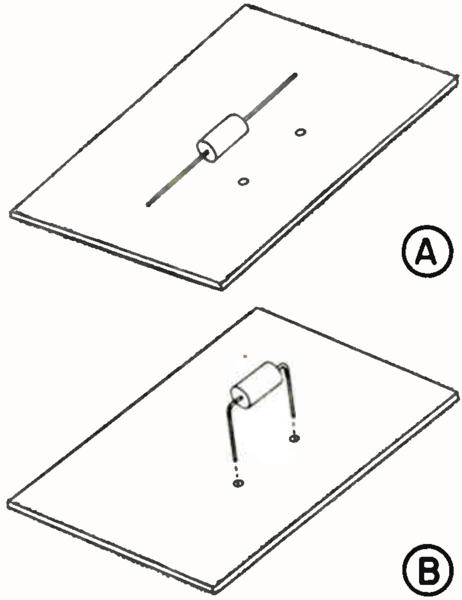


Fig. 2-2. (A) Measuring the resistor against the mounting holes; (B) resistor leads bent to correct spacing.

straight up with the tip at the edge of the hole, as shown in Fig. 2-1. Touch the end of your solder to a point where the tip touches the foil. Allow about 1/4" of solder to melt and flow onto the foil. When the solder spreads out smoothly on the foil, remove the heat and allow the foil to cool. Do not be concerned if the hole is covered with solder.

In a similar manner, apply heat to the foil surrounding hole A. Touch your solder to the iron and the foil and melt about 1/4" of the solder. Continue to heat the foil until the foil begins to loosen. This may take up to 15 seconds, depending upon the wattage rating of your iron and the condition of the tip. Remove the heat from the foil.

Notice that the phenolic around the overheated foil is charred slightly. Use a knife or your longnose pliers to peel the damaged foil off the board.

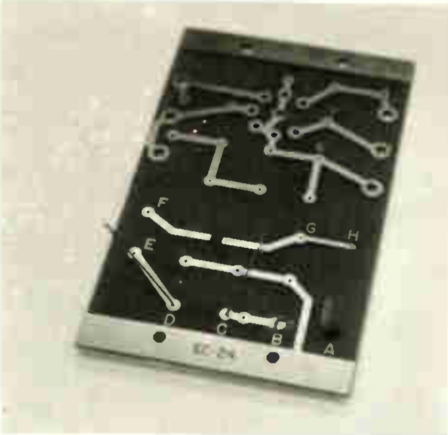


Fig. 2-3. Leads are bent outward to hold the resistor in place.

The brief experience which you have gained will give you some idea of how long it takes to make a connection and how long it takes to damage the circuit board. Next, you will mount and solder parts to the circuit board.

Install one of the 22,000-ohm resistors (red-red-orange-silver) on the phenolic side of the circuit board at holes C and D. Use the following procedure: First, "measure" the resistor against the spacing between the holes, as shown in Fig. 2-2A. In this case, the spacing between the holes is about 1/4" greater than the length of the body of the resistor, so bend both leads at right angles about 1/8" from the body of the resistor. Fig. 2-2B shows the leads ready for insertion in the holes.

Next, slip the leads through holes C and D and push the resistor down against the board. Bend the leads outward slightly, as shown in Fig. 2-3, to hold the resistor in place.

Turn the foil side of the circuit board up to solder the connections. Position the soldering iron so that the tip is in contact with both the foil and the lead. Touch the end of your solder to the point where the tip, lead and foil meet and allow about 1/4" of the solder to melt. Continue to heat the connection until the solder flows smoothly and completely surrounds the lead. Then, remove the iron and allow the connection to cool.

Finally, use your diagonal cutters to cut off the lead flush with the top of the solder connection.

Use the procedure outlined here to solder the other resistor lead to the foil.

Fig. 2-4 shows typical poorly soldered

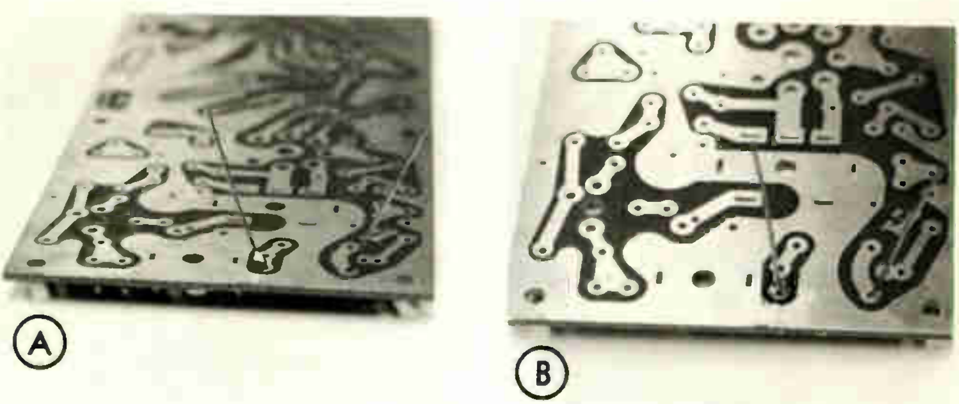


Fig. 2-4. Typical examples of poorly soldered connections.

connections. At A, too little heat was used; the solder adheres to the lead, but not to the foil. This connection could be improved by simply applying more heat. In Fig. 2-4B, too little solder was used, resulting in a minimum of strength and reliability. To improve this connection, you would apply both heat and solder.

Step 2: To demonstrate methods for removing components from etched circuit boards.

Wedge the blade of your small screwdriver between the board and the body of the resistor near hole C. (If the resistor is flat against the board, slip the screwdriver blade under the lead at hole C.) Heat the solder at hole C and lift the resistor enough to pull the lead from the hole.

Stand the circuit board on edge on your worktable. On the phenolic side of the board, grasp the lead of the resistor connected at hole D. With your forefinger and thumb pressing against the board, apply a lifting pressure to the resistor lead. Heat the connection at hole D on the foil side and when the solder melts, pull the resistor from the board and discard it.

Now you should clean the holes so that a new resistor can be installed. Heat the solder at one of the holes. While the solder is molten, insert a toothpick into the hole from the foil side of the board. Remove the soldering iron and let the foil and solder cool. When you remove the toothpick, the hole will be left clear.

Step 3: To demonstrate techniques for repairing etched circuit boards.

Cut through the foil between holes D and E to simulate a crack in the foil. You can use your pocket knife. Fig. 2-5 shows how to make a clean cut safely.

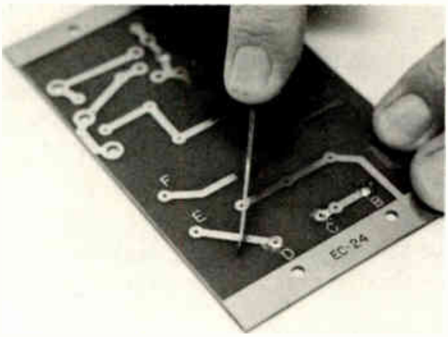


Fig. 2-5. Cutting the foil to simulate a crack in the board.

Heat the foil near the cut and melt a small amount of solder onto the foil. Use the tip of your iron to "run" the solder across the crack. The solder should adhere to the foil on both sides and bridge the narrow gap. If necessary, apply a little more solder to make a reliable repair.

A wider break, such as the one between holes F and G, requires a slightly different repair. You solder a short piece of bare wire across the break in the foil.

Remove about 2" of insulation from a length of red hookup wire. There are several ways of removing the insulation. You can peel the insulation off with a knife, or you can cut the insulation with your diagonal cutters, knife or wire strippers and simply pull off the unwanted piece. Another technique is to crush the insulation with pliers and then peel off the pieces. When stripping the insulation off wire, it is important to avoid nicking or cutting the wire because this will weaken the wire and make it break easily.

As you did previously for the narrow break, heat the foil on both sides of the break and tin the foil with solder. Lay the bare wire across the break in the foil and solder the wire to the foil. Run solder along the wire and foil for about 1/2" on each side of the break. Using your diagonal cutters, cut off the wire beyond the solder. This should leave about 1" of wire bridging the break in the foil.

Step 4: To install parts on the foil side of the circuit board.

Bend the leads of a 22,000-ohm resistor (red-red-orange-silver) at right angles close to the body of the resistor, and insert the leads through holes C and D from the foil side of the board. Position the resistor about 1/16" to 1/8" from the board. This will leave room for soldering the connections. Bend the leads outward slightly to hold the resistor in place.

Solder one lead of the resistor to the foil. Apply heat to both the foil and the lead and apply solder. Allow the solder to flow freely over the connection. Remove the heat and let the joint cool. In a similar manner, solder the other resistor lead to the foil. You will use this resistor in later experiments, so do not cut off the leads! (Normally, after installing a part from the foil side as you have just done, you would clip off the excess lead length on the other side of the board.)

Locate the 7-pin tube socket. The socket has 7 pin connections and a center locating pin. You will install the tube socket on the *foil* side of the circuit board instead of from the phenolic side. Align the pins over the holes on the circuit board. Notice that there is an open space between the pins. Install the socket on the board by pushing firmly. When the socket is properly installed, the pins project about 1/16" on the phenolic side of the board.

With the socket in position, you are ready to solder. Since the tube socket pins on the phenolic side of the board will become quite hot as you solder them to the board, it would be a good idea to lay the board on a newspaper to protect your worktable. Hold the soldering iron so the tip is at the junction of the foil and a pin of the tube socket.

The flat surface of the soldering iron tip should be turned toward the pin. Apply solder to the foil and to the pin. Melt about 1/4" of solder and let it flow around the pin. Solder should adhere to one half or more of the perimeter of the pin and to the foil. Remove the heat and let the solder cool. In the same manner, solder the six remaining pins of the tube socket. Do not try to solder the center locating pin. Fig. 2-6 shows the socket soldered in place.

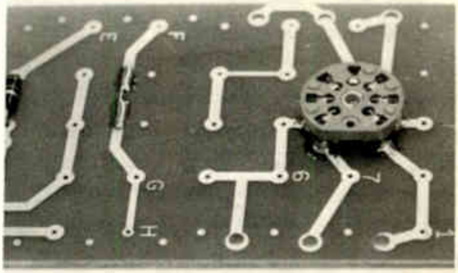


Fig. 2-6. Tube socket mounted on the etched circuit board.

Discussion: In this experiment, you have experienced working on a typical etched circuit board. You learned that you can solder to the circuit board with a moderate amount of heat. If the iron is clean and tinned, a connection can be soldered in a matter of seconds; it takes a considerable length of time to overheat and damage the circuit board.

In Step 2, you learned how to install components on the circuit board. First, you determined the lead spacing and bent the leads so you could insert the leads in the holes; then you pushed the part down against the circuit board and bent the lead to hold the part in place. Then you soldered the connection, allowed it to cool, and cut off the excess lead length, close to the soldered connection. In a good solder connection, the solder adheres to both the lead and to the foil and the solder has a smooth appearance.

You also learned how to remove parts from the etched circuit board. This is important because frequently you will have to disconnect a part to make tests and when you determine which part is bad, you will have to replace it. Before replacing a lead, clean the hole in the board. Otherwise, you may break the foil loose when you try to insert the lead.

In Step 4, you learned how to install parts on the foil side of the board. This is useful because you will sometimes find it easier to replace a part on the foil side of the board. Also, interconnecting jumper wires are sometimes connected on the foil side of the board in some pieces of equipment.

The circuit board with the tube socket attached will be used in later experiments.

Instructions for Statement No. 2: In order to answer the Report Statement for this experiment, you will have to make a few connections on your etched circuit board and trace the connections. You will need your red hookup wire.

Cut a 2" length of hookup wire and remove about 1/4" of insulation from each end. Push one end through hole E from the phenolic side of your circuit board. The holes are identified on the foil side of the board. Bend the wire and push the other end through hole F from the same side of the board. Solder both connections.

Cut a 3" length of hookup wire and remove about 1/4" insulation from each end. Push one end of the wire through hole G and push the other end through the hole identified by the number 7 from the phenolic side of the board. Solder both connections.

Trace the connections on the circuit board and answer the Report Statement. After you have completed the Report Statement, unsolder and remove the resistor and the pieces of hookup wire. Clean the holes which you used on your circuit board and clean and straighten the resistor leads.

Statement No. 2: When I traced the wiring, I found that the resistor

(1) was
(2) was not

electrically connected to the tube socket.

Using Schematic Diagrams

To service any type of electronic equipment, the technician must know how the parts are connected in the circuit.

The electrical connections in a circuit can be shown by means of a schematic diagram. In a schematic diagram, symbols are used to indicate the various parts, and the connections between the parts are shown by lines.

You have already seen many of the symbols used in schematic diagrams in your lesson texts. You have also seen some simple schematic diagrams. It is extremely important for you to become familiar with the various symbols used, and also to learn how to read schematic diagrams. You will have to use this type of diagram throughout your career, because manufacturers of electronic equipment seldom supply pictorial wiring diagrams. Even if you have a pictorial diagram, it is far easier to work from a schematic once you learn how to use it.

In your experiments, you will start first with simple schematics, and gradually work up to more complex ones. In time, you will be as much at ease reading a complex schematic diagram as you are reading your evening newspaper. You will soon learn the value of this type of diagram and see how much easier it is to use than the pictorial type.

SYMBOLS USED

Before you can read schematic diagrams, you must be able to recognize the symbols used in them. Fig. 26 shows the symbols commonly used to represent resistors, capacitors, and ground connec-

Fig. 26. Symbols often used in schematics.

tions. Study these symbols so that you will be sure to recognize them the next time you see them. You will use them in these experiments.

Connections and Crossovers. Often in a schematic diagram, one lead crosses over another. In some cases, there will be a connection between the two leads; in other cases, there will be no connection. There are three different systems in use to indicate whether or not there is a connection; the one that is used in any particular diagram depends on the preferences of the person making the diagram. You might think that this would be confusing, but it is usually very simple to see which system has been used.

Fig. 27 shows the three systems. Notice that in System 1 when there is a dot used on some crossovers and no dot used on the others, the dot indicates a connection, and the crossover without the dot indicates that there is no connection.

In System 2, a straight crossover is used to show a connection, and a loop is used to show no connection. You can easily tell when this system has been used. If you notice some crossovers with the loop, and some without the loop, you know that the straight crossovers represent connections, and the crossovers with the loop indicate no connection. Similarly, if you see some crossovers with dots and others without, you will know that System 1 has been used.

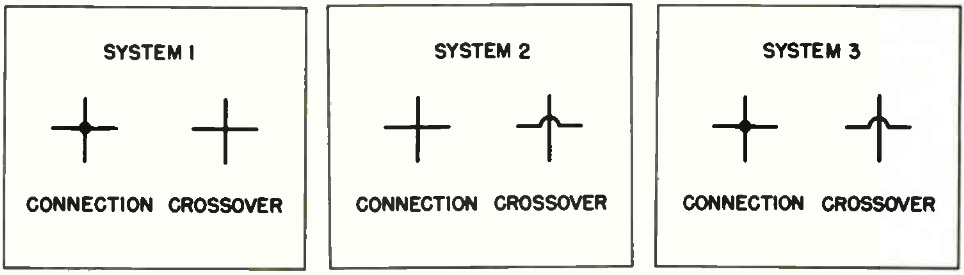


Fig. 27. Three systems used on schematics to show connections and crossovers on wires.

System 3 is a combination of the first two. We will use this system in the drawings in the experiments. The crossover with a dot indicates a connection. The crossover with a loop indicates no connection. Study these three systems - become familiar with them now, and you will have no trouble later.

Tubes. The various symbols used to represent the elements in a tube are shown in Fig. 28. The symbol for the heater is shown at A, the symbol for the cathode at B, for the grid at C, for the plate at D, and for the whole tube at E. This tube is called a triode - it has three elements plus a heater. Notice the little numbers beside each of the elements. These tell you which pin each element is connected to inside the tube. The tube we have shown is a 6C4. In this particular tube, the plate is connected to pins 5 and 1; the grid to pin 6, the cathode to pin 7, and the heater to pins 3 and 4. Nothing is connected to pin 2.

Diodes. The symbol for a semiconductor diode is shown in Fig. 29. The two elements of a diode are the cathode and the anode. The "arrow" in the symbol points toward the cathode terminal.

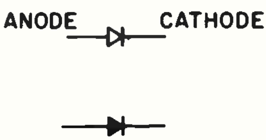


Fig. 29. Schematic symbols for a semiconductor diode.

Transistors. There are several types of transistors in wide usage. The symbols for two types are shown in Fig. 30. At A and B, we have bipolar transistors. As you can see, the only difference between the NPN and PNP symbols is the direction of the arrow. The e, b, and c labels identify the emitter, base and collector of both transistors.

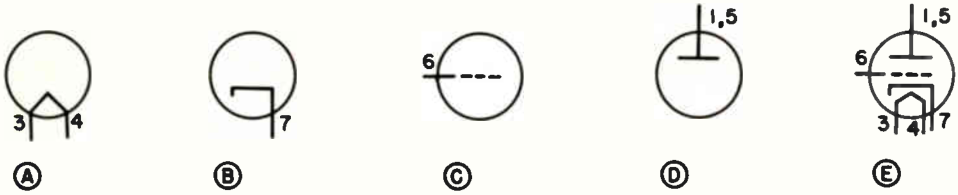


Fig. 28. Symbols used to represent the elements in a tube. Shown is tube type 6C4.

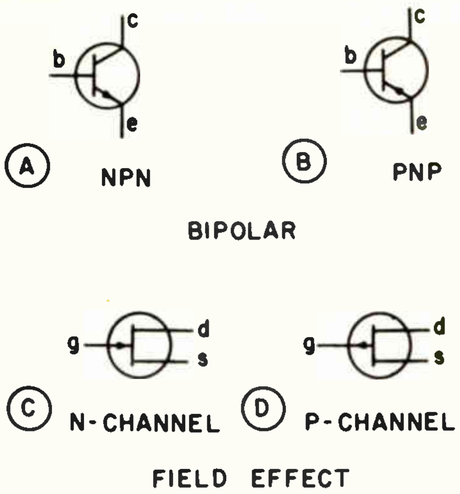


Fig. 30. Schematic symbols for transistors.

The symbols for junction field-effect transistors (FET's) are shown in Figs. 30C and 30D. You can see that the direction of the arrow is toward the junction for the N-channel and away from the junction for the P-channel FET's. In both cases, the s, g and d represent the source, gate and drain terminals. You will learn other transistor symbols later in your course.

Meters. Fig. 31 shows symbols used to represent meters on schematic diagrams. In the symbols in Fig. 31A, the letters inside the circle indicate the type of meter: V for voltmeter, μa for microammeter, ma for milliammeter, and ohm for ohmmeter. Fig. 31B shows semi-pictorial symbols that are sometimes used.

READING A SCHEMATIC

When working with schematic diagrams, you must remember that the schematic diagram shows the electrical connections, not the actual physical connections. An example of this can be seen in Fig. 32A. The schematic diagram shows the capacitor C_1 connected on the left to resistor R_1. From the junction of these two components there is a line going to the plate of the tube V_1.

In your work you will be interested only in the electrical connections. It will be unimportant to know whether the capacitor and resistor are first connected together and a lead run from the junction of the two to the tube socket, or whether the two are connected directly to the tube socket. Electrically both connections are the same.

The other side of capacitor C_1 is connected to the grid of the tube marked V_2. The schematic diagram shows C_1 connected to R_2 and then a line going from the junction over to the grid. The pictorial wiring diagram shows that both the capacitor and the resistor are connected directly to the grid terminal on the socket.

Notice on the schematic diagram that the lower end of resistor R_2 is connected to ground. In the wiring diagram, we see

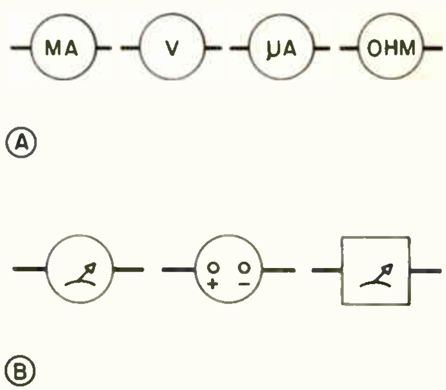


Fig. 31. Symbols used on schematics to represent meters.

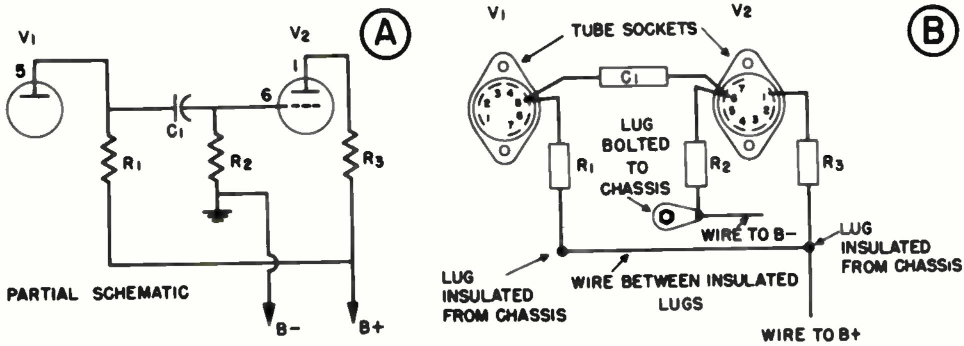


Fig. 32. (A) A schematic diagram; (B), actual wiring diagram of the same circuit.

that R_2 connects to a lug that is bolted to the chassis. Any number of ground connections can be made in this way to the chassis. When this is done, the chassis is used as part of the circuit; the chassis connects directly to B-. In some equipment the chassis is not used as part of the circuit. You will see later how to tell from a schematic diagram whether or not the chassis is part of the circuit. This information will be given to you on the schematic diagram.

Study Fig. 32 carefully. Find an electrical circuit on the schematic diagram, and then trace out the circuit on the pictorial wiring diagram. This will be valuable practical experience for you and will help you to become familiar with schematic diagrams.

EXPERIMENT 3

Purpose: To obtain practical experience in wiring from a schematic diagram.

Introductory Discussion: Fig. 3-1 is a pictorial diagram showing the actual physical location of the parts in the circuit you will wire in this experiment.

Fig. 3-2 shows the same circuit in schematic form. The circuit is that of a simple power supply. If an ac voltage were connected between terminals 1 and 2, a variable positive dc voltage would be available between terminals 17 and 15.

In a simple circuit of this type a pictorial diagram may seem easier to follow than a schematic diagram. However, a glance under the chassis of any electronic device will show how complex the pictorial diagram would become. In fact, it would be practically impossible to show how the parts are connected with a photograph or pictorial drawing. On the other hand, it is easy to show the connections with a schematic diagram.

Experimental Procedure: In this experiment, in addition to the chassis with the terminal strips and potentiometer mounted on it, you will need:

3 1000-ohm resistors (RE30; brown-black-red-silver)
1 Silicon diode (SR12)
Hookup wire
Solder

As you can see in Fig. 3-1, the diode appears similar to a resistor and is somewhat smaller. The diode is a semiconductor device which passes current in one direction only. Current can pass from cathode to anode but not from anode to

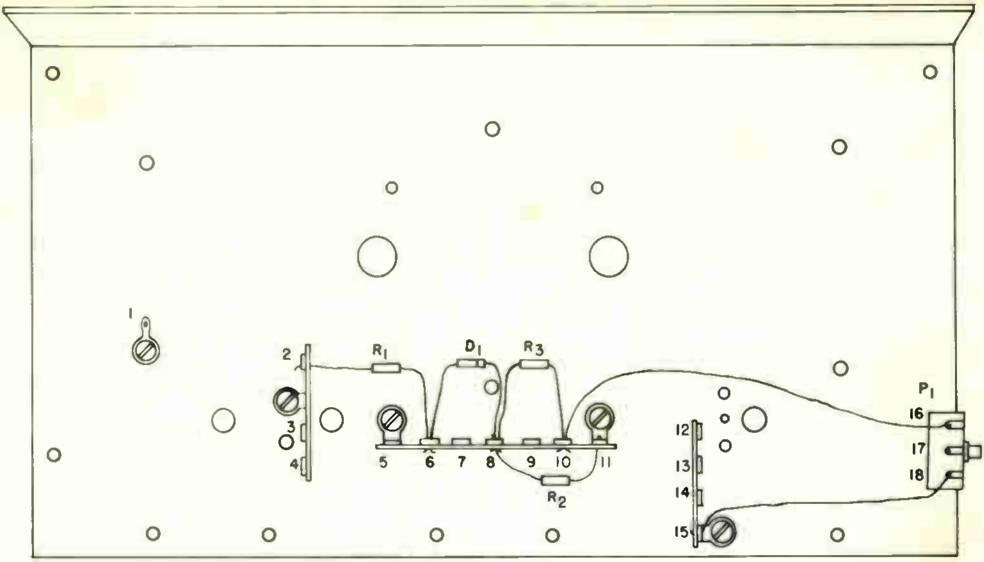


Fig. 3-1. Pictorial diagram of the circuit used in Step 1.

cathode. Thus, the diode is capable of rectifying an ac voltage.

The cathode and anode terminals of a diode are identified in one of several ways. You will usually find colored bands or a plus sign near one end of the diode, or one end of the diode may be tapered. The band, taper or other markings indicate the cathode lead of the diode as shown in Fig. 3-3.

Step 1: To determine what connections are to be made.

First, carefully study Fig. 3-2. Resistor R_1 is connected between terminal 2, which is the "input" terminal, or the terminal to which the ac voltage would be applied, and the diode D_1. The cathode lead of diode D_1 is connected to resistors R_2 and R_3. One lead of R_2 is grounded.

Resistor R_3 is connected between the junction of diode D_1 and resistor R_2 and the potentiometer, P_1. Potentiometer P_1 is connected between R_3 and ground.

Notice the ground symbols on the diagram. The metal chassis forms the common connection between the ground points.

Where possible, leads of the parts which are wired together are connected to a common terminal. For example, the cathode lead of D_1, one lead of R_2 and one lead of R_3 can all be soldered to the same terminal.

When instructed to use hookup wire, cut a length of your red wire and remove about 1/4″ of insulation from each end before making the connection. See that the insulation is about 1/16″ back from the actual solder connection. Never try to solder to the insulation.

When we instruct you to use a short length of bare wire, use your wire strippers, diagonal cutters or longnose pliers to remove the insulation from a short length of hookup wire.

In the next step, you will perform the actual wiring.

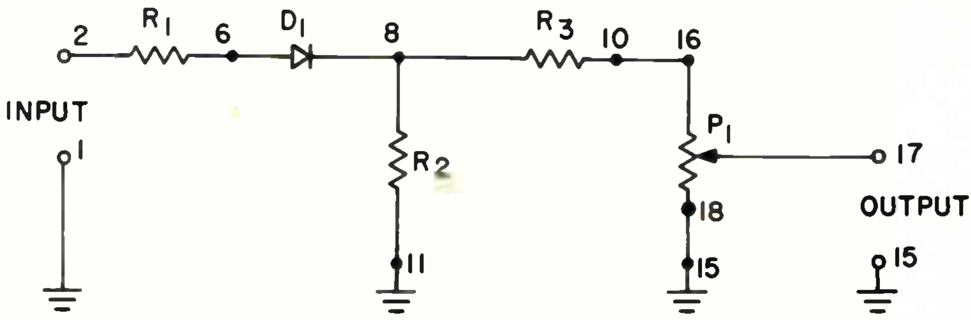


Fig. 3-2. Circuit used in Experiment 3.

Step 2: To wire the circuits from the schematic diagram.

In this step, you will mount the parts and connect wires between them to form the circuit shown in the schematic diagram in Fig. 3-2.

Connect resistor R_1 to terminals 2 and 6 as shown in Fig. 3-2. You can choose any of the three resistors since they are all the same value. Bend the leads so that the ends are spaced properly to slip through the slots in terminals 2 and 6. Slip the leads through the terminals and solder terminal 2.

Connect the diode to terminals 6 and 8 with the proper polarity. The cathode and anode leads are identified in Fig. 3-3. The cathode lead of each diode is on the right. Connect the cathode lead to terminal 8 and connect the anode lead to terminal 6. Solder terminal 6.

On the schematic diagram, notice that the cathode lead of the diode and one lead of resistor R_2 are connected together. Also, R_2 is connected from the junction with the diode lead to ground. Therefore, connect R_2 between terminals 8 and 11 as shown in Fig. 3-1. Solder terminal 11.

Next connect resistor R_3. On the schematic, this resistor is connected between the junction of diode D_1 and resistor R_2 and terminal 16 of the potentiometer. For convenience, we connect the resistor between terminals 8 and 10 and use hookup wire to complete the connection.

Install the resistor and solder terminal 8. Connect a length of hookup wire from

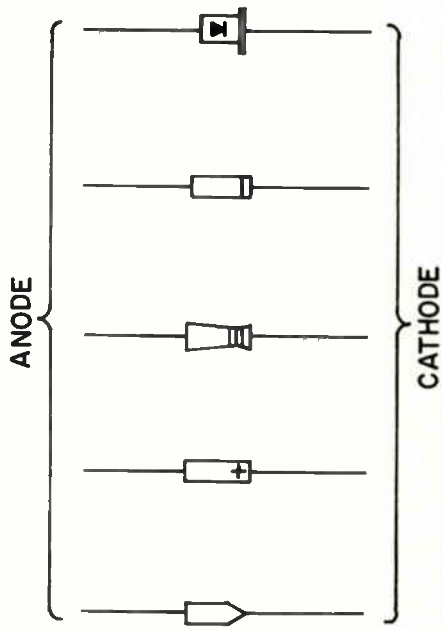


Fig. 3-3. Methods used to identify the leads of semiconductor diodes.

terminal 10 to terminal 16 and solder both connections.

The potentiometer is connected between resistor R_3 and ground. Thus, we must ground terminal 18. Again, we choose a convenient grounded terminal, which is terminal 15. Connect a length of hookup wire from terminal 18 to terminal 15 to complete the wiring. The center terminal of the potentiometer, terminal 17, is the "output" terminal.

This completes your wiring. You should have made all of the connections shown in Fig. 3-1. To make certain, check your wiring as follows:

1. There should be a resistor, R_1, between terminals 2 and 6.
2. Diode D_1 should be connected between terminals 6 and 8, with the cathode lead to terminal 8.
3. Resistor R_2 should be connected between terminals 8 and 11.
4. Resistor R_3 should be connected between terminals 8 and 10.
5. There should be hookup wire from terminal 10 to terminal 16 on the potentiometer.
6. There should be a length of hookup wire from terminal 18 on the potentiometer to terminal 15.

You should make a habit of checking your connections in this way each time you finish wiring a circuit. By checking your work, you may find and correct errors that could be serious or difficult to find later. When you check your work, pay particular attention to the soldered connections. Be sure that all connections are soldered properly. If not, resolder them.

When you are satisfied with your work, unsolder all of the connections and remove the parts. Straighten the resistor and diode leads and remove the excess solder from all terminals. Use the techniques you learned in Experiment 1.

Remove the 1000-ohm potentiometer from the mounting bracket and carefully clean the terminals. Remove the potentiometer mounting bracket and put it with the potentiometer. You will use these in a later Training Kit.

Discussion: In this experiment, we have taken you step-by-step through the wiring of a circuit from a schematic diagram. You have checked your work by comparing the actual parts layout with a list of the connections and with a pictorial diagram. This layout is not the only one that could be made from the schematic of Fig. 3-1. The same electrical circuit could have been made with the leads routed along different paths.

You should practice drawing schematic diagrams because such practice will help you to become more familiar with schematic symbols and will aid you later in tracing circuits. You need not start with elaborate diagrams; simple circuits like those shown in this experiment will be satisfactory.

The schematic diagram shows electrical connections only. Therefore, additional information is needed in order to wire more complex circuits. Experienced technicians usually sketch a layout before wiring. However, once a circuit is wired, it is easy to trace the circuit by following the schematic diagram.

Instructions for Statement No. 3: This statement is a test of your ability to relate a physical parts layout to a schematic diagram of that layout. Fig. 3-4 shows a circuit wired on your experimental chassis using resistors, a diode and a potentiometer.

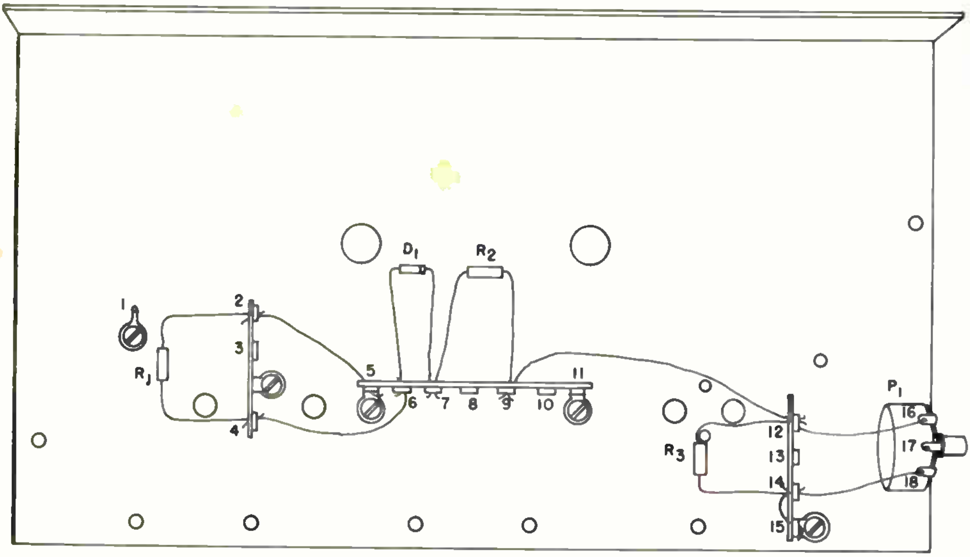


Fig. 3-4. Pictorial diagram of the circuit shown in Statement 3.

Study this circuit carefully and compare the arrangement with the four schematics in Fig. 3-5. When you are certain you have the schematic which corresponds to the circuit of Fig. 3-4, complete the statement here and on your Report Sheet.

Statement No. 3: The schematic diagram of the circuit in Fig. 3-4 is Fig. 3-5:

(1) A
(2) B
(3) C
(4) D

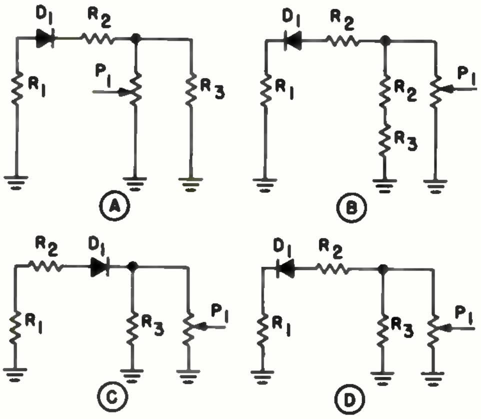


Fig. 3-5. Schematics for use with Statement No. 3.

IDENTIFYING RESISTORS

As you go ahead with your experiments, and when you work on your own, you will need to be able to identify the value of resistors.

Although the value is stamped on some resistors, on most 1/2-watt, 1-watt, and 2-watt resistors the value is indicated by means of colored bands on the resistor. You should learn to read this color code so that you can identify resistors quickly.

The colored bands on the resistor usually are nearer to one end than the other. Thus, to read the color code, turn the resistor so that the colored bands are toward the left end of the resistor as shown in Fig. 33.

Each color represents a number. These are given in Fig. 33. The first band, labeled A, gives the first figure in the value; the second band, labeled B, gives the second figure in the value; the third band, labeled C, gives the number of zeros after the second figure in the value,

COLOR	FIGURE
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9

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%

Fig. 33. Standard resistor color code.

and the fourth band gives the tolerance of the resistor (silver for ±10% tolerance, gold for ±5% tolerance). If the tolerance is ±10%, it means that the actual value of the resistor may be as much as 10% higher or lower than the value indicated. If it is ±5%, the actual value may be up to 5% higher or lower than the value indicated.

Some resistors may have a fifth color band. This band will follow the tolerance band (to the right) and is used to indicate a military reliability level. The fifth band will be Brown, Red, Orange or Yellow which indicate increasing percent of reliability. In your work you can simply ignore the fifth band.

To find the value, you need to look only at the first three bands. For example, suppose you have a resistor color-coded red, red, and black. Referring to the chart, you see that red represents 2. Therefore, the first two figures in the value are both 2. As we have said, the third band indicates the number of zeros in the value. Since black represents 0, when the third band is black, there are no zeros in the value. So the value of the resistor is 22 ohms.

If the resistor had been color-coded red, red, and brown, the first two figures would again be 2. Brown represents 1, so there would be one zero, and the value would be 220 ohms. Red, red, and red would indicate a value of 2200 ohms (often written 2.2K ohms, where the K stands for 1000); red-red-orange, a value of 22,000 ohms (often written 22K-ohms); red-red-yellow, a value of 220,000 ohms (or 220K ohms or .22 meg; a megohm is 1,000,000 ohms); red-red-green, a value of 2,200,000 ohms (or 2.2 megohms); and red-red-blue, a value of 22,000,000 ohms (or 22 megohms).

Look over the resistors you have received, and practice reading the color codes on them. You can check the values by referring to the parts list given in Fig. 1. In the next experiment you will have some practice in picking out resistors of different values.

EXPERIMENT 4

Purpose: To construct a circuit using only a schematic diagram for guidance.

Introductory Discussion: If you read construction articles in any of the radio-TV-electronics magazines, you will see that step-by-step wiring instructions are rarely given; you work from a schematic diagram. Thus, if you wanted to build some of this equipment, you would have to work out the placement of the parts and other details for yourself.

We want you to become so familiar with schematic diagrams that you can look at one and picture the arrangement of the parts. That is not hard if you start with simple circuits like those you have built so far, and gradually work up to more complex circuits. The manufacturer's servicing information on any equipment usually has a complete schematic diagram and the parts values. If you are servicing the equipment, you will have to find the defective part, determine its value, and make the replacement.

Usually connections between parts are shown by a line that follows the shortest path between the two parts. However, this is not always true. The only sure way to find the part is to trace the circuit. Often it is more convenient to run a lead over a somewhat longer path to avoid crowding a section of the diagram. An example of this is given in Fig. 4-1. We could have drawn a horizontal line directly from pin 4 of V_1 to pin 3 of V_2 to show that they are connected. However, the line would have had to cross a number of other lines, thus crowding the diagram, and perhaps causing some confusion. Drawing the line as in Fig. 4-1 avoids confusion.

Tracing circuits on a schematic diagram is in many ways like tracing a road between your home and another city on a

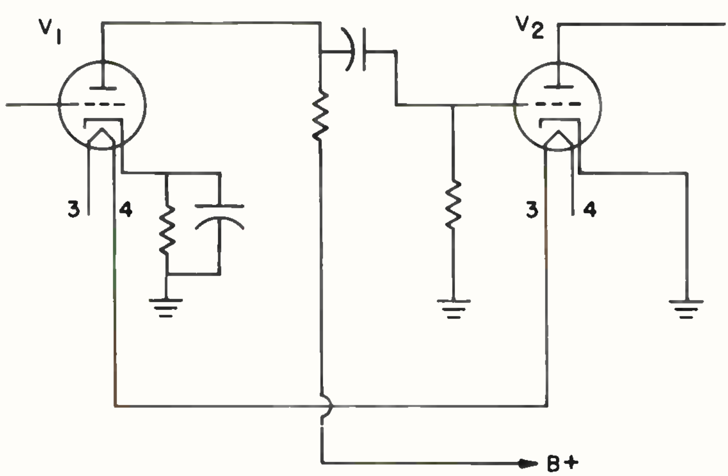


Fig. 4-1. Typical schematic diagram showing a two-stage tube circuit.

road map. You will seldom find a road that goes in a straight line from one place to another. Instead, the road will turn time and time again; you may have to go a certain distance on one road and then turn onto another. So it is in tracing the circuit on a schematic diagram. You start at one point in the circuit and trace toward another point. You may find a direct circuit between the two points, but more often you will find the circuits are connected by something other than a direct connection. In addition, you may find that to get from one point to the other you have to trace the circuit to some intermediate point, and then from that point on through an additional circuit to the point that you are interested in reaching.

Frequently in service work you will have to trace out the actual wiring in a receiver and compare the wiring with a schematic diagram. We cannot stress too strongly how important it is for you to learn to use this type of diagram. This is why we will concentrate on learning how to use diagrams.

When you work from a schematic diagram in the experiments, there may be several ways in which the various leads can be run. In general, try to use the shortest possible route. When we work on the more complicated circuits, we will give detailed instructions on exactly where to place each important lead; but during these early experiments, we will leave you on your own as much as possible to give you all the practical experience we can.

When you build equipment from a schematic diagram, you should carefully check each circuit you wire to make sure it is wired correctly. Also make sure that each connection is properly soldered. Even if you learn to work from a schematic, the equipment you build will not work properly unless all connections are properly soldered. Many people waste a great deal of time because of careless wiring and poorly soldered connections, which could easily have been spotted if a little extra time had been taken to check the work. Start right now by checking each circuit you wire against the schematic diagram and by checking each soldered connection you make. These are good habits, and the sooner you acquire them the better.

Experimental Procedure: For this experiment, in addition to the chassis with the solder lug and terminal strips, you will need the following:

1 1000-ohm resistor
1 22,000-ohm resistor
1 100,000-ohm resistor
2 1/4" X 4-40 screws
2 4-40 hex nuts
1 Etched circuit board (EC24)
Hookup wire
Solder

Use the resistor color code chart shown in Fig. 33 to help identify the three resistors used in this experiment.

Check your experimental chassis and make certain that the terminals are clean and all excess solder has been removed. At the same time, check the tip of your soldering iron to be sure it is clean and well-tinned.

For this experiment, you will use the tube socket on your circuit board and the terminals on your chassis. You will mount the circuit board along the edge of the chassis and connect "jumper" wires from the tube socket terminals in the copper foil to the 7-lug terminal strip on the chassis.

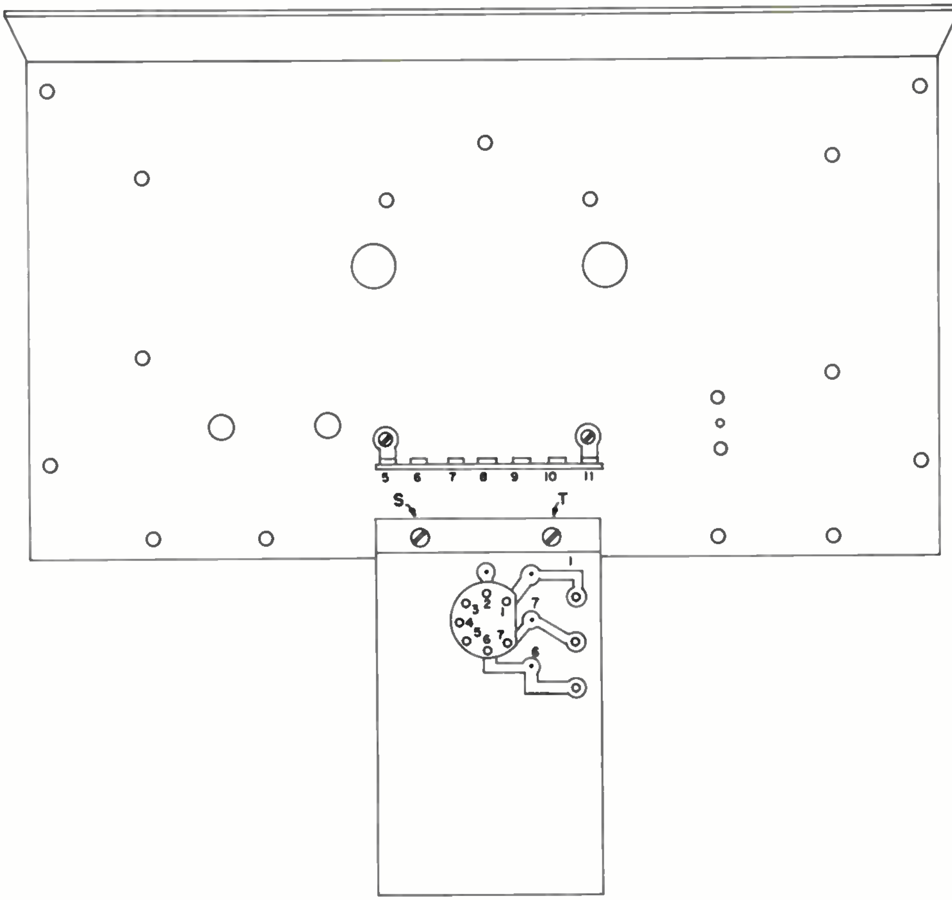


Fig. 4-2. Mounting the circuit board on the experimental chassis.

Mount the circuit board over holes S and T in the chassis (the holes are identified in Fig. 11 and Fig. 4-2). Position the circuit board over the edge of the chassis as shown in Fig. 4-2. Note that the tube socket is toward the chassis and the foil side of the board is turned upward. Attach the board with 1/4" X 4-40 screws through the mounting holes in the circuit board and chassis. Attach two 4-40 nuts and tighten.

The pins on the tube socket or tube are numbered from the blank space in a counterclockwise direction when viewed from the top. As shown in Fig. 4-3, pin 1 is at the right of the blank space, pin 2 is next, and so on. Pin 7 is to the left of the blank space. The pin in the center of the socket is not numbered. We will be primarily interested in pins 1, 6, and 7 of the socket. Connections to these holes are labeled on the foil side of EC24.

Refer to Fig. 4-4 as you make the following connections. Connect a short length of hookup wire from the hole in the foil which connects to pin 1 of the tube socket to terminal 8 on the 7-lug terminal strip. Remove about 1/4" insula-

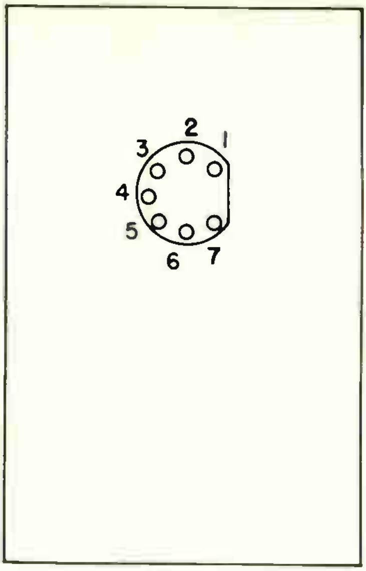


Fig. 4-3. Identifying the tube socket pins on the etched circuit board.

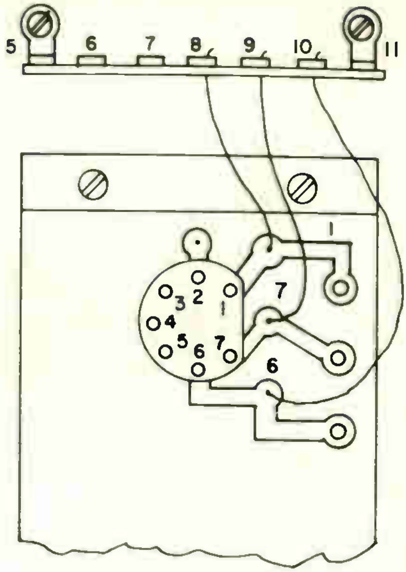


Fig. 4-4. Wiring connecting the tube socket to the terminal strip.

tion from each end of the wire. Slip the end of the wire through the hole in the circuit board from the foil side and solder to the foil.

Similarly, connect a short length of hookup wire from the hole in the foil at pin 7 to terminal 9.

In the same manner, connect a short length of hookup wire from the hole in the foil at pin 6 to terminal 10.

We often refer to a terminal or a conductor connected to a tube socket pin by the tube pin number or even by the element of the tube connected to that pin when a tube is inserted in the socket. Thus, the terminals on the chassis may be identified by the tube socket pin numbers, or as the grid, cathode and plate terminal of the 6C4 tube.

When working from schematic diagrams, remember that ground symbols indicate connections to the common return point (the chassis in this case) and that these connections can be made to anything that is connected to the chassis electrically. As your chassis is presently set up, you can use terminals 1, 5, 11, and 15 as ground connections.

If you are connecting two or more leads to a given point, do not solder until all leads are in position.

In this experiment, you are to wire a circuit directly from a schematic diagram. The diagram you are to use is shown in Fig. 4-5. The tube socket pins are indicated by the open circles nearest the tube symbol. All of the other terminals, which are shown by black dots, represent terminals on the terminal strip.

Before mounting a part, make a trial fit to determine where the part should be located. Sometimes this technique is used by experienced technicians in order to get a neat layout and prevent undue crowding of parts.

Step 1: To mount resistor R_1.

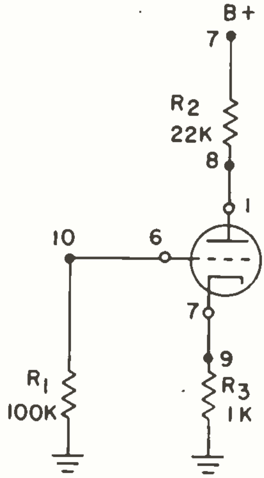


Fig. 4-5. Circuit used in Step 1.

First, find R_1 on the schematic diagram in Fig. 4-5. Notice that it is a 100,000-ohm resistor. Select a 100,000-ohm resistor from among the parts you have collected for this experiment.

From the schematic, you can see that R_1 is connected between pin 6 of the tube socket and ground. Because these connections will be made on the terminal strip, the connection will be made to terminal 10 and a ground terminal.

As stated earlier, there are four places where you can make your ground connection. The solder lug, terminal 1, and the mounting feet of the terminal strips, terminals 5, 11 and 15, are bolted directly to the chassis. Thus, they make electrical contact with the chassis and can be used for ground connections.

Connect one end of the 100,000-ohm resistor to terminal 10 and connect the other end to whichever ground point you find to be most convenient. Bend the resistor leads so that they do not touch the chassis. Also, they should not make contact with any other terminals. Solder terminal 10. Do not solder the ground terminal because you may want to make other connections to it.

Step 2: To mount resistor R_2.

Find resistor R_2 on the schematic diagram. You will see that it is a 22,000-ohm resistor (indicated by 22K on the diagram). You can also see that R_2 is connected from pin 1 of the tube socket, which is the same as terminal 8 on the terminal strip to terminal 7. Terminal 7 is marked "B+" on the schematic. Connect one lead of the 22,000-ohm resistor and solder these connections.

Step 3: To mount resistor R_3.

R_3 is a 1000-ohm resistor. On the schematic, R_3 is between pin 7 of the tube socket and ground.

Install the resistor between terminal 9 on the terminal strip (which is electrically the same as pin 7) and ground. You will have to choose a ground terminal. There are no more connections to be made. Thus, you can solder all connections which you have not yet soldered.

Step 4: To check your work.

After all wiring is in place, check your work against the schematic diagram. This check should now show:

1. A 100,000-ohm resistor between tube socket pin 6 and a ground terminal.
2. A 22,000-ohm resistor between tube socket pin 1 and terminal 7.
3. A 1000-ohm resistor between pin 7 of the tube socket and ground.

Discussion: In this experiment, you have gained experience in working from a schematic diagram. You have practiced reading resistor color codes, and you have again practiced making solder connections. You will use each of these skills every time you work on any electronic equipment.

After you have looked over your work to be sure that it is electrically equivalent to the circuit shown in Fig. 4-5, turn to the back of this manual. On page 77 you will see Fig. 4-6. This shows two ways in which you might have arranged your parts. However, these are not the only possible ways to mount the parts. As long as your arrangement is electrically the same as Fig. 4-5, you have done the experiment correctly.

Instructions For Statement No. 4: After carefully checking your work, answer the statement here and on your Report Sheet. Then unsolder the connections and remove the resistors. Disconnect the three jumper wires from the terminal strip and from the circuit board. Remove the circuit board from the chassis, clean the holes, and put the board aside. Finally, clean the resistor leads and terminals so that they will be ready for use in later experiments.

Statement No. 4: When I wired the circuit used in this experiment, I connected the 22,000-ohm resistor to the:

(1) plate
(2) cathode
(3) grid

terminal of the tube socket.

Learning to Use A Meter

An electric current is invisible, odorless and tasteless. In other words, we cannot tell that a wire is carrying current unless we use some special means of detecting it.

Although a bell or light bulb can be used to show the presence of current, neither of these devices will indicate how much current is flowing. The current in the circuit must be at a certain level before the bell will ring or the bulb will light. For example, the light bulb will light to full brilliance when its greatest current is flowing through it. As the current is decreased, the light will grow dimmer. Finally, it will reach a point where the light will give no visual indication of current, even though current may still be present in the circuit. Something is needed that will show not only whether there is current flowing, but also how much current is flowing. A meter will do both of these jobs.

MEASURING CURRENT

A meter that is used to measure current is known as an ammeter. An ammeter indicates current in amperes. The ampere, however, is much too large a unit for most measurements in electronics, so we use a meter that indicates either milliamperes (ma) or microamperes (μa). A milliampere equals one-thousandth of an ampere and a microampere equals one-millionth of an ampere. Such meters are called milliammeters and microammeters. They are made the same and operate in the same manner as an ammeter. The only difference is that the milliammeter and microammeter are much more sensitive and will respond to much smaller currents.

The meter you will use in your experiments has a range of 0 to 200 microamperes. This means that a full scale reading on the meter indicates that 200 microamperes are flowing through the meter. When the meter pointer is at half scale, half of 200 microamperes or 100 microamperes are flowing through the meter. When the meter pointer is at 1/10th scale, 20 microamperes are flowing through the meter.

PREPARING THE METER

The meter supplied in this kit is an extremely delicate instrument. It contains a jewel movement similar to that of a fine watch. Therefore, the meter must be handled with care at all times. We cannot replace any meter that has been damaged through careless handling or improper usage. If you follow carefully the instructions given, you will have no trouble with the meter. However, if you fail to follow the instructions, you may damage your meter and have to replace it.

The meter case is plastic. It can easily be scratched with a screwdriver or similar tool, or by scraping it across your workbench. Also, the plastic can be permanently damaged by heat. Be sure that you do not accidentally touch the soldering iron to the meter case.

While you are performing these experiments, the meter will be left in its box. You will connect wires to the meter terminals so that you will have easy access to the meter.

You will need the following:

2 Large solder lugs (LU7)
1 Meter (ME21)
2 Diodes (SR12)
Hookup wire
Solder

Your meter is supplied with mounting hardware and two large nuts for each terminal. These parts are in an envelope in the meter box. Save all of the hardware as you will have need for it later.

To prepare the meter, place a soft pad or towel on your workbench. Next, remove the meter from the box and place the meter carefully on the pad or towel, face down, and with the top of the meter away from you.

Remove the wire from the meter terminals. The terminals were shorted together to prevent damage to the meter during shipment. If the meter is shaken or dropped, the physical movement will cause the meter pointer to move. A voltage is generated in the coil attached to the pointer. The short circuit across the meter terminals permits the current to flow through the terminals and back through the coil. This cancels the tendency of the coil to move and protects the meter from violent pointer swing.

You will now attach the large solder lugs to the meter terminals. First, attach a large nut to one of the terminals and run it all the way down. Then slip a large solder lug over the terminal and secure it with another nut. Position the solder lug so it points toward the bottom of the meter case and tighten the nut. Hold the lower nut with a small wrench or pliers and tighten the outer nut. Do not allow the terminal to turn, since this could damage the connection inside the meter case.

In a similar manner, attach two nuts and a solder lug to the other meter terminal and tighten the nuts.

Now you will identify the lugs on the back of the meter. The one on the left as you face the back of the meter is the positive, or plus terminal of the meter; the one on the right is the negative or minus terminal. The terminals may be further identified by plus or minus signs stamped on the plastic or on the ends of the screws or "POS" and "NEG" printed near the terminals.

Examine the two diodes supplied with this kit. Refer to Fig. 3-3 to help you identify the cathode leads.

Connect the lead at the cathode end of one diode to the positive terminal of the meter. This is diode D_1 in Fig. 34. Slip the end of the lead through the lug attached to the terminal. Do not solder at this time. Slip the anode lead of D_1 through the negative terminal lug.

Connect the second diode, D_2, to the meter terminals also, but with the opposite polarity. Slip the cathode lead through the negative terminal lug and the anode lead through the positive terminal lug. Do not solder at this time.

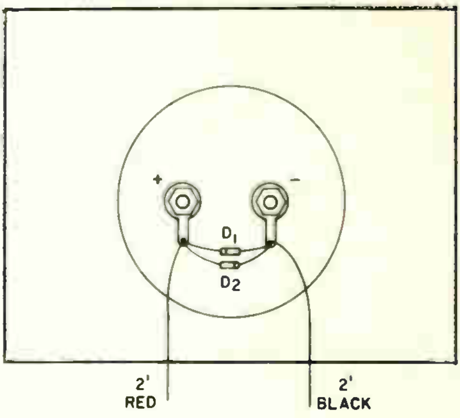


Fig. 34. Connections to the meter movement.

Prepare 2-foot lengths of red and black hookup wire. Remove about 1/4" of insulation from each end of each wire.

Connect the 2-foot length of red hookup wire to the positive meter terminal lug. Check to see that all three leads are through the hole in the terminal; then solder the connection. Be sure all three leads are soldered. After the solder cools, test the connection.

In a similar manner, connect and solder the length of black hookup wire to the negative meter terminal lug. Compare your wiring with Fig. 34 to see that you have done the work correctly.

Next, you will connect the meter leads to terminals on your chassis. Refer to Fig. 35. Connect the red lead from the meter to terminal 14. Connect the black lead from the meter to terminal 12.

Connect a 6" length of hookup wire from terminal 14 to terminal 10. Solder terminal 14.

In order to simplify the instructions, we will call terminal 10 the "positive meter terminal" and we will call terminal 12 the "negative meter terminal."

Put the meter in its box, face up. Do not attempt to make any measurements with your meter until instructed to do so.

The diodes, which you connected to the meter, are used to help protect the meter movement from excessive current. When a voltage of about .6 volt is present, one of the diodes will conduct and provide a low resistance path around the meter movement. We use two diodes connected with the opposite polarities to provide protection regardless of the polarity of the excessive voltage.

In normal operation, the voltage across the meter terminals will not exceed .15 volt. Therefore, the diodes have no significant effect on the operation of the meter unless excessive voltage is applied.

SETTING THE METER POINTER TO ZERO

The meter pointer should rest directly

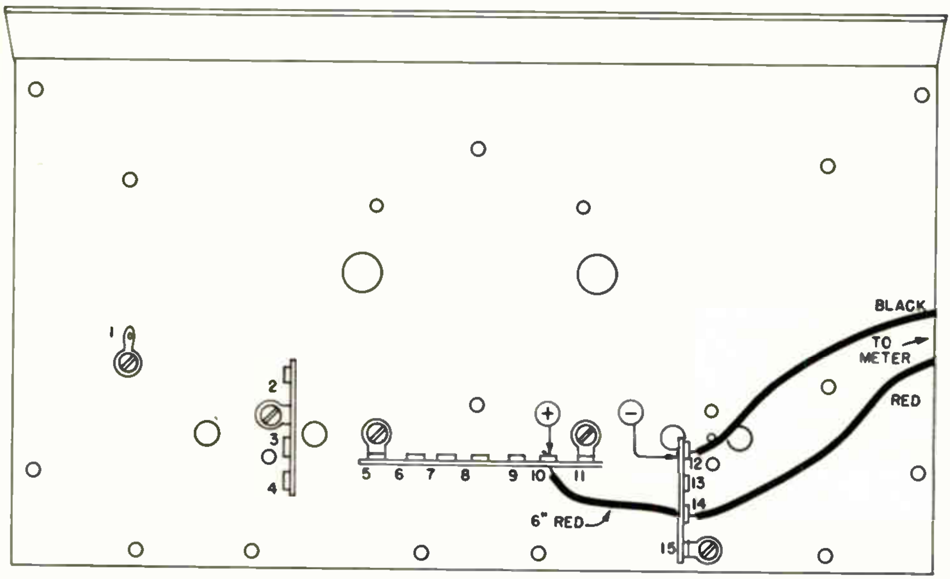


Fig. 35. The meter leads connected to terminals 12 and 14 with a jumper from 10 to 14.

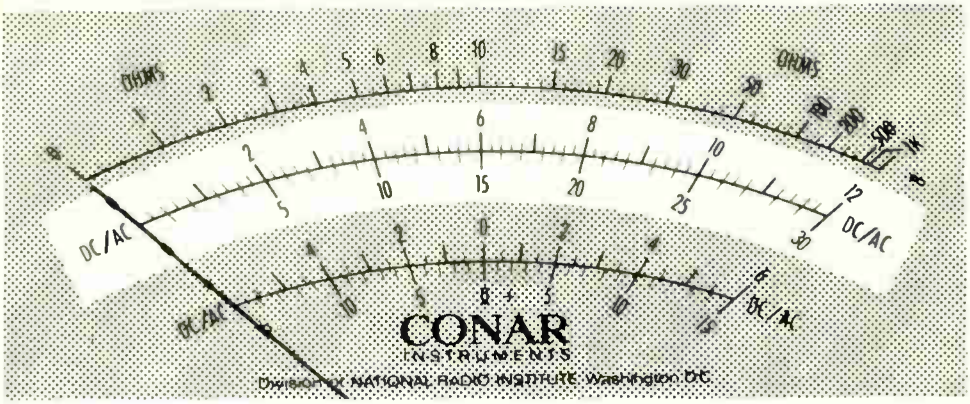


Fig. 36. The 0-12 and 0-30 volt scales on your meter.

over zero as shown in Fig. 36 when the meter is not in use. To set the pointer to zero, use a screwdriver blade that fits in the plastic screw slot on the meter face. Too small or too large a blade can damage the screw. Turn this screw, and notice that the meter pointer can be placed to the right or to the left of zero. Leave the screw adjusted so the meter pointer is over the zero mark. It is unlikely that you will have to make this adjustment again.

READING THE METER

The first time you look at the face of the meter you received in this kit, you may think that the meter is complicated and that it will be difficult to read. As a matter of fact, it is no more difficult to read a meter than it is to tell time on a clock. Of course, a meter may be something new to you, and it will take some practice to learn how to read it quickly. However, it will not be long before you will be able to read it at a glance.

At this time we will concentrate on the 0 to 12 and 0 to 30 volt scales. As you will see, the two scales may often be used together to help you obtain precise readings. These two scales are shown in white in Fig. 36. The 0 to 12 volt scale is the upper scale and has the numbers 0, 2, 4, 6, 8, 10 and 12 printed in black. The 0 to 30 volt scale is the lower scale and has the

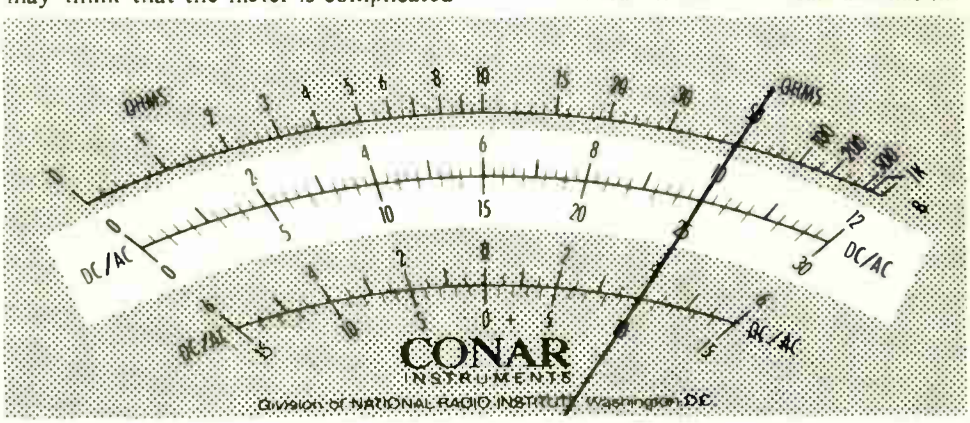


Fig. 37. A meter reading of 25 or 10.

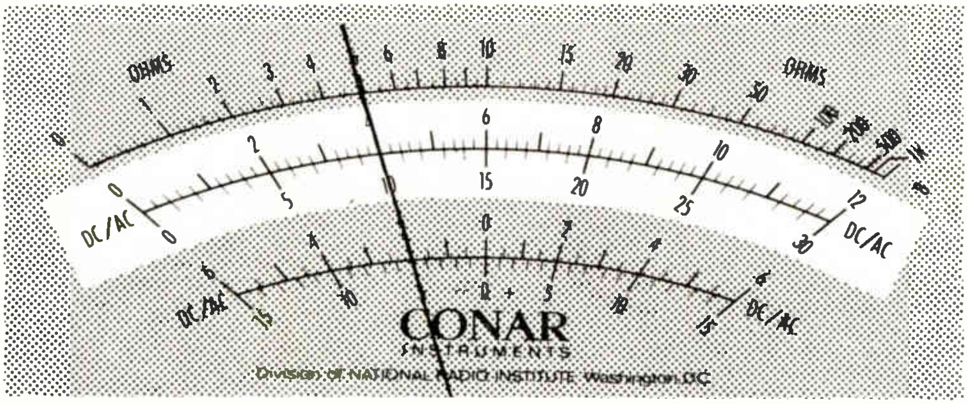


Fig. 38. A meter reading of 10 or 4.

numbers 0, 5, 10, 15, 20, 25 and 30 printed in black. Notice that the 0 to 12 volt scale has several short marks as well as some longer unnumbered marks. The 0 to 30 volt scale has four short unnumbered marks between each number.

Now look at the meter shown in Fig. 37. In this case the pointer is indicating 10 on the 0 to 12 volt scale and shows 25 on the 0 to 30 volt scale. If the pointer is as shown in Fig. 38, the reading would be 10 on the 0 to 30 volt scale and 4 on the 0 to 12 volt scale. These readings are quite easy to determine, as you can see, but what happens if the pointer is somewhere between the numbers on the scale?

Look at the scale shown in Fig. 39. Now the pointer is over one of the short marks of the 0 to 12 volt scale, but is between two short marks on the 0 to 30 volt scale! To read this value, note that on the 0 to 12 volt scale there are nine marks (or ten spaces) between 6 and 8; eight short marks and one long mark. The long mark represents 7 volts, and each short mark represents 0.2V. The pointer in Fig. 39 is on the third short mark following the 6 volt mark. Since each short mark is 0.2V, the pointer shows a reading of 6.6 volts.

Now, what is the reading of Fig. 39 on the 0 to 30 volt scale? First, notice that

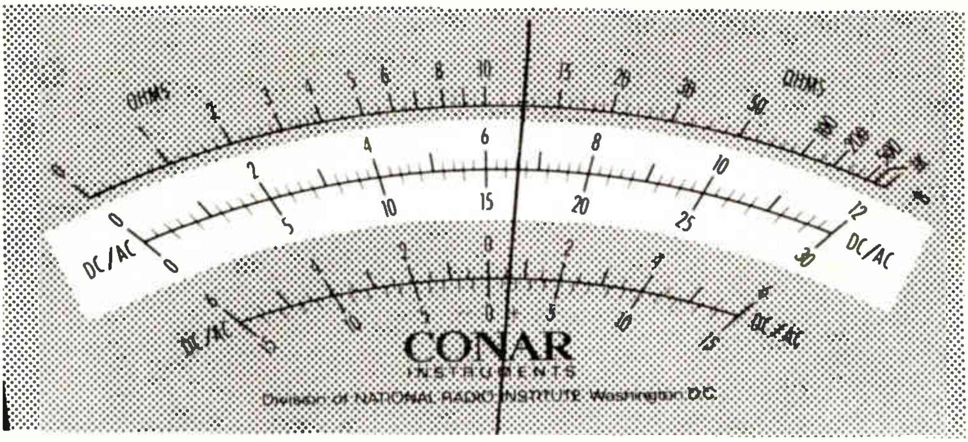


Fig. 39. Another sample meter reading.

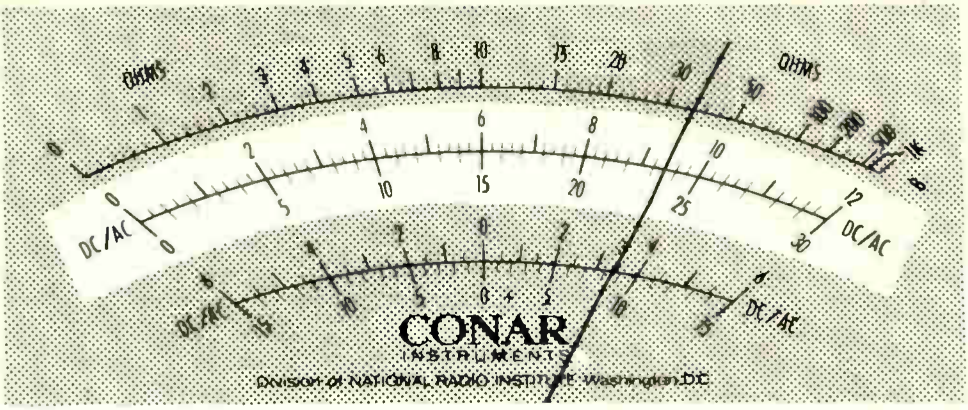


Fig. 40. Study this meter reading and see if you can tell what it is.

between 15 and 20 there are four short marks. Each mark, therefore, represents one volt. The pointer is halfway between the first and second marks following 15 so the reading is 16.5 volts. You can tell that the pointer is exactly halfway between the two marks by looking at the upper (0 to 12 volt) scale. On this scale, every other mark falls exactly halfway between the one volt marks on the 0 to 30 volt scale. This means that while the 0 to 30 volt scale is marked in one volt steps, you can determine readings to one half a volt by looking at the divisions on the 0 to 12 volt scale.

Let's look at another example. Take a look at the scale shown in Fig. 40. Using the reasoning that we applied in the previous examples, can you tell what the reading would be on the 0 to 12 and 0 to 30 volt scales? If you have trouble, go back and reread the material in the previous paragraphs. After careful study you should have no difficulty in seeing that the readings are 9.4 volts and 23.5 volts respectively on the 0 to 12 and 0 to 30 volt scales.

There is always the possibility that the pointer will not fall precisely on one of the short marks of the 0 to 12 volt scale. How are these values read? Take a look at Fig. 41. Notice here that the pointer is halfway between the second and third short marks after 4 on the 0 to 12 volt

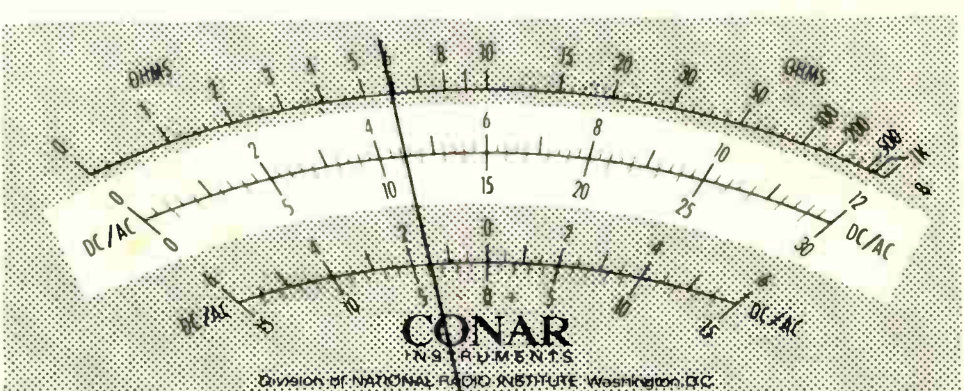


Fig. 41. Here is another meter reading for you to practice on.

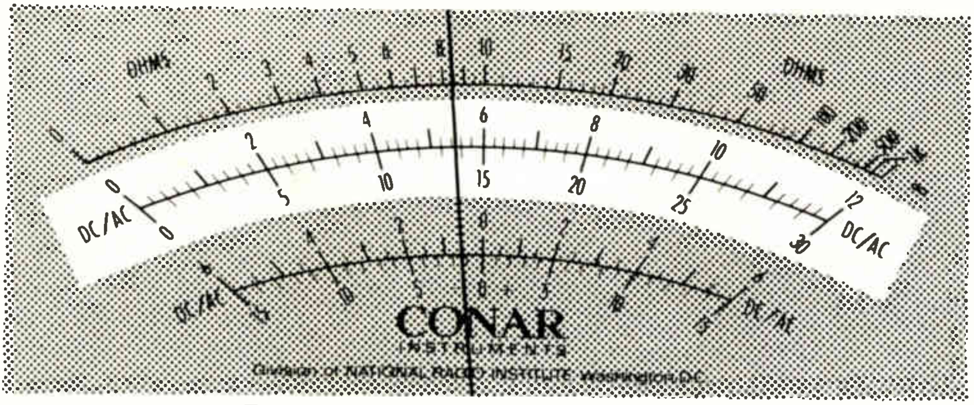


Fig. 42. What is the indication on this meter?

scale. This would be a reading of 4.5 volts. On the 0 to 30 volt scale it is just as easy. The pointer falls one fourth of the way between the first and second mark after 10, so the reading is 11.25 volts.

As a final example, try your hand at reading the two values indicated in Fig. 42. Again, the pointer does not fall on any of the scale marks of either scale. Let us see how close we can come to reading the meter by applying what we have already learned. On the 0 to 12 volt scale, the pointer is between 5 and 6. We can be more exact than that; it appears to be halfway between the second and third marks following the (unmarked) 5 volt mark. The first mark is 5.2 volts, the second mark is 5.4 volts and the third mark is 5.6 volts. Therefore the reading is between 5.4 and 5.6 volts. How much, is the question. The pointer falls about halfway between 5.4 and 5.6 volts so we would call it 5.5 volts. There is, of course, some uncertainty in this reading. For the purposes of your experiments, you would read it as 5.5 volts.

What reading does Fig. 42 represent on the 0 to 30 volt scale? Well, it is somewhere between 10 and 15 volts. Each short mark represents one volt, so the reading would be between 13 and 14 volts. Remember that the short mark on the *upper* scale (0 to 12 volts) is exactly halfway between the 13 and 14 volt marks, or in other words represents 13.5 volts. The pointer falls to the right of this mark so the reading must be between 13.5 and 14.0 volts. We would probably call this 13.75 volts; any value from 13.7 to 13.8 volts would be sufficient.

Building A Simple Series Circuit

You have already studied Ohm's Law and you know that there is a definite relationship between the voltage, current and resistance in a circuit. In Experiment 5, you will see just what happens to the current when you change either the resistance in the circuit or the voltage applied to the circuit. Before you begin Experiment 5 you will prepare the chassis by installing some parts on it. Then, when you begin Experiment 5 you will add some more parts and perform the Experiment.

In addition to your meter and chassis, you will need:

2 4.7K-ohm resistors (yellow-violet-red-silver)
1 6.8K-ohm resistor (blue-gray-red-silver)
1 1.5-volt flashlight cell
Black hookup wire
Red hookup wire
Solder

Inspect the tip of your soldering iron. If necessary, file and retin the tip.

You will connect the three resistors to terminals 7, 8, 9 and 10 on your chassis. The chassis with the resistors in place is shown in Fig. 43. Begin by connecting one lead of a 4.7K-ohm resistor to terminal 10. (There should already be a red wire connected to terminal 10.) Temporarily solder the lead and the red wire to terminal 10. Bend the resistor leads near the body of the resistor and push the free lead through the slot in terminal 9. Connect one lead of another 4.7K-ohm resistor to terminal 9. Solder terminal 9. Connect the other lead of this resistor to terminal 8. Connect one lead of the 6.8K-ohm resistor from terminal 8 to terminal 7 as shown in Fig. 43. Solder terminal 8.

Remove 1/4" of insulation from each end of a 10" length of red hookup wire. Connect and solder one end to terminal 7. Leave the other end free.

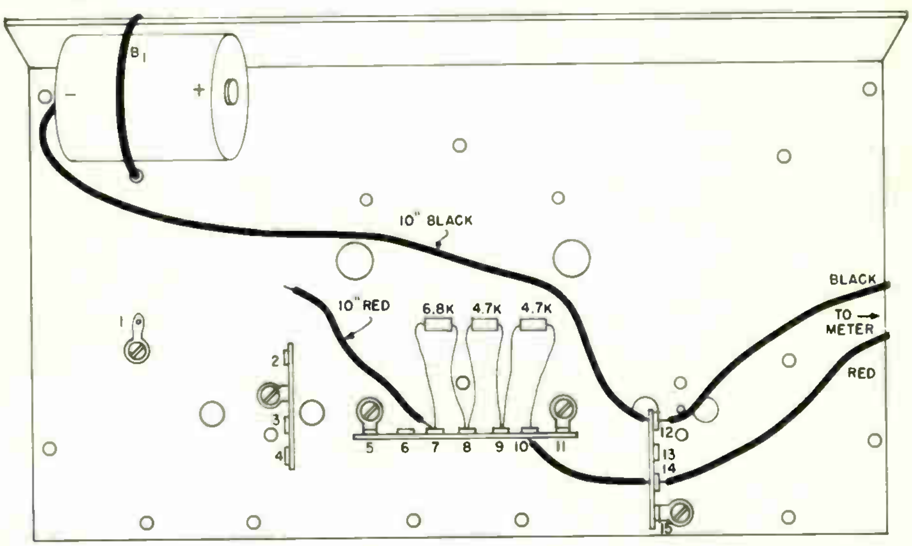


Fig. 43. Experimental chassis wired for Experiment 5.

Fig. 44. How to clean the center of the bottom of a flashlight cell with a piece of sandpaper.

You should now have three series-connected resistors going from the positive meter terminal (terminal 10) to terminal 7. The total resistance between terminal 7 and the positive meter terminal is the sum of the values of the three resistors; a total of about 16,000 ohms.

You now have a 0-200 microampere meter with approximately 16,000 ohms in series with it.

In order to measure current, your meter must be connected to a source of voltage with the proper polarity. The positive terminal of the voltage source must always be connected to the lead or circuit point that goes to the positive meter terminal.

At first, we will use a flashlight cell which produces 1.5 volts dc as a source of voltage. To do this, you are to connect a wire from the negative meter terminal, terminal 12, to the negative battery terminal. Notice that one end of your flashlight cell has a raised portion while the other end is flat. The negative battery terminal is the end with no raised section. Clean a spot in the middle of the bottom of the cell with a piece of fine sandpaper, as shown in Fig. 44.

Be sure that your soldering iron tip is clean and hot. Then, hold the end of your roll of solder on the negative terminal of the cell and touch your soldering iron to the solder. Rub the iron around so that the terminal becomes well-tinned.

Now cut a 10″ length of black hookup wire and remove 1/4″ of insulation from each end. Place one end of the 10″ length black hookup wire on the tinned area of the negative terminal of the cell. Touch the tip of your soldering iron to the wire and the tinned portion of the cell. The solder should melt and run over the wire. Remove the heat and allow the joint to cool. If the solder does not flow smoothly over the wire, add a little more solder as you heat the connection.

If you like, you can use a piece of hookup wire to secure the cell in place along the bend in the chassis as shown in Fig. 43. Note that the negative terminal is toward the left side of the chassis.

Fig. 45. Schematic symbol for a battery.

The symbol we use on schematic diagrams to represent a battery is shown in Fig. 45. Each pair of lines represents one cell of the battery. The short wide line represents the negative terminal and the longer thin line represents the positive terminal. To represent one cell, we use only one pair of lines; but to represent several cells, we do not try to show the exact number, as two or more pairs are sufficient.

EXPERIMENT 5

Purpose: To show that current flowing in a series circuit will change when the

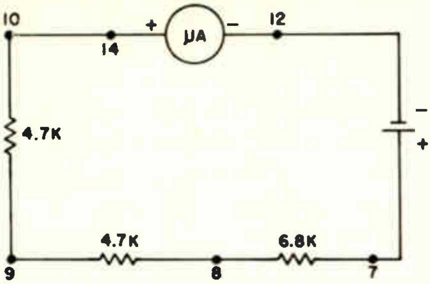


Fig. 5-1. The circuit you will use in Step 1 of Experiment 5.

resistance in the circuit or the voltage applied to the circuit is changed.

Introductory Discussion: Although the circuit you will use in this experiment is a simple circuit, it will act in the same way that a more complex circuit would act when either the resistance or voltage is changed.

This experiment will demonstrate Ohm's Law, which is one of the most important laws you will study. Do each step of the experiment carefully and make sure you understand exactly what you are doing and what the changes in current that you observe mean.

Experimental Procedure: In this experiment, in addition to the meter, chassis and the circuit you have just wired, you will need the following:

1 1.5-volt flashlight cell
Hookup wire

The first circuit you will use is shown in Fig. 5-1. When you read the meter, use the 30-volt scale which you practiced reading previously.

Step 1: To connect 1.5 volts across the meter and series resistor combination.

Touch the red wire from terminal 7 to the positive terminal of the flashlight cell. This closes the circuit and causes current to flow.

Observe the pointer on your meter. It should be slightly below one-half scale. If you get no reading, look for a bad connection or a short circuit. Check to be sure that your circuit is wired as shown in Fig. 5-1. Trace the wiring from terminals 12 and 10 back to the terminals on the meter. Also check for a short circuit between the meter terminals or leads.

The meter scale which you are using in this experiment (Fig. 5-2) is the 0 to 30 volt scale. However, in this experiment you are using this scale only as a relative indication of the amount of current in the circuit. The meter indicates a current of about 100 microamperes, since you know that a full scale reading (30) repre-

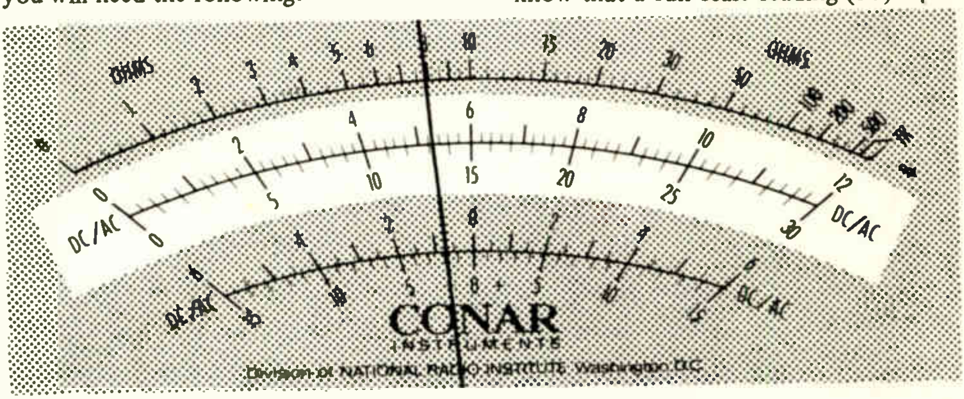


Fig. 5-2. The meter reading of Step 1 should be approximately 13 on the 0-30 scale.

STEP	READING
1	14.3
2	29.5
3	23.9

Fig. 5-3. Record your reading for Experiment 5 here.

sents a current of 200 microamperes.

In later experiments you will learn that the 0 to 30 volt scale will also be used to indicate 0 to 3 volts, and 0 to 300 volts. The 0 to 12 volt scale will also be used to indicate ranges of 0 to 1.2 volts, 0 to 120 volts and 0 to 1200 volts. For the time being, however, you need only be concerned with relative scale indications on the 0 to 30 volt scale. Read the meter carefully and write the reading of the meter in the space provided for Step 1 in Fig. 5-3. Remove the red wire from the positive terminal of the flashlight cell to open the circuit.

Step 2: To determine the effect of increasing the voltage in a series circuit.

To do this, you will connect another flashlight cell in series with the cell you used in Step 1. This is shown in the schematic diagram in Fig. 5-4.

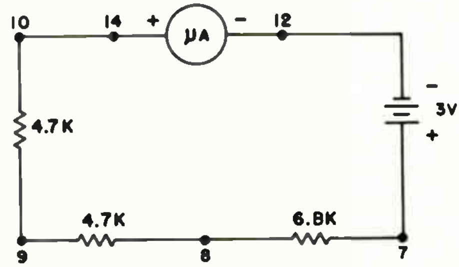


Fig. 5-4. Circuit to use for Step 2.

Clean the positive terminal of the second flashlight cell with a piece of fine sandpaper. Hold your soldering iron on the terminal and apply solder. Melt

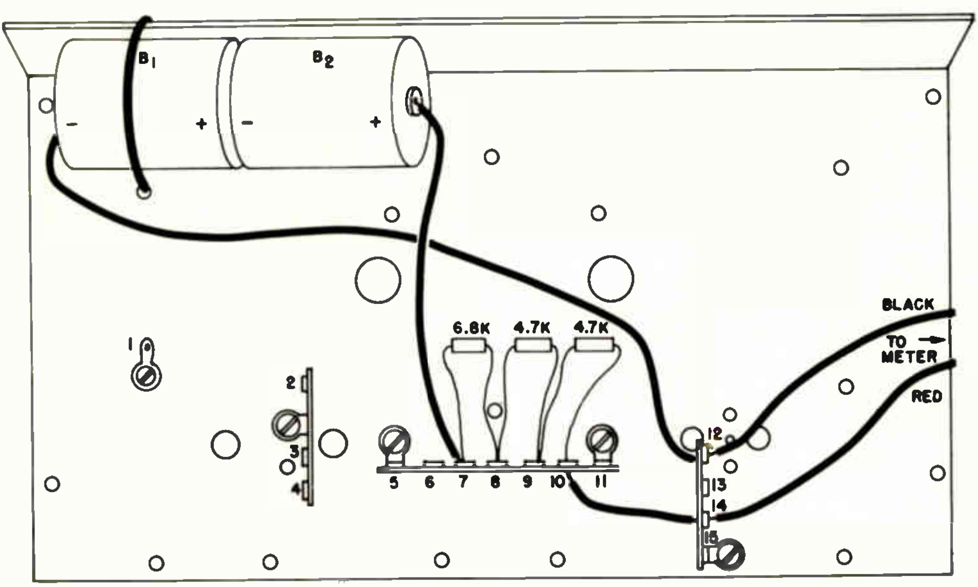


Fig. 5-5. Series resistor with 3-volt battery.

enough solder on the terminal to tin it. Rub the tip of the iron around so that the terminal is well-tinned.

Place the free end of the red wire connected to terminal 7 on the tinned area of the positive terminal of this flashlight cell and apply heat to solder the wire to the terminal. Use additional solder if necessary.

Now, to complete the circuit, hold the positive end of the first flashlight cell against the negative terminal of the second flashlight cell, as shown in Fig. 5-5. This places the two 1.5-volt cells in series, thus forming a 3-volt battery.

The meter pointer should swing to the right to just under 30 on the 30-volt scale. Look at the meter carefully, read the value as closely as you can, and write the reading in the space reserved in Fig. 5-3.

Step 3: To show that the amount of current will change when the resistance is changed.

The circuit you will use is shown in Fig. 5-6. Unsolder the red wire from the positive terminal of the second flashlight cell and from terminal 7 and set the cell to one side. Solder one end of the red wire you just removed to terminal 8.

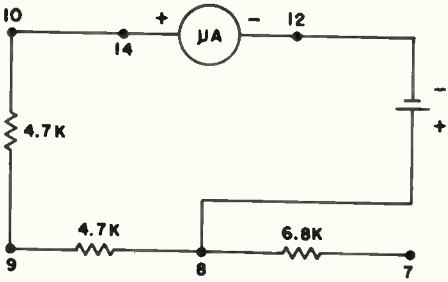


Fig. 5-6. Circuit you use for Step 3.

Touch the free end of the red wire to the positive terminal of the flashlight cell on the chassis. You now have a total of about 9,400 ohms in the circuit with a source voltage of 1.5 volts. Read the meter and record your readings in the space for Step 3 in Fig. 5-3.

Discussion: In this experiment, you have seen what happens in a series circuit when the voltage or resistance is changed. You should have a reading of something less than 15 for Step 1. When you doubled the voltage in the circuit by adding a second flashlight cell, you should have obtained a reading of about two times the original reading. In other words, when you double the voltage supplied to the circuit, the current in the circuit doubles. From this, you can see that there is a definite relationship between voltage and current in a series circuit.

In Step 3, when you reduced the resistance in the circuit, you should have found that the current was greater than in Step 1. This shows that if you reduce the resistance in a series circuit, the current will increase. We could have shown that increasing the resistance will cause the current to decrease, but this should have been obvious from the steps that you have already carried out in this experiment.

Instructions For Statement No. 5: In order to complete this statement you must obtain one additional reading. You will find the current through a resistance of approximately 7,500 ohms connected across a voltage of 1.5 volts. To get this reading, wire the circuit shown in the schematic in Fig. 5-7. Connect a short length of hookup wire from terminal 7 to terminal 9. Solder both connections. Fig.

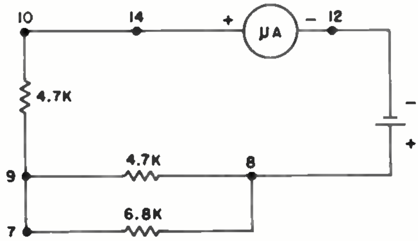


Fig. 5-7. Connect the free end of the resistors to the junction of the first and second resistors to get Statement answers.

5-8 shows the chassis wired according to Fig. 5-7. This places a 4,700-ohm resistor in parallel with the 6,800-ohm resistor. This combination is in series with the other 4,700-ohm resistor. Next, touch the red wire from terminal 8 to the positive terminal of the flashlight cell on the chassis.

Observe the meter reading on the 30-volt scale and answer the statement.

Remove the three resistors connected to terminals 7, 8, 9 and 10 and clean their leads so they will be ready for reuse. Also, disconnect and remove the short length of wire connecting terminals 7 and 9 and remove the 10″ length of red wire from terminal 8. Do not discard this wire as you can reuse it in later experiments. Do not remove any of the other wires.

Statement No. 5: When I touched the free end of the lead from terminal 8 to the 1.5-volt cell, I obtained a reading of approximately

(1) 15
(2) 30
(3) 10

EXPERIMENT 6

Purpose: To show how to connect resistors in parallel; and to show that the net resistance of a group of parallel-connected resistors is less than that of the smallest resistor in the group.

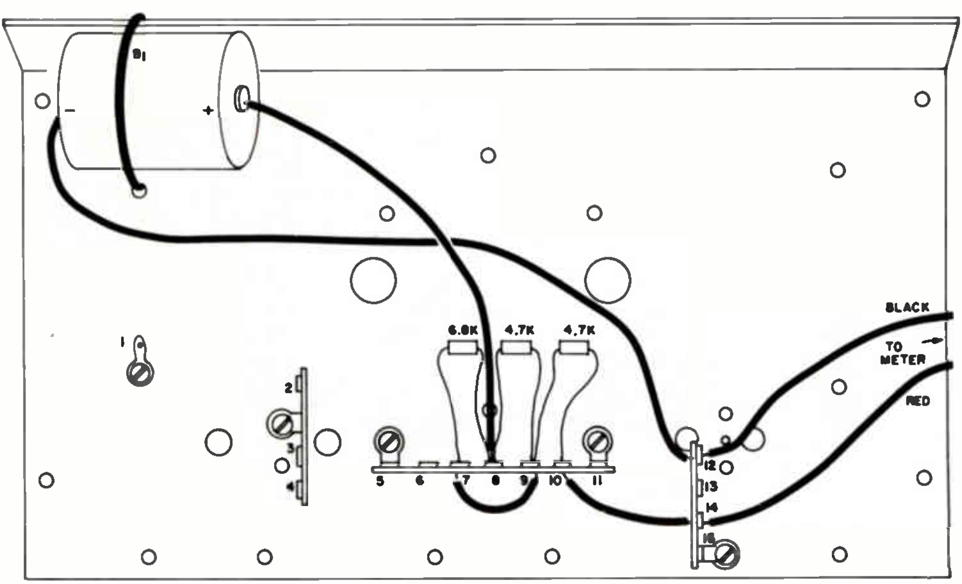


Fig. 5-8. Chassis arrangement for Statement 5.

Introductory Discussion: In the last experiment, you learned how to connect resistors in series with a source of voltage. When resistors or any other parts are connected across a voltage source, they are called a load. In a circuit of this type, each resistance, including that of the meter, can be considered as part of the total load resistance. Thus, the total load resistance is the sum of the individual resistances.

In this experiment we will show that loads can also be connected to the source voltage so that the entire source voltage is connected to each load. We will also show that when loads are connected in this manner, the net resistance of the combined load is less than the resistance of the smallest resistance in the group.

Experimental Procedure: In making these tests, you will use the following parts:

2 100,000-ohm resistors
1 82,000-ohm resistor
2 Flashlight cells
Red hookup wire

Since good connections will be required, we will solder leads to the batteries. To do this, clean the battery terminals (that you have not yet used) with a piece of sandpaper and tin them, as you learned to do in the last experiment.

Remove 1/2" of insulation from each end of an 8" length of red hookup wire. Place one end of one wire on the tinned area of the positive terminal of the cell connected to terminal 12. Touch the soldering iron to the junction. The solder on the tinned areas should melt and run over the wire. If necessary, add solder to get a good connection. Remove the heat, and let the joint cool. Solder the other end of the wire lead to the tinned area on

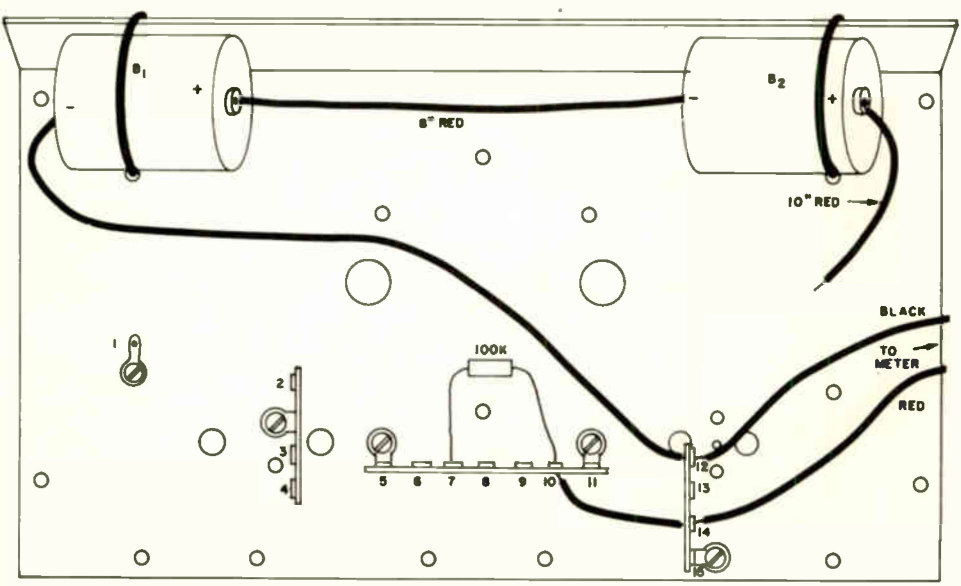


Fig. 6-1. Chassis wired for Step 1.

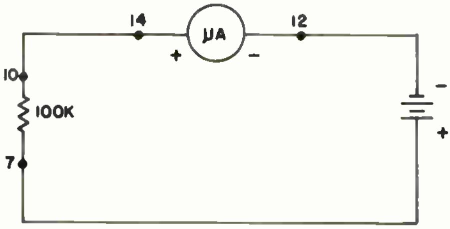


Fig. 6-2. Schematic diagram for Step 1.

the negative terminal of the second battery.

Secure the second battery to the right side of the chassis as shown in Fig. 6-1. You can pass a piece of string or hookup wire through the hole in the chassis and around the battery.

We will call the cell on the left side of the chassis B_1 and we will call the cell on the right B_2.

Locate the 10″ length of red hookup wire you used in the last experiment. Solder one end of this wire to the positive terminal of the flashlight cell, B_2. Leave the other end free.

You now have a 3-volt battery. The negative terminal of the 3-volt battery is the negative terminal of B_1 and is connected to terminal 12. The red wire connected to the positive terminal of B_2 is the "positive battery lead."

Complete the circuit shown in Figs. 6-1 and 6-2 by soldering a 100,000-ohm resistor between terminals 7 and 10.

Step 1: To get an indication of the current flowing with a 100,000-ohm resistor in the circuit.

Touch the free end of the positive battery lead, which is soldered to the positive terminal of B_2, to terminal 7. Read the meter indication on the 30-volt scale. The meter pointer should be in about the position shown in Fig. 6-3. Your reading may be somewhat higher or lower than the value shown in Fig. 6-3 because of normal tolerances in resistor values and the output voltages of different cells. Read the meter carefully and then remove the free end of the positive battery lead from terminal 7 to open the circuit. Record your reading in the space provided for Step 1 in Fig. 6-4.

Step 2: To connect a 100,000-ohm resistor in parallel with the resistor used in Step 1.

Clean the leads of the second 100,000-ohm resistor and connect it in parallel with the resistor used in the last

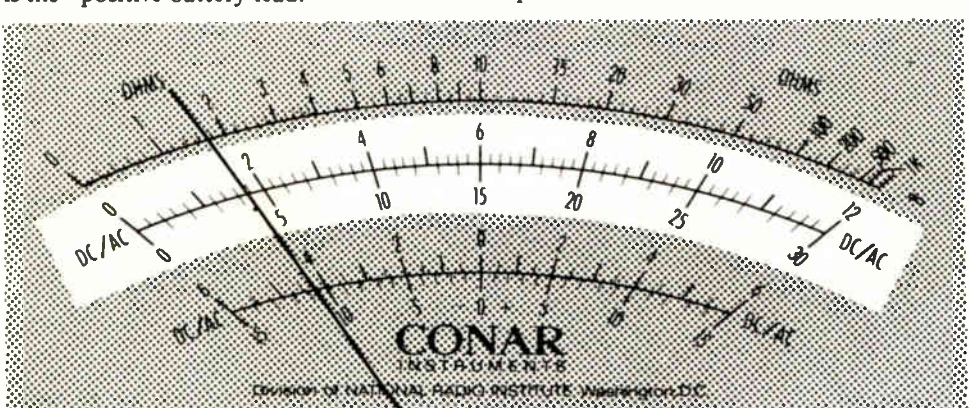


Fig. 6-3. Meter reading for Step 1.

STEP	READING
1	4.5
2	9.25
3	14.75

Fig. 6-4. Record your reading for Experiment 6 here.

step. You may solder the leads to terminal 7 and 10 or, if you prefer, you may solder the leads to the leads of the resistor already in the circuit. The circuit for this step is shown in Fig. 6-5.

Touch the positive battery lead to terminal 7 and read the meter on the 30-volt scale. Remove the positive battery lead after recording your reading in the chart in Fig. 6-4.

Step 3: To add an 82,000-ohm resistor to the parallel connected 100,000-ohm resistor.

Clean the leads of the 82,000-ohm resistor and solder it either to terminals 7 and 10 or to the leads of one of the resistors used in Step 2. The schematic diagram of the circuit for this step is shown in Fig. 6-6. Touch the positive battery lead to terminal 7 and note the reading on the meter. Open the connection after recording your reading in Fig. 6-4.

Discussion: In this experiment you have demonstrated what happens to the current in a circuit when resistors are connected in parallel. You should have discovered that as you added the second 100,000-ohm resistor to the circuit, your reading on the meter was about twice what it was with only one resistor in the circuit. When you added the third resistor, you should have found that the current increased still more.

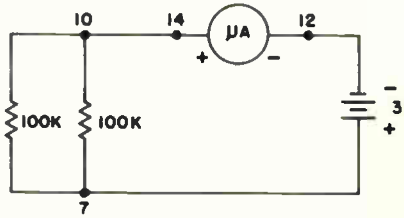


Fig. 6-5. Schematic diagram for Step 2.

You know from Ohm's Law that the amount of current that will flow in a circuit depends on the voltage applied to the circuit and the resistance in the circuit. In other words, $I = E \div R$. The value of E did not change; it was 3 volts throughout the entire experiment. Therefore, the change in current must have been entirely due to the change in resistance. In fact, the total resistance in the circuit decreased as you added more

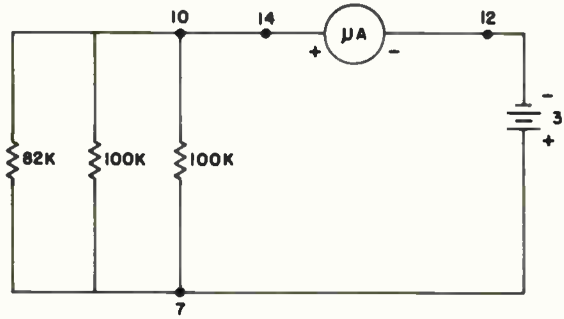


Fig. 6-6. Schematic diagram for Step 3.

resistors in parallel to produce the increase in the circuit current.

Of the three resistors used in this experiment, the 82,000-ohm resistor has the lowest resistance, and we will use this resistor by itself in the statement for this experiment.

Instructions for Statement No. 6: Remove all three resistors from terminals 7 and 10. Separate the resistors and reconnect the 82,000-ohm resistor to terminals 7 and 10.

Touch the positive battery lead to terminal 7 and note the reading on the meter. Open the circuit, and write the reading in the margin of this page. Answer the statement, and then disconnect the 82,000-ohm resistor. Clean and straighten its leads so that it will be ready for re-use. Leave all other connections alone as they will be used in the next experiment. Leave the two flashlight cells connected together and the lead from the negative terminal of the battery connected to terminal 12.

5,75

Statement No. 6: When I connected an 82,000-ohm resistor in place of the parallel group, the reading was:

(1) higher
(2) lower

than the reading obtained in Step 3.

This indicates that the resistance of the parallel group was:

(1) more than
(2) less than

that of the 82,000-ohm resistor by itself.

EXPERIMENT 7

Purpose: To show that the current is the same at every point in a series circuit.

Introductory Discussion: You already know that current in a circuit is the flow of electrons through the circuit. Electrons flow from the negative terminal of the voltage source, which is the battery in this experiment, through the load, and back to the positive terminal of the battery. Inside the battery, electrons flow from the positive terminal to the negative terminal.

In any series circuit, the current is the same throughout the entire circuit. In other words, if you connect a current-measuring instrument into the circuit to measure the current, it will not make any difference where you connect the instrument -- you will always get the same current reading. In this experiment you will demonstrate this. You will even show that the current flowing in the battery itself is the same as the current flowing in the external circuit.

Experimental Procedure: In this experiment, in addition to the meter, chassis and flashlight cells you will need the following parts:

1 100,000-ohm resistor
1 82,000-ohm resistor
1 22,000-ohm resistor
Hookup wire

Fig. 7-1 shows the circuit you will use for Step 1. This is the same setup used in

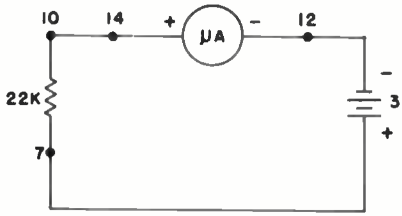


Fig. 7-1. Schematic of circuit for Step 1.

STEP	READING
1	20.5
2	20.5
3	20.25

Fig. 7-2. Record your reading for Experiment 7 here.

the last experiment. To construct the circuit, solder the leads of the 22,000-ohm resistor to terminals 7 and 10. When you have made these connections you should have:

(1) a wire from the negative battery terminal (negative terminal of B_1) to terminal 12,
(2) a wire connecting terminal 14 and terminal 10,
(3) a 22,000-ohm resistor connected from terminal 10 to terminal 7,
(4) a wire from the positive terminal of B_1 to the negative terminal of B_2, and
(5) a wire soldered to the positive battery terminal with the other end free. There should be no wire soldered to terminal 7.

If your circuit is properly wired, you may proceed with the first step.

Step 1: To measure the current leaving the battery.

Touch the free end of the positive battery lead to terminal 7. Read the meter on the 30-volt scale and record the reading in the space provided for Step 1 in Fig. 7-2. On the schematic in Fig. 7-1, you can see that the battery current flows from the negative battery terminal, through the meter to the resistor. It then flows through the resistor and back to the positive battery terminal.

Step 2: To measure the current returning to the battery.

Rewire the circuit as shown in Fig. 7-3. To do this, first unsolder and remove the red wire from terminal 10 to terminal 14. Unsolder the black negative battery lead from terminal 12. Solder the free end of the black wire to terminal 10. Connect and solder a length of hookup wire from terminal 7 to terminal 12.

Notice on the schematic in Fig. 7-3 that the meter is now between the resistor and the positive battery terminal.

Touch the free end of the positive battery lead to terminal 14 to complete the circuit. Read the meter on the 30-volt scale. Open the circuit after recording the reading for Step 2 in Fig. 7-2.

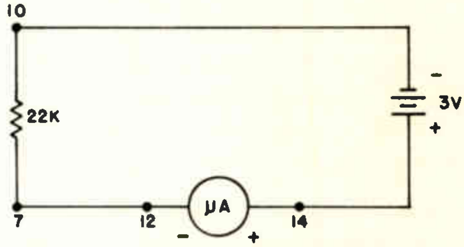


Fig. 7-3. Circuit for Step 2.

Step 3: To show that the current flowing inside the battery itself is the same as the current flowing in the external circuit.

The battery you are using in this experiment consists of two flashlight cells. Large batteries of the type used in earlier tube-type portable radios have voltages of 45 and 90 volts and are made up of groups of 1.5-volt cells, similar to flashlight cells. These are connected in series to get the required voltage. The more cells that are connected in series, the higher the voltage.

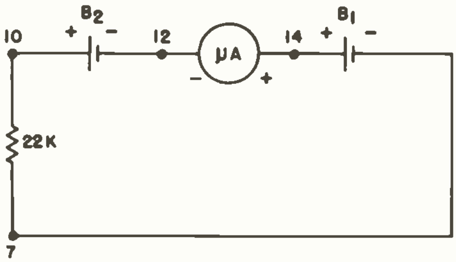


Fig. 7-4. Circuit for Step 3.

With an external circuit connected to the battery, you can measure the internal current in the battery by inserting a meter between any two adjacent cells.

To illustrate this in the experiment, wire the circuit shown in the schematic in Fig. 7-4. Fig. 7-5 shows a pictorial diagram of the wiring. Unsolder and remove the short length of hookup wire connected from terminal 7 to terminal 12.

Locate the wire connecting the two flashlight cells. Unsolder this wire from the positive terminal of B_1. Solder the free end of the wire to terminal 12.

Solder the negative battery lead to terminal 7.

Connect and solder a length of hookup wire from terminal 14 to the positive terminal of B_1. Check to see that your circuit is wired correctly.

Touch the positive battery lead (from B_2) to terminal 10 to complete the circuit. Read the meter carefully and open the circuit after recording your reading in the space provided for Step 3 in Fig. 7-2.

Discussion: In Step 3 of this experiment, the circuit is connected as shown in Fig. 7-4. Here the meter is actually placed between the two flashlight cells, and is measuring the current flowing from one cell into the second cell. Compare your readings for this step with your readings in Steps 1 and 2.

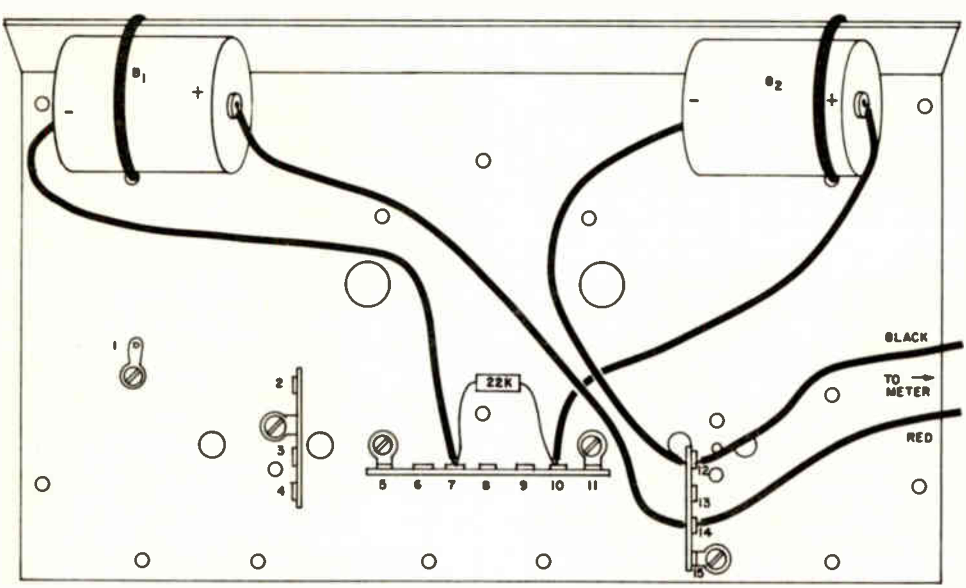


Fig. 7-5. Chassis wired for Step 3.

Notice that the readings are the same in all three steps. This demonstrates an extremely important fact. The value of the current is the same throughout the entire circuit. This means you can connect a meter at any point in a simple series circuit to measure the current; the reading will be the same regardless of where the meter is connected.

It is easy to see why the current in a series circuit is the same throughout the entire circuit. When you close the circuit by touching the battery wire to the circuit, electrons begin to leave the negative terminal of the battery. They strike other electrons and cause them to move. These electrons, in turn, strike additional electrons, and so on throughout the entire circuit. This, of course, occurs instantaneously; as soon as the circuit is completed, electrons start moving through the entire circuit.

At the same instant that electrons begin to leave the negative terminal of the battery, pushing other electrons before them, other electrons begin entering the positive terminal of the battery, because the electrons are attracted by the positive potential. The number of electrons moving in one part of the series circuit is exactly equal to the number of electrons moving in any other part of the series circuit.

Instructions for Statement No. 7: In the preceding experiment, you demonstrated that when resistors are connected in parallel, the total resistance of the combination is lowered. If the applied voltage does not change, this results in an increase in current. For this Report Statement, you will connect a low resistance in series with a high resistance. Then you will shunt each resistance with an 82,000-ohm resistor and note the effect on the total circuit current.

To carry out the experiment for this statement, you will need one 100,000-ohm resistor and one 82,000-ohm resistor. Wire the circuit as shown in Fig. 7-6. Connect a 100,000-ohm resistor from terminal 10 to terminal 13. Solder both connections. Check your circuit to see that it is wired according to Fig. 7-6. Solder the positive battery wire to terminal 13.

Note the reading on the meter on the 30-volt scale. Bend the leads of the
1.8 82,000-ohm resistor so that you can conveniently bridge the resistor across either the 100,000-ohm or the 22,000-ohm resistor. Bridge the 82,000-ohm re-
7 sistor first across the 100,000-ohm resistor and note the meter reading on the margin. Next move the 82,000-ohm re-
4 sistor over and bridge the 22,000-ohm resistor. Again, read the meter and note the reading in the margin.

Compare the two meter readings and answer the Report Statement.

Unsolder the positive battery lead from terminal 13. Unsolder and remove the 100,000-ohm resistor connected between terminals 10 and 13 and the 22,000-ohm resistor connected between terminals 7 and 10. Unsolder and remove the short red wire between the positive terminal of B_1 and terminal 14. Unsolder the red wire from terminal 12. (The other end of

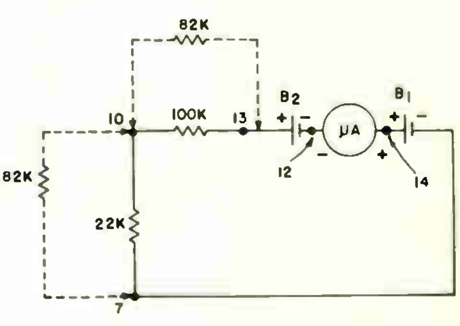


Fig. 7-6. Circuit for Statement 7.

this wire is soldered to the negative terminal of B_2.) Solder the free end of this wire to the positive terminal of B_1 to connect the two cells in series again. Clean and straighten the leads of the resistors you removed and clean all unused terminals.

Statement No. 7: When I shunted the 100K-ohm resistor with an 82K-ohm resistor, and then shunted the 22K-ohm resistor with the 82K-ohm resistor, I found that the effect on the current was:

(1) greater when the 22K-ohm resistor was shunted.
(2) greater when the 100K-ohm resistor was shunted.
(3) the same in both cases.

EXPERIMENT 8

Purpose: To show that the total current flowing in a parallel circuit is the sum of the currents flowing in the branches.

Introductory Discussion: In any piece of electronic equipment, there are usually several tubes or transistors connected across a single power supply. Each circuit, or stage, as they are usually called, generally draws a different current. The total current that the power supply must provide is equal to the sum of the currents drawn by the individual stages. Each stage acts as a separate load connected across the power supply. If a defect develops in one stage so that the stage draws more current than it should, not only will that stage be overloaded, but also the total current that the power supply must furnish will increase. As a result, the power supply may be overloaded. It is important for you to remember this when you start doing repair work. If a power transformer overheats, it does not necessarily indicate that the transformer is defective; it often indicates

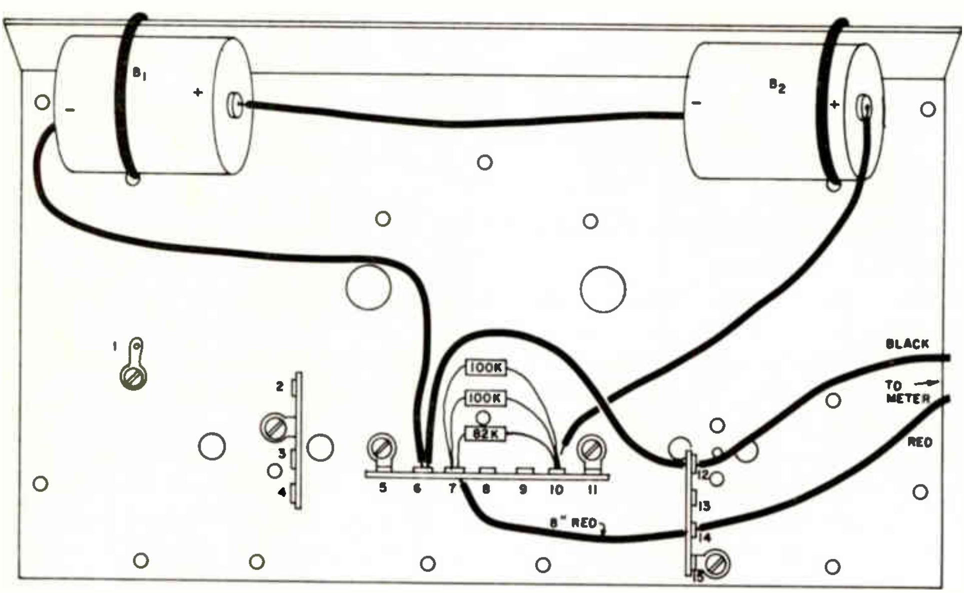


Fig. 8-1. Chassis for Step 1.

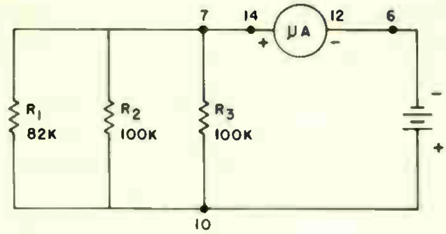


Fig. 8-2. Schematic of circuit for Step 1.

that a defect in some stage other than the power supply is causing the transformer to overheat.

In this experiment you will prove that the sum of the individual branch currents in a parallel circuit is equal to the total circuit current.

Experimental Procedure: In addition to the parts already on the experimental chassis you will need the following parts:

- **2 100K-ohm resistors**
- **1 82K-ohm resistor**
- **Hookup wire**

You should have the two flashlight cells connected to form a 3-volt battery on your chassis. For this experiment, you must wire your circuit as shown in Figs. 8-1 and 8-2.

Solder the two 100,000-ohm resistors and the 82,000-ohm resistor to terminals 10 and 7. You should then have two 100,000-ohm resistors and the 82,000-ohm resistor connected in parallel. Connect the black wire from the negative terminal of B_1 to terminal 6. Next strip 1/4" of insulation from each end of a 5" length of black hookup wire and solder this wire to terminals 6 and 12 as indicated in Fig. 8-1.

Remove about 1/4" of insulation from each end of an 8" length of red hookup wire. Solder one end to terminal 14 and solder the other end to terminal 7. Do not connect the positive battery lead at this time.

Before you go to Step 1, carefully check your work with the schematic of Fig. 8-2 and the pictorial drawing of Fig. 8-1. Make sure you have made all of the connections correctly.

Step 1: To measure the total current flow in a parallel circuit.

Touch the positive battery lead (connected to the positive terminal of B_2) to terminal 10. Observe the readings on the 30-volt scale on your meter. Remove the positive battery lead from terminal 10 after recording your reading in the space provided for Step 1 in Fig. 8-3.

STEP	READING
1	14.6
2	4.60
3	5.00
4	5.35

15.35

Fig. 8-3. Record your reading for Experiment 8 here.

With the arrangement shown in Fig. 8-2, the three resistors are in parallel and the current which you measured is the total current flowing in the circuit.

Step 2: To measure the current through a 100,000-ohm resistor.

You will use the circuit shown in the schematic diagram in Fig. 8-4. To change your wiring to make this circuit, unsolder the lead of the 82,000-ohm resistor and the lead of one 100,000-ohm resistor from terminal 7. Solder these two leads to terminal 6.

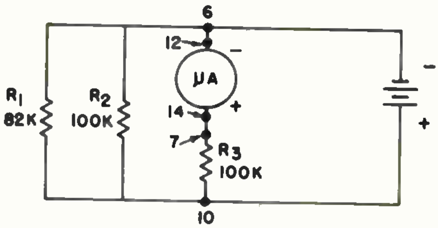


Fig. 8-4. Circuit for Step 2.

As you can see in the schematic, when the circuit is completed, current will flow through all three resistors. However, only the current through R_3 the 100,000-ohm resistor connected to terminal 7 will flow through the meter.

Touch the positive battery lead to terminal 10. Read the meter on the 30-volt scale and record your reading for Step 2 in Fig. 8-3.

Step 3: To measure the current through the second 100,000-ohm resistor, R_2.

Fig. 8-5 shows the circuit. To make the necessary changes, unsolder the 100,000-ohm resistor lead from terminal 7 and resolder it to terminal 6. Then unsolder the lead of the other 100,000-ohm resistor from terminal 6 and resolder it to terminal 7.

Touch the positive battery lead to

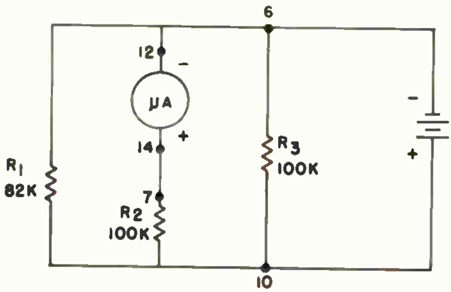


Fig. 8-5. Circuit for Step 3.

terminal 10 and observe the meter indication on the 30-volt scale. Remove the battery lead from terminal 10 after recording your reading in the space for Step 3 in Fig. 8-3.

Step 4: To measure the current through the 82,000-ohm resistor.

Modify the circuit as shown in the schematic in Fig. 8-6. Unsolder the 100,000-ohm resistor lead from terminal 7 and resolder it to terminal 6. Unsolder the lead of the 82,000-ohm resistor from terminal 6 and resolder it to terminal 7. This places the meter in the 82,000-ohm resistor circuit only.

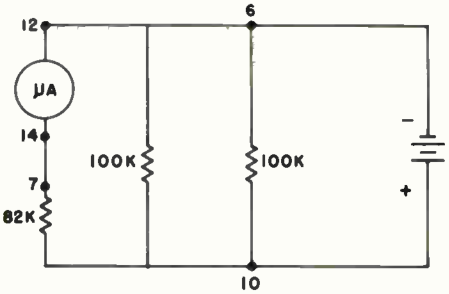


Fig. 8-6. Circuit for measuring the current through the 82K-ohm resistor.

Touch the positive battery lead to terminal 10. Read the meter on the 30-volt scale. Remove the positive battery lead from terminal 10 after recording your reading in the space provided for Step 4 in Fig. 8-3.

Discussion: In this experiment, you have measured the total current flowing in a circuit, and also the current flowing in the individual branch circuits. Since you used two 100,000-ohm resistors, you should have found that the current flowing through these resistors was the same.

In other words, the readings you obtained in Steps 2 and 3 should have been equal.

In actually taking this measurement, you may have found a slight variation because the resistors have a tolerance of 10%. Even though we call the resistor a 100K-ohm resistor, its actual resistance may be as much as 10,000 ohms more or less than 100,000 ohms. The resistance in series with the meter, therefore, may be any value between 90,000 and 110,000 ohms, which would account for the variation in your measurements. The 82,000-ohm resistor can have any value between 73,800 ohms and 90,200 ohms. Therefore, it is actually possible to have little or no difference in reading between the 82,000-ohm resistor and one or both of the 100,000-ohm resistors. In most electronics work, resistor values are not critical, and it is much more economical to use a resistor having a 10% tolerance, than it is to use a resistor having a 1% tolerance.

To show that the total current flowing in the circuit is equal to that in the individual branch circuits, add your readings for Steps 2, 3, and 4, and compare the result with the readings for Step 1. The sum of the readings recorded in Steps 2, 3, and 4 should be approximately equal to the reading you have recorded in Step 1.

Instructions for Statement No. 8: For this Statement, you do not need to take any additional measurements. You can use the readings you took in the experiment to answer the statement.

Answer the statement and unsolder and remove the two 100,000-ohm resistors and the 82,000-ohm resistor from terminals 6, 7, and 10. Remove the red wire from terminals 7 and 14 and remove the black wire from terminals 6 and 12.

Statement No. 8: When I measured the individual branch currents flowing in the circuit consisting of two 100K-ohm resistors and one 82K-ohm resistor, I found that the current was greatest

(1) through one of the 100K-ohm resistors.
(2) through the 82K-ohm resistor.

This shows that maximum current will flow through the branch in the parallel circuit having

(1) the lowest resistance.
(2) the highest resistance.

EXPERIMENT 9

Purpose: To show that a microammeter can be used as a voltmeter if a suitable resistor is placed in series with the meter.

Introductory Discussion: You have seen how a microammeter can be used to indicate the presence of current and to show if the current increases, decreases, or remains constant when circuit conditions are changed. We have not been able to measure the current in microamperes or milliamperes because the meter is not calibrated to read in microamperes. It would be possible to calculate the current from your scale readings, but since we are not interested in exact values, it is not necessary.

Your meter is a 0-200 microammeter. This means that a current of 200 microamperes must flow through the meter to give a full-scale deflection. In other words, when the pointer is at 30 on the 30-volt scale, the current flowing through the meter is 200 microamperes. (Microamperes is abbreviated μa.)

If your meter had a 200 microampere (200 μa) scale printed on it, and we inserted a resistance in series with the meter, and then connected the combination across a voltage source, you could read the current through the meter. The current would depend upon two things: the voltage of the source, and the resistance we placed in series with the meter. If we knew what the resistance was, we could read the current from the meter, and then calculate the voltage by using Ohm's Law. Ohm's Law states that $E = I \times R$. So we would multiply the current in amperes by the resistance in ohms to get the voltage of the source.

This arrangement has one drawback, however. It takes quite a bit of time to make the mathematical calculations. Actually, it is not necessary to do this, because as long as the resistance remains unchanged, the current will depend only on the voltage. Therefore, we can calibrate the meter to read directly in voltage. Now let us see how we can find out what resistor we need in order to use the 3-volt range on the meter.

To do this, we again turn to Ohm's Law. One form of Ohm's Law states that the resistance is equal to the amount of voltage divided by the amount of current. In other words, $R = E \div I$. We want the meter to read full scale when the voltage applied is 3 volts; therefore E will be equal to 3. We know that the meter is a 200 microampere meter; it takes 200 microamperes (200 μa) of current to make the meter read full scale. Converting this value to amperes, we get .0002 ampere. Now, to get the value of resistance needed, we divide 3 by .0002. This will give us 15,000. Therefore, the resistance value that should be added to the circuit is 15,000 ohms.

If we want to build an accurate meter, we will have to subtract the resistance of the meter itself from the resistance to be placed in series with the meter. However, the resistance of your microammeter is small compared to 15,000 ohms, so we will simply connect the 15,000-ohm resistor in series with the meter to give us a voltmeter that will read 3 volts on full scale. The error introduced by disregarding the meter resistance will be unimportant in this experiment.

As mentioned earlier, the scales on the meter are labeled 0 to 12 and 0 to 30. For the 3-volt scale, read the 0 to 30 volt scale but mentally divide the reading by 10, or place a decimal point before the last digit. For example, for a full scale reading, the pointer will point to 30. Dividing this by 10 gives us 3.0. Similarly, a reading of 20 is actually 2.0 on the 3-volt scale, just as 15 is 1.5 volts, 5 is 0.5 volts and so on.

Experimental Procedure: In this experiment, in addition to your meter and chassis with parts mounted, you will need the following parts:

1 15,000-ohm resistor
Hookup wire

Prepare 1′ lengths of red and black hookup wire. Remove about 1/2″ of insulation from each end of the wires.

Step 1: To convert your microammeter to a voltmeter.

Unsolder the red meter lead from terminal 14 and reconnect to terminal 13. Connect the 15,000-ohm resistor from terminal 13 to terminal 14. Solder terminal 13. Solder one end of the 1′ length of red wire to terminal 14. Leave the other end free.

Solder one end of the 1′ length of black hookup wire to terminal 12. The meter can now be used as a 0 to 3 volt voltmeter. The black wire connected to terminal 12 is your *negative voltmeter lead* and the red wire connected to terminal 14 is your *positive voltmeter lead.*

Step 2: To measure the voltage of the two flashlight cells connected in series.

The cells should still be connected in series as they were in the last experiment. Touch the negative meter lead (the black wire connected to terminal 12) to the negative terminal of the 3-volt battery, and touch the positive meter lead to the positive terminal of the 3-volt battery. Fig. 9-1 shows the circuit used in this step. Note the reading on the 3-volt scale on your meter. The reading should be approximately full scale, indicating a voltage of about 3 volts. The reading might be a little higher or lower than full scale, depending upon the tolerance of the 15,000-ohm resistor and the actual voltage of your battery. In general, new flashlight cells have a terminal voltage of 1.55 volts which drops to about 1.5 volts when the cells are heavily loaded (are supplying large current). In this circuit there is hardly any load so the battery voltage should be 2 times 1.55 volts or about 3.1 volts which would make your meter read slightly above full scale.

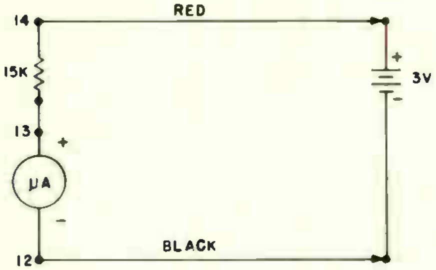


Fig. 9-1. Circuit to measure battery voltage.

Step 3: To measure the voltage of a single flashlight cell.

Touch the positive voltmeter lead to the positive terminal of one cell, and touch the negative meter lead to the negative terminal of the same flashlight cell. Note the reading on the meter. The reading should be about center scale, indicating a voltage of approximately 1.5 volts. Check the voltage of the other flashlight cell in the same way.

Discussion: The meter that you constructed in this experiment is often referred to as a 5,000-ohms per volt voltmeter. We usually write this as 5,000 ohms/volt. Notice that to convert the meter to a 3-volt voltmeter, we use a 15,000-ohm resistor. If we wanted to convert the meter to a 12-volt meter, we would have used a 60,000-ohm resistor. If we wanted to convert the meter to a 30-volt meter, we would have used a 150,000-ohm resistor. In all cases, to find the resistance needed, we multiply the required full scale voltage by 5,000.

In the early days of electronics, meters with sensitivities of 1,000 ohms/volt and 5000 ohms/volt were the only types available. Today most meters have sensitivities of 20,000 ohms/volt to 150,000 ohms/volt.

The sensitivity of the meter used in service work is important. If the meter has a sensitivity of only 5,000 ohms per volt, it is quite possible that you will not get an accurate indication of the voltage in a circuit. In the next experiment we will show you exactly how this can happen and why the sensitivity of the meter is important to the serviceman.

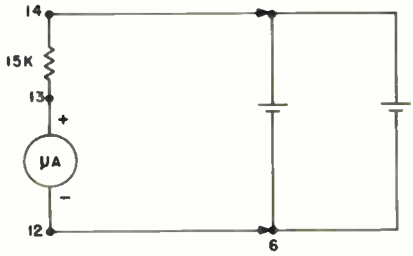


Fig. 9-2. Circuit for Statement 9.

Another type of meter, the vacuum tube voltmeter or the transistor voltmeter, has an even higher sensitivity than the meters previously discussed. For this reason most electronics technicians prefer this type to the simple voltmeter of the type you have just constructed. You will build a sensitive transistor voltmeter in the next Training Kit.

Instructions for Statement No. 9: In this statement, you are to measure the voltage of the two flashlight cells when they are connected in parallel. To do this, unsolder the red wire from the positive terminal of cell B_1 which is on the left side of your chassis. This wire should still be attached to the negative terminal of cell B_2. Solder the free end of this wire to terminal 6. Solder the free end of the positive battery lead (the wire soldered to the positive terminal of B_2) to the positive terminal of B_1. Check your work against Figs. 9-2 and 9-3.

Touch the positive voltmeter lead to the positive terminal of battery B_1 or B_2 and the negative meter lead to terminal 6. Note the reading on your meter, and answer the statement.

Unsolder the red wire from the positive terminal of battery B_1 and push the free end out of the way. Unsolder the red wire from terminal 6 and solder the free end to the positive terminal of flashlight cell B_1. Leave the 15,000-ohm resistor connected to terminals 13 and 14, and the

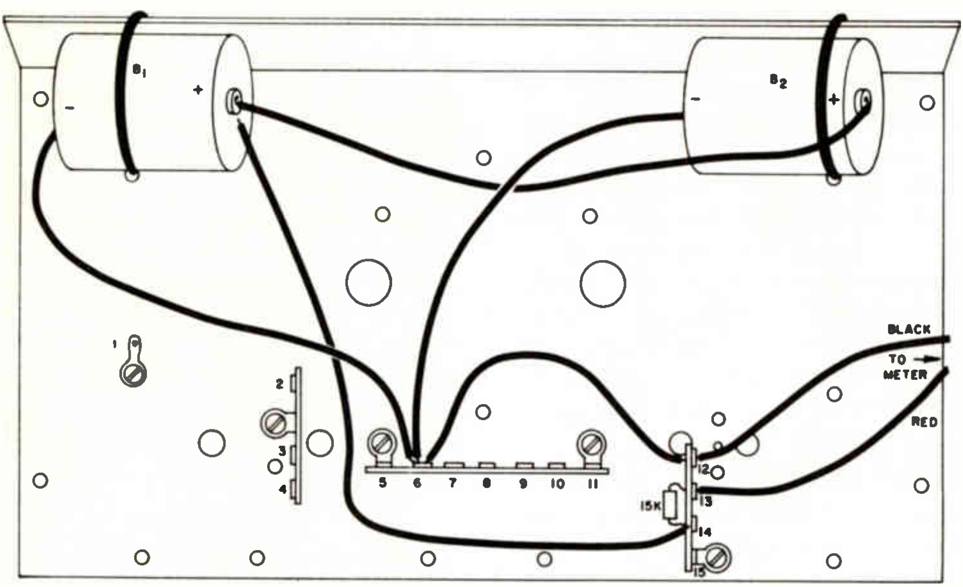


Fig. 9-3. Chassis used for Statement 9.

red and black voltmeter leads connected to terminals 12 and 13.

Statement No. 9: When I measured the voltage of the two parallel-connected flashlight cells, I found that it was approximately

(1) 3 volts.
(2) 1.5 volts.
(3) 0.

EXPERIMENT 10

Purpose: To show that in a series circuit, there is a voltage across each part, that the sum of the voltages is equal to the source voltage, and that a voltmeter can upset the voltage division.

Introductory Discussion: You already know that if you connect your voltmeter across the battery, you get an indication of the voltage produced by the battery.

When the battery is connected to a series circuit, the battery voltage drives electrons through the circuit. The electrons, in moving through each part of the circuit, set up a voltage across each part. If you accurately measure the voltage across each part and add these voltages, you will find that the sum of these voltages is equal to the source voltage.

In this experiment, you will construct a simple circuit and measure the voltage across each of the individual parts in the circuit to prove that the sum of the voltages is equal to the battery voltage.

Experimental Procedure: In this experiment, in addition to the meter and chassis, you will need:

1 470-ohm resistor
1 680-ohm resistor
1 1,000-ohm resistor
2 100,000-ohm resistors
1 82,000-ohm resistor
2 Flashlight cells

Your flashlight cells should still be connected in series to form a 3-volt battery.

Construct the circuit shown in Fig. 10-1. Solder one lead of a 1,000-ohm resistor to terminal 6. Push the free lead through the slot in terminal 4. Connect the 680-ohm resistor between terminals 3 and 4 and solder terminal 4. Connect the 470-ohm resistor between terminals 2 and 3. Solder terminal 3. Solder the resistor lead and the free end of the positive battery lead to terminal 2.

Step 1: To measure voltages in a low-resistance series circuit.

You will use your 3-volt meter to measure the voltages in the circuit shown in Fig. 10-1.

To measure the source voltage, hold the negative voltmeter lead on terminal 6, and touch the positive meter lead to terminal 2. Observe the meter on the 3-volt scale and place your reading in the space for the source voltage in Fig. 10-2.

Next, while holding the negative voltmeter lead on terminal 6, touch the positive lead to terminal 4 and measure

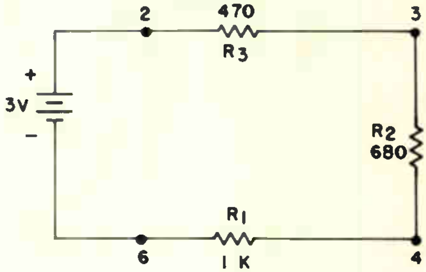


Fig. 10-1. Circuit for Experiment 10.

	READINGS
R_1	1.32V
R_2	.925V
R_3	.650V
$R_1+R_2+R_3$	2.895
SOURCE	3.1V

Fig. 10-2. Record your reading for Step 1 here.

the voltage across resistor R_1. Record this voltage in the space provided for R_1 in Fig. 10-2.

Move the positive meter lead to terminal 3 and the negative meter lead to terminal 4 and measure the voltage across resistor R_2. Record your reading in the space provided for R_2 in Fig. 10-2.

To measure the voltage across resistor R_3, touch the positive meter lead to terminal 2 and the negative meter lead to terminal 3. Read the voltage on the 3-volt scale on your meter and record your reading in the space provided for resistor R_3, in Fig. 10-2. Now add together the three voltages you recorded for R_1, R_2, and R_3 and put this value in place labeled $R_1 + R_2 + R_3$ in Fig. 10-2.

Unsolder the positive battery lead from terminal 2, to open the circuit. Unsolder and remove the 470-ohm, the 680-ohm and the 1,000-ohm resistors.

Step 2: To measure voltage in a higher resistance series circuit.

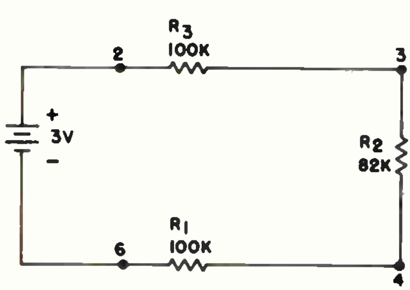


Fig. 10-3. Circuit used in Step 2.

Construct the circuit shown in Fig. 10-3. Solder one lead of a 100,000-ohm resistor, R_1, to terminal 6. Connect the other lead to terminal 4. Connect one lead of the 82,000-ohm resistor to terminal 4 and solder. Connect the other lead of this resistor to terminal 3. Connect and solder the other 100,000-ohm resistor, R_3, from terminal 3 to terminal 2. To complete the circuit, solder the positive battery lead to terminal 2.

Measure the voltage applied to the circuit by holding the positive voltmeter lead on terminal 2 and touching the negative voltmeter lead to terminal 6. Read your meter on the 3-volt scale and record your reading in the space reserved for the source voltage in Fig. 10-4.

	READINGS
R_1	.2 V
R_2	.2 V
R_3	.2 V
$R_1+R_2+R_3$	.6 V
SOURCE	3.1 V

Fig. 10-4. Record your readings for Step 2 here.

Using the same technique you used in Step 1, measure the voltages across each of the three resistors. Record these voltages in the spaces provided for it in Fig. 10-4. Now add together the three voltages you recorded for R_1, R_2, and R_3 and put this value in the place labeled $R_1 + R_2 + R_3$ in Fig. 10-4.

When you have made your readings, disconnect the positive battery lead from terminal 2.

Discussion: In Step 1, you measured the source voltage applied to the circuit and you measured the voltage across each resistor. You found that the source voltage was about 3 volts. This is the voltage across the three series-connected resistors.

The voltage drop across R_1 was about 1.4 volts, across R_2 it was about .95 volts and across R_3 about .7 volts. When you added the voltage drops across resistors R_1, R_2 and R_3, you should have found the sum to be approximately equal to the source voltage.

The voltage across a resistor is determined by the current in the resistor and the value or resistance of the resistor. As you would expect from Ohm's Law, the largest resistor has the largest voltage across it while the smallest resistor has the smallest voltage.

Another important point that you should learn from the experiment is how to connect the voltmeter to measure voltage. A voltmeter is always placed in parallel with or across the voltage you are interested in measuring.

To measure the battery voltage in the circuit in Fig. 10-1, you measure between terminals 2 and 6, which are directly across the battery. To measure the voltage across resistor R_1, you measure the voltage between terminals 4 and 6. In every case, the positive meter lead is connected to a more positive point than is the negative meter lead. The negative battery terminal is the most negative point in the circuit. In Fig. 10-1, the voltage at terminal 4 is more positive than the voltage at terminal 6. Similarly, the voltage at terminal 3 is more positive than the voltage at terminal 4 and the voltage at terminal 2 is more positive than the voltage at terminal 3.

You must always connect your voltmeter so the positive lead is connected to the more positive terminal. Otherwise, your meter will read backwards and may be damaged.

In Step 2, you also found that the supply voltage is about 3 volts. However, when you add the three readings taken for Step 2, you will find that the three voltage drops do not add up to 3 volts. At first glance, you might think that something is wrong.

Actually, the error is due to your meter resistance. The circuit you have when you connect the meter across R_1 is shown in Fig. 10-5.

Since the resistance of the voltmeter, which consists of the 15,000-ohm resistor and the resistance of the 0 to 200 microammeter, is only slightly more than

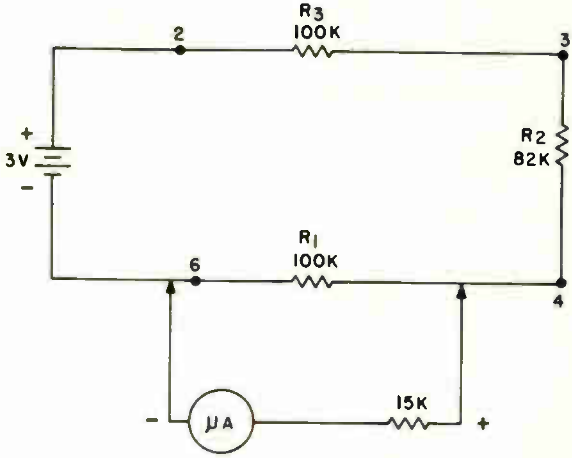


Fig. 10-5. Circuit for Experiment 10 with meter connected across R_1.

15,000 ohms, the total resistance of R_1 and the meter in parallel with it is much less than the 100,000-ohm value of R_1 alone. The resistance of the combination is very close to 15,000 ohms. Therefore, most of the voltage will be dropped across resistor R_2 and R_3, and very little will appear across the combination of R_1 and the meter circuit in parallel with it.

The same thing is true when you connect your meter across R_2 and R_3. Each time you connect the meter across a high resistance, the parallel combination of the meter and the resistor across which you are measuring voltage forms a resistance that is much lower than the original resistor value. The entire circuit, therefore, is upset and the voltage you measure is not the true voltage that is across the resistor when the meter is not connected to it.

To prevent such erroneous readings, you need a meter with a very high resistance. If your meter had a sensitivity of 100,000 ohms per volt on the 3-volt scale, you would have a total resistance of 300,000 ohms in the voltmeter circuit. Then, when you make your measurements, you would be placing 300,000 ohms in parallel with 100,000 ohms. Although the meter resistance is still low enough to upset the circuit you used in this experiment, it would not upset the circuit nearly as much as the 15,000-ohm resistance did.

The resistor values used in the first step were much less than the combined value of the meter and its series resistor. For this reason, the meter resistance has very little effect on the readings you made in the circuit in Step 1.

In your next set of experiments, you will build a transistorized voltmeter. This meter has a resistance of several megohms. Thus, when you use this meter to measure the voltage in high resistance circuits, you will get a more accurate voltage indication than you would using a simple voltmeter such as that which you used in this experiment.

Instructions for Statement 10: For this statement, you are to measure the voltage drop across two resistors. R_1 and R_2 in Fig. 10-3. Solder the positive battery lead to terminal 2. Touch your negative meter lead to terminal 6 and the positive meter lead to terminal 3. Observe your meter indication on the 3-volt scale and write the reading in the margin on this page.

Statement No. 10: When I measured the voltage across resistors R_1 and R_2, I found that the voltage was .44

(1) less than 1 volt.
(2) approximately 1.5 volts.
(3) approximately 3 volts.

After you have answered the statement, unsolder the positive battery lead from terminal 2 and push it out of the way. Unsolder and remove the red and black meter leads and all other parts and wires connected to terminals 12, 13, and 14. Straighten and clean the leads of the 15,000-ohm resistor and set it aside.

You should still have the two flashlight cells connected in series and attached to the chassis. You should also have the two 100K-ohm and one 82K-ohm resistors soldered to terminals 2, 3, 4 and 6. These resistors and the 3 volt battery will be used in the first experiment of the next training kit.

Looking Ahead

This completes the experiments in Kit 1T. One of the most important things you should have learned is how to solder correctly. As we pointed out, you will make soldered connections in all your electronics work, and one poorly soldered connection can cause you hours of unnecessary work.

In later kits you will have further experience in reading the meter. Of course, you will use the meter throughout your Practical Demonstration Course. You should have learned how to read the 0 to 30 volt and 0 to 12 volt scales in this group of experiments; in the next kit, you will learn how to read the ohmmeter scale. You also demonstrated a number of important basic circuit actions. It is much easier to study and understand the more advanced circuits that you will encounter later if you understand how the simple circuits work, and what changes in the circuit will do to voltage distribution and current flowing in the circuit.

In the next kit, you will build a transistorized voltmeter (tvom). You will find this work extremely interesting, and at the same time you will be building an instrument that will be useful to you in the rest of your experiments, and later when you start work in any branch of the electronics field. In addition to building the tvom you will continue with your studies of basic circuits.

Check to see that your training Kit Report sheet is completed and send it to NRI for grading.

While waiting for the return of this Report and for your next kit, prepare the parts you have left over for use in later kits. The parts left over are shown in Table I. *Remove the meter from its box and unsolder and remove the diodes and wires from the meter terminals.* Also, remove the solder lugs. Clean the meter terminals, and place the meter back in its box. Since the meter is a delicate instrument, be sure to put it in a safe place.

TABLE I

1	Pot mtg. bracket	2	4700-ohm resistors
1	Chassis plate	1	6800-ohm resistor
1	Etched circuit board with tube socket	1	15,000-ohm resistor
1	Marking crayon	1	22,000-ohm resistor
1	Meter	1	1/4" X 6-32 machine screw
1	6-32 hex nut	2	1/4" X 4-40 machine screws
2	4-40 hex nuts	2	Large solder lugs
1	1000-ohm potentiometer	2	Silicon diodes
1	470-ohm resistor		Hookup wire
1	680-phm resistor		Solder
3	1000-ohm resistors		

IMPORTANT: Be sure to save ALL PARTS from this Kit, including screws and nuts, because you will need them later. Keep small parts in individual envelopes or boxes.

The following parts are attached to the chassis plate:

- 2 Flashlight cells
- 1 3-lug terminal strip
- 1 4-lug terminal strip
- 1 7-lug terminal strip
- 1 Small solder lug
- 5 1/4" X 6-32 machine screws
- 5 6-32 hex nuts
- 2 100,000-ohm resistors
- 1 82,000-ohm resistor

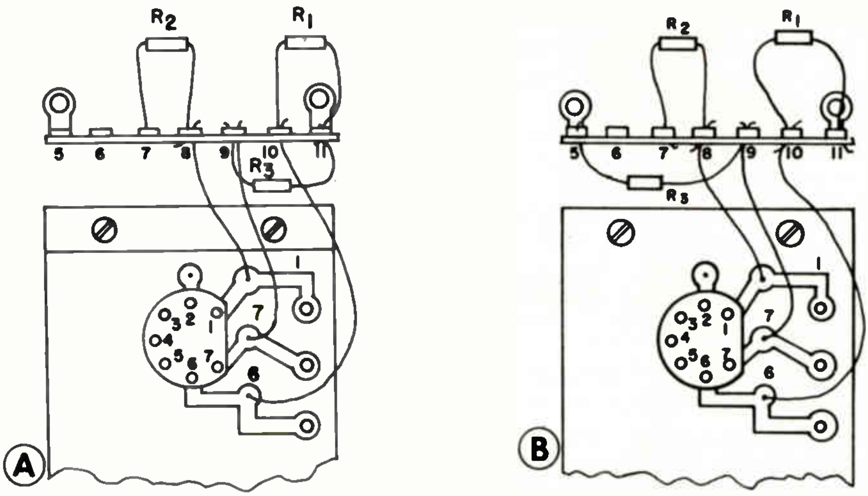


Fig. 4-6. Examples of how you could have wired the circuit used in Experiment 4.

Important Notice

As you use your soldering iron, a scale will accumulate on it. Eventually this scale will keep the iron from heating properly, and you will have to remove it. To do so, remove the tip from the barrel. Remove the scale from the tip and tap the end of the barrel against the workbench to loosen and remove the scale in the barrel. Refile the tip, if necessary, and put it back in the barrel.

If you have a soldering gun, poor contact may develop between the tip and the metal terminals of the gun. This can be eliminated by loosening and then tightening the nuts holding the tip in place. Make sure the nuts are tightened securely. Clean and re-tin the tip when it gets dirty, and replace it when it gets pitted.

Warning

You are expected to make a grade of A, B, C, or D for each group of ten experiments in this Practical Demonstration Course. If any of your reports come back to you marked "Low," you are to repeat the experiments and report statements marked "X" and then send in a complete new set of answers, using the new report blank we will send you. Since this procedure may mean that you will have to dismantle equipment that is to be used as a unit in succeeding experiments, do not begin work on the next Kit until you have received a grade of A, B, C, or D.

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.

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ACHIEVEMENT THROUGH ELECTRONICS

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TRAINING KIT MANUAL

2T

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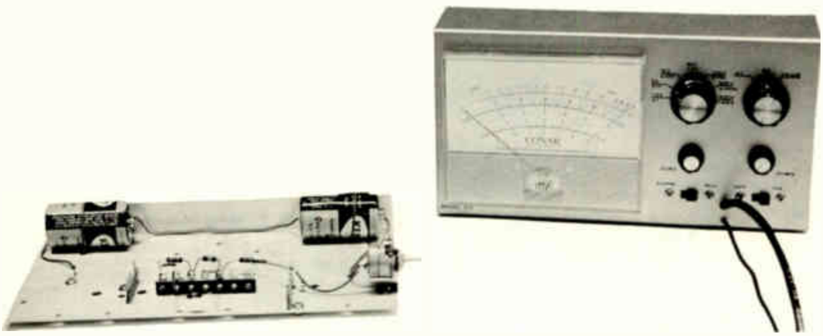
TRAINING KIT MANUAL 2T

PRACTICAL DEMONSTRATIONS
IN BASIC ELECTRONICS



INDEX OF SECTIONS

JP2M772 1975 EDITION Litho in U.S.A.

INSTRUCTIONS FOR ASSEMBLING YOUR TVOM AND PERFORMING EXPERIMENTS 11-20

In the first part of this training kit you will build a modern, battery-operated, transistorized volt-ohmmeter (abbreviated tvom), which you will use in working the experiments in the second part of this training kit as well as in later training kits. This instrument is a professional quality meter and you should do the very best work that you can in assembling it. If you follow the instructions carefully and exactly, and use the soldering practices you learned in your first training kit, you should have no trouble at all in doing an excellent construction job.

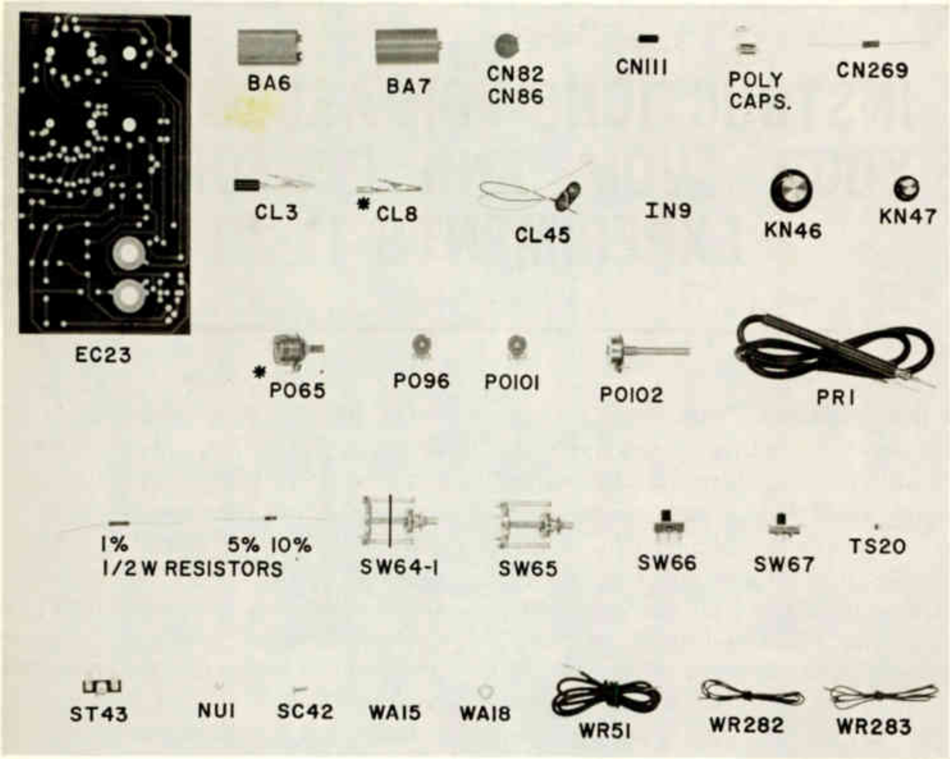
Most of the parts for the tvom are assembled on the large etched circuit board. Be very careful when soldering to the circuit board to follow the procedures given in the first training kit. If you have forgotten these procedures, or are in doubt in any way about how much heat or solder to use, go back and review the section in Training Kit 1T on soldering. The finished etched circuit board represents a fairly large amount of money, and any damage which you do to it may require replacing the entire circuit board, at your expense. We do not say this to frighten you, but merely to try to impress you with the importance of doing good work and of following the instructions *exactly*!

The parts supplied with this kit are shown in Fig. 1 and are listed below. Examine the parts you received to make certain they are all there and that no parts are obviously damaged. If any part is missing or damaged, be sure to let us know right away; we will supply the replacement part as quickly as possible so that you can begin construction of your tvom.

Before you start the actual assembly of your tvom, we want to bring to your attention certain facts about the resistors, capacitors and other parts supplied with this kit and others. This information will help you identify the various parts and ensure that you use the correct part for each step of the assembly.

CAPACITORS

There are four types of capacitors used in the assembly of your tvom: ceramic disc, polystyrene, tubular, and electrolytic. The disc capacitors are round and thin with lead wires coming from one edge. The ***value*** of the capacitor, ***type***, and ***working voltage*** are stamped on the body of the capacitor. The value will be either in picofarads (pf) or microfarads (mfd). If the number is a whole number,



* Experimental Parts

Fig. 1. Parts supplied with this kit are shown above and listed below.

Quan.	Part No.	Description	Price Each
1	BA6	9V battery	.68
1	BA7	1.5V "C" cell battery	.23
1	CL3	Alligator clip	.14
1	CL45	Battery clip	.26
1	CN82	.01 mfd, 2 KV disc cap	.22
3	CN86	.01 mfd, 1KV disc cap	.18
3	CN111	5-mfd elect. cap	.35
1	CN151	56 pf disc cap	.08
1	CN263	22 pf poly cap	.12
1	CN264	27 pf poly cap	.12
1	CN265	200 pf poly cap	.12
1	CN266	390 pf poly cap	.12
1	CN267	2000 pf poly cap	.15
1	CN268	3900 pf poly cap	.18
1	CN269	.012-mfd tubr. cap	.25
1	EC23A	Etched circuit board	4.17
1	IN9	2" spaghetti tubing	.15
2	KN46	Large knobs w/pointer	.40
2	KN47	Small knobs	.32
1	LU1	No. 6 solder lug	12/.15
5	NU1	6-32 hex nuts	12/.15
1	PA31	Panel	3.00
1	PO96	10K-ohm trimmer pot	.45
1	PO101	100K-ohm trimmer pot	.23
2	PO102	10K-ohm pot	.42
1	PR1	Probe	1.05
1	RE1	10-ohm, 5% res.	.24
1	RE3	100-ohm, 5% res.	.24
1	RE9	51K-ohm, 5% res.	.24
1	RE10	100K-ohm, 5% res.	.24
1	RE25	10-megohm, 5% res.	.24
1	RE33	22K-ohm res.	.15
1	RE34	27K-ohm res.	.15
1	RE39	1-megohm res.	.15
1	RE44	2.2-megohm, 10% res.	.15
2	RE50	6.8K-ohm res.	.15

Quan.	Part No.	Description	Price Each
1	RE73	1-megohm, 5% res.	.24
1	RE74	10K-ohm, 5% res.	.24
1	RE94	10K-ohm, 1% res.	.78
1	RE95	30K-ohm, 1% res.	.78
1	RE96	60K-ohm, 1% res.	.78
1	RE97	300K-ohm, 1% res.	.78
1	RE98	600K-ohm, 1% res.	.78
1	RE99	3-megohm, 1% res.	.78
1	RE162	6-megohm, 1% res.	.78
1	RE163	2.2-megohm, 1% res.	.78
1	RE164	1K-ohm, 5% res.	.24
5	SC42	6-32 X 3/8" Phillips head screws	12/.25

Quan.	Part No.	Description	Price Each
1	ST43	2-lug terminal strip	.06
1	SW64-1	Function switch with nut and flat washer	1.75
1	SW65	Range switch	1.76
1	SW66	DPDT slide switch	.16
1	SW67	SPST slide switch	.21
2	TS20	N channel FETs	1.00
5	WA15	No. 6 lockwashers	12/.15
4	WA18	No. 10 flat washers	12/.15
1	WR51	Ground wire	.30
1	WR282	Stranded black wire, 2'	.15
1	WR283	Stranded red wire, 2'	.15

All resistors are 1/2-watt, 10% tolerance unless otherwise specified.

2T EXPERIMENTAL PARTS

Quan.	Part No.	Description	Price Each
1	CL8	Alligator clip	.07
1	PO65	500K-ohm pot w/switch	.95
1	RE31	10K-ohm res.	.15
1	RE32	18K-ohm res.	.15
1	RE33	22K-ohm res.	.15
1	RE36	100K-ohm res.	.15
1	RE37	220K-ohm res.	.15
1	RE38	470K-ohm res.	.15
1	RE39	1-megohm res.	.15
2	RE42	10-megohm res.	.15
1	RE45	3.3K-ohm res.	.15

All resistors are 1/2-watt, 10% tolerance unless otherwise specified.

such as 120, the value is in pf. If the number has a decimal, such as .01 or .1, the value is in microfarads. The type may be any of several numbers or letters and for our purposes will be unimportant. Likewise, the voltage rating is also relatively unimportant in this kit. You should be certain, however, that the voltage rating is at least as great as that indicated for the part in the parts list.

The polystyrene capacitors are tubular in shape and have a thin lead wire coming from each end. These capacitors have a clear plastic outer covering through which you can see the aluminum foil of the capacitor plates. As with the disc capacitors, the value of the capacitor is stamped on the outside of the capacitor in pf or mfd. The largest polystyrene capacitor, CN268, may be stamped "3900" or ".0039"; either indicates a value of .0039 mfd.

There is only one tubular capacitor, CN269, a .012-mfd capacitor. This capacitor will have its value stamped on the outside of the case.

Electrolytic capacitors have polarity. They must be put into the circuit exactly as indicated, otherwise they may be damaged. The positive lead of the electrolytic, CN111, can be identified by a "+" mark printed at one end, or by the fact that one end will be colored red. The value and voltage rating are printed on the side of the capacitor.

RESISTORS

Many of the resistors used in this kit are similar to the ones you used in the first training kit. They are 1/2-watt resistors and are identified by their color code. Although you do not need to memorize this color code, it will be to your advantage to do so, as it will speed up your work to be able to identify resistors at a glance.

The fixed, color-coded resistors supplied in this kit are of 10% and 5% tolerance. It is very important that you use the correct resistor in the correct circuit. While we might possibly substitute a 5% (gold) tolerance resistor for a 10% (silver) tolerance resistor, you should *not* use a 10% tolerance resistor where a 5% tolerance resistor is called for.

There are other fixed resistors in this kit that may or may not be color-coded. These are the 1% precision resistors used in the input divider chain of the tvom. It is very important that these resistors be used *only* where called for in the instructions. If these resistors are *not* color coded, then the value will be printed right on the body of the resistor. On these resistors, the letter "K" stands for 1000, and "M" stands for one million; thus, "10K" means a 10,000-ohm resistor, and "2.2M" means a 2,200,000-ohm or 2.2-megohm resistor. If these resistors are color coded the fourth or tolerance band will be brown.

OTHER PARTS

The other parts you receive in this kit should be fairly easy to identify. For example, the two rotary switches, SW64-1 and SW65, are similar in appearance but the SW64-1 switch has two switch wafers while the SW65 switch has only one switch wafer. You can also note that the SW64-1 has 11 clips coming from the rear of the switch, while the SW65 has only 8 clips.

The two slide switches, SW67 and

SW66, do not have the part number stamped on them. They may be identified by counting the number of lugs they have; SW67 has two and SW66 has six.

The potentiometers all have their part number and value stamped on them. Be particularly careful not to confuse the two small trimmer potentiometers, PO96 and PO101. They both look alike; however, the PO96 has a value of 10K ohms and the PO101 has a value of 100K ohms.

You should have no difficulty identifying the remaining parts in this kit, using Fig. 1 and the various descriptions of the parts in the parts list under Fig. 1.

Figs. 2, 3 and 4 and a schematic diagram of the complete tvom are on the two pages in the center of this manual. You can loosen the staples and remove these pages when you assemble the tvom. When you have finished assembling the tvom, replace the pages in the center of the manual so you will have the schematic handy if you should ever need it.

Assembling Your TVOM

The assembly of your tvom is divided into several stages. In each stage you will perform only a few simple steps. In this way you can stop at frequent intervals and check to make certain that you have done what was expected for each stage. Or, if you are interrupted for any reason, there are very convenient stopping points. Just note where you stopped so that you can pick up your work conveniently.

Before you begin the assembly of any stage, read over the entire list of instructions and make sure you know exactly which parts you will need. Then select the required parts and perform the assembly steps indicated.

When you install parts on the etched circuit board, the assembly steps are given as numbered blocks around a picture of the board with arrows going from the block to the location on the board where the part is to be placed. Use the skills you learned in the first kit to install, solder and cut off leads for each step.

Some parts are installed from the foil side of the board. Be careful not to let solder bridge from one place to another when you work on the foil side of the board, and remember to clip off leftover lead lengths on the phenolic side of the board.

After you have assembled the etched circuit board you will install the meter and other parts on the panel. Then you will wire the battery, probe and switches. Finally you will fasten the circuit board to the panel and meter and perform the calibration procedure.

ETCHED CIRCUIT BOARD ASSEMBLY STAGE I

Before you begin the first assembly stage, check to make certain that your soldering iron is clean and well tinned. If it is not in good condition, plug it in and clean and retin it as described in the first training kit.

Clear a space on your worktable and put a clean, soft cloth down on which to place the circuit board as you work on it. This will protect both the circuit board and the table. Identify and gather the following parts:

- 1 Etched circuit board (EC23A)
- 1 Battery clip connector (CL45)
- 1 56 pf disc capacitor (CN151)
- 1 .01 mfd, 1KV disc capacitor (CN86)
- 2 10K-ohm pots (PO102)
- 1 10K-ohm trimmer pot (PO96)
- 1 100K-ohm trimmer pot (PO101)
- 2 6.8K-ohm, 10%, 1/2-watt resistors (RE50, blue-gray-red-silver)
- 1 22K-ohm, 10%, 1/2-watt resistor (RE33, red-red-orange-silver)
- 1 27K-ohm, 10%, 1/2-watt resistor (RE34, red-violet-orange-silver)
- 1 51K-ohm, 5%, 1/2-watt resistor (RE9, green-brown-orange-gold)
- 1 1-megohm, 10%, 1/2-watt resistor (RE39, brown-black-green-silver)
- 2 N channel FETs (TS20)
- Red stranded wire
- Black stranded wire
- Hookup wire (from Kit 1T)
- Solder

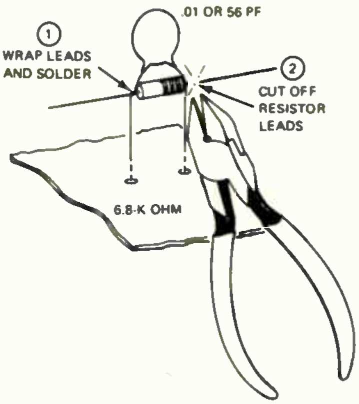


Fig. 2. Detail A.

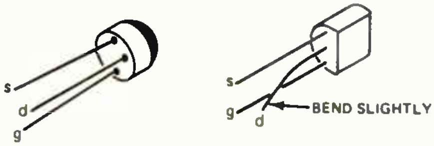


Fig. 2. Detail B.

The assembly instructions are given in Fig. 2 (centerfold).

Prepare a 7-1/2" length of red stranded wire and a 7-1/2" length of black stranded wire for use in Steps 5 and 6. Remove 1/4" of the insulation from each end of both wires, and twist the strands at the end of each wire tightly together. Tin all four ends with solder to hold the strands together. When you install these wires in Steps 5 and 6, the other end of each wire will remain free.

The red lead of the 9V battery connector installed in Step 11 goes to the "+9V" location while the white lead goes to the "-9V" location.

In Step 8 of Fig. 2 you will install a parallel combination of a 6.8K-ohm resistor and a .01 mfd disc capacitor. Detail A of Fig. 2 shows how to make this combination. Wrap each capacitor lead one time around each resistor lead close to the body of the resistor. Solder both of these connections, then clip off the resistor leads as shown. Insert the capacitor leads into the 6.8K-ohm location on the circuit board and solder as you would any other component. The 56 pf disc capacitor and the second 6.8K-ohm resistor used in Step 12 are installed in the same manner.

The two potentiometers installed in Steps 1 and 2 may have a large nut on the bushing. Remove and set aside these nuts, if present, as they will not be needed to hold the potentiometers in place. The potentiometers are installed by passing the shaft through the hole from the phenolic side of the board. Rotate the body of the control so that the three solder pins of the potentiometer line up with the corresponding holes in the circuit board as shown. With the holes lined up, push the control fully forward so the pins go through the board and the front of the control is tight up against the board. Turn the board over, making sure that the control stays tight up to the board, and solder the three pins to the foil. Do *not* try to cut off the ends of the pins.

Detail B for Fig. 2 shows two possible types of TS20 you may have received with this kit. The bottom side (lead side) of the transistors is shown. The transistor on the left in Detail B has a round case and the three leads come from the bottom of the case in a triangular configuration. The gate (g), source (s), and drain (d) leads are identified in Detail B. These symbols (g, s, d) correspond to the holes marked g, s, d on the circuit board at locations Q_1 and Q_2 (Steps 9 and 10) of Fig. 2.

The transistor on the right in Detail B has a black plastic body which is "D" shape in cross section. The three leads, g, s, d, are "in-line" on this transistor and the middle lead will have to be bent outward slightly in order to have the leads fit the holes in the circuit board.

When you are sure you have identified the leads correctly and are ready for Steps 9 and 10, push the three leads into the corresponding holes of the circuit board so that they protrude about 1/8" from the foil side of the board. Turn the board over, and while holding the transistor in place, quickly solder each of the three leads to the foil.

As mentioned earlier, be certain you use the correct trimmer potentiometers in Steps 13 and 15.

When you are certain you understand all of the steps, proceed to install the parts for Stage I, shown in Fig. 2. As you complete each step, place a check mark in the space ( ) provided.

ETCHED CIRCUIT BOARD ASSEMBLY STAGE II

In this stage of the assembly you will install the 1% resistors and the capacitors on the circuit board. Gather the following parts:

- 1 2.2 meg, 1/2W, 1% resistor (RE163)
- 1 6 meg, 1/2W, 1% resistor (RE162)
- 1 3 meg, 1/2W, 1% resistor (RE99)
- 1 600K, 1/2W, 1% resistor (RE98)
- 1 300K, 1/2W, 1% resistor (RE97)
- 1 60K, 1/2W, 1% resistor (RE96)
- 1 30K, 1/2W, 1% resistor (RE95)
- 1 10K, 1/2W, 1% resistor (RE94)
- 1 .01-mfd, 2KV disc capacitor (CN82)
- 1 22-pf polystyrene capacitor (CN263)
- 1 27-pf polystyrene capacitor (CN264)
- 1 200-pf polystyrene capacitor (CN265)
- 1 390-pf polystyrene capacitor (CN266)
- 1 2000-pf polystyrene capacitor (CN267)
- 1 3900-pf polystyrene capacitor (CN268)
- 1 .012-mfd tubular capacitor (CN269)
- 3 5-mfd electrolytic capacitors (CN111)

There are no special precautions to observe in this stage of the assembly, other than the polarity of the three electrolytic capacitors installed in Steps 5, 6, and 11. The one used in Step 5 has its "+" end to the *left*, the one used in Step 6 has its "+" to the *right*, and the one used in Step 11 has its "+" end *down.*

You will notice that the hole spacing for some of the capacitors is much greater than the length of the capacitors. Simply center the body of the capacitor between the holes and bend the leads to fit.

Now proceed to install the parts in accordance with Fig. 3, which is in the centerfold of this manual.

ETCHED CIRCUIT BOARD ASSEMBLY STAGE III

In this stage of the assembly of your circuit board you will install components on the foil side of the board as shown in Fig. 4 (centerfold). You will need:

- 1 Range switch (SW65)
- 1 Function switch (SW64-1)
- 1 .01 mfd, 1KV disc capacitor (CN86)
- 1 10-ohm, 1/2-watt, 5% resistor (RE1, brown-black-black-gold)
- 1 100-ohm, 1/2-watt, 5% resistor (RE3, brown-black-brown-gold)
- 1 1K-ohm, 1/2-watt, 5% resistor (RE164, brown-black-red-gold)
- 1 10K-ohm, 1/2-watt, 5% resistor (RE74, brown-black-orange-gold)
- 1 100K-ohm, 1/2-watt, 5% resistor (RE10, brown-black-yellow-gold)

1 1 megohm, 1/2-watt, 5% resistor (RE73, brown-black-green-gold)
1 10 megohm, 1/2-watt, 5% resistor (RE25, brown-black-blue-gold)
Hookup wire from last training kit

The two rotary switches, SW64-1 and SW65, can only fit into the holes in the circuit board one way – the right way. Examine SW65 carefully. Notice that it has eight solder lugs pointing back (away from the rear of the switch wafer) and eight solder terminals on the front side of the switch wafer. When the switch is correctly positioned, the eight lugs on the rear of the wafer will fit into the corresponding holes of the circuit board; the flat locating lug on the front of the switch will be to your left (see Fig. 4); and the two nuts which hold the switch together will fall into two larger holes of the circuit board.

If any of the lugs on the rear of the switch wafer are out of line, they must be straightened or it will be impossible to install the switch correctly. With the lugs correctly lined up, you should be able to push the switch firmly up against the board so that the shoulder of every lug is in firm contact with the foil and protrudes the same distance from the phenolic side of the board. The switch shaft will then be perpendicular to the surface of the circuit board.

Be very certain that each switch is properly installed before you solder it to the foil. If even one lug misses its hole, or if the switch is at a slight angle, your meter will not operate properly and you probably will not be able to install the board into the cabinet.

When you are absolutely certain that you have the range switch, SW65, properly positioned, solder each of the eight lugs to the foil. To do this, make sure your soldering iron is clean and hot. Melt a small amount of solder on the tip of the iron to "wet" it (this promotes good heat transfer) and touch the tip to the solder lug and the foil at the same time, just as you did when you soldered the tube socket to the circuit board in the first kit. Add enough solder so that it flows smoothly around the solder lug and also adheres to the foil. Remove the iron and allow the joint to cool. When you are satisfied that you have a good connection, proceed to solder the remaining lugs to the foil.

SW64-1 is installed in exactly the same manner. This switch has eleven lugs to be soldered to the foil and only one solder terminal on the front of the rear switch wafer. (This terminal is *not* shown in Fig. 4 as it is not used.) There are also two terminals on the front switch wafer. Position the SW64-1 as indicated in Fig. 4 and solder all eleven lugs to the foil as you did for the range switch.

In Step 1, install the .01 mfd capacitor by cutting both leads to 1/2" and soldering them to the circuit board foil, as shown in Fig. 4 and Detail A. First tin the circuit board foil in the areas shown and press the capacitor leads as close as possible against the circuit as you melt the solder on the board. Avoid shorting the leads to any of the adjacent foils; the blue solder mask material is a good insulator but is easily cut, so be careful.

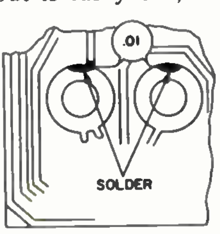


Fig. 4, Detail A.

The only remaining parts to install are the seven 5% resistors and three lengths of hookup wire. The first piece of hookup wire goes from hole number 8 of the circuit board to solder terminal 8 of SW65 as indicated in Step 9 of Fig. 4.

In Step 10, connect a 5-1/4" length of hookup wire from lug 2 of the front wafer of the Function switch to the hole marked "J" on the foil. Solder both connections. Similarly, in Step 11 connect a 7-1/2" length of hookup wire from lug 1 of the Function switch to hole "H". Solder both connections, then dress both leads close to the board, as shown in Fig. 4.

The 5% resistors go from the numbered holes to the solder terminals of SW65. Position each resistor as shown and bend one lead at right angles so it will go through the numbered hole in the board. The body of the resistor should be parallel to the circuit board and at a distance from the circuit board as determined by the location of the solder lug on SW65. As each resistor is soldered in place, cut off the excess lead length from both ends.

When you are sure you understand how to install the resistors and the hookup wire, proceed to do the steps indicated in Fig. 4.

This completes the preliminary assembly of the tvom. You will notice that there are several places on the circuit board where parts are indicated, but you have not installed the parts. These parts are installed in the next training kit to enable you to measure ac voltages. The instrument you construct in this training kit will enable you to measure dc volts in seven ranges, 1.2 volts to 1200 volts, and to measure ohms in seven ranges, R X 1 to R X 1 megohm.

MOUNTING PARTS ON THE PANEL

At this point in the assembly of your tvom you have almost completed your wiring. All that remains to be done is to mount the meter, two slide switches, assemble the probe and ground lead, install the batteries and connect the etched circuit board to the panel wiring.

You will now install the meter, prewire and mount the two switches, and assemble and install the probe and ground leads. You will need the following parts:

1 Panel (PA31)
1 Meter (ME21) and hardware (from Kit 1T)
1 .01 mfd, 1KV disc capacitor (CN86)
1 2.2 megohm, 10% resistor (RE44)
1 Probe (PR1)
1 Ground wire (WR51)
1 Alligator clip (CL3)
1 SPST slide switch (SW67)
1 DPDT slide switch (SW66)
5 6-32 X 3/8" Phillips head screws (SC42)
5 No. 6 lockwashers (WA15)
5 6-32 hex nuts (NU1)
1 2-lug terminal strip (ST43)
2 Large knobs with pointer (KN46)
2 Small round knobs (KN47)
1 2" length of insulating tubing (spaghetti, IN9)
1 No. 6 soldering lug (LU1)
Red stranded wire
Black stranded wire
Hookup wire (from Kit 1T)
Solder

Locate the panel and put it on your work area, face up in the position shown in Fig. 5. You will use the panel as a temporary support to hold the two slide

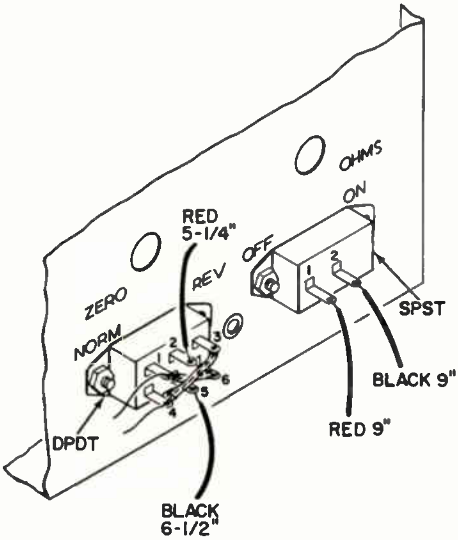


Fig. 5. Prewiring the slide switches.

switches as you wire them. As you work on the front of the panel, be very careful not to scratch or mar it with your screwdriver. Be very careful not to drip any solder onto the panel or touch the panel with your soldering iron.

Temporarily fasten the SPST slide switch as shown in Fig. 5. Position the switch so the two lugs are to the left. One screw and nut are all you need to hold the switch temporarily in place.

Prepare a 9" length of red stranded wire by removing 3/8" of the insulation from one end of the wire. Twist the strands tightly together and tin them with your soldering iron and solder to hold the wires together . . . . ( )

Do the same thing for the other end of the red wire . . . . ( )

Bend a hook in one end of the wire and pass it through terminal 1 of the SPST switch. Bend the hook closed and solder terminal 1 . . . . ( )

In a similar manner prepare both ends of a 9" black stranded wire. Solder one end of the wire to terminal 2 of the SPST switch . . . . ( )

Remove the SPST switch and set it aside . . . . ( )

Mount the 6-terminal DPDT slide switch as shown. Use one 6-32 screw and nut. NOTE: The switch can be mounted in either of two positions, both are correct . . . . ( )

Prepare a 6-1/2" length of black stranded wire as you did above and solder one end to terminal 5 . . . . ( )

In a similar manner prepare a 5-1/4" length of red stranded wire and solder one end to terminal 2 . . . . ( )

Strip 2-1/4" of insulation from a piece of solid hookup wire (left over from the last kit). Cut off the bare wire and permanently solder one end to terminal 3 of the DPDT switch . . . . ( )

Cut off a 1/2" length of the insulating tubing (spaghetti) and slip it over the bare wire soldered to terminal 3 . . . . . . ( )

Feed the free end of the bare wire coming from terminal 3 through terminal 4, leaving all the extra wire on the other side of terminal 4. The spaghetti should be between terminal 3 and terminal 4. Solder terminal 4 . . . . ( )

In a similar manner prepare a 2-1/4" length of bare wire and a 1/2" length of

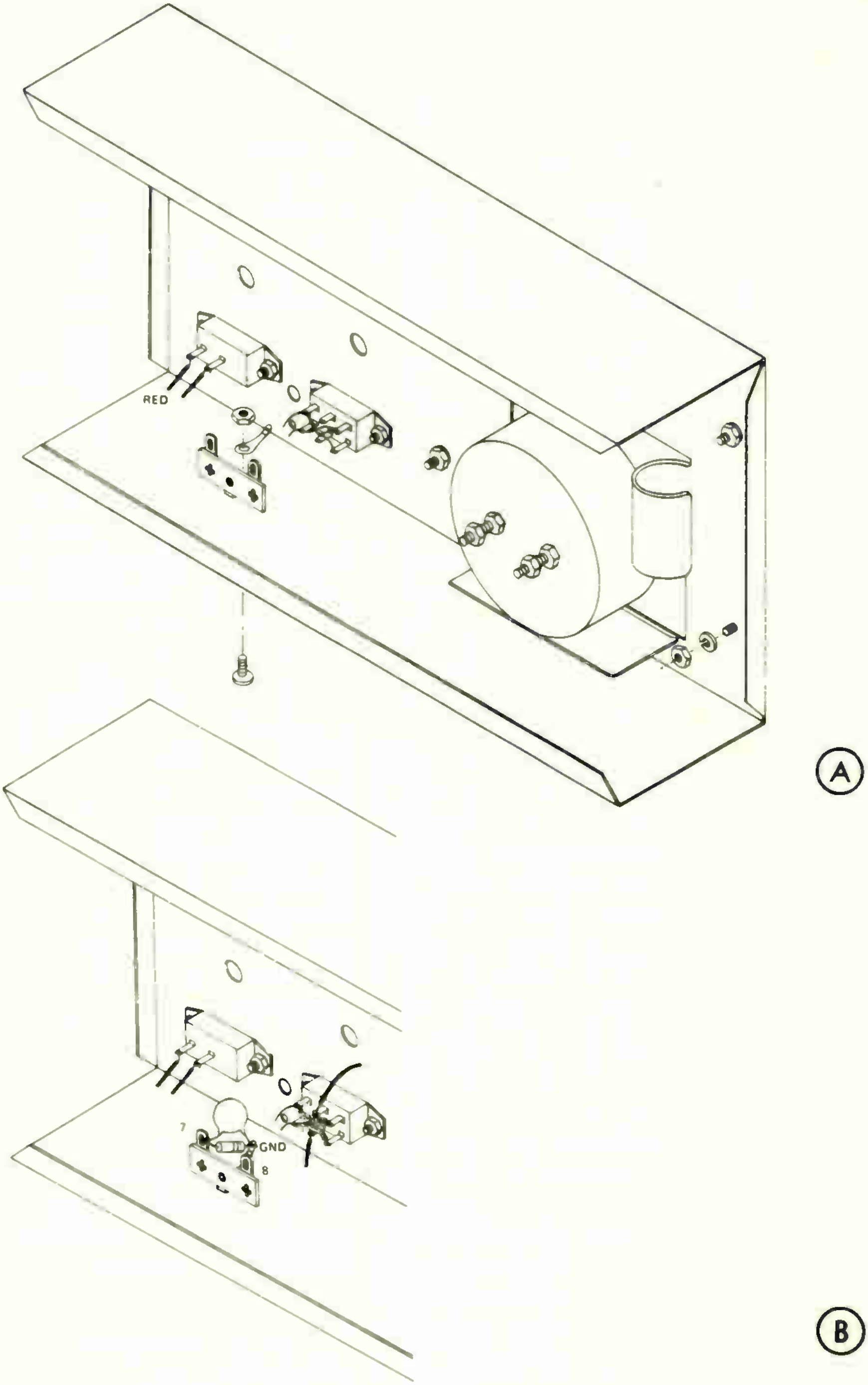


Fig. 6. Mounting parts on the panel.

spaghetti, and connect terminals 1 and 6, leaving the extra wire to the left of terminal 1 as shown in Fig. 5 . . . . . . ( )

After you have the wires in place on the DPDT switch, remove the switch and set it aside . . . . ( )

Refer to Fig. 6 for the following steps.

Position the ME21 meter over the large cutout in the panel. The four mounting screws should line up with four of the holes in the panel, as shown, with the barrel of the meter passing through the large cutout in the panel. With the meter firmly up against the panel, install a lockwasher and nut (meter hardware) on each of the four mounting screws. Save the four large nuts (meter hardware) as they will be used later . . . . ( )

CAUTION: With the meter now installed on the panel, be especially careful not to scratch or otherwise damage the meter face. Always place a clean, soft cloth on your work area to protect the meter as you work behind the panel.

Position the SPST slide switch as shown in Fig. 6 with the red wire to your left. Line up the two mounting holes with those in the panel and secure the switch with two 6-32 X 3/8" Phillips head screws, two No. 6 lockwashers and two 6-32 hex nuts . . . . ( )

Position the DPDT switch as shown in Fig. 6 with the bare wires from terminals 1 and 4 to your left. Line up the two mounting holes with those in the panel and secure the switch with two 6-32 X 3/8" Phillips head screws, two No. 6 lockwashers and two 6-32 hex nuts . . ( )

Before you mount the terminal strip, use a knife or screwdriver to scrape away the paint from around the mounting hole. Scrape off the paint on the *inside* only ( )

Install the 2-lug terminal strip and solder lug as shown in Fig. 6A with the 6-32 X 3/8" Phillips head screw, a No. 6 lockwasher and a 6-32 hex nut. Place the No. 6 solder lug between the terminal strip and the lockwasher . . . . ( )

Referring to Fig. 6B, connect the 2.2 megohm resistor from terminal 7 to the ground lug. Keep the resistor leads short and do not solder either connection ( )

Connect the .01 mfd disc capacitor from terminal 7 to the ground lug. Keep the leads short and solder *only* the ground lug . . . . ( )

Examine the red test probe with the coaxial cable attached (PR1). You will notice that the end of the probe lead looks like Fig. 7 with a bare wire surrounded by a length of insulation, a braided shield wire and an outer covering. To install the probe lead, pass the end of the lead through the bushing in hole T from the front of the panel . . . . . ( )

Rotate the lead wire so that the bare wire can be connected to terminal 8 of the 2-lug terminal strip and the braid lead

Fig. 7. End of probe lead.

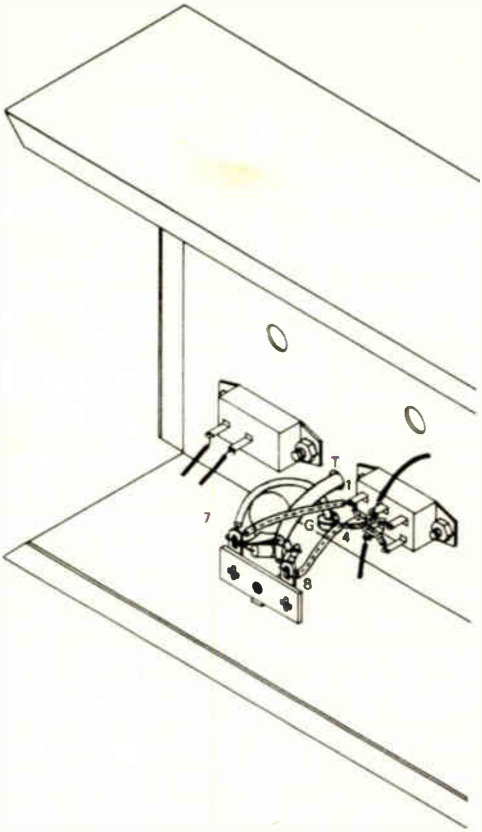


Fig. 8. Connections to terminals 7 and 8 of the 2-lug terminal strip.

can be connected to terminal 7 as shown in Fig. 8. Make these connections but do not solder . . . . ( )

Remove 1/2" of the rubber insulation from each end of the 3' ground wire (WR51), twist the strands and tin the wire . . . . ( )

Pass one end of this wire through the small bushing at hole G, and tie a knot in the wire approximately 2" from the end. Bring the end of the wire over to terminal 7 and connect but do not solder . . . . ( )

Cover the bare wire coming from terminal 1 of the switch with a length of spaghetti. Connect and solder this wire to terminal 7 of the 2-lug strip. Be sure to solder all the leads at this terminal. You will probably have to heat this connection for quite a long time before the solder will flow smoothly over all five leads . . . . ( )

In a similar manner, cover the bare wire coming from terminal 4 of the switch with a length of spaghetti and solder the wire to terminal 8 of the 2-lug strip . . . . ( )

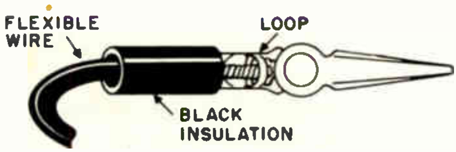


Fig. 9. How to attach the flexible wire to the alligator clip.

Now take the alligator clip with the plastic handle (CL3) and pass the free end of the 3′ ground wire through the plastic handle and the solder loop as shown in Fig. 9. Solder the ground wire to the solder loop . . . . (✓)

This completes the panel assembly. You will next fasten the etched circuit board into position, complete the wiring and then calibrate your tvom.

COMPLETING AND CALIBRATING THE TVOM

You will need the following parts:

1 1.5-volt "C" size flashlight cell (BA7)
1 9-volt battery (BA6)
2 Control nuts
2 Large flat washers
4 No. 10 washers (WA18)
4 10-32 nuts (meter hardware)
Solder

With the panel and etched circuit board in the positions shown in Fig. 10, take the red and black wires which are fastened to terminals 1 and 2 of the SPST switch, and twist them together loosely. Insert the black lead into the upper hole of the etched circuit board labeled "SW"

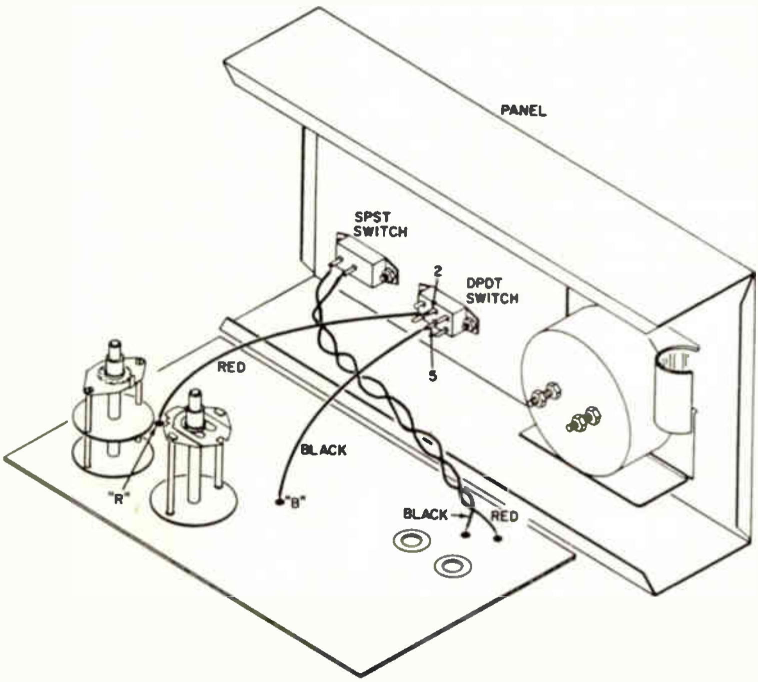


Fig. 10. Connecting the wires from the panel to the circuit board.

and the red lead into the lower hole labeled "SW" as shown. Solder both leads and clip off any excess lead length . . ( )

Place the free end of the red lead from terminal 2 of the DPDT switch into the hole labeled "R" near the function switch. Solder this lead and clip off any excess lead length from the phenolic side of the board . . . . ( )

In a similar manner, solder the black wire from terminal 5 of the DPDT switch to the hole labeled "B" on the foil side of the board . . . . ( )

Take two of the 10-32 nuts supplied with the meter and run one down on each meter terminal stud so the top of the nut is 5/16" from the end of the stud as shown in Fig. 11 . . . . ( )

Place one No. 10 flat washer on each meter stud . . . . ( )

Now carefully rotate the etched circuit board into position so that the two switch shafts will come through the upper holes in the panel and the two potentiometer shafts will come through the lower holes in the panel. The two meter studs should pass through the two large holes of the etched circuit board. Make certain that the wires from the two slide switches on the panel are free and not pinched between the switch bushings and the panel. The locating lugs of the two switches should pass through the small slots in the panels.

When you are sure the switches are correctly seated, place a large flat washer over each of the switch bushings and lightly fasten the switches with the two large control nuts. Tighten these nuts only "finger tight" for now . . . . . . ( )

Now sight along the etched circuit board from the end near the meter. The board should be straight and resting on the two washers on the meter studs. If the board is "bowed" out or must be pushed in to rest on the washers, adjust the position of the 10-32 nuts on the meter studs so the board rests on the washers without bowing . . . . ( )

Place the remaining No. 10 flat washers over the meter studs and fasten lightly (finger tight) with the remaining 10-32 nuts. Be careful not to strike Q_1 or Q_2 as you tighten the nuts . . . . ( )

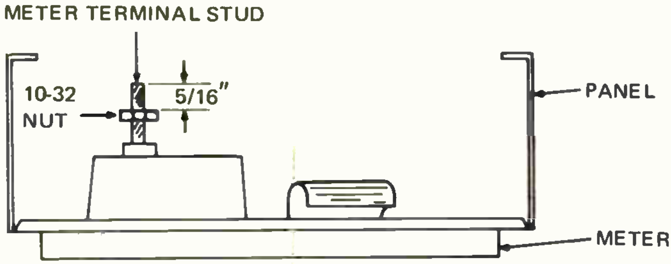


Fig. 11. Put 10-32 nuts on meter terminal studs 5/16" from end.

Now look at the two potentiometer shafts coming from the front of the panel. They should be fairly well centered in the panel holes. If they are not, slightly loosen the two control nuts, which secure the two rotary switches and the two meter stud nuts. With these four nuts loosened, you can move the etched circuit board around enough to center the potentiometer shafts. With the shafts centered, hold the circuit board in place and tighten securely the two control nuts of the rotary switches . . . .( )

Now tighten securely the two nuts that fasten the circuit board to the meter studs, being careful not to damage Q_1 or Q_2 . . . .( )

Now take the 1.5-volt "C" flashlight cell and tin a spot in the center of the bottom of the cell. Also tin the positive terminal of the cell . . . .( )

Slip the "C" cell into the curved clamp beside the meter barrel, so that the positive terminal is toward the top of the panel . . . .( )

Now locate the red and black wires which go to the + and − 1.5V locations on the circuit board. Bring the black wire over to the battery and solder to the negative battery terminal . . . .( )

In a similar manner solder the red wire to the positive battery terminal . . . .( )

Make sure that the SPST slide switch is in the "off" position, then take the battery clip (connected to the "9V" location on the circuit board) and snap the connector onto the terminals of the 9-volt battery . . . .( )

If you look into the end of your tvom where the "C" cell is mounted, you will see that there is a small shelf of metal directly below the barrel of the meter. This shelf forms a spring clamp which will hold the 9-volt battery securely. To install the 9-volt battery, bend the shelf up very slightly with your finger and slide the 9-volt battery under the shelf so that it rests on one side of the battery, holding it between the shelf and the inside wall of the panel . . . .( )

Take one of the large knobs, with pointer, and check to see that the set screw does not protrude into the shaft opening. Place this knob on the shaft of the range switch so that the set screw will bear on the flat part of the shaft. Tighten the set screw . . . .( )

In a similar manner install the other pointer knob on the function switch .( )

There are no flats on the ZERO adjust and OHMS adjust potentiometer shafts so install the two small round knobs on these shafts in any position you like .( )

This completes the assembly of the DC and OHMS portion of your tvom. Before you can use it, you must balance the circuit and calibrate it. These procedures are covered in the next section.

Balancing and Calibrating the TVOM

To balance and calibrate the tvom, clip the ground lead to the probe tip and set the controls as indicated:

FRONT PANEL	
Range Switch	3V - X10
Function Switch	DC
Polarity Switch	NORM
ON-OFF Switch	OFF
Zero Control	Fully Clockwise
Ohms Control	Fully Counter-clockwise

CIRCUIT BOARD	
Balance Pot	Mid-position
DC Cal Pot	Mid-position

Fig. 12 shows the settings of the front panel controls. The two potentiometers on the circuit board can be adjusted either by using your fingers on the edge of the adjusting disc or by using a screwdriver with a small blade through the access holes in the edge of the panel. These holes are identified by "DC" and "BAL" stamped in the metal over the holes. For ease of adjustment, it is suggested that you use the small-blade screwdriver to make these adjustments. You can practice finding the potentiometer slot with your screwdriver before you start the actual adjustments.

MECHANICAL ZERO ADJUST

Place the tvom on your work area so that the meter and controls are facing up. Look carefully at the pointer of the meter. It should be resting squarely over the "zero" marks at the left side of the scales. If the pointer is not over the zero marks, turn the plastic screw in the lower center of the meter with a screwdriver, until the pointer is over the zero marks as shown in Fig. 13. Use a screwdriver which fits the plastic screw slot or you may damage the screw. You will seldom have to make this adjustment, as the mechanical zero will not usually change. However, if you do need to do it at some later time,

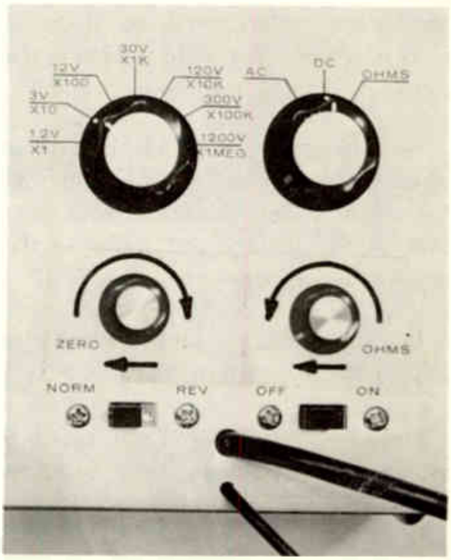


Fig. 12. Setting of the front panel controls.

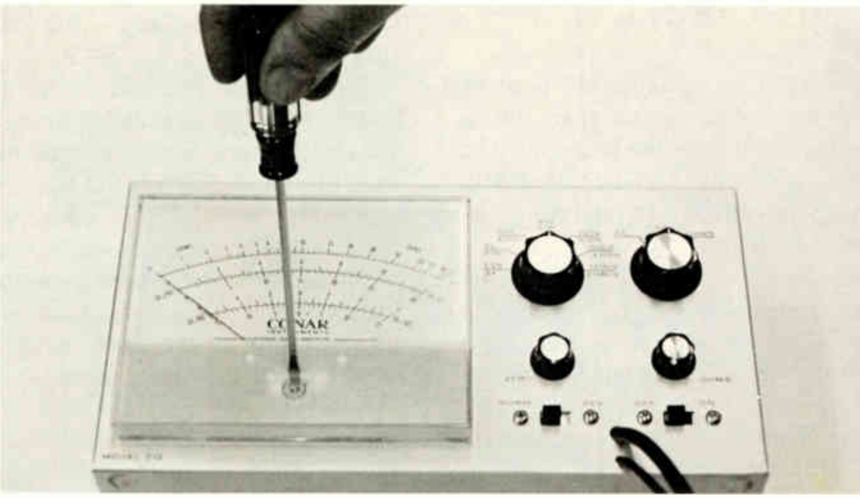


Fig. 13. Adjusting the meter pointer to zero.

remember that the tvom must be OFF when you make the adjustment.

BALANCING THE TVOM

The two field-effect transistors used in your tvom in all likelihood have slightly different characteristics even though they are both the same type of transistor. Since the basic principle of the tvom is one of a balanced bridge circuit, we must adjust the operating voltages of the two transistors so that the bridge circuit is truly balanced. There are two controls which affect the balance of the circuit. The first control is the zero adjust control on the front panel. This control is used on a day-to-day basis to insure correct balance. It could be considered a "fine tuning" adjustment. The other control is the balance potentiometer on the circuit board. This control is used to compensate for the difference in transistor characteristics, as mentioned earlier.

With all the controls adjusted and set as previously indicated, you are now ready to balance the circuit. Read the following instructions through first and then, when you are sure you know what to do, carry them out to balance the circuit.

With the tvom facing up in front of you, insert your screwdriver through the hole marked BAL and into the slot of the balance potentiometer. When you tum the power on with the panel switch, the meter pointer will, in all probability, go upscale past the highest marking on the right or, it may possibly move violently to the left, past zero. In either case, quickly adjust the balance potentiometer with your screwdriver to bring the pointer approximately to midscale (15). Now turn the zero adjust knob to the left (counterclockwise) to see if you can bring the pointer back to zero with the zero adjust. Readjust the balance potentiometer slightly, if necessary, so that you can zero the meter with the zero adjust control. This provides the preliminary balance of the tvom, and after you carry out the calibration procedure you may have to readjust the balance control.

CALIBRATING THE TVOM

With the tvom on and in the position used in the balancing procedure, unclip the ground lead from the probe tip. The range switch should be set to 3V - X10, the function switch to DC and the polarity switch to NORM.

Touch the tip of the probe to the positive terminal of the "C" cell and the meter pointer should swing upscale, to the right. Now, while holding the probe on the positive terminal of the "C" cell, insert your small-blade screwdriver through the hole labeled "DC" and engage the slot of the DC CAL potentiometer. Slowly adjust this control until the pointer indicates exactly 1.55 volts on the 3-volt scale. The pointer will then be just 1/2 division to the right of the center mark on the 3-volt scale. This is halfway between the 1.5-volt marking and the next (1.6-volt) marking and can be precisely located by using the short mark on the other (12-volt) scale as you learned in the last training kit . . . . ( )

When you have made this adjustment, remove the probe from the "C" cell and touch it to the ground clip. Readjust the zero adjust control for zero and repeat the procedure . . . . ( )

Now turn the zero adjust knob fully clockwise and note the scale reading. If it is not indicating at least 2 volts on the 3-volt scale, readjust the balance control with your screwdriver to bring it to about 2 volts. If you had to adjust the balance control, you will have to check the calibration procedure you just went through, following each step exactly. When you have completed the calibration and balancing, record the scale reading you obtain with the zero adjust control fully clockwise here: 2.75

This reading will serve as a check of the battery condition later on. As the battery voltage decreases, the reading you obtain with the zero adjust control fully clockwise will change. It may go higher or lower, depending upon the characteristics of the particular transistors in your tvom. In any case, if this reading changes more than 0.5 volt on the 3-volt range, you should replace the 9-volt battery.

If you should ever have occasion to replace one or both of the transistors, you will have to go through the entire balance/calibration procedure again. However, if you use your tvom intelligently and observe the operating procedures which follow in your second experimental manual, you should not need to replace a transistor.

IN CASE OF DIFFICULTY

If you are not able to calibrate your tvom according to the preceding instructions, one or more of the parts may be defective, there may be an error in the wiring of the instrument, or you may have a poor solder connection. If you have trouble calibrating the tvom, read the following before writing to us.

If you get no meter reading whatever, check to be sure that the two meter terminal nuts are tight and that the 9-volt battery is good. Check to be certain you have installed the two transistors correctly as well as the leads from the two slide switches. Check all soldered connections and if you are in doubt about any of them, reheat with your soldering iron and resolder. Beware of letting solder run over from one terminal to another, particularly in the area around the 1% resistors.

After checking your soldered connections, attempt to balance and calibrate the tvom again. If you still have no success, go back to the beginning of the manual and check your work in each assembly stage with the various figures. Be certain always that the correct part was installed in the correct position on the circuit board.

If you still cannot get your tvom to operate satisfactorily, write to us on a Consultation Sheet, giving full details of how the tvom behaves, and the results you obtained when you attempted to calibrate the instrument, and the results of any tests you may have made (such as the battery voltage). Be sure to give us enough information so that we will have a clear picture of your difficulty and can help you get your tvom in proper operating condition.

When you have your tvom operating properly, you are ready to go ahead with your second set of experiments.

Instructions for Performing the Experiments

The experiments in this manual and in the following ones will familiarize you with the mechanical operation of your tvom -- how to set the knobs, read the scales, and connect the test leads. At the same time, you will learn the causes of incorrect voltage and resistance measurements in electronic circuits.

You are now ready to begin learning how to troubleshoot with a tvom. Remember, taking measurements is only the beginning; it is what you can do with the results of your measurements that counts.

You cannot get a better tvom of the service type than your CONAR Model 212 TVOM. It was designed by service engineers for the service expert. Learn to use it understandingly, and it will be your most powerful tool. It will give you information quickly and accurately; your regular lessons and these experiments teach you what to do with this information.

The parts to be used in the experiments are listed in the parts list on page 3. You should have checked them when you checked your other parts.

In doing the experiments in this manual, you will also use some of the parts left over from Kit 1. All of the parts you will need for each experiment will be listed at the start of the Experimental Procedure for each experiment.

In carrying out your experiments, be sure to follow these steps:

1. Read the entire experiment, paying particular attention to the discussion of the experiment.

2. Carry out the experimental procedure, and perform each step of the experiment exactly as directed. Record

your results in the charts or tables provided for that purpose.

3. Study the discussion of the experiment and analyze your results. If they do not seem to be right, repeat the measurements to make sure you did not make a mistake. Do not go ahead with the next experiment until you get the desired results.

4. Follow the instructions for carrying out the Statement that accompanies each experiment. Fill in the correct answer in the blank space provided at the end of each experiment, and again on the Report Sheet you received with this manual.

You will notice instructions to turn off the tvom at the end of many of the experiments. However, it is not necessary to turn off the instrument if you are going to perform more than one experiment without stopping. These instructions were given as a reminder, and they should be used as such. When you have performed all of the experiments that you are going to do at one time, then turn off the tvom.

WARNING

Failure to follow the instructions given in the experiments may result in serious damage to your meter. Be sure that you carefully read and fully understand the instructions before proceeding with the experiments.

EXPERIMENT 11

Purpose: To show that the tvom will give more accurate readings than the 1000 ohms-per-volt meter in high-resistance circuits.

Introductory Discussion: The sensitivity of a voltmeter consisting of a current meter with a series multiplier resistor is given in ohms-per-volt. This is necessary because the meter usually has several different ranges, and the technician needs to know the total meter resistance he is connecting across the voltage source being measured. To determine the resistance, multiply the ohms-per-volt rating by the full-scale value for the particular range being used.

In the 3-volt meter you constructed in Kit 1, the sensitivity was 5000 ohms-per-volt; the total meter resistance was 3 X 5000, or 15,000 ohms. If the meter range had been extended to 30 volts, a 150,000-ohm multiplier resistor would have been used, and the total meter resistance would have been 150,000 ohms. These figures are true regardless of the amount of voltage being measured on a particular range.

A tvom uses a voltage divider; a switch mechanism is used to connect the input of the bridge circuit to the proper point on the divider for the scale in use. The bridge circuit must be adjusted, or balanced, so that when no voltage is applied to the input, the meter reads zero, regardless of the setting of the voltage divider.

In your tvom, approximately 1 volt is used to give maximum meter deflection. If you are using the 1200-volt range, the selector switch connects the input of the bridge to the lowest tap on the divider; and although 1200 volts is applied to the probes, only 1 volt is applied to the bridge. The same thing happens with the lower ranges. The selector switch connects the bridge to the proper tap on the divider for the range in use, and when maximum voltage for that range is measured, 1 volt is fed to the bridge.

Because of this arrangement, the resistance across the source being measured is always constant, and for this reason transistor voltmeters are not rated in ohms-per-volt. Instead, they are rated according to the voltage-divider network resistance, which is called the input resistance. In your tvom, the input resistance is approximately 12.2 megohms. When you make a measurement, you are connecting 12.2 megohms across the source being measured. Since this is such a very high resistance, the original circuit values in a low-resistance circuit change only slightly, and you measure the true operating voltages. Only in extremely high resistance circuits will there be an appreciable change, and then the measured values will be somewhat different from the true values that exist when the voltmeter is not connected.

Experimental Procedure: In this experiment, in addition to your experimental chassis and tvom, you will need:

1 **500K potentiometer with switch**
1 **Potentiometer mounting bracket**
1 **6-32 hex nut**
2 **10-megohm resistors**
1 **1/4" X 6-32 screw**

Turn the tvom "on" and set the function switch to dc, the polarity switch to normal.

In the first part of this experiment you will repeat the measurements made in Experiment 10 of Kit 1, using your completed tvom instead of the 5,000 ohms-per-volt meter of Kit 1. The experimental chassis used in Kit 1 should still have the two 1.5-volt flashlight cells, the three terminal strips and the three series connected resistors in place, as shown in Fig. 11-1.

Install the potentiometer mounting bracket at hole W, using a 1/4" X 6-32 screw and a 6-32 nut. Then install the 500K-ohm potentiometer with on-off switch (PO65) in the potentiometer mounting bracket. Position as shown, attach a control nut and tighten.

Terminals 19 and 20, on the back of the potentiometer, are the on-off switch terminals. Terminals 16, 17 and 18 are the potentiometer terminals.

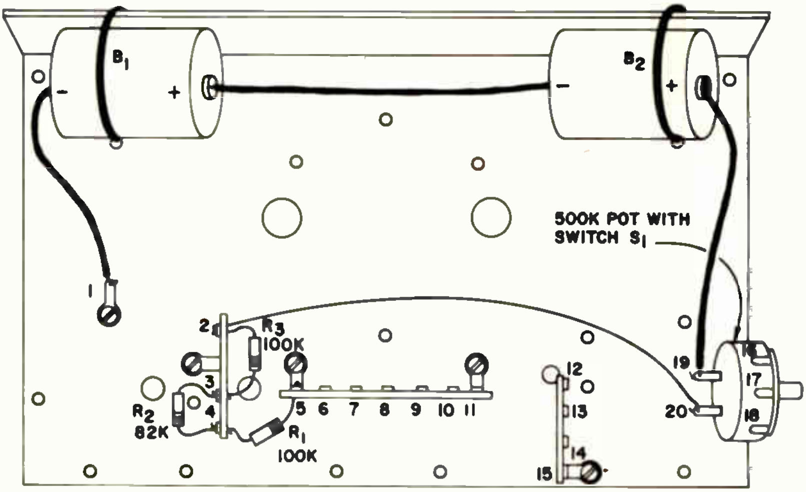


Fig. 11-1. Circuit for Experiment 11.

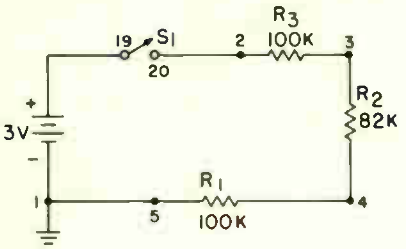


Fig. 11-2. Schematic diagram of circuit for Experiment 11.

Turn the shaft of the potentiometer fully counterclockwise to insure that the switch is off. Then, proceed to wire the circuit shown in Figs. 11-1 and 11-2. Solder the lead from the + terminal of the 3-volt battery to terminal 19 of the on-off switch. Disconnect the negative battery lead from terminal 6 and solder it to the solder lug, terminal 1. Disconnect the lead of the 100K-ohm resistor from terminal 6 and solder it to terminal 5. Finally, connect a length of hookup wire from terminal 2 to terminal 20 of the on-off switch.

The circuit becomes a complete series circuit when you turn the switch on, the return path from the 100K-ohm resistor, R_1, to the negative battery terminal being made through the chassis (ground) from terminal 5 to terminal 1. This arrangement of using the chassis as part of the circuit is quite common and will be used frequently from now on in your experiments.

Step 1: To measure the source voltage.

Clip the "ground" test lead of the tvom to the chassis. Touch the probe of the tvom to the positive battery terminal, and read the meter on the 3.0-volt dc scale. This is the scale you used in the experiments in your first kit. Record the reading in the space provided opposite Step 1 in Fig. 11-3. This may be slightly over 3 volts. If so, mark the value 3+.

Step 2: To measure the voltage across R_1.

Turn on switch S_1 by rotating the potentiometer shaft clockwise. With the ground lead of the tvom still connected to the chassis, touch the probe to the junction of the 100K-ohm and 82K-ohm resistor leads, terminal 4. Observe your reading on the 3-volt dc scale, and record it in the space provided for Step 2 in Fig. 11-3.

Step 3: To measure the voltage across R_2.

Move the ground lead of the tvom to terminal 4 and touch the probe to terminal 3. Record the voltage measured across resistor R_2 beside Step 3 in Fig. 11-3.

Step 4: To measure the voltage across R_3.

Move the ground lead of the tvom to terminal 3 and touch the probe to terminal-

STEP	READING
1	2.99
2	1.08
3	.85
4	1.25

Fig. 11-3. Record your readings for Experiment 11 here.

nal 2. Again read the voltage on the 3-volt dc scale, and record your reading in the space provided in Fig. 11-3. Turn off switch S_1.

Discussion: Since the circuit in Fig. 11-2 is exactly the same as the circuit you constructed in Experiment 10, the voltage distribution across the resistors is the same. You should have noticed, however, that the measured values in Experiment 11 are considerably different from those you measured in Step 2 of Experiment 10. When you connected the tvom across a resistor, the resistance value in that part of the circuit did not change appreciably, because the parallel resistance of the tvom was extremely high compared to the value of the resistor.

With the 15,000-ohm meter resistance connected across a resistor, the resistance value was lowered, which changed the entire voltage distribution throughout the circuit while the meter was connected.

The readings you recorded in Fig. 11-3 are for all practical purposes the same as the voltage drops across the resistors with the meter disconnected. If you add them, they will be quite close to the source voltage you measured in Step 1.

This means that in measuring voltages in fairly high resistance circuits, the meter will not affect the voltage appreciably, and you will get an accurate idea of the true operating conditions.

In service work, the fact that the measured value may be slightly lower than the actual value is relatively unimportant. Many manufacturers of electronic equipment list the voltages that should be measured with a tvom. These may be taken as the actual operating values, and variations above and below normal indicate trouble that should be located and corrected.

You have used the tvom just as you did the 5,000 ohms-per-volt meter; you connected the positive meter probe to the end of the resistor nearest the positive battery terminal and the ground lead to the end of the resistor nearest the negative battery terminal.

Because you have a reversing switch on the meter, you could have put the selector switch in the reverse position and connected the ground terminal of the tvom to the positive terminal of the battery and the hot probe to the junction of resistors R_2 and R_3, moving around the circuit in the opposite way. The results would have been almost identical with those taken with the switch in the positive voltage position.

In later experiments, you will see just how the positive and negative dc voltage settings of the polarity switch are used.

Instructions for Statement No. 11: Although, as we have shown, the sensitivity of the tvom is far superior to that of the 5,000 ohms-per-volt meter, you should remember that the tvom does have a definite amount of resistance, and under some conditions can upset the operating voltages.

To obtain data for your statement, solder one lead of a 10-megohm resistor to terminal 2 of Fig. 11-1. Solder one lead of the other 10-megohm resistor to terminal 1 (ground) of Fig. 11-1. Now tack-solder the free ends of the two resistors together to form a 20-megohm voltage divider.

Clip the ground lead of your tvom to the chassis and measure the battery voltage at terminal 19. Enter this value in Fig.

SOURCE VOLTAGE	2.99
VOLTAGE ACROSS FIRST 10 MEG RESISTOR	1.06
VOLTAGE ACROSS SECOND 10 MEG RESISTOR	1.05
SUM OF VOLTAGES ACROSS THE TWO 10 MEG RESISTORS	2.11

Fig. 11-4. Record your readings for the Statement for Experiment 11 here.

11-4 on the top line. Turn S_1 on and measure the voltage at the junction of the two 10-megohm resistors. Enter this value on the second line of Fig. 11-4. Finally, reconnect your tvom to read the voltage across the other 10-megohm resistor and enter your reading on the third line of Fig. 11-4. Now add the voltages across the two resistors and compare this sum with the battery voltage.

Turn off S_1 and your tvom and unsolder and remove all 5 resistors.

Answer the Report Statement here and on the Report Sheet.

Statement No. 11: I found that the sum of the voltages across the two 10-megohm resistors was:

(1) greater than
(2) less than
(3) approximately equal to

the voltage measured across the battery terminals.

EXPERIMENT 12

Purpose: To show that a certain point in a circuit may be positive with respect to one point, and negative with respect to another point.

Introductory Discussion: Many of the expressions used in radio and TV servicing do not seem to have any sensible meaning to the beginner until he uses them himself in practical work.

One expression that causes confusion is "positive or negative with respect to". This means that a point in a circuit is at a positive or negative potential if the voltmeter probes are touched to it and to some other point in the circuit.

For example, we may say that the plate of a tube is 250 volts positive. This statement has no real meaning since a point by itself cannot have a voltage. Voltage means a potential difference between two points. Thus, when we say there is 250 volts on the plate of a tube, we mean there is a potential difference of 250 volts between the plate and the cathode. Another way of saying this is that the plate is positive with respect to, or with regard to, the cathode.

It follows that if the plate is positive with respect to the cathode, the cathode is negative with respect to the plate. At the same time, the grid may be negative with respect to the cathode or, what is the same thing, the cathode may be positive with respect to the grid.

Thus, the cathode can be both positive and negative at the same time, depending on the reference points we have in mind.

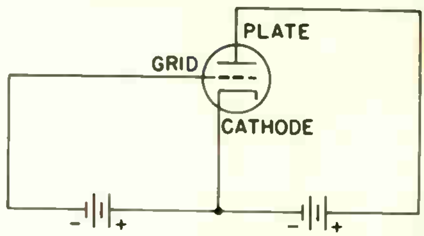


Fig. 12-1. A typical triode tube with batteries for the plate-to-cathode and grid-to-cathode supplies.

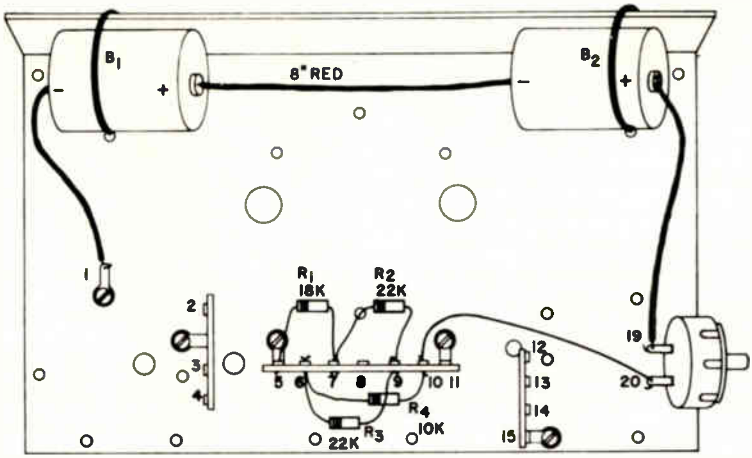


Fig. 12-2. Circuit for Experiment 12.

Fig. 12-1 shows a typical triode tube with batteries for the grid-to-cathode and plate-to-cathode supplies. When the voltage between the grid and the cathode is measured, the positive meter probe should be connected to the cathode, and the negative probe should be connected to the grid. When the plate-to-cathode voltage is measured, the negative meter probe should be connected to the cathode, and the positive probe to the plate. From this you can see that the cathode can be either positive or negative, depending on whether we are referring to the cathode and the grid or to the cathode and the plate. In later kits we will measure grid-to-cathode and plate-to-cathode voltages many times in actual tube circuits.

In this experiment, however, we will use resistors and our 3-volt battery supply. Just remember that a plate or any other point cannot correctly be called positive or negative by itself.

Experimental Procedure: To perform the experiment, in addition to your tvom, you will need the experimental chassis with parts previously installed and:

1 18K-ohm resistor
2 22K-ohm resistors
1 10K-ohm resistor

For this experiment, you will construct the circuit shown in Fig. 12-2. The schematic of this circuit is shown in Fig. 12-3. Connect an 18K-ohm resistor from terminal 5 to terminal 7, connect a 22K-ohm resistor from terminal 7 to terminal 9, connect a 22K-ohm resistor between terminals 6 and 9 and connect a 10K-ohm resistor from terminal 6 to

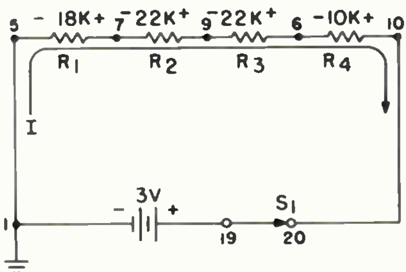


Fig. 12-3. Schematic diagram of the circuit used in Experiment 12.

terminal 10. Disconnect the length of hookup wire from terminal 2 and connect it to terminal 10. Solder all connections.

Fig. 12-3 is a schematic of the circuit you have just constructed. With S_1 closed, a current I will flow as indicated in Fig. 12-3. You know that current goes from minus to plus through a resistor, therefore we have indicated the polarity of the voltage appearing across each resistor in the divider. The left end of each resistor is negative with respect to the right end. It is this fact that you will establish in this experiment.

With your tvom in the dc position and the polarity switch in the normal position, the ground lead is the negative meter lead, while the probe is the positive lead. When the ground lead is connected to one point and the probe is connected to a second point that is positive with respect to the first point, the meter will read upscale in a normal manner. If the probe is connected to a point that is negative with respect to the point to which the ground lead is connected, the meter pointer will move downscale, to the left of zero.

To prove this, turn the tvom on and zero it, and then turn S_1 on. With the tvom set to dc, normal, clip the ground lead of the meter to the chassis and touch the probe to the positive terminal of the battery. The meter will read upscale. Now connect the meter ground lead to the positive terminal of the battery and momentarily touch the probe to the chassis. Note that the meter pointer deflects sharply downscale, to the left past zero, showing that the meter probe is negative with respect to the ground lead.

Step 1: To show that terminal 5 is negative with respect to terminal 7.

GROUND LEAD TO	PROBE TO	UP-SCALE	DOWN-SCALE
CHASSIS	7	✓	
7	CHASSIS		✓
7	9	✓	
9	7		✓
9	6	✓	
6	9		✓

Fig. 12-4. For each step, make a check in the proper box to indicate whether your meter pointer moves upscale or downscale.

Connect the ground lead of the tvom to the chassis, and the probe to terminal 7. Make a check mark in the proper box in Fig. 12-4 to indicate whether the meter pointer moves upscale or downscale. We will not record the exact readings since they are not important in this part of the experiment.

Now reverse the connections of the tvom by connecting the ground lead to terminal 7, and the probe to the chassis. Record the meter pointer movement in the space provided in Fig. 12-4.

An upscale reading on the meter indicates that the meter is connected with the proper polarity. A downscale reading means that the meter is connected with the wrong polarity. Since the meter reading was upscale when the negative lead was connected to the chassis and downscale when the negative lead was connected to terminal 7, the chassis must be negative with respect to terminal 7.

Step 2: To show whether terminal 7 is positive or negative with respect to terminal 9.

Connect the ground lead of the tvom

to terminal 7 and touch the probe to terminal 9. Record the direction of the meter pointer movement in Fig. 12-4.

Connect the ground lead of the tvom to terminal 9, and touch the probe to terminal 7. Again record the meter pointer indication.

Step 3: To show whether terminal 9 is positive or negative with respect to terminal 6.

Connect the ground clip to terminal 9 and touch the probe to terminal 6, and record the meter pointer indication.

Connect the ground clip to terminal 6 and touch the probe to terminal 9, and again record the indication. Open the circuit temporarily by turning S_1 off.

Discussion: If your experiment was conducted successfully, you should have had upscale readings on the first, third, and fifth measurements, and downscale readings on the others. This means that the chassis is negative with respect to terminal 7, terminal 7 is negative with respect to terminal 9, and terminal 9 is negative with respect to terminal 6.

You will notice that terminal 7 is positive with respect to the chassis. However, terminal 7 is negative with respect to terminal 9.

We can also say that terminal 9 is positive with respect to terminal 7 and negative with respect to terminal 6.

Thus, in a series circuit consisting of two or more parts, one point may be either positive or negative, depending upon what other point it is compared with.

In this experiment, we have left the function switch in the dc position and the polarity switch in the normal position, making the ground clip of the tvom the negative terminal and the probe the positive terminal. The probes had to be connected in a certain way in order to give an upscale reading.

In actual practice, this is not done. The function switch is placed in the dc position and the polarity switch is set to normal or reverse -- whichever one will give an upscale reading -- and by looking at the polarity switch you can tell whether the voltage at the probe is positive or negative with respect to the ground clip reference point. You will do this many times in later experiments.

For the present, remember that when we speak of a point as positive or negative, we mean with respect to another point. On a plate, we mean with respect to the cathode of the tube.

Instructions for Statement No. 12: To answer the Statement, we will make use of the polarity switch of the tvom to get an upscale reading and to show that terminal 9 in Fig. 12-3 can be positive with respect to the chassis and negative with respect to terminal 10.

Turn on S_1, and connect the ground clip of the tvom to terminal 9. Touch the probe to the chassis. If the meter reads downscale, slide the polarity switch to the reverse position, and record the actual voltage reading between terminal 9 and the chassis in volts on the margin of this -1.2 page. Now touch the probe to terminal 10, reset the polarity switch for an upscale reading, and again record the actual voltage measured on the margin of +1.36 this page. Turn off S_1 and answer Statement 12.

Statement No. 12: I found that the polarity of the voltage at terminal 9 with respect to the chassis was:

(1) positive
(2) negative

and the value was

(1) greater than
(2) less than
(3) the same as

that measured from terminal 9 to terminal 10.

EXPERIMENT 13

Purpose: To show that a change in the resistance of one part of a series circuit will cause a change in the voltage drops across all of the series-connected parts.

Introductory Discussion: This experiment proves one of the basic facts that you as a technician will use time and again in your work.

The way a set is working may lead you to suspect that the voltage is too low at some point in a circuit or perhaps the voltage is too high at some point. You will use your tvom to see if the voltage is too high or too low. Then, you will look at the circuit diagram to see what could have happened to cause the abnormal readings. After deciding what the probable cause is, you will check the part you suspect of causing the trouble. Your regular lessons and your work on these kits will teach you to do this.

Let us take an example. Suppose you have a voltage divider with the correct source voltage applied to it. What will cause the voltage drop to be too high across some sections of the divider and too low across others?

Ohm's Law ($E = I \times R$) gives the answer. If the voltage E is lower than expected, then I, the current through the part, or R, the resistance of the part, has decreased. You would look for a change in the resistance of the part or for some defect in another part that has decreased the circuit current.

If the voltage is higher than expected, you know that I or R has increased. In this case, you would check for an increase in the part resistance or for a decrease in resistance elsewhere in the circuit that would increase current flow through the entire circuit.

In this experiment you will demonstrate these facts so you will know what to look for when you find similar abnormal voltage readings in your maintenance work.

Remember, it is not enough to know how to take readings -- the important thing is to know what to do with the results of your readings.

Experimental Procedure: In this experiment you will use your tvom and the parts already in place on your experimental chassis.

To construct the circuit in Fig. 13-1, remove the 10K resistor, R_4, from terminals 6 and 10 and resolder the resistor

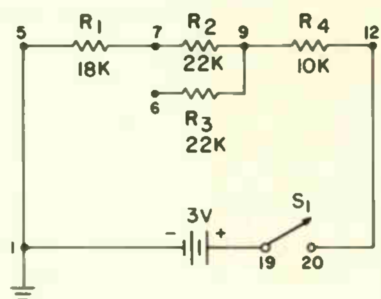


Fig. 13-1. This is the first circuit you will use in Experiment 13.

from terminal 9 to terminal 12. Terminal 12 is on the strip near the switch, S_1. Disconnect the switch lead from terminal 10 and connect it to terminal 12.

After you have constructed the divider circuit of Fig. 13-1, turn on S_1 and set your tvom to read dc normal.

Step 1: To measure the voltages in the circuit.

To measure the source voltage, connect the ground clip of your tvom to the chassis, and the probe to terminal 12. Read your meter on the 3-volt scale and record your reading in Fig. 13-2 in the column for normal resistance (the first blank column) beside "source."

VOLTAGE MEASURED ACROSS	RESISTANCE NORMAL	R_2 DECREASED	R_4 INCREASED
SOURCE	3+	3+	3+
R_1	1.05	1.34	.8
R_2	1.37	.93	1.05
R_4	.56	.72	1.15
	2.98	2.99	3.00

Fig. 13-2. Record your readings for Experiment 13 here.

To measure the voltage across R_1, move the probe to terminal 7. Record your reading beside R_1 in the first blank column of Fig. 13-2.

To measure the voltage across R_2, move the ground clip to terminal 7 and the probe to terminal 9. Record your reading beside R_2 in Fig. 13-2.

To measure the voltage across R_4, move the ground clip to terminal 9 and the probe to terminal 12. Again record your reading in Fig. 13-2.

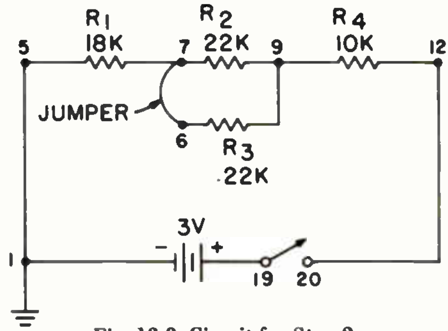


Fig. 13-3. Circuit for Step 2.

Step 2: To show that decreasing the resistance of one section of a voltage divider reduces the voltage drop across that section, and increases the voltage drop across the other sections.

You are to decrease the resistance of R_2 by adding another 22K-ohm resistor in parallel with it, as shown in Fig. 13-3.

To do this, simply solder a short jumper wire from terminal 6 to terminal 7 as indicated in Fig. 13-3.

As you have learned, the resistance of two equal resistors in parallel is equal to half the resistance of one alone. Therefore, we now have 11,000 ohms for R_2 and R_3 in parallel instead of 22,000.

Measure the voltages as you did in Step 1, and record your readings in Fig. 13-2 in the column for decreased resistance in R_2.

Step 3: To show that increasing the resistance of one section of a voltage divider increases the voltage drop across that section, and decreases the voltage drop across the other section.

Rewire the circuit as shown in Fig. 13-4. To do this, remove the jumper from between terminal 6 and terminal 7 and unsolder the switch lead from terminal

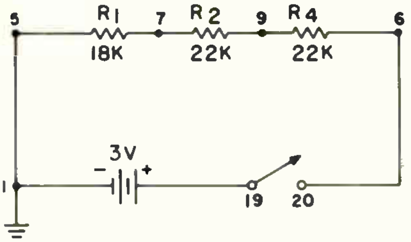


Fig. 13-4. Circuit for Step 3.

12. Resolder this lead to terminal 6 to complete the circuit of Fig. 13-4. The 22K-ohm resistor is now R_4.

Again measure the source voltage and the voltages across R_1, R_2, and R_4 as you did in Steps 1 and 2. Record your readings in Fig. 13-2 in the column for increased resistance of R_4. Turn off switch S_1.

Discussion: Look at the voltages you have recorded in Fig. 13-2. In Step 2, you decreased the resistance of R_2. What happened to the voltage across R_2? It should have decreased. However, the voltage drops across R_1 and R_4 should have increased, since the source voltage is the same, and the sum of the voltage drops is always equal to the source voltage.

Now let us look at the readings for Step 3. Here we increased the resistance of R_4. What happened to the voltage? The voltage across R_4 should have increased. Since the source voltage is still the same and the sum of the voltage drops must equal the source voltage, the other voltage drops should have been lower than they were in Step 1. Here you have seen a practical application of Kirchhoff's voltage law. The sum of the voltage drops in a closed circuit must equal the source voltage. From this we can see that, if the voltage drop across one part in a series circuit changes, the voltage drop across the other components must change in the opposite direction.

There is one thing to keep in mind. Although it is absolutely true that the sum of the voltage drops always equals the source voltage, the sum of the *measured* voltage drops may not exactly equal the source voltage for two reasons.

First, a good servicing type of tvom, such as your CONAR Model 212, has an accuracy of about 5% of the full scale reading. Although more accurate hand-calibrated meters can be made, they are not used in servicing equipment, because such accuracy is not necessary, they are costly, and they cannot stand up under rough treatment. Therefore, measured values can be .15V higher or lower than the true values, indicated on the 3V range (.15 = .05 X 3.0).

Second, you may not be able to read the actual values on the meter. For example, the actual voltage drops across a three-section voltage divider with a 3-volt source might be: .752 volt, 1.527 volts, and .721 volt. The closest you could read these values on your meter would be .75 volt, 1.5 volts, and .7 volt. When you add these, you get 2.95 volts instead of the 3 volts you would actually have. This is close enough. Even if the measured voltages added up to only 2.8 volts, it would be considered entirely normal. A variation of as much as 25% is usually considered normal in most circuits. Thus, if you read your meter scale to the nearest division, the reading will be accurate enough.

Instructions for Statement No. 13: For the Statement, you will use the same circuit used in Step 3. Connect the ground clip of your tvom to terminal 9 and the probe to terminal 6. Turn on S_1

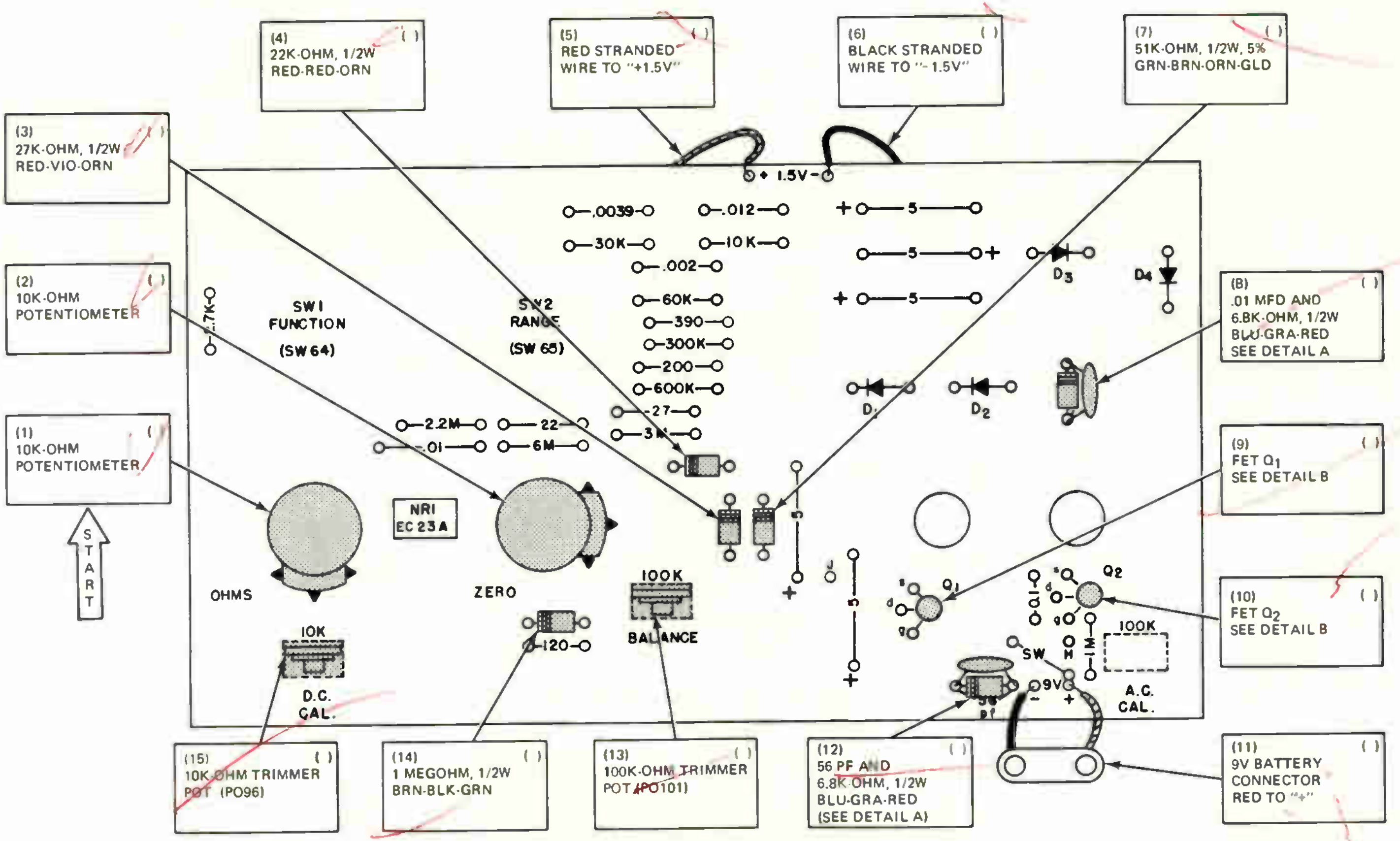


Fig. 2. Stage I Assembly.

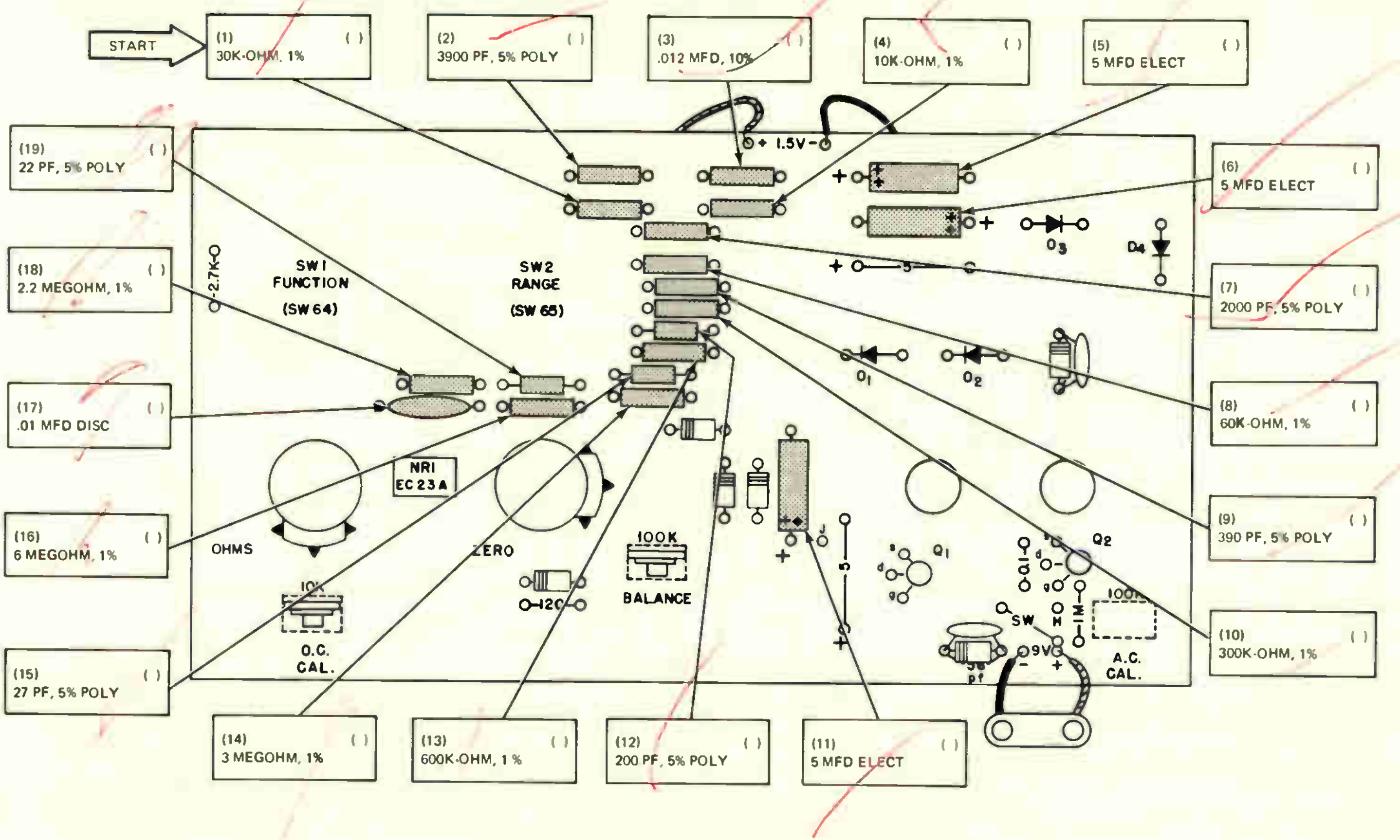


Fig. 3. Stage II Assembly.

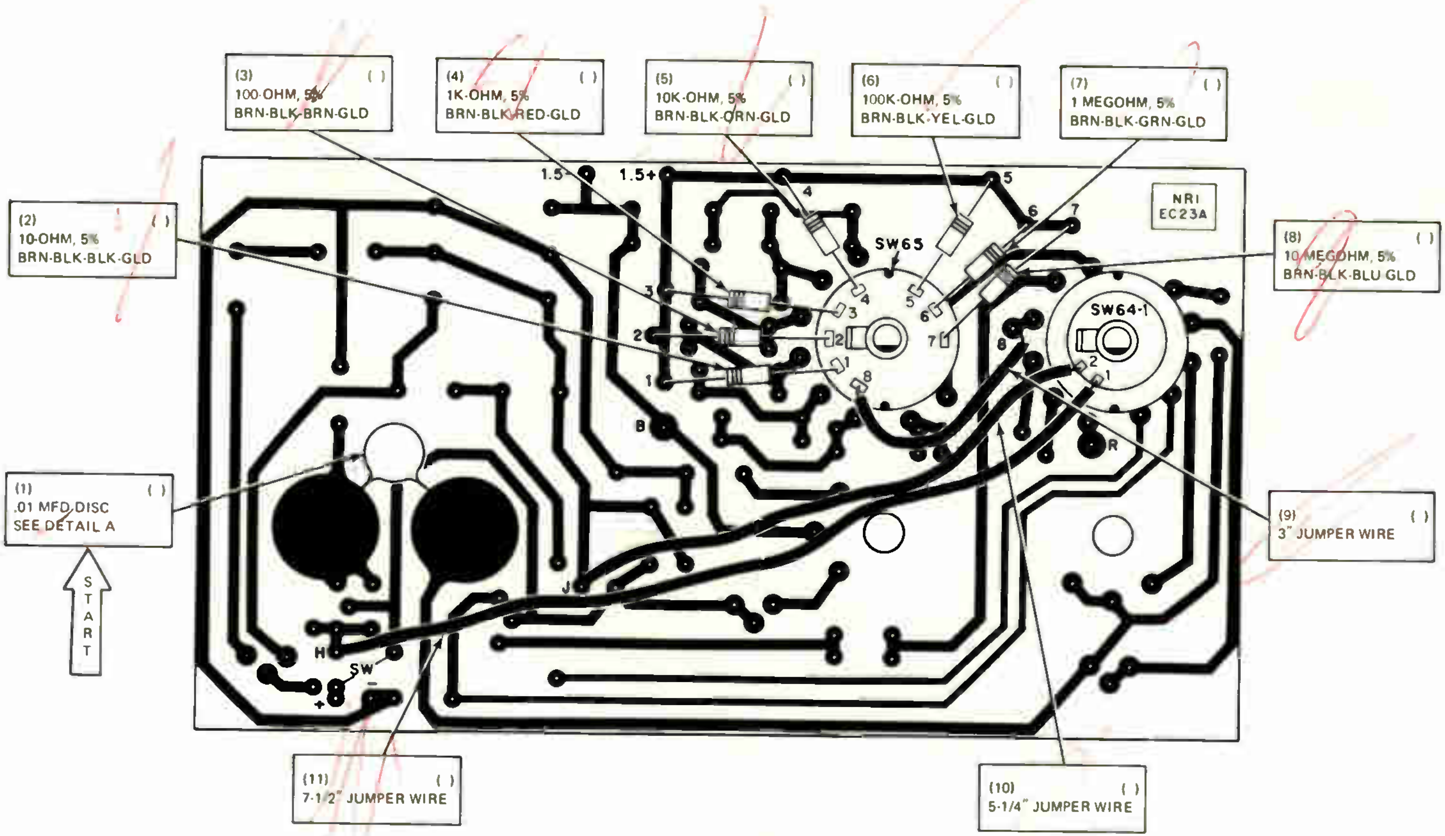
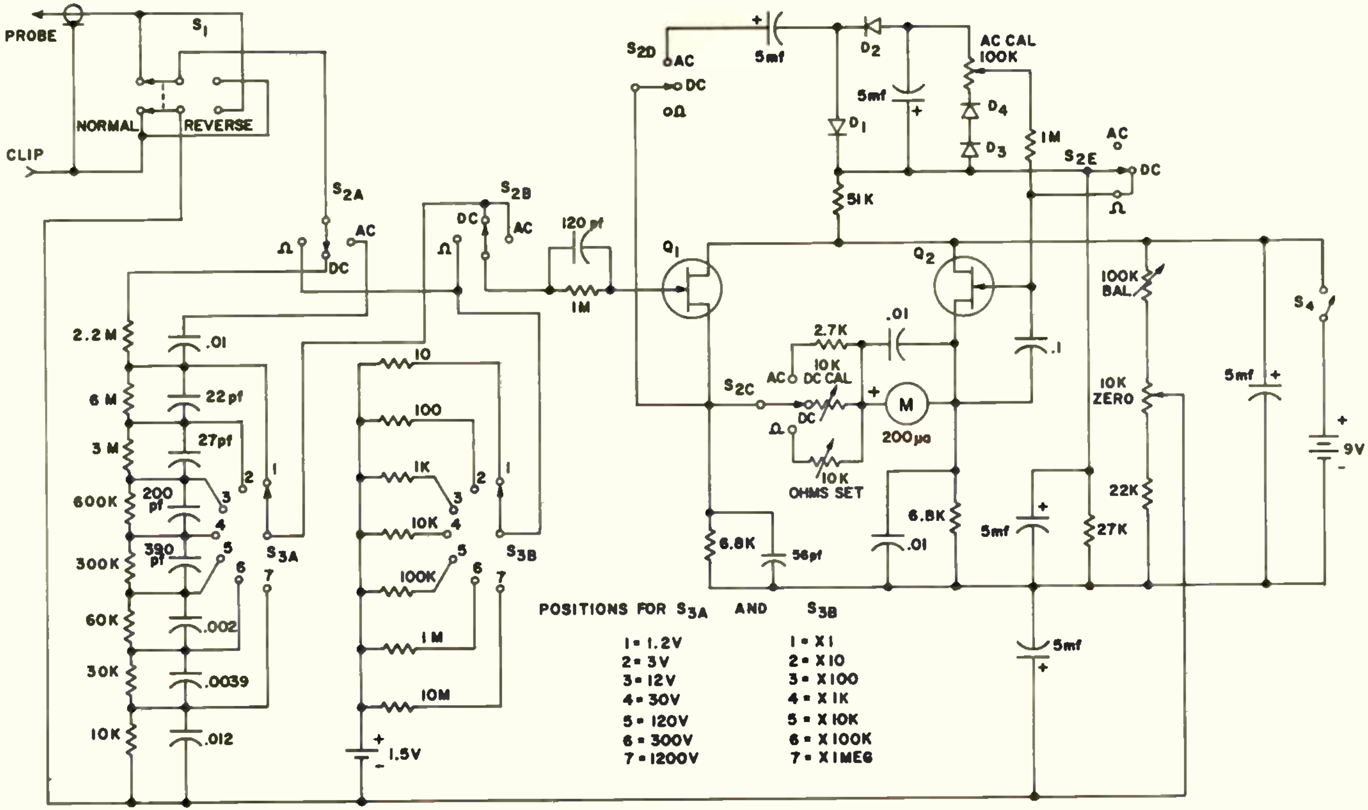


Fig. 4. Stage III Assembly.



Schematic diagram of the Model 212 TVOM.

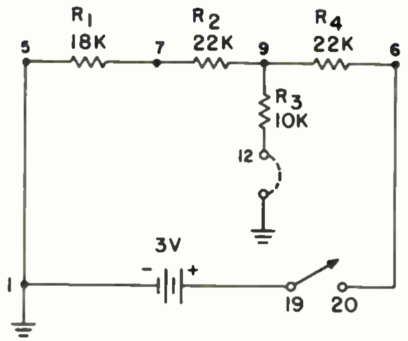


Fig. 13-5. Circuit for Statement 13.

and note the reading in the margin of this page.

1.14

For the statement you are to see what happens to the voltage across R_4 when you shunt R_1 and R_2 with a 10K-ohm resistor. To do this, simply short terminal 12 to the chassis with a screwdriver or a piece of wire as indicated in Fig. 13-5. Measure the drop across R_4 between terminal 9 and terminal 6 with terminal 12 shorted to the chassis. Compare your two voltage readings, and answer the

2.31 statement here and on the Report Sheet. Turn off your tvom and S_1.

Statement No. 13: When I shunted R_1 and R_2 with a 10K-ohm resistor I found the voltage across R_4:

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

EXPERIMENT 14

Purpose: To show the effects of resistance variations in series-type voltage dividers; and to show how the resultant voltage variations can be kept to a minimum by using a resistor, called a bleeder.

Introductory Discussion: As you have seen in preceding experiments, if any resistance in a series circuit is changed in value, the voltage across each resistor changes. In some circuits we will want to have a changing resistance and yet have the voltage remain fairly steady as the resistance changes. The changing resistance is often referred to as a "load".

As you have previously learned, when a large resistor and a small resistor are in parallel, the combined resistance is essentially that of the smaller resistor. This means that even though the larger resistance may vary, it will still be enough higher than the smaller resistance so that the combined resistances will remain essentially the same. This very important fact is put to good use where we wish to stabilize the voltage across a load whose resistance varies. By properly designing the voltage divider, these voltage variations can be kept quite small.

In this experiment you will see how this is done. You will build a circuit in which the load resistance can be varied and in which the load requires considerably less than the source voltage of 3 volts. You will see how the voltage across the load changes when the load resistance is changed. Then, you will change the circuit so that the effects of the variations in a load resistance are reduced to a minimum.

As a technician you will not be particularly interested in being able to design voltage dividers, but you certainly will want to know how they work. If you find that a particular circuit is not operating satisfactorily, you must rely on your voltage measurements to tell you what could have happened in the circuit. A knowledge of how voltage dividers operate will go a long ways.

Experimental Procedure: In this experiment you will need your tvom, most of the parts on the experimental chassis and the following parts:

- **1 220K-ohm resistor**
- **1 470K-ohm resistor**
- **1 Slip-on alligator clip**
- **Hookup wire**

If you have not done so recently, check the tip of your soldering iron. It may have become covered with the typical black insulating oxide that prevents heat from flowing from the iron to the parts, or the tip may have become pitted. If so, file and retin it as described in Kit 1. Check the tip frequently throughout all your experiments, and don't let it become dirty.

Begin by removing the 22K-ohm resistor connected between terminals 6 and 9 and the 10K-ohm resistor connected between terminals 9 and 12, leaving in place the 18K-ohm and 22K-ohm resistors shown in Fig. 14-1. You may leave the

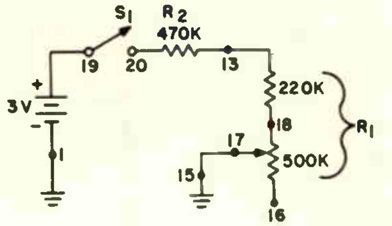


Fig. 14-2. Schematic of the circuit of Step 1.

wire from terminal 20 to terminal 6 in place (although it is not shown in Fig. 14-1) as it will be used in later steps of this experiment.

Now construct the circuit shown in Fig. 14-2 and detailed in Fig. 14-1. Terminals 16, 17 and 18 are the three potentiometer terminals.

Slip the alligator clip over the tvom probe as shown in Fig. 14-3 so you can clip both leads of the meter to the circuit under test. It may be necessary to bend down the solder loop in the clip so that the clip will slip easily onto the probe. If the clip is too loose, squeeze the clip with

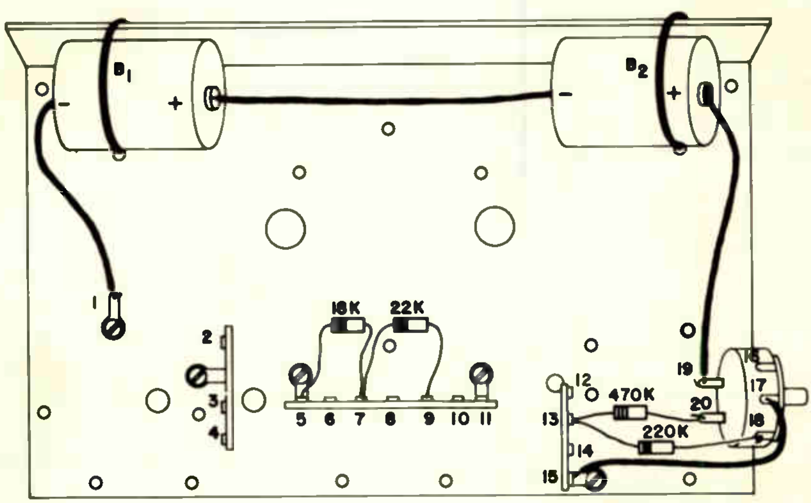


Fig. 14-1. Chassis connections for the circuit of Step 1.

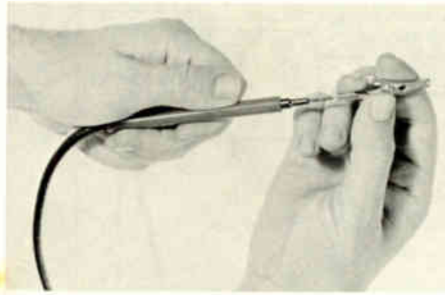


Fig. 14-3. How to slip the alligator clip onto the positive probe.

your combination pliers so it is tightly clamped on the probe tip.

You are now ready to see how the circuit works.

Step 1: To show how a variation in load resistance affects the load voltage.

Clip the ground lead of the tvom to the chassis. Now measure the load voltage by clipping the probe to terminal 13 in Fig. 14-2. In taking measurements, it is sometimes easier to clip it on and leave it there. In this step, it will be easier to clip the lead in place so that you will have both hands free. The meter is now connected across the 220K-ohm resistor and part of the 500K-ohm potentiometer. These two parts make up the load resistor R_1 in Fig. 14-2.

Turn the shaft of the potentiometer clockwise to turn on S_1. Adjust the potentiometer so that the meter reads 1.3 volts. This can be considered to be the normal resistance of R_1.

With the red probe still clipped to terminal 13, turn the potentiometer shaft all the way counterclockwise. This increases the resistance of the load and increases the voltage across the load. This increased load resistance is a smaller load because the circuit draws less current and dissipates less power. Record the voltage across the load at this time in the space provided for voltage with minimum load in Step 1 of Fig. 14-4.

Now rotate the potentiometer shaft fully clockwise, reducing its resistance practically to zero. The load resistance then consists of only the 220K-ohm resistor. This decreased load resistance is a larger or heavier load because the circuit draws more current and dissipates more power. Note the meter reading, and record it in the space for voltage with maximum load in Step 1 of Fig. 14-4.

	VOLTAGE WITH MINIMUM LOAD	VOLTAGE WITH MAXIMUM LOAD
STEP 1	1.52	8.6
STEP 2	1.26	1.22

Fig. 14-4. Record your readings for Experiment 14 here.

Step 2: To show how the load voltage can be kept fairly constant even though the load resistance varies.

Turn S_1 off and remove the 470K-ohm resistor from between terminals 13 and 20. Rewire the circuit to conform to Fig. 14-5. You will need to reconnect and solder the lead from terminal 20 to

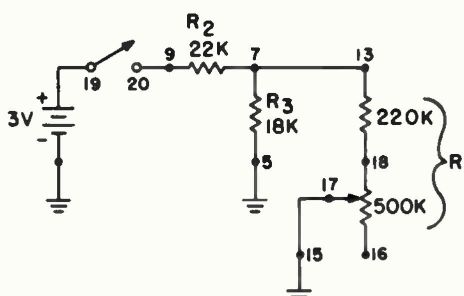


Fig. 14-5. Schematic diagram of circuit used in Step 2.

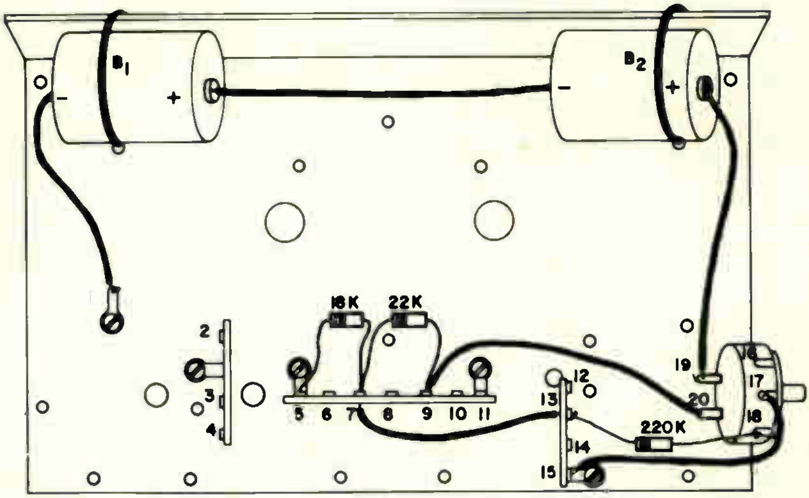


Fig. 14-6. Chassis arrangement for Step 2.

terminal 9, and add a length of wire between terminals 7 and 13 to make these changes as indicated in Fig. 14-6.

Turn S_1 on and adjust the potentiometer shaft fully counterclockwise, and measure the load voltage between the chassis and terminal 13. Record this as the voltage with minimum load for Step 2 in the space provided in Fig. 14-4.

Now turn the potentiometer shaft clockwise as far as it will go to reduce the value of R_1. Record the reading as the voltage with maximum load in Fig. 14-4. Turn off S_1.

Discussion: Look over the figures you have recorded in Fig. 14-4, and compare the two sets of readings. There should be a greater difference between the maximum and minimum voltages in Step 1 than in Step 2.

In any voltage divider, the source voltage divides between the circuit parts, the voltage across a part being proportional to its resistance. If there are two parts having equal resistances, the source voltage will divide equally between them. Both will have the same voltage drop. If one part is variable, some of the time it will have more than half the voltage across it, and some of the time less than half.

In Step 1, the difference between the voltages should have been large, because with the potentiometer set so that none of its resistance was in the circuit, the total load resistance was only 220K ohms -- less than half the 470K-ohm resistance of R_2 -- so there would be much less than half of the source voltage across the load. With the potentiometer set so that its total resistance was in the circuit, the load resistance was 720K ohms -- more than one and a half times the resistance of R_2 -- so there would be much more than half the source voltage across the load. The only time we would have the desired 1.3 volts across the load would be when the potentiometer was set so that the total load resistance of R_1 was slightly less than 470K-ohms.

In Step 2, the voltage difference should have been very small. Here you modified the circuit and put in a bleeder resistor. When two resistors are in parallel, the combined resistance will be less than that of the smaller resistor. Therefore, the combined resistance of R_1 and the 18K-ohm bleeder resistor R_3 in Fig. 14-5 will be less than 18K ohms, whether R_1 is at its maximum of 720K ohms or its minimum of 220K ohms. The combined resistance will vary from about 16.5K ohms to about 17.5K ohms. The voltage will divide almost equally between R_1 and R_2, and, therefore, will always be close to the desired 1.3 volts across R_1.

In your work, be on the lookout for bleeders. They can open or change in value just like any other part, and they must be taken into consideration when the parts with which they are in shunt are checked.

Instructions for Statement No. 14: For this Statement we will simulate a burned-out bleeder resistor R_3 in the circuit shown in Fig. 14-5. Unsolder the 18K-ohm resistor R_3 from terminal 5 and turn on S_1. Measure the voltage across load resistor R_1 by connecting the ground lead of your tvom to the chassis and the probe to terminal 7. Compare the reading you obtain with the voltage reading you have recorded for Step 2 in Fig. 14-4. Answer
2.35 the following Statement and mark your answer on your Report Sheet. Turn off
29.3 S_1 and your tvom, disassemble the circuit and clean the parts. Do not remove the leads from the positive and negative terminals of the 3-volt battery going to terminal 19 and terminal 1.

Statement No. 14: With the 18K-ohm bleeder resistor open, I found that the voltage applied to the load:

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

EXPERIMENT 15

Purpose: To show that the current flowing in a circuit can be determined by measuring the voltage across a known resistance and applying Ohm's Law.

Introductory Discussion: Ohm's Law tells us that current in amperes is equal to voltage in volts divided by resistance in ohms. Therefore, if we measure the voltage drop across a known resistor, we can accurately determine the current through it by dividing the voltage by the resistance.

In this experiment, you will see that you can determine the current flowing in a circuit by measuring the voltage across any known resistor and applying Ohm's Law. You will also see that you can use the voltmeter scale to indicate current in milliamperes if there is a 1K-ohm resistor in the circuit.

Experimental Procedure: For this experiment, you will need your tvom, the experimental chassis and the following parts:

2 1K-ohm resistors
1 3.3K-ohm resistor

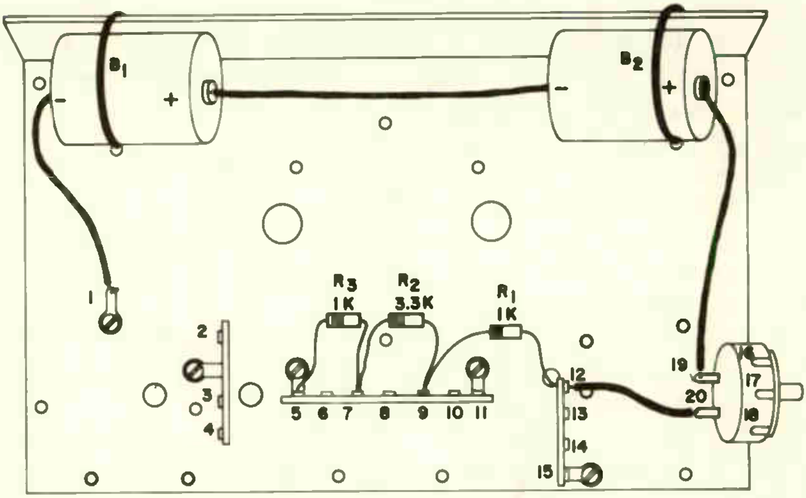


Fig. 15-1. Parts placement for Experiment 15.

First construct the series circuit shown in Fig. 15-1 and shown schematically in Fig. 15-2. Make sure S_1 is off.

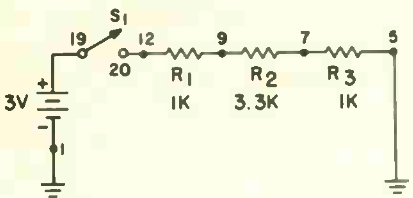


Fig. 15-2. Schematic diagram for the circuit used in Experiment 15.

Step 1: To find the current flowing through the 1K-ohm resistor R_1.

Turn on S_1. Measure the voltage across the 1K-ohm resistor by clipping the ground lead of your tvom to the junction of R_1 and R_2 and touching the probe to terminal 12. Record your reading in Fig. 15-3 in the space for the voltage reading across R_1.

Now, to find the current, we use Ohm's Law, which tells us that the current in amperes is equal to the voltage in volts divided by the resistance in ohms, I = E/R. By substituting the proper numbers for the letters in the formula (1000 for R, and the voltage you have just measured and recorded for E), you can find the current in amperes. To change the answer to milliamperes, we multiply by 1000, moving the decimal point three places to the right.

	VOLTAGE READING	CURRENT IN MA.
R_1 1K	.55v	.55ma.
R_2 3.3K	1.85V	.56ma
R_3 1K	.57V	.55ma.

Fig. 15-3. Record your readings for Experiment 15 here.

Here is how to figure the current. When we measured the voltage across the 1K-ohm resistor, we obtained a voltage of about 0.6 volt. Using this figure we get:

$$I = E \div R$$

$$I = \frac{0.6}{1000} = .0006 \text{ amp}$$

To change this to milliamperes we multiply by 1000 which gives us:

$$.0006 \times 1000 = .6 \text{ milliamperes}$$

Notice that in performing the operation we simply had to move the decimal point three places to the right.

Now you determine the current through the 1K-ohm resistor from your experimental results. Remember that because of normal parts tolerances, you may not get exactly the same result that we got. Record your current in Fig. 15-3.

Step 2: To find the current through the 3.3K-ohm resistor R_2.

Measure the voltage across R_2 by connecting the tvom with the ground lead to the junction of R_2 and R_3 (terminal 7), and the probe to the junction of R_1 and R_2 (terminal 9). Record the reading in Fig. 15-3. Figure the current through R_2 just as you did for R_1 in Step 1. This time substitute 3300 for R in the formula, and the second voltage measurement for E. Record the current in Fig. 15-3, after multiplying the answer by 1000 to change amperes to milliamperes.

Step 3: To find the current through resistor R_3.

Measure the voltage across R_3 by connecting the ground lead to the chassis and the probe to the junction of R_2 and R_3 (terminal 7). Figure the current as before, again using the last voltage measured for E and 1000 for R. Record this in Fig. 15-3, after multiplying by 1000. Turn off S_1.

Discussion: Now let us compare your results for Steps 1, 2, and 3. The three current values should be approximately the same, because the same current flows through all components in a series circuit. Actually, the current is exactly the same anywhere in the circuit, but because of parts tolerances and the difficulty in reading the meter accurately, your figures may show slight differences.

Notice the voltage value you measured across the 1K-ohm resistor R_1 and the current you calculated for R_1. The number of volts across R_1 and the number of milliamperes flowing through it should be the same, because you divided the voltage by 1000 to find the current, and then multiplied by 1000 to change it to milliamperes. This means that when the resistance equals 1000, the voltage across it in volts is equal to the current through it in milliamperes. Because of this fact, you can read the current directly on the voltmeter scale if you are measuring across a 1K-ohm resistor. If the voltmeter indicates .2 volt, you have .2 milliampere of current. If it indicates 1.5 volts, you have 1.5 milliamperes of current, etc.

If you wanted to measure current with a voltmeter and there was no 1K-ohm resistor in the circuit, you could add a

1K-ohm resistor in series, and measure the voltage across it, provided the resistance already in the circuit is reasonably high so that the addition of the 1K-ohm resistor will not appreciably increase the total resistance in the circuit. However, technicians seldom go to the trouble of inserting a resistor in a circuit so they can read the current value from their voltmeter scale. It takes too long to unsolder leads to install a resistor and then remove the resistor and reconnect the circuit after the measurement has been completed. Also, the busy technician will not use Ohm's Law each time he wants to know something about the current in a circuit. In practical work, you seldom want to know the amount of current. All you want to know is whether the amount is correct, and it will be if the voltage is correct.

Circuit current values are not given for most electronic equipment. However, voltage values are generally given. If the correct voltage drop appears across a part, you can assume that the amount of current is correct for that circuit.

The technician is interested in three possibilities as far as current is concerned. These are:

1. Is the current normal?
2. Is the current too high?
3. Is the current too low?

Voltage measurements give all three answers without the use of Ohm's Law or the necessity of unsoldering and resoldering connections.

Instructions for Statement No. 15: For the statement, you will short out R_3 and determine the current in the series circuit composed of R_1 and R_2. To do this, connect your tvom to read the voltage across R_1, turn on S_1, and short terminal 7 to the chassis with a wire or a screwdriver. Since R_1 is a 1K-ohm resistor, the voltage across it will be equal to the circuit current in milliamperes. Write this value down in the margin of this page. Now turn off S_1 and answer the Report Statement. You will use the circuit already connected for the next experiment, so do not dismantle the experimental chassis.

6.9ma.

Statement No. 15: When I shorted R_3 I found that the circuit current was:

(1) greater than
(2) less than
(3) the same as

the circuit current measured in Steps 1, 2, and 3.

EXPERIMENT 16

Purpose: To show that continuity can be checked by taking voltage measurements.

Introductory Discussion: The word "continuity" as used in electronics refers to the completeness of the path through which current is to flow. If there is no continuity, in other words, if the path is broken at some point, current cannot flow.

You know from studying your lessons and from the experiments you have already performed, that current flows only in a complete circuit, and that when current flows through a resistance, there is always a voltage drop across the resistance. These two facts are of utmost importance to a technician, because he uses them constantly in troubleshooting.

A complete circuit has a voltage source, connecting wires, and one or more parts through which current can flow. The parts in the circuit do not necessarily have to be resistors -- all parts through which current can flow have some resistance. Examples of these parts are coils, transformers, series tube filaments, and connecting wires. The fact that such parts have some resistance means that there is a voltage drop across each part.

You cannot measure a voltage drop across the connecting wires in a circuit because the resistance of the wire is so close to zero that the voltage drop across it is essentially zero. You can get a pretty good idea of what the voltage drop across each part in a circuit should be by looking at the schematic diagram. For example, if there are three resistors having approximately the same resistance in a series circuit, you should find that the voltage drop across each of the resistors is equal to about one-third of the source voltage. On the other hand, if one very high resistance is in series with one or more low resistances, the voltage drop across the high resistance will be very nearly equal to the source voltage, and the voltage drop across the low resistance will be almost zero.

If there is no voltage drop across one part in a circuit and there is a voltage drop across the other parts, there must be a complete short circuit across the part with no voltage drop. Then the current flows through the short rather than through the part. Since the resistance is essentially zero through the short, there is no voltage drop to measure.

If you measure the full source voltage across a part in a series circuit, you can assume the part is open (will not pass current). The full source voltage across a part indicates there is no voltage across the other parts in the circuit, and no current is flowing through them. The break, as you will prove, is in the part across which you measure the source voltage.

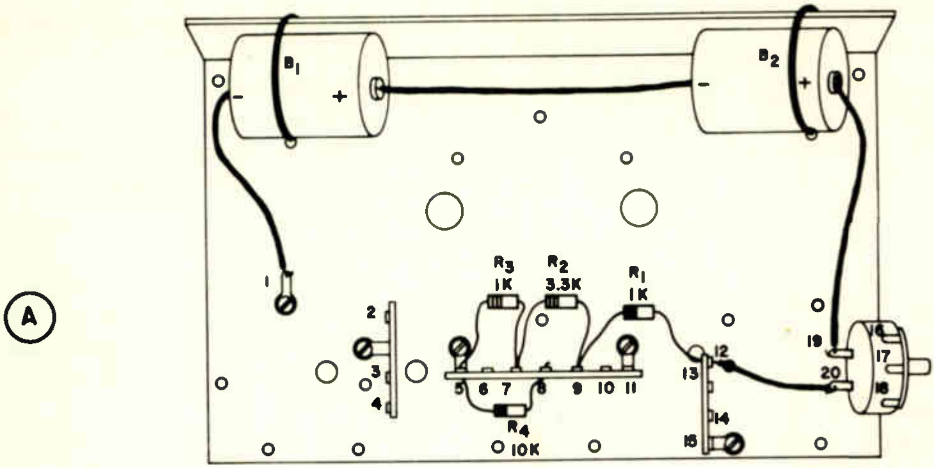
We will investigate these conditions in this experiment so that when you run across them in service work, you will know what to expect.

Here, of course, we are working with low voltages and simple circuits that show only the desired effects. In later kits you will apply the same tests to circuits using the voltage from your power line. You will work with circuits that amplify, that detect, that rectify, and that produce signals of their own. In short, you will learn all you need to know about the circuits.

Experimental Procedure: To perform this experiment you will need the tvom, the circuit you constructed in the last experiment, and the following parts:

1 10K-ohm resistor
1 10-megohm resistor
Hookup wire

For this experiment you will use the circuit shown in Fig. 16-1. As you can see, all you need to do is add the 10K-ohm resistor from terminal 5 to terminal 8 to make the circuit.



B

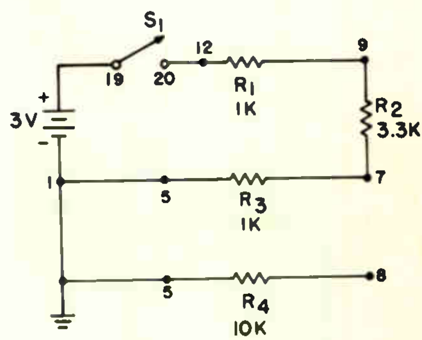


Fig. 16-1. The chassis layout is shown at (A) and the schematic diagram of the circuit for Experiment 16 is shown at (B).

Step 1: To show that there is a voltage drop across each part in a complete circuit.

Examine Fig. 16-1. You can see that there is a complete circuit consisting of R_1, R_2, and R_3 in series across the 3-volt source. Electrons will be pulled through the circuit into the positive terminal of the battery and pushed out into the circuit from the negative terminal of the battery. Electrons cannot be pushed into resistor R_4 because the electrons have no place to go. Unless electrons are removed from terminal 8, none can enter from ground. Since there is no current through this resistor, there will be no voltage drop across it.

Turn on S_1 and clip the negative terminal of your voltmeter to the chassis. Touch the probe to terminal 8. Although there may be a momentary quiver of the meter needle, there will be no steady reading. This shows that there is no voltage drop across R_4. Now touch the probe to terminal 7. Here there will be voltage, which will be less than the source voltage. Touch the probe to terminal 9. You will get a voltage reading greater than the one you measured at terminal 7. Move the probe to terminal 12 and you will measure the full source voltage. This indicates that there is continuity throughout the complete circuit. The fact that the voltage increased from terminal 7 to terminal 9 showed that there was a voltage drop across each part.

Previously, we have measured the voltage across individual resistors. We could have done so in this case, but in actual electronics work you usually make all your measurements with respect to one point in the equipment.

Step 2: To show that the lack of a voltage drop across only one part in a complete circuit shows that that part is shorted.

Cut a piece of hookup wire about two inches long and strip the insulation from it. Solder this lead from terminal 7 to terminal 5. R_3 is now shorted.

With the negative voltmeter lead clipped to the chassis, touch the probe to terminal 7. You should not get a reading because, although current flows through this part of the circuit, there is no appreciable resistance between these points. The current takes the easy path through the bare wire instead of the high resistance path through R_3. Touch the probe to terminal 9; this should give you a reading -- showing that current is flowing through R_2 and also through R_1. Move the probe to terminal 12. You will measure the full source voltage here. Remove the bare wire shorting R_3, and you are ready to go on to the next step.

Step 3: To show that an open part in an otherwise complete circuit has the full source voltage across it and that there are no voltage drops across the other parts.

Fig. 16-2. How to make a dummy open part with two pieces of wire.

Let us assume that R_3 has burned out. Rather than ruin a good resistor, we will make up a dummy part to simulate the effect of an open resistor. To do this, cut two pieces of hookup wire each about 1-1/2 inches long. Remove the insulation from only one end of each wire. Wrap the insulated ends of the wires over each other so you will have an "open part" with two leads. It should look something like Fig. 16-2.

Unsolder R_3 from terminal 7 and solder one lead of the dummy resistor to terminal 5 (leave R_3 and R_4 connected to this point). Solder the other lead of the dummy resistor to terminal 7 and imagine that this is R_3 after it has burned out and become open.

Clip the ground lead of the tvom to the chassis. Touch the probe to terminal 12. You should measure the full source voltage. Now touch the tvom probe to terminal 9. Again you should measure the full source voltage, showing that there is no voltage drop across R_1. Now move the probe to terminal 7. Again you should measure the full source voltage, showing that there is no drop across resistor R_2 and that all of the source voltage is across the dummy open resistor. To further prove that there is no voltage drop across the good parts, connect your ground clip to terminal 7 -- the junction of R_2 and dummy resistor R_3. Touch the probe to terminal 9. Except for a momentary flicker of the meter pointer, you will get no reading. Now move the ground clip to terminal 9 and touch the probe to terminal 12. Again you should get no reading, showing that there is no voltage drop across the parts.

This method of testing across each part individually is a more certain check than measuring from a fixed point such as ground.

Now remove the dummy resistor and resolder the free end of R_3 to terminal 7, completing the original circuit.

Step 4: To show that a check of the source voltage does not indicate the presence of continuity in the circuit connected to it.

Connect the ground clip of the tvom to the chassis. Touch the probe to terminal 19 of switch S_1 in Fig. 16-1. Note the exact reading. Now open the circuit by turning S_1 off. Repeat the measurement by touching the probe again to terminal 19. You will note that there is no difference in voltage at this point whether the circuit is open or closed. Because of this, a check of voltage across a part or across a series of parts directly at the source does not show if current can flow through the circuit or the part. Such a measurement only checks the condition of the voltage supply and not the parts connected to the source.

Step 5: To show that both ends of a part having no voltage drop are at the same potential, and that the continuity of the part can be checked by voltage measurements.

In Step 1 of this experiment, you found that there was no voltage drop across resistor R_4. Let us prove by measurements that terminals 5 and 8 are at the same ground potential. Turn on S_1 and clip the ground lead of your tvom to the chassis, and touch the probe to terminal 8. You will not get a reading. Now clip the ground lead to terminal 8 and touch the probe to the chassis. Again you will not get a reading. With the ground clip on terminal 8, touch the probe to terminal 7. This time there will be a reading. Note its value carefully, and jot it down on the side of the page. Now .59 connect the ground clip to the chassis, and touch the probe to terminal 7. You should measure the same voltage between .59 the chassis and terminal 7 as you did between terminals 8 and 7. Terminals 5 (chassis) and 8 are both negative with respect to terminal 7.

Discussion: The facts that this experiment brings out are of such importance that they are listed here. Refer to this listing whenever you need refreshing on these points. Eventually, you will become so familiar with all of these facts that you will know at once what to look for when you run across similar conditions in your service work.

1. If current can flow through a circuit there will be a voltage drop across all unshorted parts in the circuit.

2. If one part in a complete circuit has no voltage drop across it, but there are voltage drops across all other parts, the one with no voltage drop is shorted. The short may be in the part itself or in some other part shunting it.

3. If in a circuit that should be complete, you find full source voltage across one part and no voltage across the other parts, the part with full source voltage across it is open.

4. If only one part is connected across a source, the presence of voltage across the part is meaningless, since full source voltage will be across it whether or not the part is open.

5. If there is no voltage drop across the part, but one lead of the part connects to an operating circuit, both ends of the part will be at the same potential with respect to all other points in the circuit.

Instructions for Statement No. 16: If the resistance of a part being checked is fairly large compared to the resistance of your tvom, you will not get the expected voltage measurements when you check the continuity of the part. We will prove this point in this statement experiment. We will substitute the 10-megohm resistor for R_4. To do this, solder one end of the 10-megohm resistor to terminal 15 (chassis). Leave the other end free. Clip the tvom ground clip to the free end of this resistor and touch the probe to terminal 7. A reading here indicates that .34 continuity exists through the 10-megohm resistor. Now touch the probe to terminal 1.65 12. Jot down the approximate reading, and answer the Statement. Turn off S_1 and your tvom, unsolder the 10-megohm resistor but leave the batteries as well as R_1, R_2, and R_3 connected. Save the dummy resistor for later use.

Statement No. 16: When I measured the voltage between the free end of the 10-megohm resistor and terminal 12, I found that the meter pointer was closest to:

(1) zero
(2) 1.5 volts
(3) 3 volts

on the 0-3 volt dc scale.

3 / 18 meg

.17 µA

EXPERIMENT 17

Purpose: To show that the sum of the currents flowing away from a point is equal to the current flowing to that point.

Introductory Discussion: In this experiment we will construct the series-parallel circuit shown in Fig. 17-1. Current I_1 flows through the branch consisting of R_1 and R_4, and current I_2 flows through the branch consisting of R_2 and R_3. Both of these currents, which together make up the total current drawn from the battery, flow through resistor R.

Since R, R_1, and R_2 are 1K-ohm resistors, we can measure the three currents in terms of milliamperes. As you have learned, the voltage drop in volts across a 1K-ohm resistor is equal to the current in milliamperes flowing through it.

The accuracy of the measurements will depend on the tolerances of the three resistors. If each is exactly 1K ohm, then the current measured for I will exactly equal I_1 plus I_2. However, since the resistors have a tolerance of plus or minus 10 percent and therefore may not be exactly 1K ohm each, the readings may be off a little.

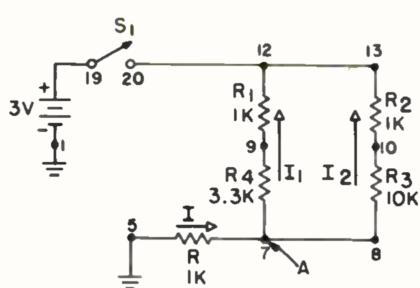


Fig. 17-1. Circuit for Experiment 17.

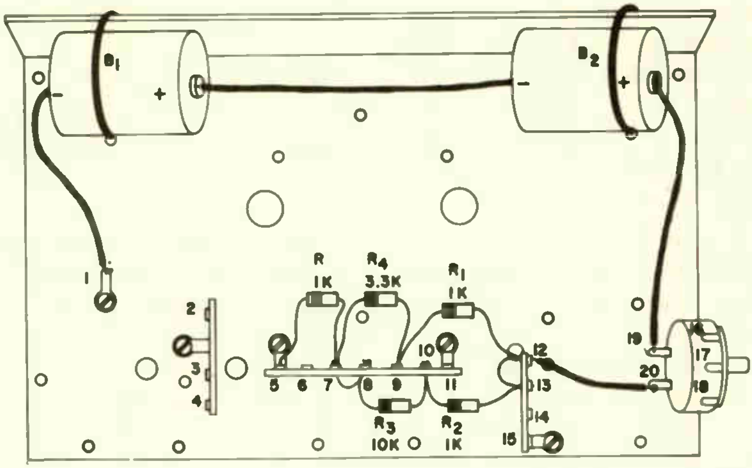


Fig. 17-2. Chassis arrangement for Experiment 17.

Experimental Procedure: For this experiment, you will need your tvom, the chassis with parts installed, and the following parts:

1 **1K-ohm resistor**
Hookup wire

Fig. 17-2 shows the parts arrangement needed to perform this experiment. To construct this circuit, unsolder the 10K-ohm resistor lead from terminal 5 and resolder it to terminal 10. Then install the 1K-ohm resistor from terminal 10 to terminal 13.

Finally, connect terminals 7 and 8 with a 2" length of hookup wire, and connect terminals 12 and 13 with another 2" length of hookup wire. These jumpers are purposely made longer than necessary so that the circuit can be changed easily later. Turn on S_1 and your tvom and proceed with Step 1.

Step 1: To measure current I through resistor R.

Clip the ground lead of your meter to the chassis and touch the probe to terminal 7. Record your reading on the 3-volt scale in Fig. 17-3 as the current I in milliamperes. As you can see from examining the schematic in Fig. 17-1, all the electrons making up the current drawn from the battery flow through resistor R.

Step 2: To measure current I_1.

Current I_1 flows through resistors R_1 and R_4. Since this is a series circuit, the

CURRENT MEASURED	YOUR READING
CURRENT I THROUGH R	.75 ma
CURRENT I_1 THROUGH R_1	.52 ma
CURRENT I_2 THROUGH R_2	.22 ma.
CURRENT $I_1 + I_2$	.74 ma

Fig. 17-3. Record your readings for Experiment 17 here.

same current flows through both resistors. By measuring the voltage drop across R_1 we can interpret this as current I_1 in milliamperes through both resistors. To make the measurement, clip the ground lead of the tvom to terminal 9, the junction of R_1 and R_4, and touch the probe to the end of R_1 going to terminal 12, the positive battery terminal. Record your reading in Fig. 17-3 as the current I_1 in milliamperes.

Step 3: To measure current I_2.

Since R_2 and R_3 are in series, the same current flows through each. Measuring the voltage drop across the 1K-ohm resistor R_2 gives us the current in milliamperes. To make the measurement, clip the ground lead of the tvom to terminal 10, the junction of R_2 and R_3, and touch the probe to terminal 12 or 13, the end of R_2 going to the positive battery terminal. Record in Fig. 17-3 the voltage across R_2 as the current I_2 in milliamperes. Turn off S_1.

Step 4: To find the sum of I_1 and I_2.

Add the values you obtained for I_1 and I_2 and record their sum in the space provided in Fig. 17-3.

Discussion: Compare the current you measured for I with the sum of the currents you measured for I_1 and I_2. They should be approximately equal. However, you must remember that because of parts tolerances, the measured values may not be exactly equal. If these values are equal, it means that the three 1K-ohm resistors that you have are exactly equal and that the measurements in each case happen to fall on a marked scale division so that you could read them exactly. This is extremely unlikely, although possible. If the difference between the sum of I_1 and I_2 and current I is not greater than ±20%, your results are good.

The current flowing to point A in Fig. 17-1 is the current I. The current flowing away from point A is the sum of I_1 and I_2. You should have found that this sum was approximately equal to I. In other words, the current flow to point A is equal to the current flowing away from it. This is an important law known as Kirchhoff's Current Law. You will see applications of it time and time again in your electronics career.

Instructions for Statement No. 17: For the Statement we will change the circuit in Fig. 17-1 by placing resistor R between the positive battery terminal and the junction of R_1 and R_2. The new circuit will be like Fig. 17-4. With the circuit changed, we will see if the currents flowing to point B add up to the current flowing away from this point.

By simply reconnecting the two jumpers used in Fig. 17-2, we can change the circuit to that of Fig. 17-4. Resistors R and R_1 become interchanged. That is, resistor R in Fig. 17-4 was R_1 in Fig. 17-2 and resistor R_1 in Fig. 17-4 was R in Fig.

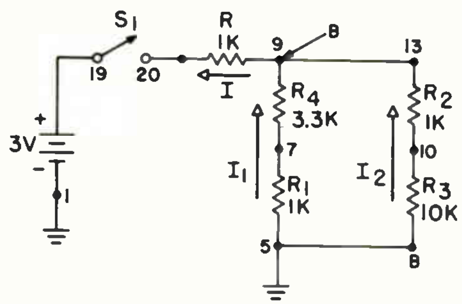


Fig. 17-4. Circuit for Statement 17.

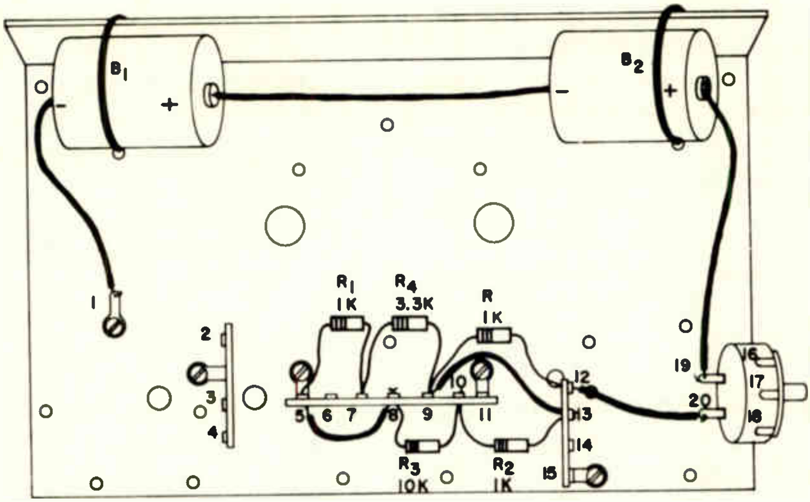


Fig. 17-5. Parts arrangement of Fig. 17-4.

17-2. Both resistors are 1K-ohm, so all is well.

To change the circuit, unsolder the jumper wire going to terminal 7 and resolder it to terminal 5. Unsolder the jumper lead going to terminal 12 and resolder it to terminal 9 as shown in Fig. 17-5. With the circuit changed, we will see if the currents flowing to point B add up to the current flowing away from this point.

Turn on S_1 and measure the current through R by connecting the meter clip to terminal 9 and the probe to terminal 12. Record your reading for I in Fig. 17-6. Now measure the current through R_1 by connecting the meter ground clip to the chassis and touching the probe to terminal 7. Record this reading as I_1 in Fig. 17-6. Finally, measure I_2 by connecting the meter ground clip to terminal 10 and the probe to terminal 13. Record your reading in Fig. 17-6. Add up the currents I_1 and I_2 and enter the sum in Fig. 17-6. Now you can answer the statement.

Turn S_1 off and unsolder and remove the resistors and jumper wires. Leave the battery connected to terminals 1 and 19.

Statement No. 17: I found that the sum of I_1 and I_2 was:

(1) approximately equal to
(2) considerably greater than
(3) considerably less than

current I.

CURRENT MEASURED	YOUR READING
CURRENT I THROUGH R	.725
CURRENT I_1 THROUGH R_1	.54
CURRENT I_2 THROUGH R_2	.22
CURRENT $I_1 + I_2$	.76

Fig. 17-6. Record the readings for Statement No. 17 here.

Putting Your Ohmmeter Into Operation

The ohmmeter section of your tvom should be ready to operate. You assembled it and installed the battery when you constructed the unit. If your tvom has been operating properly up to this point, you should have no difficulty with the ohmmeter.

TRYING OUT THE OHMMETER

Turn on the tvom and set the function switch to dc, and the range switch to R X 1. Carefully adjust the zero set knob on the front panel. Look to see that the test leads from the meter are not touching, and rotate the function switch to the "ohms" position. The meter pointer should move upscale. If it moves downscale, you have the flashlight cell installed backwards.

Bring the meter pointer over the last mark on the right on the ohmmeter scale (the red scale on the meter) by adjusting the front panel ohms set knob.

If you cannot get it to the last mark, the flashlight cell voltage is too low, and you should install another cell. You should check the calibration adjustment of the voltmeter when the flashlight cell is replaced.

Turn the range knob through its various positions. The meter pointer should remain in approximately the same position for any position of the range switch. If there is much variation, the meter reading can be brought back to the last mark on the ohmmeter scale by means of the ohms set knob.

Turn the range switch to the R X 1 position and clip the ground lead to the probe tip. The meter will indicate a fraction of an ohm. This reading is normal and is due to the small resistance in the ground lead and the probe cable.

Turn the range switch to the R X 1M position. The meter pointer will swing to the left, coming to a stop approximately at zero on the ohms scale. This indicates there is zero resistance between the clip and the probe. The fraction of an ohm of resistance in the ground lead and cable is not indicated with high range switch settings. When you separate the clip and the probe, the meter pointer will swing all the way to the right to the last mark on the ohmmeter scale.

It is important that you know the meaning of these two marks. The one at the right means that the resistance between the test leads is too high to be read, and the zero mark at the left means that the resistance between the two probes is too low to be read.

Let us see how the ohmmeter works.

HOW YOUR OHMMETER WORKS

An ohmmeter does not measure the resistance of a part directly. It measures either the current flowing through the part or the voltage drop across the part. Your Model 212 and most commercial tvom's use the latter method.

As you already know from the discussion in Experiment 11, the bridge circuit in your tvom when balanced gives a zero reading on the meter scale. When a voltage is applied to the bridge, unbalancing it, there is a reading which depends upon the amount of the voltage.

A schematic diagram of your ohm-

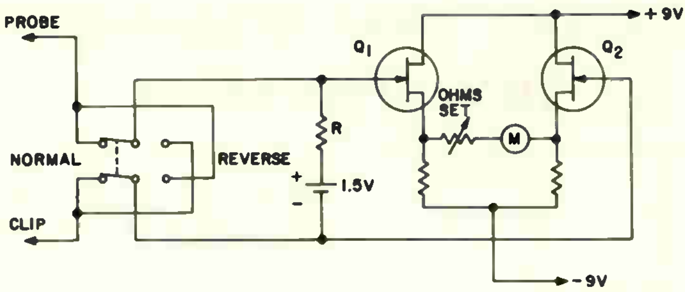


Fig. 14. Ohms circuit of TVOM.

meter circuit is shown in Fig. 14. When the ohmmeter is in use, the additional parts consist of the 1.5-volt cell, a resistor, and the ohms set rheostat in series with the meter. When the probes are separated, there is no voltage drop across the resistor, and the 1.5 volts is applied directly to the bridge circuit. When the ohmmeter is to be used, the ohms set is adjusted so the meter pointer moves all the way to the right. When the test probes are held together, no voltage is applied to the bridge circuit, and the meter pointer goes all the way to the left on the ohms scale.

If a resistor is connected between the ground clip and the probe, the 1.5-volt source voltage divides between the resistor built into the tvom and the external resistance under test. The voltage drop across the resistor being tested is applied to the bridge circuit. The meter is calibrated to give readings in ohms, corresponding to these voltage drops. Thus, the meter is actually measuring the voltage drop, but the scale is marked in ohms to give a direct resistance reading.

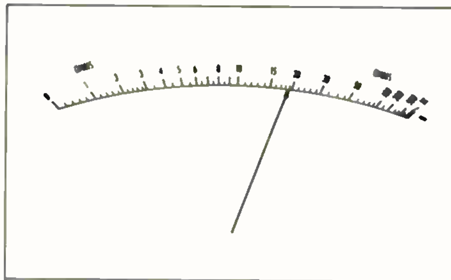
For each ohmmeter range position a definite resistor value is switched into the circuit. On the R X 1 range, we have a 10-ohm resistor; on the R X 10, a 100-ohm resistor; on the R X 100, a 1K-ohm resistor; on the R X 1K, a 10K-ohm resistor; on the R X 10K, a 100K-ohm resistor; on the R X 100K, a 1-meg resistor; and on the R X 1M, a 10-meg resistor. Since all of these ranges are multiples of 10, we can use the same ohmmeter scale for each range. On R X 1, the scale can be read directly. On the R X 10 range, we multiply the scale reading by 10. On the R X 100 range, we multiply the scale reading by 100. On the R X 1K range, we multiply the scale reading by 1000. On the R X 10K range, we multiply the scale reading by 10,000. On the R X 100K range, we multiply the scale reading by 100,000, and on the R X 1M range, we multiply the reading by 1,000,000. On this range we simply read the scale directly in terms of megohms (million ohms) rather than ohms.

The scale is arranged so that 10 falls in the center of the scale. If we measure a 10-ohm resistor on the R X 1 range, the resistance in the tvom and the external resistance will be equal, and the meter will read half-scale. The cell voltage divides equally between the resistance in the tvom and the external resistance. The meter will read half-scale on each range when the resistor under test equals the internal resistance of the ohmmeter. If a resistance higher than the internal resistance is measured, more of the voltage will be dropped across it and applied to the bridge circuit, and a higher value will be indicated. If a resistor lower than the one in the ohmmeter being tested, less of the voltage will be dropped across it, and a smaller voltage will be applied to the bridge circuit, giving a smaller deflection and a lower resistance reading.

The values that can be read on any range are the ones included between the first mark on the ohmmeter scale to the right of zero and the 1K mark.

Thus, on the R X 1 scale, we can read values from .2 ohm to 1000 ohms. On the R X 10 scale, we can read values from 2 ohms to 10,000 ohms. On the R X 100 scale, we can read values from 20 ohms to 100K ohms. On the R X 1K range, we can read values between 200 ohms and 1 megohm. On the R X 10K range, we can read values between 2000 ohms and 10 megohms. On the R X 100K range, we can read values between 20,000 ohms and 100 megohms. On the R X 1M range, we can read values between 200,000 ohms and 1000 megohms.

These are the maximum extremes that can be measured on the various ranges. Actually, a range should be used that will give a deflection as near the center of the scale as possible. Avoid using a range that gives a reading on the extreme right.



RANGE SETTING	VALUE INDICATED
R X I	19
RX10	190
RX100	1,900
R X IK	19,000
R X IOK	190,000
R X IOOK	1,900,000
R X IM	19 MEG

Fig. 16. When the meter points to the first line before 20 on the ohms scale, the value indicated depends on the setting of the range switch.

READING THE METER SCALE

An expanded view of the meter scale is shown in Fig. 15 with the values of the in-between markings clearly illustrated. Study this and the scale on your meter until you are able to identify the values of the unmarked divisions quickly.

For practice assume that the meter pointer rests at a certain position and then figure out what value this position would indicate on the various ranges.

Assume that the meter pointer points to the division just before 20. Write down the value this would indicate for each range of the ohmmeter. Then compare your reading to the ones in Fig. 16.

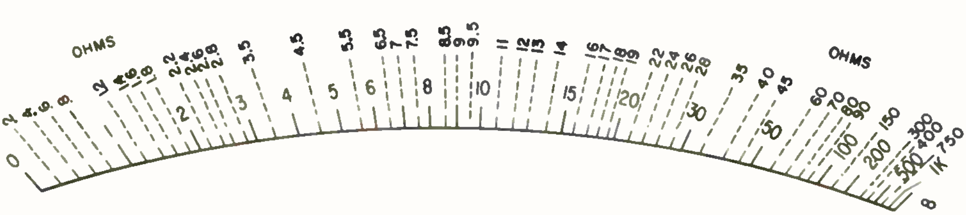


Fig. 15. An expanded view of the ohmmeter scale of the tvom.

Remember that the R X 1 scale is read directly in ohms, and the R X 1M scale is read directly in megohms.

Although, as we have said, your ohmmeter works by voltage division, you must remember that some current is drawn from the cell. With the range switch in the R X 1 position and the test leads shorted together, you have a 10-ohm resistor connected directly across the cell and considerable current is drawn from the cell. Do not leave the probes together for any length of time on the two lowest ohmmeter ranges. Make the readings quickly so you can disconnect the test probes and prolong the life of your flashlight cell. However, since replacement cells are inexpensive and are easy to install, you should take enough time to get satisfactory readings.

EXPERIMENT 18

Purpose: To show how practical measurements on individual resistors are made with an ohmmeter; and to show the precautions necessary for satisfactory results.

Introductory Discussion: In checking parts with an ohmmeter there are three important rules to bear in mind. These are:

1. Make sure the equipment in which the part under test is used is turned off. If it is supplied from the power line, turning the equipment power switch to the off position is usually sufficient. Many technicians, however, make it a rule to remove the power line plug of the equipment from the wall socket. Then there is no question that the power has been disconnected, and there is no chance of turning the switch on while checking the volume control, which may be part of the switch.

If the equipment is battery operated, all the batteries should be disconnected, because the on-off switch might disconnect only one battery terminal, leaving the other terminal connected to the circuits. In making tests with your ohmmeter, you might complete the battery circuit through your meter. If there is voltage across the part being tested, the resistance measurement is meaningless and if the voltage is high, the ohmmeter might be damaged. We will show what happens when voltage is present across a resistor being checked with an ohmmeter.

2. Use the correct range of the ohmmeter. As you will demonstrate, if you use the wrong range, the ohmmeter may indicate a good part is open or shorted.

3. Keep your fingers off the parts under test when measuring high resistances. The resistance of your body can affect the results of your measurements. On low resistances it does not matter. Do not touch the probes when checking iron-core devices, such as transformers or chokes, or you may receive a serious shock.

As you continue working with your ohmmeter, you will learn other valuable tricks of the trade that will enable you to get the greatest use from the ohmmeter section of your tvom.

Experimental Procedure: In this experiment you will need your tvom, the 3-volt battery, and the following parts:

1 10-megohm resistor
1 1-megohm resistor

1 100K-ohm resistor
1 22K-ohm resistor
1 18K-ohm resistor
1 10K-ohm resistor
1 3.3K-ohm resistor
3 1K-ohm resistors
1 Alligator clip

Turn the tvom on and turn the function switch to the dc position. Carefully adjust the zero set control. Now turn the function switch to the ohms position, and the range switch to the R X 1M position. Adjust the ohms set control so that the meter pointer is over the last division at the right on the ohms scale. Now hold the test leads together; the pointer should move to zero on the left of the scale. You are now ready to demonstrate the first step in the experiment. Slip the alligator clip over the tvom probe as you did in Experiment 14. This will make it easier to connect the ohmmeter to the circuits used in this experiment.

Step 1: To show the effect of touching the circuit under test when measuring large resistance values.

In this step you will first use the 10-meg resistor. With the resistor on your workbench, clip the ground lead of the tvom to one lead of the resistor and the probe to the other resistor lead. You will get a reading of approximately 10 megohms. Let us see how we read this. The meter pointer should point to about 10 on the ohms scale and this, of course, means 10 megohms on this range.

Now with the ground lead and the probe clipped to the 10-megohm resistor, grasp one test clip in each hand. This places your body in parallel with the 10-megohm resistor. Note the change in the meter reading. The large reduction in the reading shows that your body resistance is in parallel with that of the 10-megohm resistor. You might measure 2 megohms, 4 megohms, or 6 megohms, depending upon the moisture on the surface of your skin and the pressure you exert in touching the test leads. In any event, you can see that such a test of the resistor gives meaningless results.

Lay the 10-megohm resistor to one side, and set the range switch to the R X 10K position. Connect the ground clip to one lead of the 100K-ohm resistor, and the probe to the other end, and note the reading. Grasp one test clip in each hand, placing yourself across the resistor. Again note that there is a reduction in the resistance reading, although considerably less than in the case of the 10-megohm resistor. The reduction is less because the resistance of your body across the 100K-ohm resistor causes less of a change in the resistance between the ohmmeter leads.

Now disconnect the 100K-ohm resistor and lay it to one side. Place the range switch in the R X 1K position. Connect the ground clip to one lead of a 10K-ohm resistor, and the probe to the other end. Your reading will be somewhere near 10 on the ohms scale. Multiplying this by 1000 will give you the approximate value of the resistor. Now touch the ground clip with the fingers of one hand, and touch the probe with your other hand. Note that there is only a slight change in the resistance value.

This step showed you that touching the ohmmeter leads with your hands is not very important when measuring low resistances, but is extremely important when measuring high resistances. You should make it a habit to keep your hands off the circuit under test.

Step 2: To show that using the incorrect ohmmeter range may give misleading results.

Connect the ground clip to one lead of the 100K-ohm resistor, set the range switch to the R X 1 position, and touch the probe of the tvom to the free lead of the resistor. Note that there is no appreciable movement of the meter pointer, indicating, as far as this range is concerned, that the resistor is open. Now, remove the probe from the resistor, and switch the range switch to the R X 1M position. Again touch the probe against the free lead of the resistor. The pointer will move almost to zero, and you might conclude that the resistor was either completely or partially shorted. Now, remove the probe from the 100K-ohm resistor, and change the range switch to the R X 10K position. Touch the probe to the resistor again and you will find that the meter pointer swings to 10. Multiplying this by 10,000 gives us 100,000 for the value of the resistor.

From this demonstration you can see how important the choice of range is. Let us learn how to choose the right range.

Step 3: To show how to choose a suitable ohmmeter range.

A suitable ohmmeter range is one that is easily read. Before demonstrating this statement, examine Fig. 18-1. This chart lists the resistance values covered by each range. It also shows how many places to move the decimal point for each multiplying factor. For example, if the meter reads 10 when using the R X 10 range,

RANGE	COVERAGE	NO. OF PLACES TO RIGHT TO MOVE DECIMAL POINT
R X 1	.2 OHM TO 1K OHMS	0
R X 10	2 OHMS TO 10K OHMS	1
R X 100	20 OHMS TO 100K OHMS	2
R X 1K	200 OHMS TO 1 MEGOHM	3
R X 10K	2K OHMS TO 10 MEGOHMS	4
R X 100K	20K OHMS TO 100 MEGOHMS	5
R X 1M	200K OHMS TO 1000 MEGOHMS	6

Fig. 18-1. The resistance values covered by each range of the ohmmeter.

move the decimal one place to the right, which gives you 100, the value of the resistor under test.

To find the ohmic value when the meter reads 30 using the R X 100K range, move the decimal point five places to the right, which gives 3,000,000 or 3 megohms.

When the readings fall on unmarked values to the left of 6, the meter value will end with a decimal. Thus the line between 5 and 6 is 5.5. On the R X 10 range, a meter reading of 5.5 is 55 ohms. Also notice that the long mark between 6 and 8 is not numbered and it represents 7. Likewise, the long mark between 8 and 10 is not numbered and it represents 9. The short marks between 6 and 7, 7 and 8 and 8 and 9 indicate a value ending in .5.

Suppose you are using the R X 10K range, and the meter pointer is on the third mark past zero. This is .6. To get the reading in ohms, multiply .6 by 10,000 or move the decimal point four places to the right. The answer is 6000 ohms.

With practice you will be able to read

values quickly and easily. Many times you can tell the range to use by reading what the value is supposed to be on the schematic diagram.

Let us see which range to use for your 18K-ohm resistor. First, put the range switch in the R X 1 position. Clip the ground lead to one lead of the resistor, and the probe to the other lead. Record your reading in Fig. 18-2. Now, move the range switch to each of the other positions, and watch the meter. Record your meter readings in the spaces marked "Reading" in Fig. 18-2. Figure out the value in ohms by multiplying each reading by the multiplying factor for each range setting. Write these under "Value" for each range.

When you use the R X 1 range, the pointer will be all the way over to the right, so you know the resistance is more than 1000 ohms, so you switch to the next range. On R X 10, the pointer still stays all the way over to the right, so again you switch to a higher range. On R X 100, the pointer should be between 150 and 200, so switch to a higher range. On R X 1K, the pointer should be at about 18; on R X 10K, it will be anywhere from 1.6 to 2; on R X 100K, it will move past the first scale division on the left, .2; and on the R X 1M range, there will be no perceptible reading.

From these, you know that the resistance you are measuring will be more than 1000 ohms, and less than 20,000 ohms. You could read it on the R X 100, the R X 1K or the R X 10K range. You will get a more accurate reading on the R X 1K range, because at that part of the scale, each division represents 1, and the reading is near the center of the scale. On the R X 100 range the reading is way over to the right, and each division represents 50 or 100. On the R X 10K range the reading is way over to the left, and each division represents 2.

The readings you obtain might be closer together or even farther apart than those shown in Fig. 18-2. Exact agreement is very unusual and, as you will learn, unnecessary. Since the readings are taken on different parts of the scale, the error introduced by the meter itself and by the resistors in the instrument may vary. For service and general electronic work such an error is unimportant.

Now check each of your resistors on

RANGE	R X 1		R X 10		R X 100		R X 1K		R X 10K		R X 100K	
	READING	VALUE	READING	VALUE	READING	VALUE	READING	VALUE	READING	VALUE	READING	VALUE
SAMPLE FIGURES	1K +	1K +	1K +	10K +	150 +	15K+	18	18 K	1.6 +	16 K +	LESS THAN .2	LESS THAN 20K
YOUR FIGURES	1K+	1K+	1K+	10K+	200+	20K+	16	16K	1.7	17K	.2-	20K

Fig. 18-2. Record your reading for each range setting under the column headed "Reading". Record the value that reading indicates on each range under the heading "Value".

each range, recording your scale readings in Fig. 18-3, and the value this reading indicates. Clip the ground lead to either lead of the resistor being measured, and the probe to the other lead. Turn the range switch to the positions indicated on the top of the table, and enter the meter reading you obtain under the heading marked "Reading." Compute the ohmic value of the resistor, and enter it in the space marked "Value."

For the 1K-ohm reading, use any one of the 1K-ohm resistors. For the 330-ohm resistance you are to measure, connect the three 1K-ohm resistors in parallel. To do this, clip the tvom ground lead to one end of all three 1K-ohm resistors, and the probe to the other ends.

Practice working out the ohmic value of each reading you record in Fig. 18-3. If you find one range is as easy to read as another, it does not matter which range you use.

If you want the greatest accuracy, use the range that gives an indication nearest the center of the scale. For example, when you measure the 330-ohm resistance on the R X 1 range, the pointer will move between 200 and 300 at the right-hand side of the scale, but that is about as close as you can read it. On the R X 1K range, it will move between .2 and .4, so you know the value is between 200 and 400. However, on the R X 100 range, it will move to the first division past 3, so you know the value is between 300 and 350. This is the best scale to use for this particular resistance value.

Step 4: To show that power must not be applied to a circuit when ohmmeter tests are made.

Connect a 1K-ohm resistor, a 10K-ohm resistor and a 22K-ohm resistor in series. Connect the free lead of the 1K-ohm resistor to terminal 15 and connect the 22K-ohm resistor to terminal 20, as shown in Fig. 18-4. Make sure S_1 is off. To make the connections to the 10K-ohm resistor, simply twist the resistor leads together for this temporary connection. Note that the circuit is not completed,

RESIS.	R X 1		R X 10		R X 100		R X 1K		R X 10K		R X 100K		R X 1MEG	
	READING	VALUE	READING	VALUE	READING	VALUE	READING	VALUE	READING	VALUE	READING	VALUE	READING	VALUE
10 MEG	>1K	>1K	>1K	>10K	> 1K	>100K	>1K	>1000 K	>1K	>10M	100	10M	9.7	9.7M
1 MEG	> 1K	>1K	>1K	>10K	>1K	>100K	>1K	>1M	100	1M	10	1M	1.5	[illegible]
100K	>1K	>1K	>1K	>10K	1K	100K	100	100K	9.5	95K	1	100K	.1	100K
22K	>1K	>1K	>1K	>10K	300	30K	22	22K	2.4	24K	.15	15K	0	0K
10K														
3.3K														
1K														
330														

Fig. 18-3. Record the reading and the indicated value on each range for each of the resistances listed.

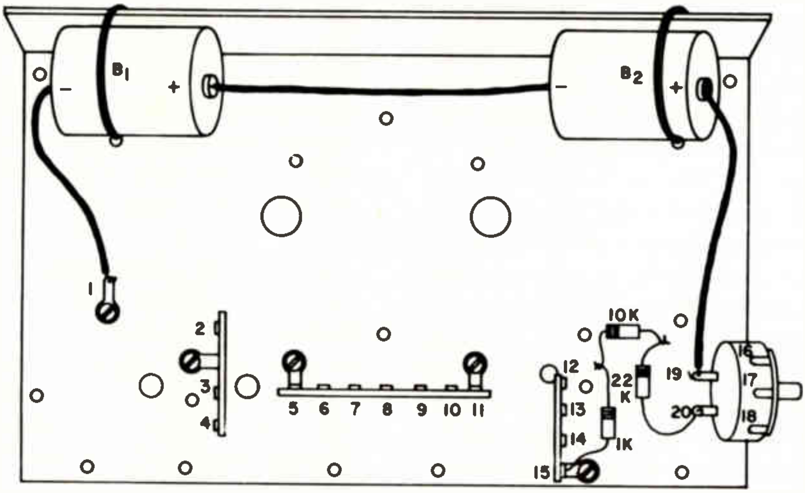


Fig. 18-4. Circuit for Step 4.

since S_1 is off and the 22K-ohm resistor is not connected to the positive terminal of the battery. Consequently, there will be no voltage drops across the resistors, and no current flow through the circuit.

Measure the resistance of the 1K-ohm resistor by clipping the ground lead to the chassis. Set the range switch of the tvom to the R X 1K position, and clip the probe to the junction of the 1K-ohm and 10K-ohm resistors. The meter needle will indicate approximately 1; multiplying this by 1000, you get 1000 ohms for the resistance of the resistor.

Clip the probe to the junction of the two resistors and turn on S_1. Note that there is a marked increase in the resistance reading, so much so, in fact, that you might suspect that the resistor was defective. Turn off S_1 but do not dismantle the circuit. You will use it again to answer the statement.

Discussion: In this experiment you have learned that you must choose a suitable ohmmeter range. The wrong range might indicate that a good resistor is open or that it is shorted. Also, you must choose a suitable range so that the value can be read easily and accurately.

You have seen that if power is applied to a circuit in which a resistance measurement is being made, the measurement will be so far off as to be meaningless.

You have found that the ohmmeter is not 100% accurate. However, in service work, this is unimportant. When making resistance measurements on equipment you have been called upon to repair, you are looking for an open, for a short, or for a radical change in resistance value. If a part has changed sufficiently in resistance so that the equipment operates improperly, the change will be large. You would not expect a change of 25% to cause trouble in most circuits. In general, the change, if that is what the trouble is, will be 50% or more. For example, you might find that the plate load resistor of an amplifier had changed from its normal value of 100,000 ohms to 20,000 ohms. This would cause a marked loss in gain, and cause excessively high plate voltage.

When a technician has improperly operating equipment, he does not check the value of each and every resistor with his ohmmeter. He localizes the trouble to a section and then to a stage. Then he decides whether to make ohmmeter measurements or other measurements according to the symptoms he discovers. You will be taught how to localize trouble to a stage, and from the symptoms, to decide what type of test should be made.

There are, of course, many uses for an ohmmeter besides just checking individual resistor values. We will describe other uses in later experiments.

Instructions for Statement No. 18: In Step 4, you saw that if voltage was applied to the resistor under test, the reading was incorrect. We are now going to see if the polarity of this voltage has any effect on the reading by reversing the ohmmeter connections.

Make sure the tvom polarity switch is set to normal. Connect the ground clip of your tvom to the junction of the 10K-ohm and 1K-ohm resistors. Set the range switch to R X 1K, and touch the probe to the chassis. You are again measuring the 1K-ohm resistor. While holding the probe against the chassis, turn on S_1. Note the new ohmmeter reading. You now have sufficient information to answer the statement. Take the circuit apart, but leave the batteries connected and in place on the chassis.

Statement No. 18: When I turned on S_1, the ohmmeter reading:

(1) increased.
(2) decreased.
(3) remained unchanged.

EXPERIMENT 19

Purpose: To show how circuit continuity can be checked with an ohmmeter; and to show that the presence of continuity does not indicate the condition of all parts in the circuit.

Introductory Discussion: You have seen how circuit continuity can be checked with a voltmeter and that continuity indicates only that the circuit will carry current. Parts may be shorted or may have changed in value without affecting the ability of the circuit to carry current. If a circuit has continuity, it simply means that the circuit is not open.

Most technicians prefer the ohmmeter for continuity testing, since it can easily be shifted to various points in the circuit to measure their actual resistance. When making continuity tests, the ohmmeter is not used to measure the total resistance of the circuit, although it does show the approximate sum of the resistances. The true purpose is to show that the circuit is complete. In making continuity measurements, technicians seldom bother to determine the resistance of the circuit. They simply check to see if there is a reading showing continuity.

In this experiment, you will demonstrate that in a circuit containing large and small resistances, a small resistor could be shorted without materially affecting the resistance measurement. To find such a short, a check of the individual resistors would be required. This would be done only if the symptoms indicated that it was the cause of the difficulty.

Experimental Procedure: In this experiment, you will need your tvom, the dummy resistor you built in Experiment 16 and the following parts:

- 1 10-megohm resistor
- 1 1-megohm resistor
- 1 100K-ohm resistor
- 1 22K-ohm resistor
- 1 10K-ohm resistor
- 1 1K-ohm resistor

In this experiment, you will make up a voltage divider using five resistors in series, and check the continuity. You will not use the chassis for this experiment, simply solder the 10-megohm, the 1-megohm, the 100K-ohm, the 1K-ohm, and the 10K-ohm resistors together as shown in Fig. 19-1. You are now ready to conduct the first step in this experiment.

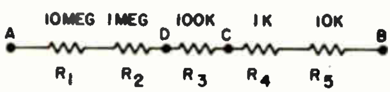


Fig. 19-1. Voltage divider you will use in Experiment 19.

Step 1: To determine accurately the resistance between terminals A and B of the voltage divider.

STEP	MEASUREMENT	VALUE
1	R_1	9.6 Meg
	R_2	1. Meg
	R_3	.96 K
	R_4	.900K
	R_5	8.8K
	TOTAL	10.7057 Meg
2	A TO B	11 Meg
3	R_4 AND R_5 SHORTED	11 Meg
4	R_4 - 22K	

Fig. 19-2. Record your readings for Experiment 19 here.

9.6 Meg
1.
.096
.0009
.0088
10.7057

Measure the value of each resistor in the divider, and record the resistance in ohms in the spaces provided in Fig. 19-2 for Step 1. Now add up the values of all five resistors and record this as the total resistance in the space provided.

Step 2: To measure the resistance between terminals A and B of the voltage divider.

Connect the ground clip to the end of the divider marked A in Fig. 19-1. Touch the probe to the end of the divider marked B, adjust the range switch to give a reasonable indication, and record the value in Fig. 19-2. Your reading should be approximately the same as the sum of your individual resistance measurements.

Step 3: To show the effect on the total resistance of shorting a relatively small resistance.

To simulate a short across resistors R_4 and R_5, solder a short piece of wire from point C to point B. Connect the ground clip to point A, and the probe to point B. Record your reading in the space provided in Fig. 19-2. The value should be almost the same as that obtained in Step 2, showing that the two resistors could be completely shorted without materially affecting the ohmmeter measurements.

Step 4: To show that an increase in a relatively small resistor in a circuit will have no noticeable effect on the total resistance of the circuit.

Remove the 1K-ohm resistor, R_4, from the circuit, and replace it with the 22K-ohm resistor. A change in resistance value from 1000 ohms to 22,000 ohms is perfectly apparent, if you check the individual resistors. Let us see how it affects the total resistance. Check the resistance from A to B, and record your result in Fig. 19-2.

Step 5: To show how lack of continuity is indicated in a resistance circuit.

Remove the 22K-ohm resistor, and in its place substitute the dummy resistor you made in an earlier experiment, between R_3 and R_5. Now measure the resistance between A and B. You will find that the circuit is either open, indicated by no movement of the meter needle from the open position at the extreme right, or that the resistance is extremely high. You might read a value such as 1K, which would mean 1000 megohms. This would be through the resistance of the insulation around the wires of the dummy resistor where they are wrapped together. A value of 1000 megohms, however, would be interpreted as an open in a circuit with an original total resistance of approximately 11 megohms.

Step 6: To find the open part in a circuit having no continuity.

To find the open in the voltage divider consisting of R_1, R_2, R_3, the dummy resistor, and R_5, connect the ground clip to point A. Now touch the probe to point B. Notice that there is no continuity. Move the probe to the junction of the dummy resistor and R_5. Again note that there is no continuity reading. Move the probe to point C, the junction of R_3 and R_4. Here there is continuity, showing that in making your measurements, you just passed over the defective part. You can check the part by connecting the ohmmeter test probes directly across it, proving that there is an open.

Discussion: In this experiment, you have seen that continuity can be checked with an ohmmeter. If the battery in the ohmmeter can force even an extremely small amount of current through the circuit, there will be an indication on the proper ohmmeter range. If there is no continuity, the meter needle will not move at all or will move only slightly, giving an extremely high resistance reading. By examining the diagram of the circuit whose continuity you wish to measure, you can, by adding the values of the resistors as marked on the diagram, determine what the approximate total resistance will be. This will show you what to expect and help you to choose an appropriate resistance range if you want to check the resistance. However, if you simply wish to check for continuity, you can use any range that gives a reasonable meter pointer movement.

You have seen that we can reduce the resistance of the divider in Fig. 19-1 by completely shorting out R_4 and R_5 without changing the measured total resistance.

Because of this fact, it is apparent that to check this condition of individual resistors in a circuit having a high resistance, you must connect the ohmmeter directly across each resistor in question. You have also seen that a radical increase in resistance of one of the low resistance parts will have no apparent effect on the total measured resistance. These are points to remember when troubleshooting electronic equipment. You make continumeasurements when you suspect a circuit is open. This does not show the value of the individual parts.

Instructions for Statement No. 19: In working with the voltage divider shown in Fig. 19-1, you saw that there was no change in the total resistance when resistors R_4 and R_5 were shorted. These, however, have a relatively low value. Now we will see what happens when R_3, R_4, and R_5 are shorted. First, remove the dummy resistor from the circuit, and reconnect the 1K-ohm resistor so that the circuit again is like that shown in Fig. 19-1. Recheck the resistance between A and B, and jot down your reading. Then, solder a piece of wire between point D and point B on the divider to simulate a short across R_3, R_4, and R_5. Again measure the resistance from A to B and note the reading. You now have sufficient information to answer the statement. Unsolder the resistors.

Statement No. 19: When measuring the divider resistance with R_3, R_4, and R_5 shorted, I found that this value was:

(1) *the same as*
(2) *noticeably more than*
(3) *noticeably less than*

the value measured between A and B with all of the resistors in the circuit.

EXPERIMENT 20

Purpose: To show how to find the combined resistance of resistors connected in parallel; and to show that the resistance of one cannot be measured without being disconnected from the others.

Introductory Discussion: You already know that parts connected in parallel have a combined resistance less than that of the smallest resistor in the group. However, the serviceman may want to know what the exact combined resistance should be so he can measure the combined resistance and decide if the parts are in good condition.

In Experiment 18, you connected three 1K-ohm resistors in parallel to get a resistance of approximately 330 ohms. When the parallel-connected parts have the same resistance, it is easy to decide what the combined resistance should be. The rule is as follows: The combined resistance of equal parts in parallel is equal to the resistance of one of the resistors divided by the number of resistors in the group.

Thus, if we connect three 1K-ohm resistors in parallel, the combined resistance is 1000 divided by 3, or 333 ohms. Three 3.3K-ohm resistors in parallel have a resistance of 1000 ohms; two 22K-ohm resistors in parallel have a combined resistance of 11,000 ohms.

Parallel-connected resistors are not necessarily equal in value. The combined resistance, R, can be found by using the formula,

$$R = \frac{R_1 \times R_2}{R_1 + R_2}$$

For example, if we have a 1K-ohm resistor and a 3.3K-ohm resistor in parallel,

$$R = \frac{1000 \times 3300}{1000 + 3300}$$

$$= \frac{3,300,000}{4300}$$

$$= 769 \text{ ohms}$$

It is not important for you to be able to do these computations, because as a busy technician you won't waste time on them. Instead, if you cannot tell the combined resistance at a glance, you will unsolder one end of each one of the resistors and check the resistors individually. If you have the time to spare, and find the computations easy to do, then you do not need to go to the trouble of unsoldering a component to find out whether or not the combined resistance is correct.

When resistors do not have any shunting (parallel connected) parts, the resistance value is checked without unsoldering the leads, by connecting the test probes directly across the resistor.

In this experiment you will connect resistors in parallel and check their measured combined resistance against their computed resistance to prove that the computed value is correct and to note the variations to be expected between the computed and measured values.

Experimental Procedure: In this experiment you will need your tvom and the following parts:

- 1 1K-ohm resistor
- 1 3.3K-ohm resistor
- 1 10K-ohm resistor
- 2 22K-ohm resistors
- 1 100K-ohm resistor
- 1 10-megohm resistor

In connecting the parts in parallel, it is not necessary to use your soldering iron. Hold the two resistors so two of their leads cross as shown in Fig. 20-1. Clip the ground lead directly to the point where the leads cross each other. Bend the free leads together and clip the probe to them.

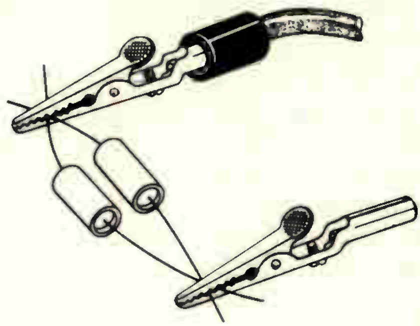


Fig. 20-1. How to measure two resistors in parallel.

You can then adjust the range selector switch for a reasonable reading.

Step 1: To find the combined resistance of a 1K-ohm and a 3.3K-ohm resistor in parallel.

As we have already shown, the computed resistance of a 1K-ohm and a 3.3K-ohm resistor in parallel is 769 ohms. To measure the combined resistance, connect the 1K-ohm and the 3.3K-ohm resistors in parallel. Clip one lead of your tvom to one end, and the other lead to the other end of the combination as shown in Fig. 20-1. Record the reading in the space in Fig. 20-2.

PARALLEL COMBINATION	COMPUTED VALUE	MEASURED VALUE
1K AND 3.3K	769 OHMS	
1K AND 10K	909 OHMS	780
10K AND 22K	6875 OHMS	6.9K
10MEG AND 100K	99K OHMS	97K
22K AND 22K	11K OHMS	11.3K

Fig. 20-2. Record your readings for Experiment 20 here.

Step 2: To find the combined resistance of a 1K-ohm and a 10K-ohm resistor in parallel.

Again we can compute the resistance of the combination from the formula:

$$R = \frac{R_1 \times R_2}{R_1 + R_2}$$

Substituting the values of the resistors, we have:

$$R = \frac{1000 \times 10{,}000}{1000 + 10{,}000} = 909 \text{ ohms}$$

Now let us measure the resistance of the combination. Clip the ground lead to one lead of each resistor, and the probe to the other end of each resistor. The correct way to do this is shown in Fig. 20-1. Record the reading in Fig. 20-2.

Step 3: To find the combined resistance of other parallel combinations of resistors.

Following the same procedure, measure the combined resistance of the other parallel combinations listed in Fig. 20-2. In each case, the computed value is given so that you can check your measured value with it.

Discussion: Now compare your measured values with the computed values given in the chart. They should be fairly close in most cases. However, because of the tolerances of the resistors, you may find that they differ quite a bit in some cases.

When two resistors are in parallel, and one is much larger than the other, the resistance of the larger cannot be checked unless it is disconnected. For example, when you measured the 10-megohm and the 100K-ohm resistors in parallel, their combined resistance should have been close to 100,000 ohms, the resistance of the smaller resistor. Even with the 10-megohm resistor completely removed, the resistance would still be close to the parallel value.

When there is only a slight difference in the values of the parallel resistors, if one is disconnected or is defective, there will be considerable change in measured value across the combination.

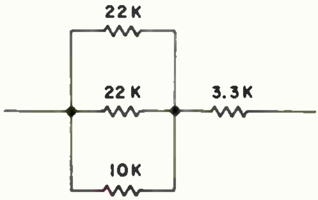


Fig. 20-3. Series-parallel circuit for Statement No. 20.

Instructions for Statement No. 20: To answer this statement, you are to build the series-parallel circuit shown in Fig. 20-3. You do not need to solder the resistor leads. Twisting them together is enough. Twist one end of a 10K-ohm resistor and two 22K-ohm resistors together. Twist the other ends and one end of a 3.3K-ohm resistor together as shown in Fig. 20-4.

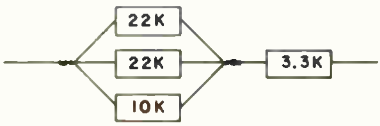


Fig. 20-4. How to arrange the parts for the circuit shown in Fig. 20-3.

Before you measure the combined resistance, examine the circuit carefully and see if you can decide in advance what the total resistance will be. As a matter of interest to yourself, jot down what you think it is on a separate sheet of paper. Now, connect the ground clip to one lead of the circuit and the probe to the other. Choose an appropriate range on your ohmmeter, and read the resistance value. Compare this with the value you chose by inspecting the circuit. You now have enough information to answer the statement. Separate the resistors.

Statement No. 20: When I measured the resistance of the circuit shown in Fig. 20-4, I found that the resistance was:

(1) approximately 5500 ohms.
(2) approximately 8500 ohms.
(3) approximately 13,000 ohms.

LOOKING AHEAD

This completes the experiments in Kit 2T. When you have completed the second kit, remove the resistors and the potentiometer and clean the terminals. Leave the terminal strips, solder lugs, and battery connected. Make sure you have answered all the statements on the Report Sheet, fill in the top of the Report Sheet, and mail it to NRI for grading. While waiting for your graded answers to return, place your tvom in a safe place where it will not be damaged. Place all the left-over parts, listed in Table I, in a box and store them where they will not be lost. You can leave the two flashlight cells, the potentiometer and the terminal strips on the chassis plate. You may also leave the wires to the flashlight cells in place. Be sure to clean all excess solder from all of

1	Chassis plate	2	10,000-ohm resistors
1	Alligator clip	1	15,000-ohm resistor
1	Etched circuit board with tube socket	1	18,000-ohm resistor
2	Large solder lugs	2	22,000-ohm resistors
1	Marking crayon	1	82,000-ohm resistor
2	4-40 hex nuts	3	100,000-ohm resistors
1	1000-ohm potentiometer	1	220,000-ohm resistor
1	470-ohm resistor	1	470,000-ohm resistor
1	680-ohm resistor	1	1-megohm resistor
3	1000-ohm resistors	2	10-megohm resistors
1	3,300-ohm resistor	2	1/4" X 4-40 machine screws
2	4700-ohm resistors	2	Silicon diodes
1	6,800-ohm resistor		Hookup wire
			Solder

Table I. Left-over parts to be stored for use later.

the terminals. The following parts are attached to the chassis plate:

- 2 Flashlight cells
- 1 3-lug terminal strip
- 1 4-lug terminal strip
- 1 7-lug terminal strip
- 1 Small solder lug
- 6 1/4" X 6-32 machine screws
- 6 6-32 hex nuts
- 1 Potentiometer mounting bracket
- 1 500K-ohm pot. with switch

While you are waiting to start on the next kit, clean the leads on the parts you have left over so you'll be ready to start your experiments when your graded answers are returned. Do not start the next kit until you have received a passing grade on the experiments in Kit 2.

In the next kit you will add parts to the circuit board of your tvom so you can measure ac. You will begin your study of ac circuits and see that many of the laws that you have verified for dc circuits can also be applied to ac circuits. You will also see how capacitors and coils act in ac circuits. Both audio signals and radio frequency signals are ac signals. Your next kit will be a big step forward for you. The experiments are designed to show how ac signals behave. The fundamentals you will study in Kit 3 will be used in later kits in your study of more complex circuits using vacuum tubes and transistors.

HEADING TOWARD SUCCESS

You have every reason to expect real success in your Electronics career. I base this statement on the following facts:

. . . you like Electronics and have much natural ability in this science.

. . . you are willing to work to increase your knowledge of Electronics, as proved by the progress you have made with your NRI course.

The above qualifications make for success, in the opinion of most experts. As Mark Sullivan once put it: "To find a career to which you are adapted by nature, and then to work hard at it, is about as near a formula for success and happiness as the world provides."

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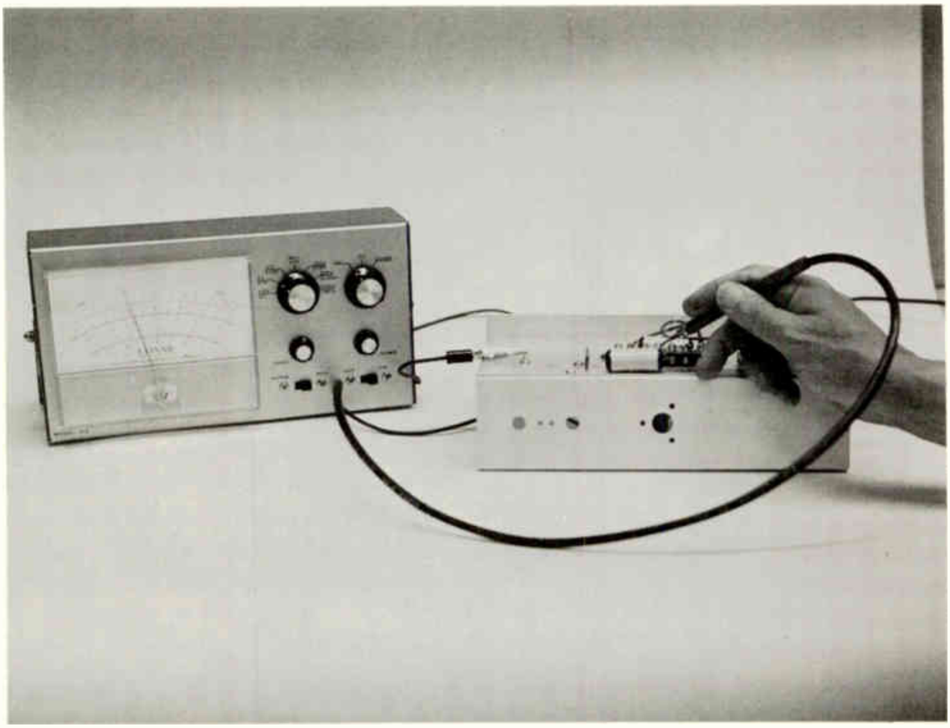
PRACTICAL DEMONSTRATIONS

OF BASIC ELECTRONICS



The completed tvom being used to make ac measurements.

INDEX OF SECTIONS

JP2M1075 1975 EDITION Litho in U.S.A.

INSTRUCTIONS FOR PERFORMING EXPERIMENTS 21 THROUGH 30

Now that you have experimentally proved Ohm's Law, Kirchhoff's Voltage Law, and Kirchhoff's Current Law for dc circuits, you are ready to prove that the laws also hold for ac circuits. It is extremely important for you to become thoroughly familiar with ac circuits, because they are the ones through which all radio and television signals pass. These experiments, in which you will see for yourself how ac circuits work, are a very valuable part of your training.

To perform these experiments, you will have to measure ac voltages with your tvom. As you already know, your tvom is capable of measuring dc and resistance. You demonstrated this in the previous experiments. In the experiments you are about to perform, most of the measurements to be made are ac measurements.

You have probably been wondering why one of the test leads is very much heavier than the other. It is a special type of low capacity cable known as coaxial cable. It is so designed that a very low capacitance exists between the center conductor and the outer shield braid, which is covered by an insulated coating. With this low capacitance cable, it is possible to measure ac voltages with frequencies up to several thousand kilohertz. The outer braid shield is necessary when using your tvom on the low ac ranges to prevent stray capacitive pick-up.

CONTENTS OF THIS KIT

The parts included in this kit are illustrated in Figs. 1 and 2, and listed in the captions. Check the parts you received against this list to be sure that you have all of them.

If any part of this kit is obviously defective or is damaged in shipment, return it to NRI immediately for replacement, as directed on the packing slip accompanying this kit.

Gather the parts left over from the previous kits and put them in some convenient place. You will need them in your experiments.

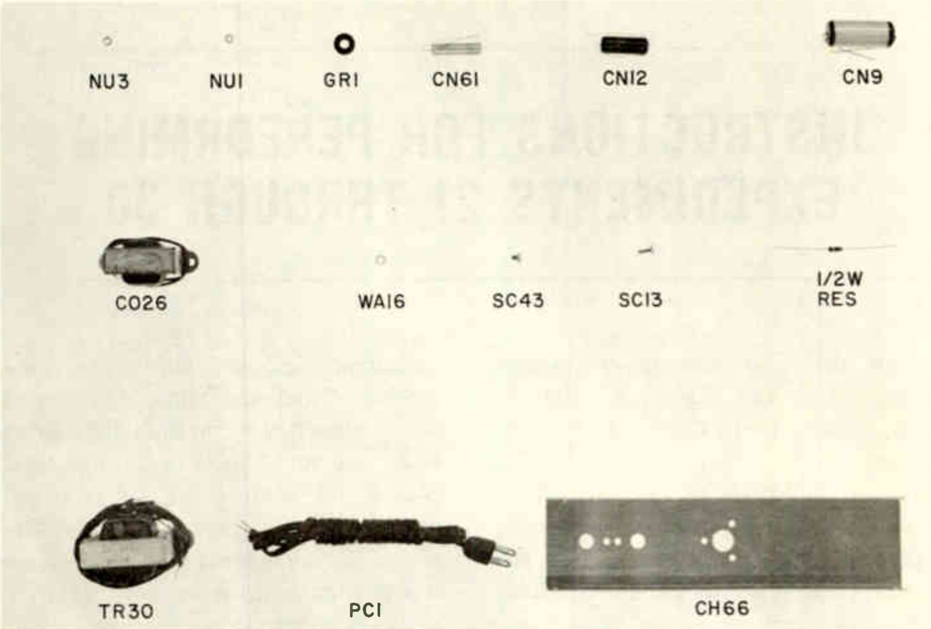


Fig. 1. The experimental parts for this training kit are shown above and listed below.

Quan.	Part No.	Description	Price Each	Quan.	Part No.	Description	Price Each
1	CH66	Chassis rail	.79	1	PC1	Power cord	.40
2	CN9	.25 mfd tubular cap.	.25	1	RE27	220-ohm, 1/2W res.	.15
1	CN12	.1 mfd tubular cap.	.18	1	RE35	47K-ohm, 1/2W res.	.15
2	CN61	20 mfd, 150V elect. cap.	.65	1	RE93	1.8 megohm, 1/2W res.	.15
				1	RE102	3K-ohm, 1/2W res., 5%	.24
1	CO26	Iron core choke coil	1.30	2	SC13	3/8" X 6-32 screw	12/.15
2	GR1	3/8" grommet	12/.25	4	SC43	1/4" X 8-32 screw	12/.25
1	NU1	6-32 hex nut	12/.15	1	TR30	Power transformer	2.50
4	NU3	8-32 hex nut	12/.15	4	WA16	No. 8 lockwasher	12/.15

All resistors are 1/2-watt, 10% tolerance unless otherwise specified.

Before you begin your experiments in this Training Kit you will install components on the etched circuit board of your tvom to enable you to read ac voltages. You will also calibrate the ac portion of your tvom, recheck the dc calibration, and install the tvom in its cabinet.

ADDING THE AC FUNCTION TO YOUR TVOM

The parts needed to add the ac function to your tvom are shown in Fig. 2 and listed under the figure. Gather together those parts shown in Fig. 2.

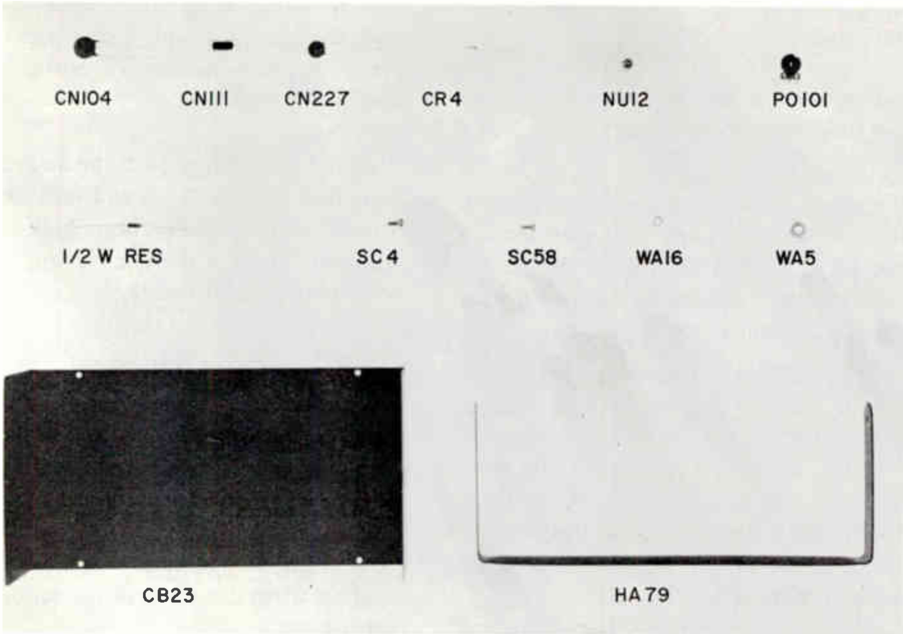


Fig. 2. The ac parts for your tvom are shown above and listed below.

Quan.	Part No.	Description	Price Each
1	CB23	Cabinet	2.95
1	CN104	.1 mfd disc cap.	.36
2	CN111	5 mfd elect. cap.	.35
1	CN227	120 pf disc cap.	.15
4	CR4	1N60 diode	.45
1	HA79	Handle	2.18
2	NU12	8-32 cap nut	12/.25
1	PO101	100K-ohm trimmer pot.	.23
1	RE39	1 megohm, 1/2W res.	.15
1	RE48	2.7K-ohm, 1/2W res.	.15
2	SC4	3/8" X 8-32 screw	12/.15
4	SC58	3/8" X 6-32 thread cutting screw	12/.25
2	WA5	No. 8 flat metal washer	12/.15
2	WA16	No. 8 lockwasher	12/.15

All resistors are 1/2 watt, 10% tolerance unless otherwise specified.

To add the parts to the circuit board, you must first remove the circuit board from its installation behind the panel. First, make sure the meter is "off," then remove the 9V battery and the battery connector . . . . ( )

Remove the two bar knobs from the Range and Function switches and the two round knobs from the Zero and Ohms Adjust controls . . . . ( )

Loosen the two nuts which secure the circuit board to the meter terminals. Be careful not to damage Q_1 and Q_2 . . . ( )

Remove the two nuts that secure the

Range switch and Function switches to the panel . . . . ( )

Remove the two meter terminal nuts and the two washers . . . . ( )

The etched circuit board is now free of the panel and may be carefully pulled to the rear of the panel. You may remove the 1.5V "C" cell from its holder to give a little more working room. You do ***not*** have to disconnect any of the wires ( )

The assembly instructions are given in Fig. 3. The four glass diodes have colored bands at the cathode end and ***must*** be installed as shown in Fig. 3. Be very careful when you bend the diode leads not to bend them too close to the body of the diode or you may break the glass seal and ruin the diode.

Also, be sure to observe the polarity of the two electrolytic capacitors, as you did in the last kit.

When you are sure you know how to mount all the parts, proceed with the assembly instructions in Fig. 3.

After completing the assembly, reinstall the circuit board to the panel and meter. Replace the battery, battery connector and the knobs . . . . ( )

Before proceeding with the ac calibration, turn the meter on and recheck the Balance and DC calibration. Follow the procedure given in the last training kit to perform these adjustments . . . . ( )

AC CALIBRATION

After you have checked the dc calibration and balance, you will calibrate the ac portion of the tvom. You will use the voltage at your wall outlet to calibrate your tvom, so you must exercise extreme caution when carrying out the calibration procedures.

Commercial ac voltage, while nominally 117 volts, varies from one part of the country to another, and, indeed, from hour to hour at any given location. These variations are due to the varying demand

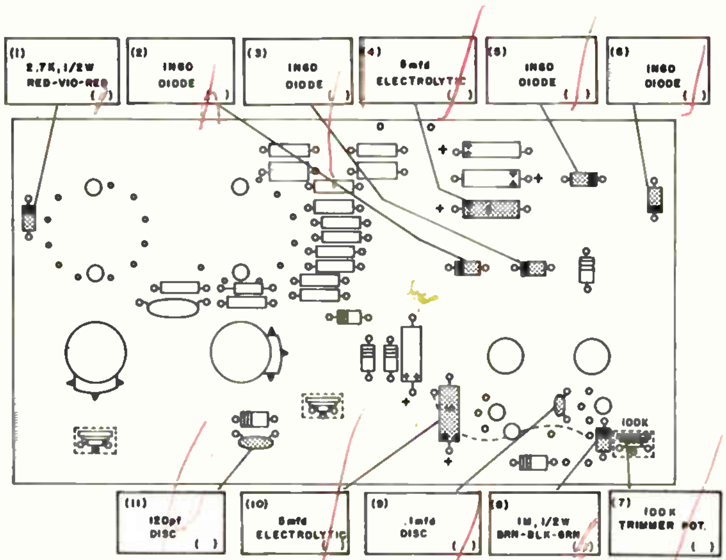


Fig. 3. Steps used for assembling your tvom.

on the power company generators. During high usage times the voltage may drop as low as 95 volts and at other times may rise to 125 volts. The high usage times are around mealtimes (morning, midday, and 6-7 p.m.) and during hot, humid days when many air conditioners are in use. It would be best to perform your calibration at some time ***other*** than these high usage times.

For purposes of calibrating your tvom you can assume the line voltage to be 120 volts and use this value as your calibration reference. To calibrate your tvom, place the meter face up so that you have access to the AC Calibrate trimmer potentiometer through the hole labeled "AC." Set the Range switch to "1200V", the Function switch to "AC", the Polarity switch to "Norm." and turn the meter "ON". Short the probe tip to the ground clip and zero the meter with the Zero adjust control.

With a thin bladed screwdriver, turn the AC Calibrate control fully clockwise (to the right). Now touch the ground clip to the screw head which holds the cover of a wall outlet in place, and insert the probe tip into one of the openings of the ac outlet. If you get no reading at all on your meter, try the probe in the other opening of the ac outlet. When you have found the "hot" opening, remove the probe and ground clip and switch the meter to the "300V" range. You can loosen the screw holding the cover of the ac outlet slightly so that you can clip the ground clip in place without having to hold it. With the ground clip in place, insert the probe tip into the "hot" ac opening and watch the meter. The pointer should move upscale. Adjust the AC Calibrate control until the meter reads 120 volts. (This is the second division after "10" on the 0 to 30 range.)

Remove the probe from the ac outlet and switch to the 120V range. Again insert the probe into the "hot" opening and adjust the AC Calibrate control for exactly full scale.

ASSEMBLING THE CABINET AND HANDLE

To assemble the handle to the cabinet, first place a No. 8 lockwasher over one of the 3/8" X 8–32 screws. Pass the screw through one of the holes in the center of one end of the cabinet from the ***inside*** to the ***outside***. While holding the screw head and lockwasher against the inside of the cabinet, place a No. 8 flat metal washer over the screw, then position the handle so that the screw can also pass through one of the holes in the handle. Secure this assembly temporarily with one of the cap nuts. Tighten only finger-tight for now.

Following exactly the same procedure just described, secure the other end of the handle to the cabinet with a 3/8" X 8–32 screw, No. 8 lockwasher, No. 8 flat washer and a cap nut.

With both ends of the handle fastened, tighten both screws as much as possible. This will secure the handle and yet allow you to move it around to serve as a stand for the completed tvom.

To fasten the cabinet and tvom together, lay the tvom face down on a clean, soft surface such as a tablecloth or bedspread. Put the cabinet into place, being sure that the four small holes in the back of the tvom panel line up with the holes in the cabinet. Now fasten the cabinet to the tvom with the four 3/8" X 6-32 thread-cutting screws. **DO NOT OVERTIGHTEN THESE SCREWS.** The tvom panel is aluminum, and if you overtighten the screws they will probably pull out of the aluminum.

Performing The Experiments

The experiments you are to do will demonstrate many of the basic facts you should know about resistance, inductance, and capacitance, and their effect in ac circuits. Do not skip any of the experiments; each of them is vitally important to your training. Follow the same procedure for carrying them out that you used in the previous manuals.

(1) Check the condition of the tip of your soldering iron. Clean it or retin it, if necessary.

(2) Read the experiment through completely, paying particular attention to the Introductory Discussion and the Experimental Procedure to get an idea of what is to be accomplished.

(3) At the beginning of each section describing the procedure to be followed, we will give you a list of the parts you will need. We will not, however, list the tools, solder, or hookup wire you will need. Just remember to keep them handy and to have your soldering iron ready.

We will not give the color code of the various resistors you will need. By this time you should be familiar enough with the resistor color code to select the correct ones. Gather the parts listed at the start of each experimental procedure from the parts you received in this kit and those left over from earlier kits.

(4) With the parts at hand, and with your soldering iron hot and ready for use, read the experiment again, this time carrying out the instructions exactly as given and in the order listed. Record all data in the tables provided, make the necessary computations, and prepare any graphs that are required.

(5) Read the Discussion of the experiment. If your experimental results don't seem to be right, repeat the experiment.

IMPORTANT: If you cannot do an experiment successfully, don't just give up and go on to the next one. Reread the experiment carefully to be sure you are performing it correctly. Look for loose solder joints, incorrect connections, or wrong parts. If you cannot find the trouble, write to us on the special consultation blank you received with this kit.

Give an accurate and complete description of the action that takes place and include the results of any measurements you have made that have a direct bearing on the problem. Be sure to tell us exactly which experiment you are working on and the step or steps in the experiment that you can't carry out successfully so that we can help you as quickly as possible.

(6) Read the instructions for each Statement carefully. Carry out any experimental procedures required. Read the Statement carefully, and put a circle around the choice that best completes the Statement according to your findings. Then, on the Report Sheet, write the statement number and your choice(s) for the Statement. When you have finished all the Statements, fill in the rest of the spaces as instructed on the Report Sheet, and send in the Report Sheet to NRI for grading.

At this point, you should have a solder lug, three terminal strips, a 500K-ohm potentiometer with on-off switch, and two series-connected flashlight cells mounted on your chassis (Fig. 4).

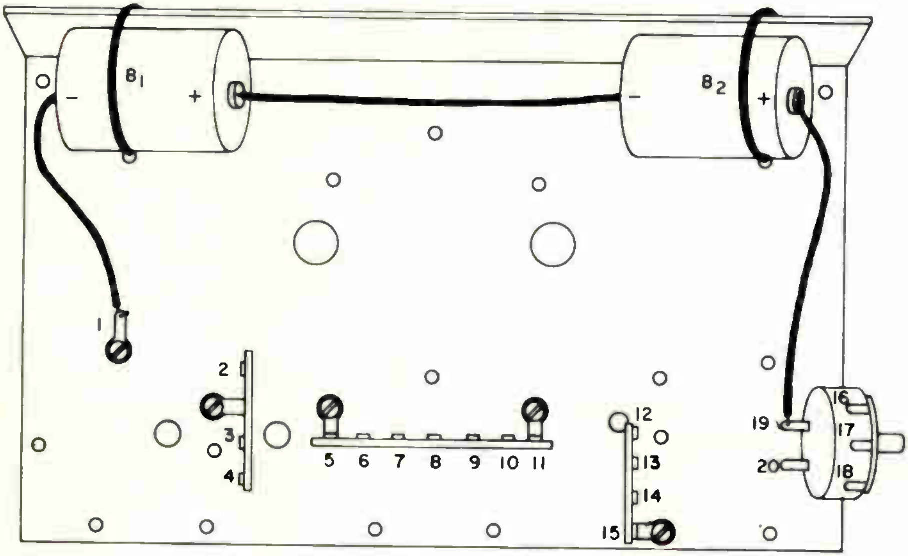


Fig. 4. Chassis before Experiment 21.

EXPERIMENT 21

Purpose: To show that the period of time required to charge or discharge a capacitor through a resistance depends upon the values of the resistance and the capacitance.

Introductory Discussion: As you learned in your regular lessons, a momentary surge of current takes place when the terminals of a charged capacitor are connected together. The period of time that this current flows is usually too brief to have any practical value, except when high currents over short periods of time are required, as in some forms of electric welding. However, if the rate of charge and discharge can be controlled, the practical applications are almost unlimited. The operation of the sweep circuits that move the electron beam in the picture tube of a TV receiver is a practical example of the charging and discharging of a capacitor.

In this experiment, we will show that the rate at which a capacitor charges or discharges depends upon the amount of resistance in the circuit as well as on the capacitance. Thus, with any given capacitor value, we can control the rate of charge and discharge by changing the resistance in the circuit. The time in seconds required for a capacitor to charge up to 63% of the applied voltage, or discharge to 37% of the applied voltage, is equal to the product of the resistance in megohms and the capacitance in microfarads. This is known as the "time-constant" of the combination.

In this experiment, you will show the effect on the time-constant of changing the resistance in the circuit.

Experimental Procedure: To perform this experiment, in addition to your experimental chassis and your tvom, you will need the following parts.

2 .25-mfd paper capacitors
1 1.8-megohm resistor

Step 1. To charge a .5-mfd capacitor through a 12-megohm resistance.

The circuit we will use is shown in Fig. 21-1. The 12-megohm resistance is the internal resistance of your tvom. For the 3-volt source, you will use the series-connected flashlight cells.

To get the .5-mfd capacitance, we will use two .25-mfd capacitors. As you have learned in your regular lessons, when two capacitors are connected in parallel, the total capacitance is the sum of the capacitance of the individual capacitors. Therefore, two .25-mfd capacitors in parallel will give us .5 mfd.

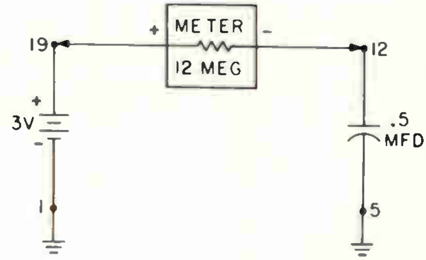


Fig. 21-1. Charging a capacitor through a resistance.

First, connect the two .25-mfd capacitors in parallel from terminal 5 to terminal 12, as shown in Fig. 21-2. Solder both connections.

Arrange the capacitors so their leads do not touch the chassis. Then short-circuit their leads for a few moments with a screwdriver to be sure they are fully

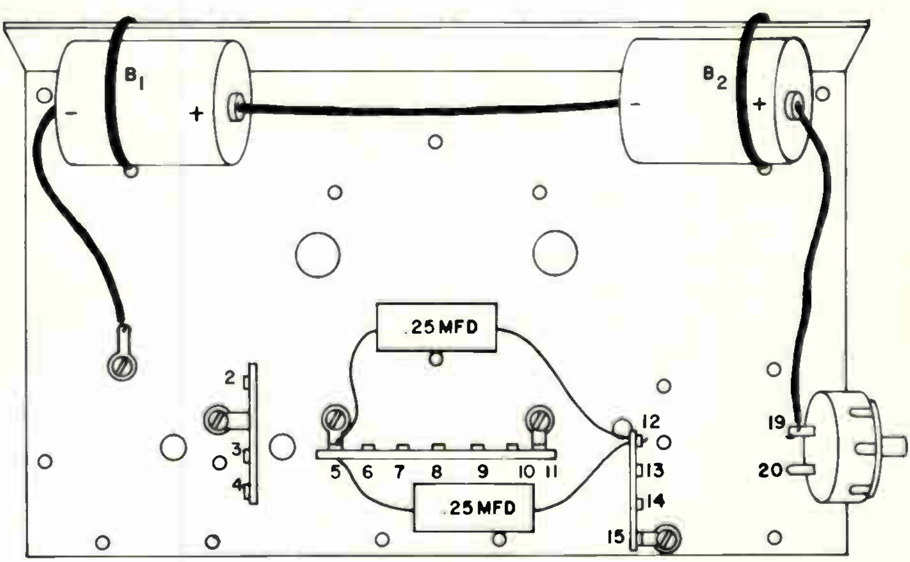


Fig. 21-2. Record results for Experiment 21 here.

discharged. Touch the screwdriver blade to terminal 12 and the chassis at the same time. Do not touch the capacitor leads while doing this experiment or the resistance of your body will affect your reading.

Now, be sure you still have the flashlight cells connected in series with the negative terminal grounded to terminal 1, and the positive lead connected to terminal 19 of the ON-OFF switch, as shown in Fig. 21-2. The battery connects to the capacitor leads at terminal 5 through the chassis ground.

Turn your tvom on to dc; turn the range switch to 3V, and set the polarity switch to normal. Then clip the ground lead to terminal 12, and touch the probe to the positive battery terminal (or terminal 19), and watch the meter pointer.

The meter pointer will move rapidly to the extreme right-hand end of the 3V scale, and then move gradually back toward 0.

To find the time-constant, you will count the number of seconds it takes for the capacitor to reach 63% (approximately two-thirds) of full charge. Since the full voltage is 3 volts, two-thirds will be 2 volts.

Here, the meter is actually indicating the voltage across the 12-megohm input resistance of the tvom. As you have learned, the sum of the voltage drops in a series circuit is equal to the source voltage. Therefore, when you first connect the circuit, the voltage across the resistance of the tvom will be the full 3 volts, making the meter pointer swing all the way over to the right. Then, as the capacitor charges, the voltage across the resistance gradually decreases. When the voltage across the resistance is 1 volt, you know there must be 2 volts across the capacitor, so you count the number of seconds it takes for the meter pointer to move from 3 to 1 on the 3-volt scale.

STEP	MEASUREMENT	YOUR TIME IN SECONDS	COMPUTED TIME IN SECONDS
1	CHARGING .5 MFD THROUGH 12 MEGOHMS	6	6
2	DISCHARGING .5 MFD THROUGH 12 MEGOHMS	5	6
3	CHARGING .5 MFD THROUGH 1.5 MEGOHMS	1	.75
4	DISCHARGING .5 MFD THROUGH 1.5 MEGOHMS	1	.75

Fig. 21-3. Record results of Experiment 21 here.

You can estimate the time in seconds by counting at a normal speaking rate as follows: "one hundred and one," "one hundred and two," etc. The length of time it takes to speak the words will be very close to one second. If you practice counting while watching the second hand of a watch or clock, you can do this very accurately. Record in Fig. 21-3 the number of seconds it takes the meter pointer to move from 3 to 1.

We can compute the time-constant mathematically by multiplying the resistance in megohms by the capacitance in microfarads. This would be 12 X .5, or 6 seconds. Compare the time you estimated with this computed time.

Step 2. To discharge the .5-mfd capacitance through the 12-megohm resistance.

Leave the circuit as it was in Step 1, and hold the meter probe on terminal 19 until the meter pointer swings all

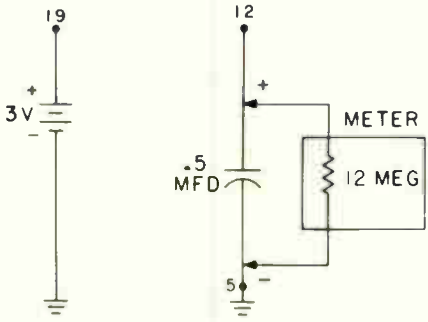


Fig. 21-4. Measuring the voltage across the capacitors as they discharge through the meter resistance.

the way to zero. At that point the capacitors will be fully charged.

Remove the probe from terminal 19. Switch the polarity switch on your tvom to reverse and touch the probe to the chassis ground. You should have the circuit shown in Fig. 21-4.

With the meter connected this way, you are measuring the voltage across the capacitors. As they discharge, the meter pointer will move from 3 down to 0. You want to know how long it takes for the capacitors to discharge to 37% of full charge. This is approximately two-thirds, so you count the number of seconds it takes for the pointer to reach 1 on the 3-volt dc scale. Record your reading in Fig. 21-3.

Step 3. To charge the .5-mfd capacitance through a lower resistance.

We will use the circuit shown in Fig. 21-5, in which we have a 1.8-megohm resistor in parallel with the resistance of the meter. As you have learned, when two resistors are connected in parallel, the combined resistance is less than that of the smaller resistor. In this case, the total resistance will be approximately 1.5 megohms. (You can place an alligator clip on your tvom probe for convenience in making the measurements.)

Connect the positive tvom lead to terminal 20. Set the polarity switch to normal. Connect and solder the 1.8-megohm resistor from terminal 12 to terminal 20. (See Fig. 21-2.) Then, clip the negative test lead of your tvom to terminal 12.

Turn the switch on by rotating the 500K-ohm potentiometer shaft clockwise and watch the meter. As in Step 1, the meter pointer will swing over to 3, and then move back toward 0. This time notice that the meter pointer moves from 3 to 1 so rapidly that it is difficult to estimate the time.

To compute the time-constant, we multiply 1.5 megohms times .5 microfarad, which gives us .75, or less than one second for the time-constant. Estimate the time-constant of the combination you have, and record your result in Fig. 21-3.

Step 4. To discharge the .5-mfd capacitor through the 1.5-megohm resistance.

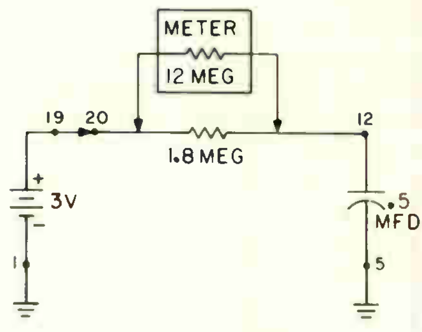


Fig. 21-5. Charging the capacitor through a lower resistance.

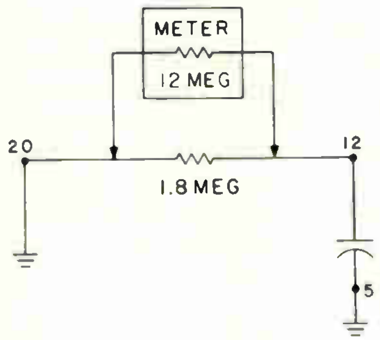


Fig. 21-6. Circuit for discharging the capacitor through a lower resistance.

With the circuit as in Fig. 21-5, leave the switch on until the capacitors are fully charged (until the meter pointer moves all the way to 0). Then, turn the switch off and set the polarity switch on your tvom to reverse. The circuit for this step is shown in Fig. 21-6. To see how long it takes the capacitors to discharge to one-third, short terminal 20 to the chassis with a screwdriver to complete the circuit shown in Fig. 21-6 and count the time it takes the pointer to move from 3 to 1. Again, record the time in Fig. 21-3. It should be the same as the time for Step 3 – less than one second.

Discussion: In Steps 1 and 2 of this experiment you saw that for a given capacitance and resistance in a circuit, the time it takes the capacitor to charge to 63% of full charge is the same as the time it takes it to discharge to 37% of full charge. This time, in seconds, is called the time-constant. It can be computed by multiplying the capacitance in microfarads and the resistance in megohms.

In Steps 3 and 4, you demonstrated that decreasing the resistance in the circuit caused the time-constant to decrease. If you had increased the resistance, the time-constant would have increased.

Instructions for Report Statement No. 21: In this experiment you showed that decreasing the resistance in the discharging circuit of a capacitor reduces the time-constant of the circuit. It can also be shown that decreasing the capacitance of the capacitor without changing the resistance reduces the time-constant.

For the Statement you will prove this by reducing the capacitance to .125 mfd by connecting the two .25-mfd capacitors in series. When two capacitors having the same value are connected in series, the combined capacitance is equal to half the capacitance of one alone.

Unsolder and lay aside the 1.8-megohm resistor and unsolder one end of one capacitor from terminal 5, but leave the other capacitor lead connected to terminal 12. Solder the free lead to terminal 20.

Set the polarity switch on your tvom to normal, and clip the negative test lead to terminal 5. Clip the probe of your meter to terminal 20. Turn the switch on to complete the circuit shown in Fig. 21-7. When the meter pointer goes all the way to 3, the capacitors are fully charged.

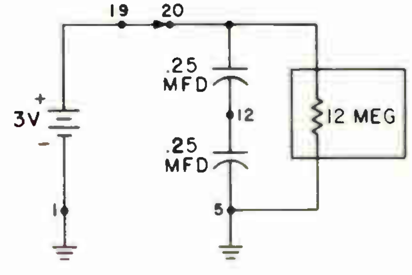


Fig. 21-7. Circuit for connecting capacitors in series.

Turn the switch off, but leave the probe clipped to the capacitor lead. Count the time it takes for the meter pointer to move from 3 down to 1. Then, answer the Statement below and on the Report Sheet.

Turn off the tvom, and unsolder and remove the capacitors from your chassis and store them for future use.

Statement No. 21: When I discharged the .125-mfd capacitance through the 12-megohm input resistance of the tvom, I estimated that the meter pointer dropped from 3 volts to 1 volt:

(1) instantly.
(2) in about two seconds.
(3) in about ten seconds.

EXPERIMENT 22

Purpose: To show that when a dc voltage is applied to an electrolytic capacitor, the connections must be made with the proper polarity to prevent excessive leakage.

Introductory Discussion: As you learned in your lesson on capacitors, an electrolytic capacitor is quite different in many respects from paper or mica capacitors. One very important difference is that the dielectric in an electrolytic is a very thin film of aluminum oxide that has been formed on the anode by electrochemical action during manufacture. The insulating properties of this oxide depend on the amount of voltage used to form it initially, the amount of voltage applied to the capacitor in use, the temperature, the type of material used for the electrodes, and the kind of electrolyte used.

At best, the dielectric in an electrolytic capacitor is not a perfect insulator, so there will always be some current flow through the dielectric whenever voltage is applied to the capacitor. In a good capacitor, this current flow will be small if the voltage is applied with the proper polarity (the negative terminal of the voltage source connected to the negative terminal of the capacitor and the positive terminal of the source connected to the positive terminal of the capacitor). If the voltage is applied with the wrong polarity, the oxide film will break down. The unit will then cease to act as a capacitor and will instead act as a very low resistance. Pure ac voltage is constantly changing in polarity. Therefore, it should never be applied to an electrolytic capacitor.

The oxide film will also be destroyed if too high a voltage is applied to an electrolytic capacitor, even if the polarity of the voltage is correct. An electrolytic capacitor always has a dc working voltage rating that shows the maximum voltage that can be continuously applied to the capacitor without causing it to break down. Whenever you find it necessary to replace such a capacitor, make sure that the voltage rating of the replacement is at least as high as that of the original.

In this experiment, you will prove that an electrolytic capacitor passes direct current, and that the amount of current passed depends on the polarity of the applied voltage. Because the dc source voltage you have available is low, the current may be rather small when the voltage is applied with the correct polarity. In fact, the current may be too low to be detected with the equipment you have. The characteristics of your particular electrolytic will also affect the amount of current. Some capacitors have higher leakage currents than others, even though they are normal in all other respects. What we want you to observe in this experiment is that reversing the polarity of the source voltage changes the current through the capacitor.

Each of the electrolytic capacitors sent to you in this kit is made in dry form (that is, it contains a paste electrolyte). Its schematic symbol is the same as the symbol for any other capacitor except that it has a + sign near the positive lead.

Experimental Procedure: For this experiment, you will need your experimental chassis, tvom, and the following parts:

2 20-mfd electrolytic capacitors
1 47K-ohm resistor

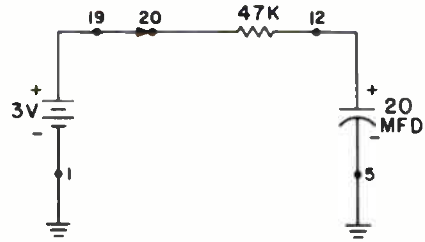


Fig. 22-1. Schematic showing an electrolytic capacitor in series with a resistor and a battery.

Turn your tvom on; set the polarity, range and function switches to measure +3V dc.

It is desirable to make as many measurements as possible in any given experiment on the same range of your test instrument to avoid errors due to differences between ranges. For example, a dc source may produce exactly full-scale deflection on the 3V range, but a meter

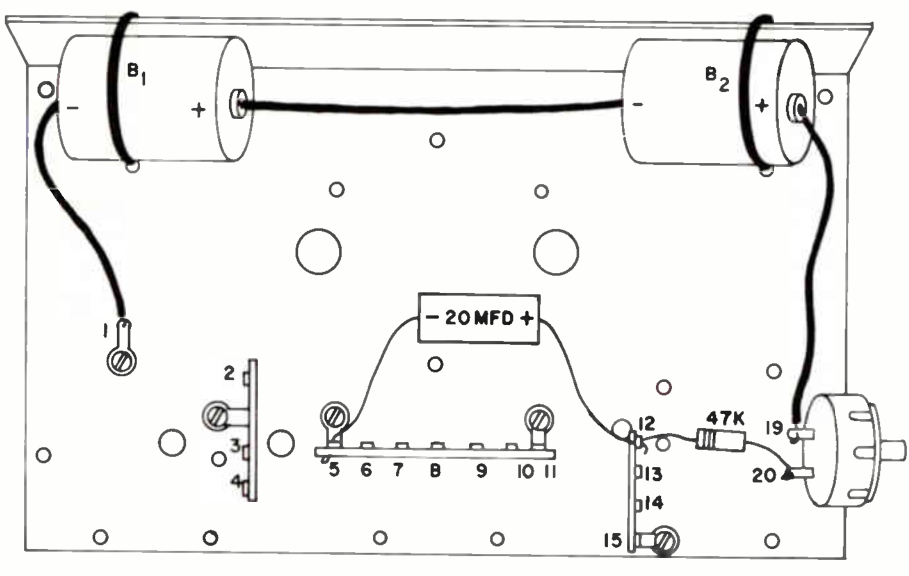


Fig. 22-2. Pictorial of the circuit in Fig. 22-1.

reading of 2.5 to 3.5 volts on the 12V range. Such variations are well within normal tolerances, and for ordinary purposes could be overlooked. However, they may prove troublesome when you are performing experiments that require accurate readings. Remember, the maximum tolerance of the meter movement alone is about 2 or 3 percent of the full-scale value. Also, the resistors in the voltage divider network of the tvom have a 1% tolerance, so a slight difference in reading on two ranges could occur even with everything normal. Using a single range whenever possible removes this cause of error.

The capacitor leads are identified by a + sign or by both + and – markings on the body of the capacitors. Solder the negative lead of one electrolytic capacitor lead to terminal 5. Connect the positive capacitor lead to terminal 12. Connect a 47K-ohm resistor from terminal 12 to terminal 20. Solder the connections.

The circuit for this step is shown in Fig. 22-1. The wiring is shown in the pictorial diagram in Fig. 22-2.

Step 1. To determine how much current flows through the electrolytic capacitor when it is connected with the correct polarity. To do this, you will measure the voltage drop across the 47K-ohm resistor.

Connect the probe of your tvom to terminal 20. Connect the ground clip to terminal 12. Turn the switch on and observe the meter. When the pointer becomes stationary, read the meter. Enter the voltage measured on the top line in Fig. 22-3. Turn off the switch.

Step 2. To determine how much current flows through the electrolytic capacitor when it is connected with the reverse polarity.

STEP	CIRCUIT USED	VOLTAGE
1	+ CAPACITOR LEAD TO + BATTERY TERMINAL	.8V
2	+ CAPACITOR LEAD TO – BATTERY TERMINAL	1.3V

Fig. 22-3. Results of Experiment 22.

Reverse the capacitor connections by unsoldering and interchanging them, so that the positive lead of the capacitor goes to terminal 5 and the negative lead is connected to the 47K-ohm resistor at terminal 12.

Again, turn the switch on and measure the voltage drop across the 47K-ohm resistor. Leave the tvom connected to terminal 12 and to terminal 20 as in the previous step. Enter the voltage reading on the second line of Fig. 22-3. Turn the switch off to open the circuit.

Discussion: The voltage drop across the resistor is produced by the current flowing through the capacitor and the resistor. The amount of current can be found by dividing the measured voltage by 47,000. The current is very small.

Do not conclude from this experiment that the direct current passed by an electrolytic capacitor is negligible, however. Remember, you have a source voltage that is far less than the voltage that is usually applied to a capacitor in a practical circuit. With the normal circuit voltage applied to the capacitor, you could measure the current directly with a milliammeter, instead of using the indirect method you have followed here.

The amount of voltage drop across the resistor in Step 1 will vary with different capacitors. Some of the capacitors that we tried in the NRI laboratory had so little leakage that we were unable to measure any voltage drop at all across the resistor. Do not be concerned, therefore, if your voltage reading for Step 1 is 0.

You should, however, find a definite voltage drop across the resistor after you have reversed the capacitor connections to carry out Step 2. Here again the exact voltage depends on the characteristics of your capacitor, but the voltage should be greater than that measured in Step 1. This increase in voltage represents a corresponding increase in the current in the circuit; therefore, you have shown that the amount of current through the capacitor depends upon the polarity of the capacitor.

Because of this characteristic of electrolytic capacitors, be sure that you connect them with the proper polarity (positive terminal of the capacitor to positive terminal of the voltage source) when you install them in a circuit. Furthermore, you must not apply an ac voltage to an electrolytic capacitor unless the ac is superimposed on a larger dc voltage so that the total voltage applied to the capacitor never reverses itself.

Instructions for Statement No. 22: In the experiment for this Statement, you are to find out whether or not the capacitance of an electrolytic capacitor has any effect on the leakage current produced by connecting the capacitor with the wrong polarity.

Connect the two 20-mfd electrolytic capacitors in parallel. Solder the positive leads of both capacitors to terminal 5. Then, solder the negative capacitor leads to terminal 12. This puts the two capacitors in parallel, giving a capacitance of about 40 mfd. The circuit for this statement is shown in Fig. 22-4.

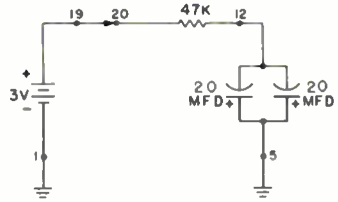


Fig. 22-4. The two capacitors are connected in parallel and placed in series with the resistor.

To measure the voltage drop across the 47K-ohm resistor, connect the probe of your tvom to terminal 20, and the ground clip to terminal 12. Turn the switch on and take a voltage reading. Compare this reading with the voltage for Step 2. Choose the answer to the Statement below, and also on the Report Sheet that most nearly corresponds to the results of your comparison. Turn the switch off and disconnect the tvom leads.

1.5V

Unsolder and remove the 47K-ohm resistor and the electrolytic capacitors. Leave the flashlight cells in place, but unsolder the positive lead from terminal 19.

Statement No. 22: When I connected the two capacitors in parallel, the leakage current (as indicated by the voltage drop across the resistor):

(1) remained unchanged.
(2) increased.
(3) decreased.

Building An AC Voltage Divider

To do the rest of the experiments in this kit, you must have a source of ac voltage with some way of adjusting the output. You will use the 117 volts supplied by the ac power line and a transformer to produce about 12 volts across a potentiometer. By adjusting the potentiometer, you will be able to get the exact voltage needed for the experiments.

To build this assembly, you will need:

1 Power transformer (TR30)
1 Chassis rail (CH66)
1 1K-ohm potentiometer (PO7 from Kit 1)
2 3/8" rubber grommets (GR1)
2 1/4" X 8-32 screws (SC43)
2 3/8" X 6-32 screws (SC13)
2 8-32 hex nuts (NU3)
1 6-32 hex nut (NU1)
2 No. 8 lockwashers (WA16)
1 5' power cord (PC1)

The transformer and potentiometer will be mounted on the chassis. The transformer will be mounted in its permanent location on the underside of the chassis plate. Fig. 5 shows where to mount the parts. Fig. 11 of your IT Manual shows the hole locations. The power transformer is represented by the broken lines.

Install the rubber grommets in holes E and J, which are the large holes near the middle of your chassis plate. Squeeze one of the grommets into an oblong shape and push it into one of the holes so that the hole in the chassis fits into the groove in the grommet. Install the second grommet in the same manner.

Place the power transformer on your worktable with its mounting feet up. Push the two green leads and the green/yellow lead of the transformer through the grommet (shown in Fig. 5) in hole J

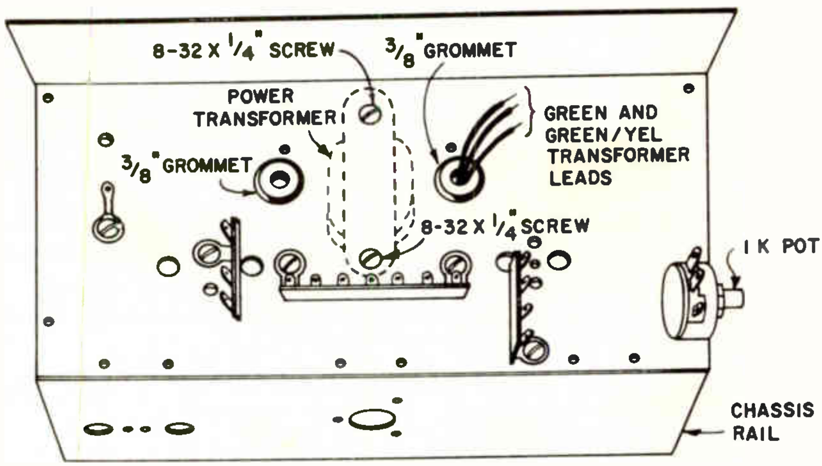


Fig. 5. Mounting the parts.

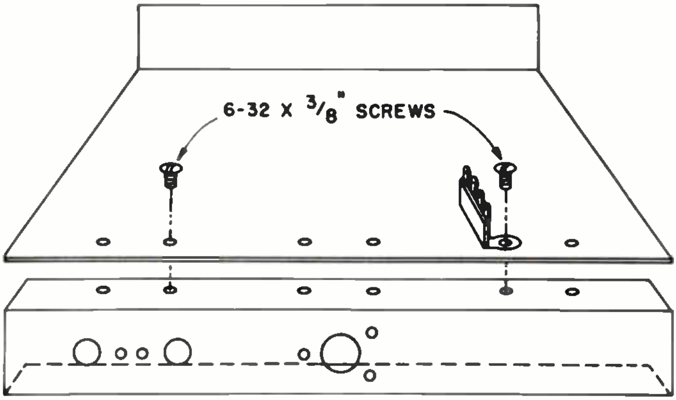


Fig. 6. Mounting the chassis rail.

from the underside of the chassis. Line up the mounting holes in the chassis, holes G and H, over the mounting feet in the transformer. Attach the transformer to the chassis with two 1/4" X 8-32 screws, two No. 8 lockwashers and two 8-32 hex nuts.

Remove the 500K-ohm potentiometer with On-Off switch and replace it with the 1K-ohm potentiometer (PO7).

Position the 1K-ohm potentiometer so that its terminals are pointing upward, and tighten the mounting nut.

Mount the chassis rail along the front edge of the chassis. Turn the rail so that the lip having six holes in it is up. These six holes mate with the six holes in the edge of the chassis, as shown in Fig. 6. Remove the screw holding the 4-lug terminal strip and replace it with the 3/8" X 6-32 screw. Pass the screw through the mounting foot in the terminal strip, the hole in the chassis and the mating hole in the chassis rail. Attach a nut and tighten.

Pass a 3/8" X 6-32 screw through the second hole from the left side of the chassis and the mating hole in the chassis rail. Attach a nut and tighten.

During the remainder of this kit, the chassis will be supported by the chassis rail and the power transformer.

WIRING THE AC CIRCUIT

Connect the power cord to the **BLACK** power transformer leads. Separate the two conductors at the end of the power cord. Connect each conductor to a black transformer lead. Solder both connections and wrap them with electrical tape.

Carefully wrap the bare ends of the two red and the red/yellow power transformer leads with tape. Do not connect these leads together. Coil them up near the chassis as these leads will not be used in this kit.

On the top of the chassis, make the following temporary connections which are shown in Fig. 7. Connect and solder one green power transformer lead to terminal 11. Connect the other green transformer lead to terminal 12. Connect and solder the green/yellow transformer lead to terminal 9.

Cut a 3" length of hookup wire and

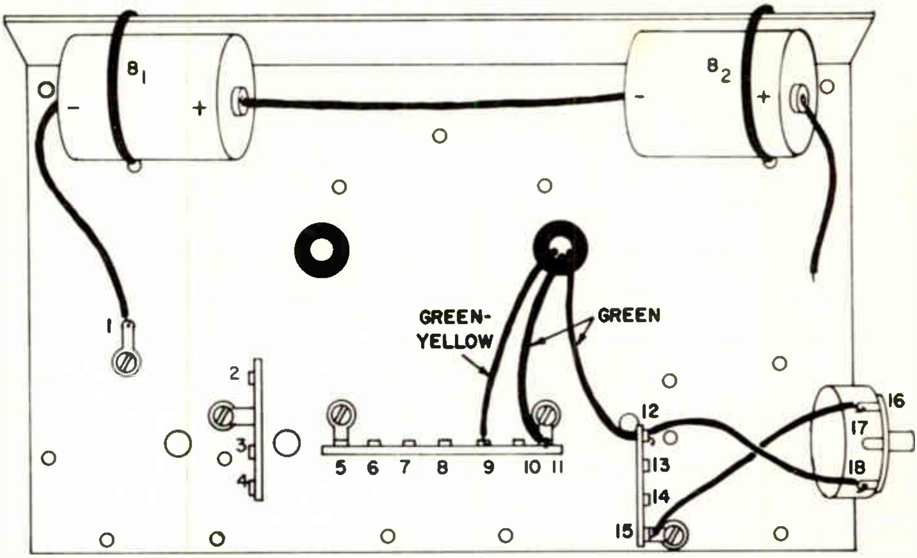


Fig. 7. Wiring the ac voltage divider.

remove 1/4″ of insulation from each end. Using temporary connections, connect this wire from terminal 12 to terminal 18 on the 1K-ohm potentiometer.

Prepare a 4″ length of hookup wire. Connect it from terminal 15 to terminal 16. Solder both connections. Check to see that your circuit is wired according to Fig. 7.

The schematic of the circuit you have wired is shown in Fig. 8.

Caution: It is extremely important that you perform all ac experiments on an insulated work surface. An ordinary wooden table, either bare or covered with linoleum or oilcloth, is ideal. A porcelain-top table is unsatisfactory, because the porcelain is applied over a metal base. For safety's sake, you should perform all experiments where you will not be able to touch any grounded object, such as a radiator, a water pipe, or a damp concrete basement floor. If you must carry out your experiments in the basement, be sure that you always stand on a dry board while working on the ac supply.

Be sure to disconnect the plug from the ac line before making changes in your circuit or before moving the meter lead clipped to a terminal or lead.

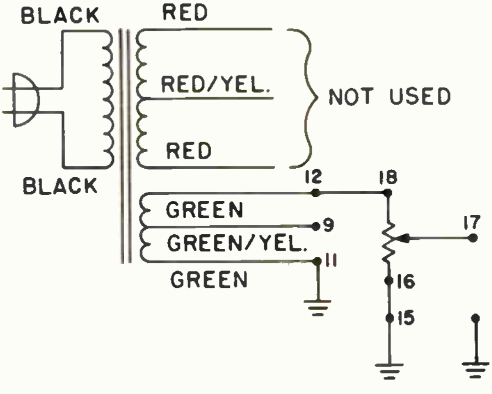


Fig. 8. Schematic diagram of the ac voltage divider circuit.

EXPERIMENT 23

Purpose: To show that a capacitor will block dc but will pass ac.

Introductory Discussion: A capacitor is a device for storing electrical energy. It cannot do this, however, unless the dielectric used to separate the plates has certain characteristics, the most important of which is that it must electrically insulate the plates from each other.

It might seem that insulating the plates so that there is no conductive path between them would block the flow of an electric current completely. However, as you have learned from your course, this is not true. Although a capacitor does block direct current, it passes ac in the circuit. You are going to demonstrate these capacitor actions experimentally.

To demonstrate the insulating properties of a capacitor with a solid dielectric, you will measure the current through the capacitor for each type of voltage. Your tvom will not measure current directly. You must determine the current in a circuit indirectly by measuring the voltage across a resistor in the circuit, and then dividing the measured voltage by the resistance across which you measured the voltage. The result will be the current in amperes. This is the same method you used to determine the current in the last experiment.

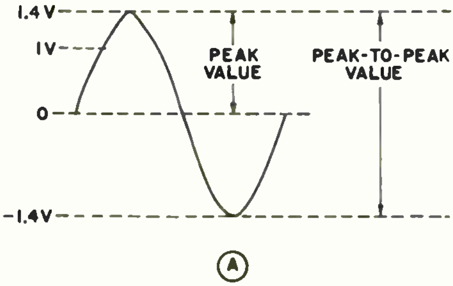
You learned that pure ac should not be applied to an electrolytic capacitor. The reversing ac voltage will either put a positive potential on the negative plate of the capacitor or a negative potential on the positive plate of the capacitor. When this wrong polarity is applied to the oxide film dielectric of an electrolytic capacitor, the dielectric breaks down, causing leakage between the capacitor plates. However, an electrolytic capacitor can be safely used to pass ac if we also apply a dc potential of the correct polarity to the capacitor. By doing this, we no longer have pure ac. Instead, we have dc with an ac component superimposed on the dc. The voltage across the capacitor plates does not reverse polarity and the dielectric does not break down.

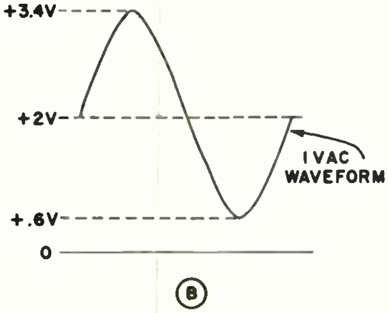
To demonstrate a circuit condition having ac superimposed on dc, you will connect the 3-volt battery into a circuit with the electrolytic capacitor and measure the dc and ac voltages.

You will determine the peak-to-peak value of the ac voltage applied to the capacitor. Knowing the peak-to-peak amplitude of the ac waveform enables you to compare the ac component with the dc component. From your studies in the regular lessons, you know that the ac scales on your tvom indicate the effective or rms value of the ac waveform.

To refresh your memory, examine the ac waveform shown in Fig. 23-1A. It shows one cycle of an ac voltage having an effective value of 1 volt. Notice that the waveform rises to a peak value of 1.4 volts above zero on the positive half-cycle and to -1.4 volts on the negative half-cycle. The total height of the waveform from the negative peak to the positive peak is twice the peak value, or 2.8 volts peak-to-peak.

Now let's superimpose this ac waveform on a dc voltage as shown in Fig. 23-1B. The figure shows +2 volts dc with a 1 volt ac waveform varying above and below the 2 volt level. Notice that with 1 volt ac superimposed on 2 volts dc, the resultant voltage never goes to zero. When





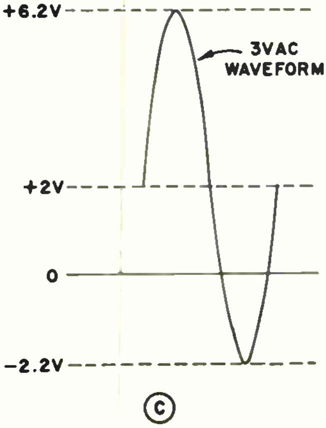


Fig. 23-1. Waveform of 1 volt (effective) with peak value and peak-to-peak value indicated (A); 1 volt ac superimposed on +2 volts dc (B); 3 volts ac superimposed on +2 volts dc (C).

the 1 volt ac waveform is zero, the resultant voltage is 2 volts, or the value of the dc voltage alone. When the ac waveform rises to a peak of 1.4 volts, the resultant voltage is 3.4 volts, or the su of the peak voltage plus the dc value. When the waveform falls to its lowest value, the resultant voltage is the difference between the peak value and the dc value, or 2 – 1.4 = 0.6 volt. From this you can see that the voltage never goes to a negative value.

A large ac waveform superimposed on a dc voltage can cause the voltage to reverse if the peak of the ac value is greater than the dc voltage. Fig. 23-1C shows a 3-volt ac waveform superimposed on +2 volts dc. Again the instantaneous values of the ac voltage combine with the dc voltage to produce the resultant voltage. The peak value (one-half the peak-to-peak value) of a 3-volt ac waveform is 4.2 volts. When the ac waveform reaches its maximum negative peak, the resultant voltage goes to a negative value, or -2.2 volts. Thus, the resultant voltage reverses its polarity for a small portion of the ac cycle.

From this discussion you can see that if we apply a dc potential of the proper polarity to the plates of the electrolytic capacitor we can prevent an ac voltage from reversing the polarity on the plates of the capacitor. Also you can see that we know what value of dc will be needed to prevent a given ac waveform from reversing the polarity on the capacitor plates.

In these experiments, we have placed resistors in the circuits where current values must be determined. However, in actual service work, if there is no suitable resistance in the circuit, one can be inserted. If you do this, you must be careful to choose a suitable value. Too low a resistance will not develop a measurable voltage when a small current flows through it, and too high a resistance will change the total impedance of the circuit enough to cause a significant decrease in the amount of current.

Experimental Procedure: For this experiment, you need your experimental chassis, your tvom, and:

1 18K-ohm resistor
1 .25-mfd capacitor
1 1K-ohm resistor
1 20-mfd electrolytic capacitor

Wire the circuit shown in Fig. 23-2. The chassis layout is shown in Fig. 23-3. Connect the 18K-ohm resistor from terminal 11 to terminal 14 and connect a

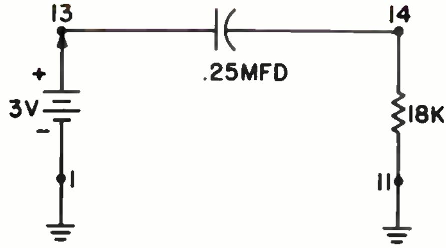


Fig. 23-2. Schematic of circuit used to measure current through the capacitor.

.25 mfd capacitor from terminal 14 to terminal 13. Solder all three connections.

Step 1. To measure the dc voltage drop across the 18K-ohm resistor.

First set up your tvom for use as a dc voltmeter. Set the function switch to dc, the range switch to 3V and set the polarity switch to normal. Connect the

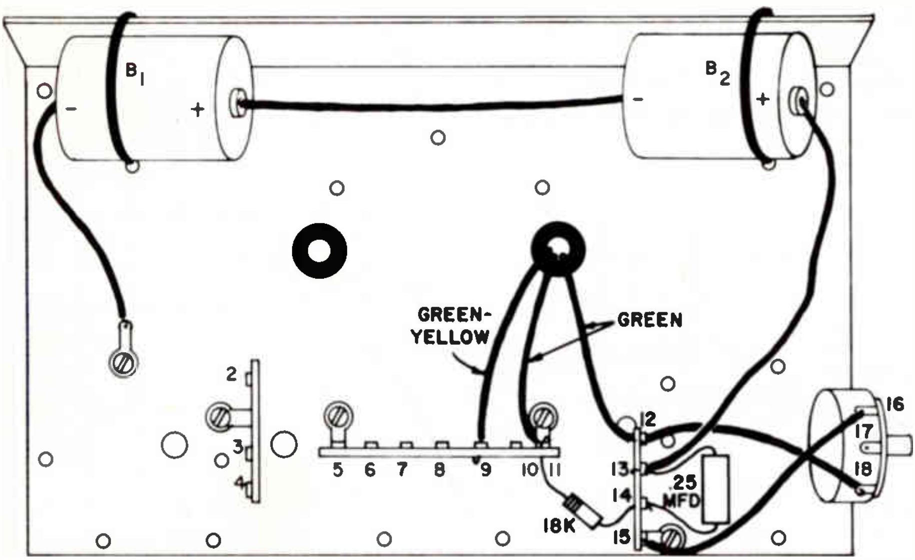


Fig. 23-3. Circuit wired for Step 1.

VOLTAGE ACROSS RESISTOR	
STEP 1 DC	0
STEP 3 AC	2.55V

Fig. 23-4. Results of Steps 1 and 3.

ground clip of your tvom to the chassis and clip the probe to terminal 14. Touch the positive battery lead to terminal 13 and read the voltage. The reading will depend upon the characteristics of your particular capacitor. Ideally, it should be zero, but an imperfect dielectric or leakage along the outside of the capacitor case may allow enough current through the circuit to give you some small reading. Record your reading on the top line of Fig. 23-4.

Remove the positive battery lead from terminal 13 and disconnect your tvom from terminal 14.

Step 2. To apply an ac voltage to the resistor-capacitor network that you used in Step 1.

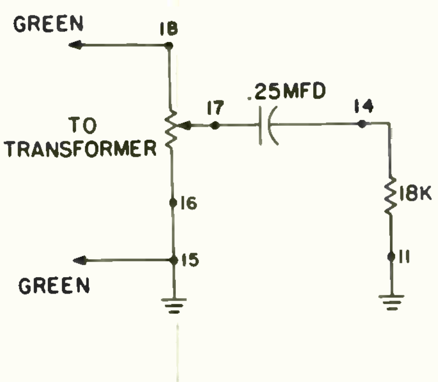


Fig. 23-5. Schematic of the circuit in Fig. 23-4.

Unsolder and disconnect the lead of the .25-mfd capacitor from terminal 13. Solder the capacitor lead to terminal 17, which is the center terminal of the 1K-ohm potentiometer.

Position the resistor and the capacit r so that their leads cannot touch any of the exposed terminals or the metal chassis. The circuit is shown in schematic form in Fig. 23-5.

Now, prepare your tvom for making ac measurements. Set the function switch to ac and the range switch to 12V. When measuring ac or dc voltages on this range, read the meter scale that is numbered from 0 to 12. The reading is given directly in volts.

Clip the ground lead of your tvom to the chassis. Plug the power cord from your experimental chassis into an ac receptacle.

Hold the probe by the insulated handle so as not to touch the metal tip. Touch the meter probe to the center terminal (terminal 17) of the potentiometer, and rotate the control shaft of the potentiometer with your fingers until the meter pointer indicates less than 3 volts. Now turn the range switch on the tvom to the 3V position, and carefully adjust the potentiometer to give you a reading of exactly 3 volts.

Your voltage divider will now have an output voltage that is equivalent to the dc voltage you used in Step 1 of this experiment.

Step 3. To measure the voltage across the 18K-ohm resistor.

Leave the ground clip of the tvom clipped to the chassis. Touch the probe to terminal 14, and read the 3-volt scale of the meter. Record the meter reading in Fig. 23-4 as the voltage across the resistor in Step 3.

Remove the plug from the ac outlet. Disconnect the tvom test probes from the circuit. Unsolder and remove the .25-mfd capacitor. Unsolder and remove the lead of the 18K-ohm resistor from terminal 11 and connect this lead to terminal 8.

Step 4. To apply both ac and dc to a circuit containing the electrolytic capacitor.

You will use the circuit shown in Fig. 23-6. Solder the negative lead of the 20-mfd electrolytic capacitor to terminal 17 of the ac voltage divider. Solder the positive lead of the electrolytic capacitor to terminal 14 and the lead of the 18K-ohm resistor.

Solder the positive battery lead to terminal 8. If necessary, splice a piece of hookup wire to the lead. Check your work against Fig. 23-6.

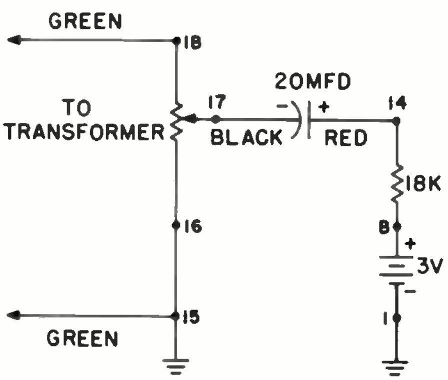


Fig. 23-6. Schematic of the circuit for Step 4.

	DC	AC	PEAK TO PEAK
BATTERY VOLTAGE	3V		
VOLTAGE ACROSS 18K-OHM RESISTOR	0	1	2.8
VOLTAGE ACROSS CAPACITOR	3V	0	[illegible]

Fig. 23-7. Record the values measured in Step 4.

Clip the ground lead of the tvom to the chassis. Set the function switch to dc and the range switch to 3V. Touch the probe to the positive terminal of the battery. Record the voltage in the space provided in Fig. 23-7. Move the ground clip to terminal 14. Touch the probe to the other lead of the 18K-ohm resistor at terminal 8. Record the reading in the space provided in the dc column in Fig. 23-7. This reading should be very nearly zero and indicates the amount of leakage through the electrolytic capacitor.

Clip the ground lead of your tvom to terminal 17 of the ac voltage divider. Touch the probe to the junction of the capacitor lead and the 18K-ohm resistor at terminal 14. Record your reading in the dc column of Fig. 23-7 for the voltage across the capacitor.

Set the function switch to ac and the range switch to 12V. Plug the power cord into the ac receptacle. Touch the probe to the chassis. Adjust the potentiometer until the meter indicates less than 2 volts on the 12V scale. Switch the range switch to 3V and adjust the potentiometer for exactly 1V. Move the probe to terminal 14. Read the meter and record the voltage across the capacitor in the ac column of Fig. 23-7. Compute the peak-to-peak value by multiplying the meter reading by 2.8. Record this in the peak-to-peak column.

Next, measure the ac voltage across the resistor. Unplug the power cord and clip the ground lead of the tvom to terminal 8. Plug the power cord in and touch the probe to terminal 14. Read the ac voltage across the 18K-ohm resistor. Record the reading in the space provided in Fig. 23-7. Compute the peak-to-peak value of the ac voltage across the resistor. Put the value also in Fig. 23-7. Unplug the power cord and disconnect your meter leads. Also unsolder the positive battery lead from terminal 8.

Discussion: The voltage you measured across the series resistor in Step 1 depends on the quality of the dielectric and the amount of leakage along the outside of the capacitor case. You probably will not measure any voltage drop across the resistor. If you had more sensitive measuring equipment and the dc voltage had been considerably higher, you would have measured a voltage drop across the resistor as the result of a dc flow through the dielectric of the capacitor, because no dielectric is a perfect insulator.

Of course, if we exceed the voltage rating of a dielectric, it will break down, and we no longer have a capacitor. A capacitor having a solid dielectric will block the flow of dc only if the applied voltage is kept below the rated working voltage of the capacitor.

In practical radio and TV circuits we also have to consider the effects of leakage along the outside of a capacitor. Moisture, dirt, and grease form conductive paths and decrease the effectiveness of the capacitor. It is essential, therefore, to keep equipment clean and dry.

In Step 2 you obtained some valuable experience using your tvom. Notice we first set the instrument on the 12-volt range, adjusted the potentiometer to less than 3 volts, and then switched to the 3-volt range. When you measure an unknown voltage, you should always begin by turning the range switch to one of the higher ranges. Then, when you are sure it is safe to do so, switch to a lower range to get more accurate readings.

The voltage you measured across the resistor in Step 3 with ac applied to the test circuit is clear evidence that a capacitor with a solid dielectric will pass ac. As we pointed out in your regular lesson on capacitors, the electrons do not actually pass through the dielectric of a capacitor; instead, they move to and from the capacitor plates, thus permitting a back and forth or ac flow in the circuit connected to the capacitor. As far as the rest of the circuit is concerned, the effect of this back and forth movement is the same as if the current actually passed through the dielectric of a capacitor.

You can consider that the readings you obtain in Steps 1, 2 and 3 are correct if you find that the voltage across the resistor is greater when ac is applied to the circuit than when dc is applied.

In Step 4 you worked with a circuit having both ac and dc voltages applied to the capacitor. The nearly 0 volt dc reading across the 18K-ohm resistor shows that the electrolytic capacitor blocks the dc current. This is to be expected because the dc voltage is applied with the correct polarity to the plates of the capacitor. The 3-volt dc reading across the capacitor shows that in this circuit the battery potential appears across the plates of the capacitor. When the ac voltage is applied to the circuit, the capacitor couples the ac voltage through the capacitor and almost the entire applied ac voltage appears across the 18K-ohm resistor. The large 20-mfd electrolytic capacitor offers almost no opposition to the flow of alternating current at a frequency of 60 Hertz. Therefore, the ac voltage reading across the capacitor is nearly zero. You will often find electrolytic capacitors used as coupling capacitors in transistor circuits. The value of these electrolytic coupling capacitors is frequently 5 mfd or greater.

At low audio frequencies, a sizable ac voltage develops across a capacitor of this size. You will find that the capacitors are connected in the circuit in such a way that a dc bias potential is placed on the capacitor. The dc potential has the correct polarity to prevent the voltage on the capacitor plates from reversing when an ac signal is applied to it.

Instructions for Statement No. 23: For the Statement in this experiment, you are to determine the opposition offered by your .25-mfd capacitor to the flow of 60 Hertz ac.

When we speak of opposition to ac, we actually mean impedance. However, if the ac resistance of the capacitor is very low, as it is in a capacitor with a good solid dielectric, the impedance is practically the same as the reactance of the capacitor. Therefore, although you will really determine the impedance of your capacitor for 60 Hertz ac in this experiment, you can consider your result to be its reactance at that frequency also.

To get the information you need to calculate the impedance of the capacitor, disconnect and remove the 20-mfd capacitor and the 18K-ohm resistor. Solder one lead of a 1K-ohm resistor to terminal 17 of the 1K-ohm potentiometer. Connect the other lead to terminal 14. Solder a .25-mfd capacitor from terminal 14 to terminal 5. See Fig. 23-8.

Connect the ground clip of your tvom to terminal 14 and plug the power cord into an ac receptacle. With your tvom on the 3-volt ac range, touch the probe to terminal 17, and adjust the potentiometer to give you a voltage of less than 1.2V across the 1K-ohm resistor. Switch to the 1.2V range and adjust for .5V. The current in the circuit will now be .5 milliampere or .0005 ampere.

Turn the range switch on your tvom to the 12V position, and touch the probe to the chassis. The reading on your tvom is the voltage across the capacitor with an alternating current of .0005 ampere flowing through it. Remember to read your tvom on the 12V scale when you measure this voltage.

To determine the impedance of the capacitor, all you need do is apply Ohm's Law. Divide the voltage that you mea-

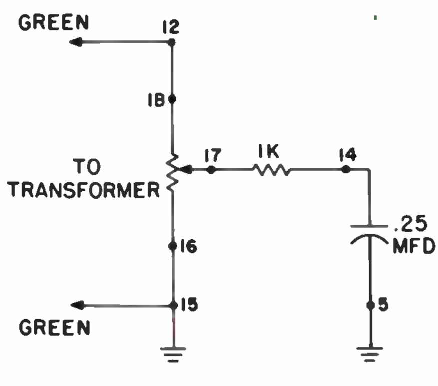


Fig. 23-8. Circuit used for Statement 23.

5.2V / .5ma   10.4K $X_C = \frac{1}{2\pi FC}$

sured across the capacitor by the current (.0005 ampere), and you will have the impedance. Perform this computation and answer the Statement. Disconnect your power cord from the power line. Do not disconnect the 1K-ohm resistor and the .25-mfd capacitor. You will use them in the following experiment.

Statement No. 23: I found that the impedance of my .25-mfd capacitor was:

(1) approximately 3,000 ohms.
(2) approximately 10,000 ohms.
(3) approximately 30,000 ohms.

EXPERIMENT 24

Purpose: To show that when capacitors are connected in parallel, their combined capacitance is equal to the sum of their individual capacitances; and to show that when capacitors are connected in series, their combined capacitance is less than that of the smallest capacitor.

Introductory Discussion: The capacitance of a capacitor depends upon four things: (1) the area of the plates, (2) the number of plates, (3) the distance between adjacent plates, and (4) the kind of dielectric or plate separator material used. If any one or any combination of these four things is varied, the capacitance changes.

As you have learned in your lessons, when capacitors are connected in parallel, the plate area is effectively increased. Therefore, the capacitance should increase. In this experiment, you will show that the capacitance increases, and that it is equal to the sum of the capacitance of the individual capacitors.

Capacitors can also be connected in series. As you learned in your lessons, connecting capacitors in series is electrically equivalent to increasing the thickness of the dielectric material between the plates. This should decrease the capacitance. You will show that this is actually what does take place.

To show exactly how much the capacitance changes, you will use the same procedure you used in the Statement of the preceding experiment to determine the impedance of the combination of capacitors.

The capacitance of a capacitor can be calculated by rearranging the formula for capacitive reactance, if you know the reactance and the frequency. For all practical purposes, the reactance of the capacitor at that frequency is equal to its impedance. Thus, since we know the impedance we can find the capacitance by using the formula

$$X_C = \frac{1}{6.28fC}$$

If we rearrange this formula, we can write it in the form

$$C = \frac{1}{6.28fX_C}$$

By substituting the impedance value you determine for X_C and 60 for f, you can get the capacitance in farads. You can convert this to microfarads by multiplying by 1,000,000.

As a serviceman, you will not have to make this type of calculation. Therefore, we have prepared a graph that you can use to determine the capacitance once you have the impedance. The graph is a plot of reactance in ohms at 60 Hertz plotted against capacitance in mfd. If you know the value of the capacitor, you can find its reactance in ohms at 60 Hertz. Or if you know the reactance in ohms at 60 Hertz, you can find the capacitance in mfds. You get the same information from the graph that you would get by working out the reactance formula.

The important thing for you to watch in this experiment is what happens to the total capacity when you put capacitors in parallel or in series.

Your first set of measurements will be made with two capacitors connected in parallel. The capacitance you compute should be nearly equal to the sum of the rated capacitances. Because of manufacturing tolerances, the actual capacitance will probably not be the same as the rated capacitance, so the calculated capacitance will probably be somewhat different from the sum of the rated values.

After making measurements and computations for capacitors connected in parallel, you will connect the same two capacitors in series and repeat the measurements. This time you should find that your computed capacitance is less that that of the rated value of the smallest capacitor in the combination.

Experimental Procedure: For this experiment, you need the circuit from the preceding experiment and:

1 10K-ohm resistor
1 .1-mfd capacitor (CN12)
1 .25-mfd capacitor

From now on, we will not give you step-by-step instructions for using your tvom in making all the measurements required in your experiments. We will

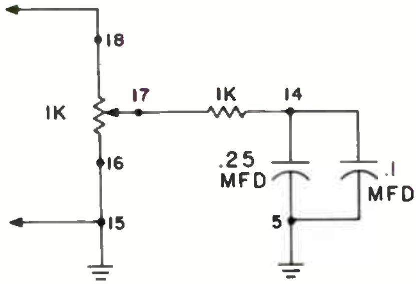


Fig. 24-1. Schematic showing capacitors in parallel across the potentiometer.

occasionally tell you how to connect the test leads, but for the most part we will merely tell you to make the measurements and leave it up to you to set up the tvom properly from them. Of course, we will give you help when you use the instrument on a range that you have not used before in the experiments.

To connect the capacitors in parallel, set up the circuit shown in the schematic diagram in Fig. 24-1 and the pictorial diagram in Fig. 24-2. Since you already have the 1K-ohm resistor and the .25-mfd capacitor in place, all you need to do is connect the .1-mfd capacitor in parallel with the .25-mfd capacitor from terminal 5 to terminal 14.

Step 1. To adjust the voltage across the resistor to a fixed value.

Connect the tvom across the 1K-ohm resistor and set the range switch to 12V. Apply ac power to the voltage divider, and adjust the potentiometer to produce a meter reading of less than 1 volt on the 12V scale. Now switch to the 1.2-volt range and adjust the potentiometer to give you a voltage of .5 volt across the

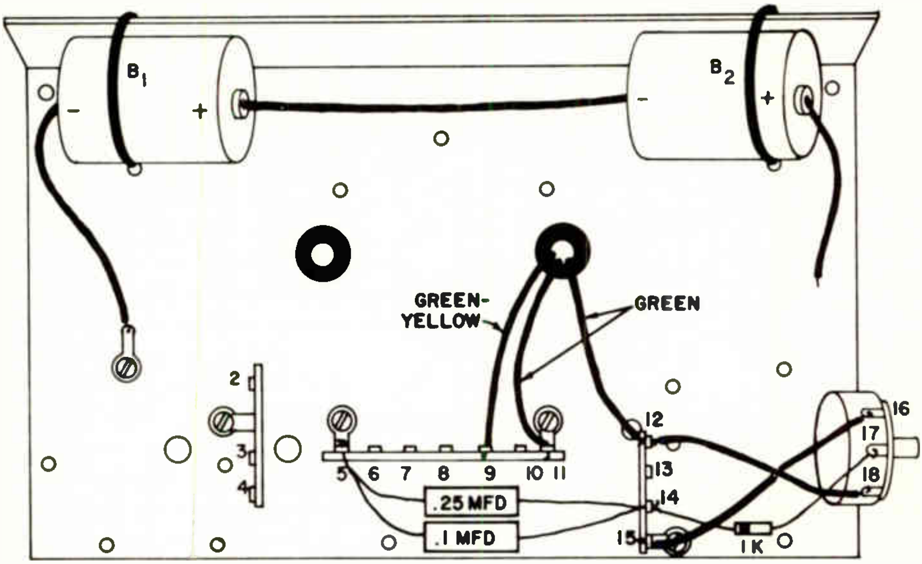


Fig. 24-2. Chassis layout for Step 1.

1K-ohm resistor. You now have a current of .5 milliampere flowing in the circuit. Adjust this voltage as accurately as you can. A small error here will cause a considerable error in your computed capacitance value. Unplug the power cord.

Step 2. To measure the ac voltage drop across the capacitors.

Switch the tvom to the 12V range and connect it across the parallel-connected capacitors. Plug the power cord into the ac outlet. Record the measured voltage in Fig. 24-3. Unplug the power cord.

Step 3. To determine the impedance of the parallel-connected capacitors.

You know the current in the circuit is .5 milliampere. To calculate the impedance, divide this current value into the voltage value you measured across the capacitors. An easy way to do this is to multiply the voltage by 10,000 and then simply divide by 5.

When we carried out this experiment in the laboratory, we had a voltage of 3.5 volts across the combination. Multiplying this by 10,000 gave us 35,000, and dividing this by 5 we got 7000 ohms as

CAPACITOR GROUPING	VOLTAGE ACROSS CAPACITORS	CURRENT IN AMPS	REACTANCE IN OHMS	CAPACITANCE IN MFD
PARALLEL	3.6V	.0005	7.2K	.35
SERIES	4V	.0001	40K	

Fig. 24-3. Results of Experiment 24.

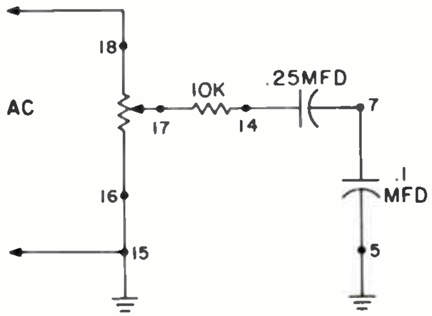


Fig. 24-4. The capacitors are connected in series.

the impedance of the combination. Your value should be reasonably close to this figure. Record the impedance you calculated in Fig. 24-3 in the column headed "Reactance in Ohms."

Connect the capacitors in series, as shown in Fig. 24-4. Unsolder the lead of the .1-mfd capacitor from terminal 14 and connect it to terminal 7. Unsolder the lead of the .25-mfd capacitor from terminal 5 and solder it to terminal 7. Unsolder and remove the 1K-ohm resistor and replace it with the 10K-ohm resistor from terminal 14 to terminal 17 of the potentiometer.

Step 4. To adjust the voltage across the resistor to 1 volt, and measure the voltage across the series-connected capacitors.

Connect the tvom across the 10K-ohm resistor. With the range switch in the 12-volt position, energize your circuit and adjust the potentiometer to give you a voltage less than 3 volts. Then switch to the 3V range, and adjust the potentiometer to give you a voltage of 1 volt.

Unplug the power cord to the voltage divider, switch the range switch to the 12V position, and connect the tvom across the two capacitors connected in series from the chassis to terminal 14. Plug in the power cord to the voltage divider and read the meter. Be sure to switch to the 3V range if the voltage is less than about 2.5 volts. Record your reading in Fig. 24-3. Disconnect the ac power.

Step 5. To determine the impedance of the series-connected capacitors.

You can easily determine the value of the current in the circuit. Since you have one volt across a 10K-ohm resistor, the current must be 1 ÷ 10,000, which is .0001 ampere. To determine the impedance, you must divide the voltage across the two capacitors by this current. Again, an easy way to do this is to multiply the voltage by 10,000. Do this and enter your value in Fig. 24-3.

Step 6. To find the net capacitance of the two capacitors connected in parallel.

Use the graph shown in Fig. 24-5. Notice the dark vertical lines. Each one of these lines represents 5000 ohms. The lines representing 30,000 and 60,000 ohms are marked. In the example we gave, where we had an impedance of 7000 ohms, we would find the vertical line representing 7000 ohms. This is the seventh line from the left. The first dark line to the right of the zero line is 5000 ohms; the second light line to the right of the 5000-ohm line is the 7000-ohm line. Now follow this line up until it crosses the curve on the graph, and then follow the nearest horizontal line to the left side of the graph.

In our example, the vertical 7000-ohm

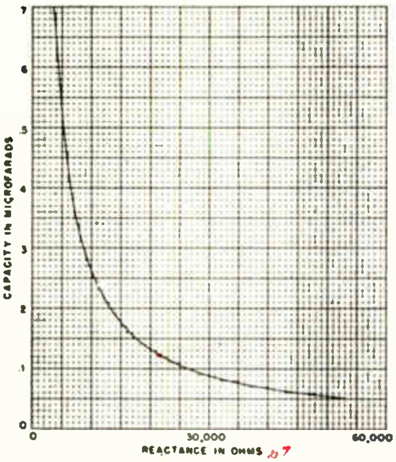


Fig. 24-5. Graphic plot of reactance in ohms at 60 cycles plotted against capacitance in mfd. You will use this graph in Steps 6 and 7.

line intersects the curve about 2 lines above the dark horizontal line, midway between .3 and .4. This dark line represents .35 mfd, and since there are five lines between it and .4 mfd, the second line above .35 represents .37-mfd. This means the parallel capacitance is .37-mfd, which is close to the value we obtain by adding .25-mfd and .1-mfd. Now, determine the capacitance of your parallel combination using Fig. 24-5.

Step 7. To determine the net capacitance of the capacitors when they are connected in series.

Use the value of reactance in ohms that you obtained in Step 5 when the capacitors were connected in series. Enter this value of reactance in the graph in Fig. 24-5 and find the value of capacitance. You should find that the total capacitance of the two in series is about .07-mfd.

Discussion: The actual value of your capacitors may be quite different from the capacitance marked on them. Most capacitors of this type have tolerances of +20% and -10%. Thus, the actual capacitance of your .25-mfd capacitor may be anything between .225-mfd and .3-mfd, and the actual capacitance of your .1-mfd capacitor may be any value between .09 and .12 mfd. Therefore, the sum of their actual capacitance may be anywhere from .32-mfd to .42-mfd, even though the sum of their rated capacitance is .35-mfd. However, as far as any of the experiments in your practical training course are concerned, you can find the capacitance of a group of capacitors accurately enough for all practical purposes by using the rated capacitance of the individual capacitors in your computations.

This experiment has proved that the capacitance of a group of capacitors connected in parallel is larger than that of any of the individual capacitors, and that the capacitance of a group connected in series is less than that of the smallest of the group. We can find the capacitance of a group of capacitors connected in parallel by adding the value of the individual capacitors. To find the capacitance of two capacitors connected in series, you can use the formula:

$$C = \frac{C_1 \times C_2}{C_1 + C_2}$$

If there are more than two in the series group, work with just two at a time, and find the net capacitance by applying the formula as many times as necessary.

Instructions for Statement No. 24: Remove the .1-mfd capacitor from the circuit and connect a .25-mfd capacitor in its place between terminals 5 and 7. You should now have two .25-mfd capacitors in series with the ac voltage source and the 10K-ohm resistor. Connect your tvom across the 10K-ohm resistor, and apply power to the voltage divider. Adjust the potentiometer for a voltage of 1 volt across the 10K-ohm resistor. Next, measure the voltage across the two .25-mfd capacitors in series. Unplug the power cord, compute the impedance, and then determine the net capacitance of the combination from the graph in Fig. 24-5. Use exactly the same procedure you followed in the experiment.

Compare the net capacitance you have computed with the capacitance of one of the two capacitors. Then, choose the answer in the Statement below and on the Report Sheet that most nearly represents the results of your comparison.

When you have done this, disconnect the 10K-ohm resistor and put it aside. Do not remove the two .25-mfd capacitors from the circuit, however. They will be used in the following experiment.

Statement No. 24: When I connected two capacitors of equal capacitance in series, the net capacitance was approximately: .12 μfd.

(1) one-half
(2) four times
(3) the same as
(4) twice

that of one capacitor alone.

EXPERIMENT 25

Purpose: To show that when ac is applied to two or more capacitors connected in series, the sum of the voltage drops across the capacitors equals the source voltage; and

To show that the capacitor with the lowest capacitance will have the most voltage across it.

Introductory Discussion: In this experiment, you will show that voltage applied to several series-connected capacitors divides among them in accordance with their individual reactances. You will do so by connecting three capacitors in series, and measuring the ac voltage drop across each. You will remember that you performed a similar experiment to show that in a dc circuit the sum of the voltage drops is equal to the source voltage. This is Kirchhoff's Voltage Law. You have seen that it works for dc; you will now prove that it is also true in ac circuits.

Experimental Procedure: In addition to your chassis and tvom, the parts you need for this experiment are:

1 .1-mfd capacitor
1 47K-ohm resistor
1 18K-ohm resistor

Set up the circuit shown in Fig. 25-1 as follows:

You should have two .25-mfd capaci-

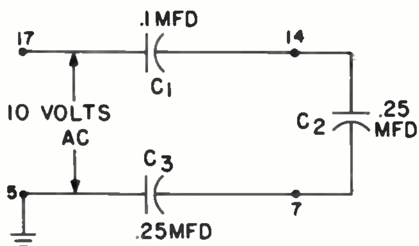


Fig. 25-1. Schematic of the circuit for Exp. 25.

2.2 V / .0001 A = 22KΩ

tors connected in series, one from terminal 5 to terminal 7 and the other from terminal 7 to terminal 14. Connect one lead of a .1-mfd capacitor to terminal 14. Solder the connection. Solder the other lead of the .1-mfd capacitor to terminal 17 of the potentiometer. The chassis should now appear as shown in Fig. 25-2.

Now connect the ground clip of the tvom to the chassis. Touch the probe to terminal 17 of the potentiometer. Switch your tvom to the 12V range, apply power to the circuit, and adjust the voltage until the meter indicates exactly 10 volts.

Step 1. To measure the ac voltage across one of the .25-mfd capacitors.

You already have the ground lead of your tvom connected to the chassis ground. To measure the voltage across capacitor C_3, touch the meter probe to terminal 7. Record your reading on the first line in Fig. 25-3.

Step 2. To measure the ac voltage across the second .25-mfd capacitor.

Remove the power cord. You must do this, because it is not good practice to change the connections of the tvom while the circuit is energized. The safest procedure, both for yourself and for the tvom, is to unplug the power cord of the circuit you are working on before changing the connections of the tvom test leads. Do not plug the power cord in again until you have the tvom connected for the next measurement.

Transfer the ground clip of the tvom to terminal 7, which is the junction point of the two .25-mfd capacitors. Apply the ac power, and touch the tvom probe to terminal 14. Read the meter carefully,

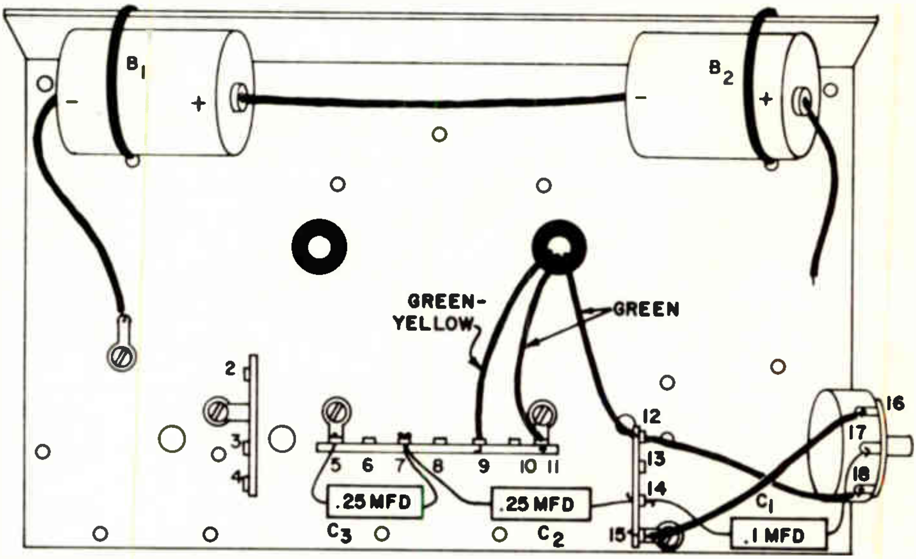


Fig. 25-2. The wiring for Step 1.

	YOUR READING
STEP 1	2.2V
STEP 2	2.15V
STEP 3	5.4V
TOTAL	9.75V

Fig. 25-3. Results of Experiment 25.

and record your reading on the second line in Fig. 25-3.

Step 3. To measure the voltage across the .1-mfd capacitor.

Unplug the power cord from the ac source, and move the ground clip to the junction of the .1-mfd capacitor and the .25-mfd capacitor at terminal 14. Then, reapply the power, touch the probe to terminal 17 of the potentiometer, and read the meter carefully. Record your voltage measurement on line 3 of Fig. 25-3.

Unplug the circuit and unsolder and remove all three capacitors from the circuit. Keep them handy for use in the Statement of this experiment.

Discussion: The voltages you recorded in the table in Fig. 25-3 should show you two things. First, the sum of the individual drops should be approximately equal to the source voltage. Add the voltages you measured in Steps 1, 2 and 3, and record the total in the space provided in Fig. 25-3. Since it is difficult to read small voltages accurately, the sum of your voltage may not be exactly 10 volts. You should, however, come close enough to be able to say that the sum of the voltage drops equals the source voltage within the limits of accuracy of your experimental measurements.

From the readings, you should also notice that the greatest voltage drop is across the smallest capacitance. Since it is the smallest capacitance that has the highest reactance at any given frequency, your measurements prove that the greatest voltage drop is across the highest reactance. The voltage drops across the two .25-mfd capacitors should be approximately equal. If you were to compute the reactance of each capacitor, you would see that the voltage drops were proportional to the individual reactances.

If you want to do this, find the reactance by using the formula

$$X_C = \frac{159{,}000}{fC}$$

in which f is the frequency in Hertz of the applied voltage and C is the capacitance in microfarads.

For example, to find the reactance of the .1-mfd capacitor, multiply 60 (the power-supply frequency) by .1. This answer is 6. Dividing this into 159,000, you get the value 26,500, which is the reactance in ohms of the capacitor at 60 Hertz. You can compute the reactance of the .25-mfd capacitors in exactly the same way.

Instructions for Statement No. 25: For your report on this experiment, you are going to determine what happens when a coupling capacitor has leakage.

A very common radio and TV circuit uses a capacitor to pass the ac signal from the plate circuit of one stage to the grid circuit of the next stage. We can simulate

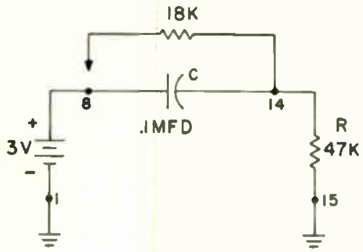


Fig. 25-4. Circuit used for Statement 25.

such a circuit as shown in Fig. 25-4. The 3-volt battery represents the plate supply, capacitor C acts as the coupling capacitor, and resistor R represents the grid resistor of the next stage. We know that ac passes through the capacitor, but should there be a dc voltage across R? Will there be if C is leaking? To find out, we will use the 18K-ohm resistor to simulate leakage in the capacitor. Wire the circuit shown in Fig. 25-4. Notice that one lead of the 18K-ohm resistor is not connected as yet.

Use your tvom as a dc voltmeter and measure the dc voltage across the 47K-ohm resistor. Make a note of your reading in the margin of this page.

0V

Next, simulate leakage in the .1-mfd capacitor by connecting the 18K-ohm resistor in parallel with it. To do this, solder the free lead of this resistor to terminal 8. Again measure the dc voltage across the 47K-ohm resistor R. Make a note of your reading in the margin.

1.6V

Unsolder and remove the capacitor and the two resistors. Leave the battery and the ac voltage divider. Complete the Statement below and on the Report Sheet.

Statement No. 25: When I simulated leakage by connecting the 18K-ohm resistor across the capacitor, I found that the dc voltage across resistor R was:

(1) the same as
(2) greater than
(3) less than

it was before the leakage resistor was connected.

Using Vectors To Combine AC Quantities

In a circuit in which the resistance is the only device that opposes the flow of alternating current, the voltage drop across each resistor is in phase with the current. By this we mean that during each cycle, the voltage and current maximums and minimums occur at the same instant.

In other words, at the instant when the ac voltage is zero, the current also is zero; and at the instant the voltage is at its peak value, the current is at its peak value. Consequently, the sum of the individual voltage drops in the circuit is equal to the source voltage.

When the circuit contains reactance as well as resistance, however, the resulting phase shifts make it impossible to simply add the voltage drops, because the voltages do not reach their peaks at the same time. Complex mathematics can be used to combine ac values, but there is a much simpler graphical method. This is in the use of vectors. Vectors are important because they help you see exactly what is happening in an ac circuit. You will also use them later, particularly when you study color television.

A vector is a line whose length is proportional to the magnitude of a voltage or current, and whose position with respect to other vectors or to a reference position indicates phase relationship. In other words, both the length of the vector and its position convey information.

A simple vector is shown in Fig. 9. If the line OA is a voltage vector, the length of the line indicates an amount of voltage. For example, if a scale in which 1 inch equals 1 volt is being used, a line 5 inches long would represent a voltage of 5 volts. If line OA is a current vector, its length represents an amount of current, depending on the scale used.

Fig. 9. A simple vector.

The reference or starting position for vectors is along a line drawn to the right of the point of origin, O.

A vector is considered to rotate in a counterclockwise direction only. If it forms an angle with the reference vector and is pointing upward, it is considered to be ahead of, or leading, the reference vector. If it is pointing downward, it is considered to be lagging behind the reference vector.

For example, in Fig. 10, vector OB is said to be 90° ahead of OA, and vector OC is said to be 90° behind OA. A complete cycle is 360°. Therefore, we

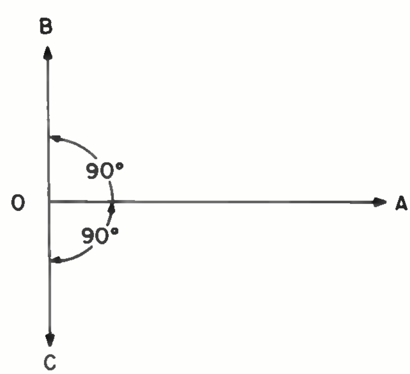


Fig. 10. Vectors show magnitude and phase.

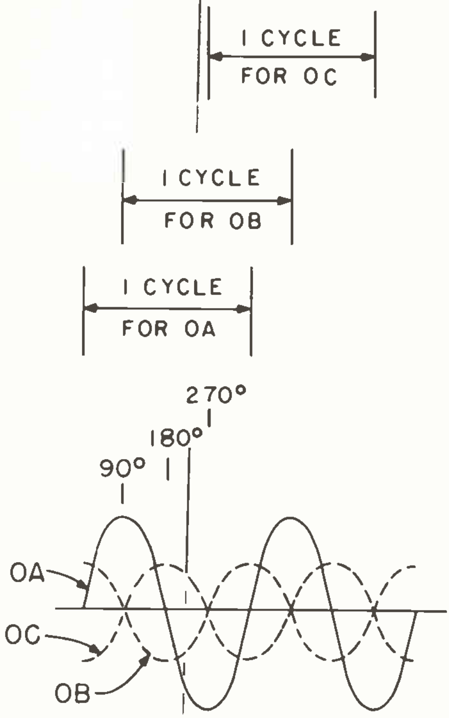


Fig. 11. Another way of showing Fig. 10 values.

could consider OC to be 270° ahead of OA; but if one cycle of OC is 270° ahead of one cycle of OA, that same cycle is 90° behind the next cycle of OA. Thus, it is customary to say that OC lags behind OA by 90° rather than leads it by 270°. This is illustrated in Fig. 11, in which each voltage is represented by a sine wave.

When two or more voltages or currents are to be compared, one vector is drawn for each. One is usually placed in the reference position and the others are drawn at an angle from the same point of origin. This angle represents the phase difference between the vectors. For example, vectors OA and OB, shown in Fig. 12A, represent two voltages. The voltage represented by OA is twice as great as the one represented by OB, and they are 90° out-of-phase. The phase difference between them is represented by the angle θ (the Greek letter theta is used to indicate a phase angle). Since the direction of rotation of vectors is always counterclockwise, we know vector OB leads vector OA by 90°. When voltage OB is one-quarter of the way through its cycle, OA is starting its cycle. The phase of two voltages or currents can be compared vectorially only if they have the same frequency so that one cycle of each frequency takes the same length of time.

The vector sum of the two voltages can be found by drawing the parallelogram shown in Fig. 12B. (A parallelogram is a four-sided figure, the opposite sides of which are parallel. Squares and rectangles are parallelograms in which all of the angles are 90°, or right angles.) To form this parallelogram, line BC is drawn parallel to vector OA, and line AC is drawn parallel to vector OB. Vector OC, the diagonal from point O to the point where the broken lines intersect, is the vector sum or "resultant" of the two voltages.

The angle between vectors OA and OB does not have to be a right angle (90°). For example, Fig. 12C shows two voltages that are considerably less than 90° out-of-phase. Whatever the angle may be, the vector sum can be found in the same way. Construct a parallelogram by drawing a line BC parallel to vector OA, and a line AC parallel to OB. The diagonal OC is the resultant.

If you compare the length of OC in Fig. 12C with the length of OC in Fig. 12B, you will find that they are different, even though the lengths of OB and OA are the same in both figures. This is

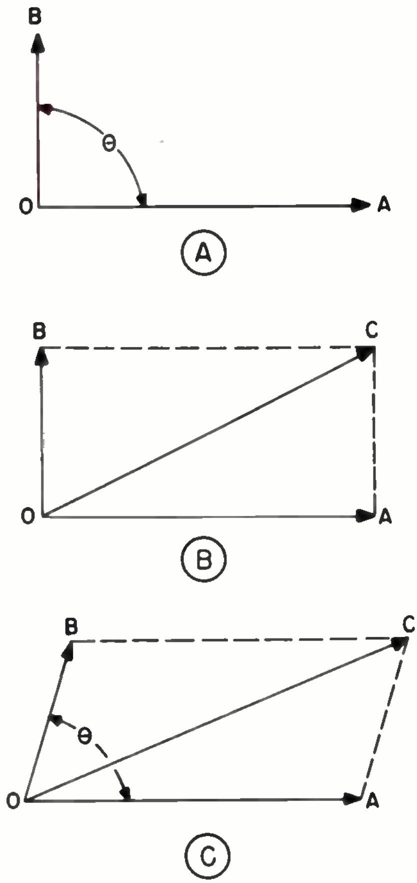


Fig. 12. How vectors are combined.

because the phase angle (θ) or relationship is not the same in both cases. Therefore, as you can see, the vector addition takes both amplitude and phase into account.

There is a form of vector shorthand that you should know about. It is illustrated in Fig. 13. A, C, and E show the standard method of completing the parallelograms. However, since the length of line AC is exactly that of line OB, there is really no need to draw OB -- we can draw AC instead, and thus find the resultant without having to construct the entire parallelogram.

B, D, and F of Fig. 13 show this short-cut method of finding the resultant. As you can see, all you need to do is to draw AC the same length and at the same angle that OB would be if it were drawn, and then draw in OC.

Whether you use the standard or the short-cut method of vector addition, you must make sure that the length of each vector corresponds to the amplitude of the voltage or current it represents, and that the phase angle is correct.

This brief explanation by no means covers the subject fully, but it covers the basic facts you need to know about vectors to work with the fundamental ac circuits used in the following experiments.

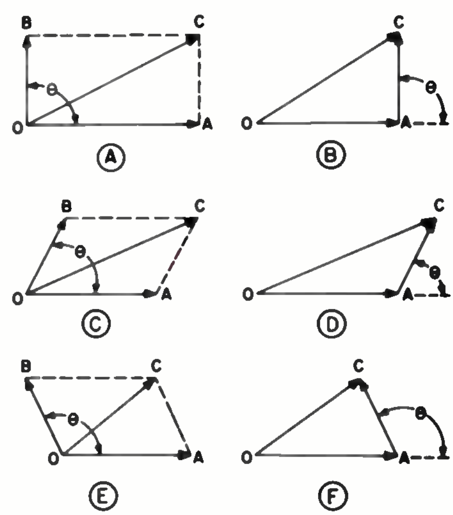


Fig. 13. A comparison between the "shorthand" method of adding two vectors by completing a triangle, and the conventional method of adding by completing a parallelogram. The result is the same in both cases.

EXPERIMENT 26

Purpose: To show that in an ac circuit containing only resistance, the sum of the individual voltage drops equals the source voltage with the greatest voltage being across the highest resistance; and

To show that in an ac circuit containing a capacitor and a resistor in series, the vector sum of the individual voltage drops equals the source voltage.

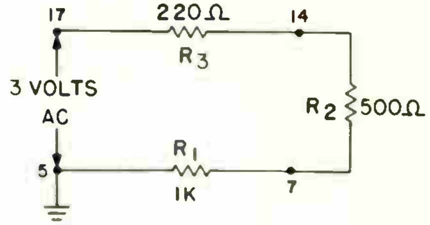


Fig. 26-1. Schematic of circuit for Steps 1,2,3.

Introductory Discussion: In carrying out the following experiment, you will first set up a circuit with three resistors connected in series, apply a specified ac voltage across the series circuit, and measure the ac voltage drop across each of the resistors. The sum of the individual voltage drops should equal the source voltage, because the voltages across the resistors are all in phase with each other.

Next, you will build a circuit with a capacitor in series with a resistor, apply an ac voltage across the combination, and measure the voltage drop across each component. The voltage drop across the capacitor lags behind the current through the capacitor by approximately 90°, but the current through the resistor is in phase with the capacitor current.

Therefore, the voltage across the capacitor is 90° out-of-phase with the voltage across the resistor. You will draw a vector

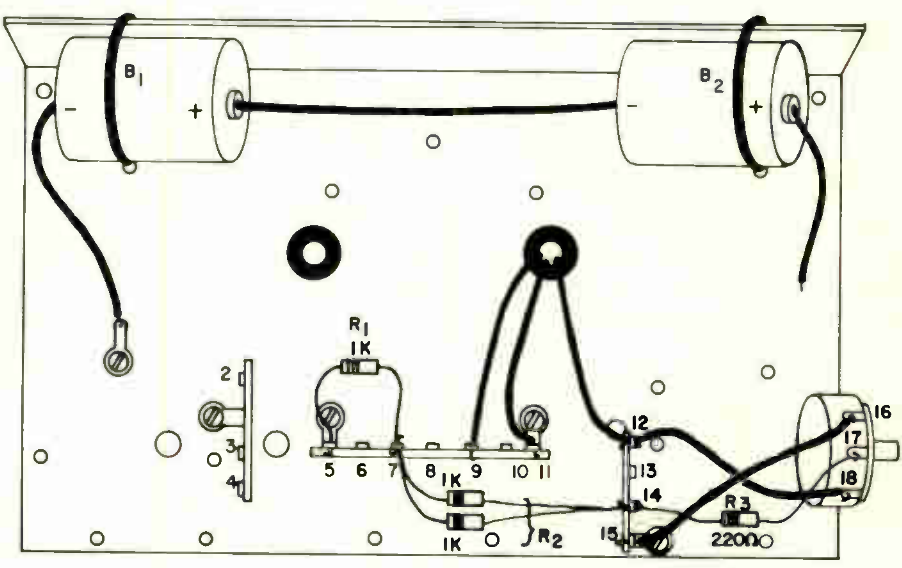


Fig. 26-2. Pictorial of circuit in Fig. 26-1.

diagram to show that the sum of the resistor voltage and the capacitor voltage is equal to the source voltage when the phase difference is taken into account.

Experimental Procedure: For this experiment, you need your experimental chassis, tvom and the following:

3 1K-ohm resistors
1 220-ohm resistor
1 18K-ohm resistor
1 .1-mfd capacitor
2 .25-mfd capacitors

You are to set up the simple series circuit shown in Fig. 26-1 across the ac voltage divider. A pictorial diagram is shown in Fig. 26-2.

Connect a 1K-ohm resistor from terminal 5 to terminal 7. Solder terminal 5. Now connect two 1000-ohm resistors in parallel from terminal 7 to terminal 14. Solder terminal 7. Connect the 220-ohm resistor from terminal 14 to terminal 17 on the potentiometer. Solder both terminals.

Connect the tvom ground clip to the chassis, plug in the power cord, touch the probe to terminal 17 and adjust the potentiometer to produce a voltage of exactly 3 volts ac. Remember to make an approximate adjustment on the 12V range first, and then switch to the 3V range.

Step 1. To measure the ac voltage drop across the 1K-ohm resistor R_1.

Leave the ground lead of the tvom clipped to the chassis and touch the probe to terminal 7. Read the meter carefully, then enter your reading on the first line of Fig. 26-3.

STEP	MEASUREMENT	YOUR VALUE
1	VOLTAGE ACROSS 1K	1.35
2	VOLTAGE ACROSS 500 Ω	.83
3	VOLTAGE ACROSS 220 Ω	.36
	TOTAL	2.94

Fig. 26-3. Results of Experiment 26.

Step 2. To measure the ac voltage across the 500-ohm resistance R_2.

Transfer the ground lead of the tvom to terminal 7. Touch the probe to terminal 14. Read the voltage, and record your reading on line 2 of Fig. 26-3.

Step 3. To measure the voltage across the 220-ohm resistor R_3.

Move the tvom ground clip to terminal 14. Touch the probe to terminal 17 of the potentiometer. Read the voltage, and enter your reading on line 3 of Fig. 26-3.

Unplug the line cord and remove all of the resistors. Wire the circuit shown in Fig. 26-4. Connect the 18K-ohm resistor from terminal 17 of the potentiometer to terminal 14. Connect the .1-mfd capaci-

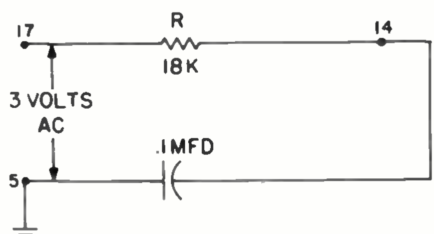


Fig. 26-4. Schematic diagram of the circuit used in Steps 4 and 5.

tor from terminal 14 to terminal 5. Solder all three connections.

Set your meter to the 12V range. Connect the ground clip of the tvom to the chassis, apply power to the voltage divider, and touch the probe to terminal 17. Adjust the potentiometer so that exactly 3 volts ac is applied to the test circuit.

Remember, the potentiometer that controls the supply voltage must be reset every time you change the parts used in an experimental setup. Each combination of parts draws a different current through the potentiometer and thus causes a different voltage drop across it, resulting in a different output from the voltage divider. Since we want to compare the results, we must set the divider voltage to the right value in each case. Also remember to switch your tvom to the 12V range when you start to adjust the potentiometer, and switch to a lower range only after you are sure it is safe to do so.

Step 4. To measure the ac voltage drop across the 18K-ohm resistor.

Connect the tvom negative lead to terminal 14. Touch the probe to the other lead of the resistor at terminal 17. Read the voltage and enter your reading

STEP NO.	NATURE OF MEASUREMENT	YOUR READING
4	VOLTAGE ACROSS 18K RESISTOR	1.6V
5	VOLTAGE ACROSS .1 MFD CAPACITOR	2.5V
	TOTAL	4.1V
	VECTOR TOTAL	2.968V

Fig. 26-5. Results of Steps 4 and 5.

in Fig. 26-5 as the voltage across the resistor for Step 4.

Step 5. To measure the ac voltage across the .1-mfd capacitor.

Transfer the black test clip to the chassis. Touch the probe to terminal 14. Measure the voltage, and enter your reading in Fig. 26-5 as the voltage across the capacitor fo Step 5. Unplug the power cord.

Discussion: The sum of the voltages you measured in Steps 1, 2 and 3 should be approximately equal to the source voltage. It will probably vary somewhat because of parts tolerances. However, add the voltages you have recorded for Steps 1, 2 and 3, and record your total in Fig. 26-3.

Next, add the voltages you measured in Steps 4 and 5, and record the sum on the line marked "Total" in Fig. 26-5. The sum of the voltages you measured across the capacitor and the resistor in Steps 4 and 5 should be greater than the source voltage, because the two voltage drops are not in phase. In fact, they are 90° out-of-phase. Therefore, we must add these voltages vectorially.

In drawing a vector diagram, we must have some starting point. In working with a series circuit, the current vector is used as a reference because current is common to all parts of a series circuit. The usual procedure is to draw the current vector first as a reference vector. In other words, the other vectors are drawn to show their relationship to the current vector. However, we have an 18K-ohm resistor in the circuit in Fig. 26-4, and the voltage across a resistor is always in phase with the current. Therefore, we can first draw the vector representing the voltage across the resistor and show the relationship of the other voltages to this vector.

As an example, let us suppose that we measured 1.75 volts across the resistor and 2.35 volts across the capacitor. We start the vector diagram by drawing a vector to represent the voltage across the 18K-ohm resistor. To do so, we draw a line OA as shown in Fig. 26-6, with the

Fig. 26-6. OA represents the voltage drop across the resistor.

amount of voltage drawn according to some convenient scale. If we use a scale of 1 volt per inch to draw the vector, line OA will be 1-3/4 inches long.

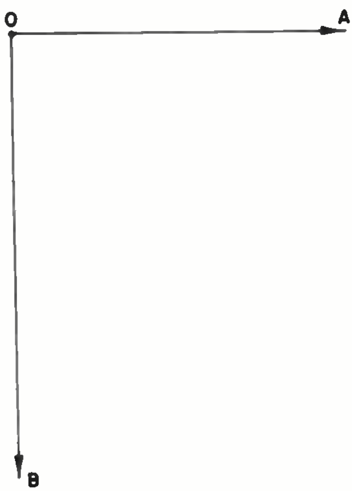


Fig. 26-7. OB represents the voltage drop across the capacitor.

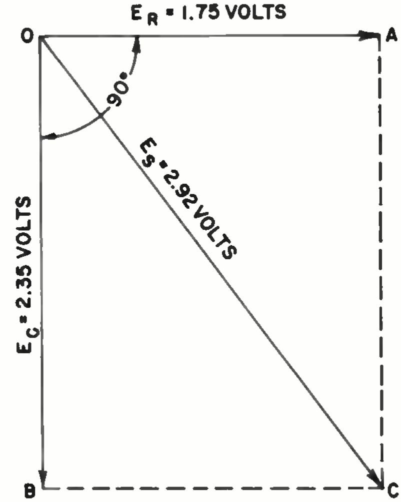


Fig. 26-8. Vector diagram of the sum of the voltage drops across the resistor and capacitor.

The voltage drop across the capacitor lags 90° behind the current, and hence lags 90° behind the resistor voltage drop also. Therefore, we draw the capacitor voltage vector straight downward from the origin O as line OB in Fig. 26-7, using the same scale to determine its length. If we measured 2.35 volts across the capacitor, this line will be a little over 2-5/16 inches long.

Now we complete the parallelogram by drawing line BC parallel to OA and line AC parallel to line OB. Next we draw the diagonal OC, as in Fig. 26-8, to represent the vector sum of the capacitor and resistor voltages. To find out how many volts OC represents, we measure its length and compare it with the voltage per-inch scale we used in drawing OA and OB. If you used a scale of one volt per inch, you should find that the length of OC is close to three inches.

The resultant could also be computed

mathematically by the process commonly used to solve right triangles. If you know how to solve this type of problem, using the Pythagorean Theorem, you can determine the vector sum in this way. If you are not familiar with this type of operation do not worry about it; use the graphical method.

Instructions for Statement No. 26: You have learned that the reactance of a capacitor decreases as its capacitance increases. If the capacitance is large enough, the current in a circuit can be almost as large as it would be if no capacitor were there.

We can, therefore, have a peculiar situation in a circuit that contains a large capacitor in series with the resistor. Even though the voltage drop across the capacitor may be appreciable, the fact that the voltage drops across the capacitor and the resistor are out-of-phase may mean that the voltage across the resistor is just about what it would be if the capacitor were out of the circuit.

To show this, connect the two .25-mfd capacitors in parallel with the .1-mfd capacitor as shown in Fig. 26-9. The total capacitance in the circuit is now .6-mfd.

Apply power to the voltage divider, and adjust the potentiometer until exactly 3 volts is applied between terminal 17 and the chassis. Measure the voltage drops across the 18K-ohm resistor and the .6-mfd capacity, and make notes of both. 7.4V 2.92

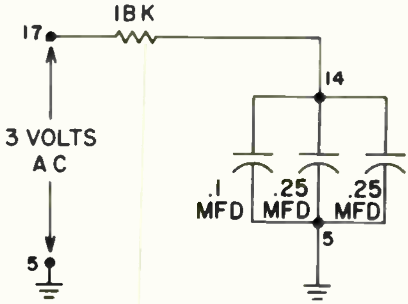


Fig. 26-9. Circuit for Statement 26.

Compare the resistor voltage you obtained in this Statement experiment with the one you found in Step 4. Bearing in mind that the voltage across the resistor is proportional to the current flowing in the circuit, determine what effect increasing the capacitance has had on the current. Finally, compare the voltage drop across the resistor with your source voltage of 3 volts. Complete the Statement below and on the Report Sheet.

Disconnect the power cord and turn off the tvom. Unsolder and remove the three capacitors and the resistor from the chassis, and lay them aside for future experiments.

Statement No. 26: When I used a capacity of .6-mfd instead of .1-mfd, I found that the current through the circuit:

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

I found the resistor voltage to be:

(1) much higher than
(2) much lower than
(3) almost equal to

the source voltage.

MOUNTING THE CHOKE COIL

Before going on to the next experiment, you must mount the choke coil on

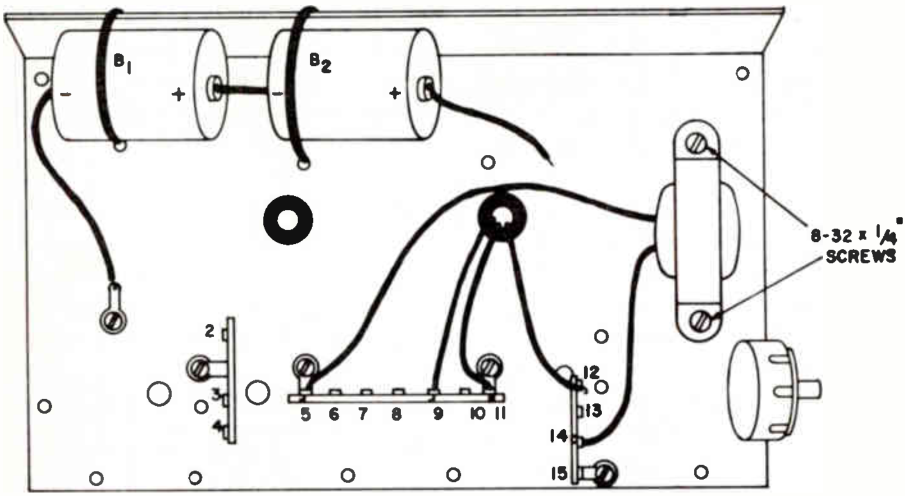


Fig. 14. The choke mounted on the experimental chassis.

the chassis. You will have to move one of the flashlight cells to make room.

You will need the following:

1 Choke coil (CO26)
2 1/4" X 8-32 screws
2 8-32 hex nuts
2 No. 8 lockwashers

Move flashlight cell B_2 from the right side of your chassis to the left as shown in Fig. 14. Shorten the wire connecting the two cells together if you wish. To secure the cell to the chassis, you can run a length of hookup wire or string through hole F in the chassis between the unused rubber grommet and the bend in the chassis.

Position the choke on top of the chassis exactly as shown in Fig. 14. Pass 1/4" X 8-32 screws down through the holes in the mounting feet of the choke and through holes M and N in the chassis. Attach with No. 8 lockwashers and 8-32 hex nuts and tighten.

Connect and solder one choke lead to terminal 5. Connect and solder the other choke lead to terminal 14.

EXPERIMENT 27

Purpose: To show that the opposition offered by a coil to the flow of an alternating current is many times its opposition to the flow of a direct current.

Introductory Discussion: Coils are usually wound of copper wire, which, when stretched out, is practically as good a conductor for low frequency ac as it is for dc. Winding the wire in the form of a coil makes no change in its dc resistance, but it does cause a great increase in its inductance, thereby increasing its inductive reactance and its impedance. The opposition that the coil offers to ac, therefore, is much greater than its opposition to dc.

You have studied these properties in your lessons. We shall consider only the opposition of the coil to ac as compared to its opposition to dc in this experiment, but we suggest that you review these lessons to refresh your memory concerning the impedance, reactance, and inductance of coils and the application of Ohm's Law to them.

You will first determine the current through an iron-core choke coil when it is connected in series with a resistance of 1000 ohms to a 3-volt dc source. Next, you will apply 3 volts ac to the circuit, and determine the current. Finally, you will compare the two currents. Your results will show that the alternating current is much less than the direct current.

Experimental Procedure: You will need the experimental chassis, the tvom and the following:

2 1K-ohm resistors

Wire the circuit shown in Fig. 27-1.

The symbol **L** is used on schematic diagrams to represent a coil or an inductance. The parallel lines beside it indicate that the coil has an iron core.

Solder one lead of a 1K-ohm resistor to terminal 14. Connect the other resistor lead to terminal 13. Solder the free end of the positive battery lead to terminal 13.

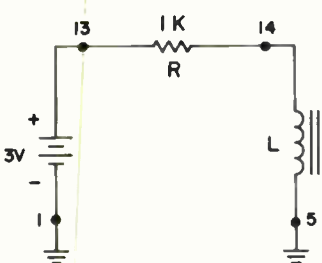


Fig. 27-1. Schematic for Step 1.

Step 1. To measure the dc voltage drop across the 1K-ohm resistor.

First, prepare your tvom for dc measurements on the 3V range. Fasten the ground clip to terminal 14 and touch the probe to terminal 13. Read the meter, and record your reading in Fig. 27-2.

STEP NO.	NATURE OF MEASUREMENT	YOUR VALUE IN VOLTS
1	DC VOLTS ACROSS R	1.75
3	AC VOLTS ACROSS R	.5V

Fig. 27-2. Results of Steps 1 and 3.

Since the resistance is 1000 ohms, the voltage across the resistor in volts will be equal to the current in milliamperes through the resistor. This was demonstrated in an earlier experiment.

Now, disconnect the test leads from the resistor, and unsolder the positive battery lead.

Step 2. To apply an ac voltage equivalent to the dc voltage used in Step 1 to the circuit.

Set up the circuit shown in Fig. 27-3. Unsolder the lead of the 1K-ohm resistor from terminal 13 and solder it to terminal 17 on the potentiometer. Switch the function switch in your tvom to ac. Connect the ground lead to the chassis, apply power to the voltage divider, touch the probe to terminal 17, and adjust the potentiometer to produce a voltage of exactly 3 volts.

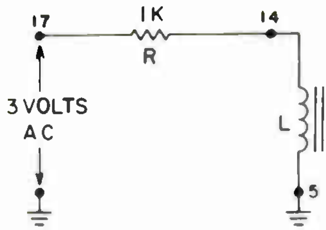


Fig. 27-3. Schematic of the circuit used in Step 2 and Step 3.

Step 3. To measure the ac voltage across the 1K-ohm resistor.

Move the ground clip to terminal 14, and touch the probe to terminal 17. Read the meter carefully on the 3V scale. Record your reading in Fig. 27-2, and unplug the voltage divider.

Discussion. The voltage you measured across the 1K-ohm resistor when a dc voltage was applied in Step 1 should have been considerably greater than the ac voltage drop you measured in Step 3, thus proving that the circuit current was less. Since the only difference between the circuits used for these two steps is the nature of the source voltage, we can say that the opposition offered by a coil is much greater for ac than for dc.

The opposition that your coil offers to alternating current is known as its impedance and is measured in ohms. There are several ways in which it can be determined. One quick method, which does not involve complex equipment and yet is reasonably accurate, is to connect the coil in series with a resistor, apply an ac voltage of known frequency, and measure the voltage drops across the resistor and the coil. Since the voltage drop across each part is proportional to the opposition offered by that part, we can set up the following equation:

$$\frac{E_L}{E_R} = \frac{Z}{R}$$

where E_L is the voltage across the coil, E_R is the voltage across the resistor, R is the resistance of the resistor, and Z is the impedance of the coil. This can be simplified by writing the equation in this form:

$$Z = \frac{E_L \times R}{E_R}$$

For your report on this experiment, you will find the approximate impedance of the coil by using this method. The impedance of the coil establishes the amount of current through the coil at the time of the measurement.

Instructions for Statement No. 27: Use the circuit shown in Fig. 27-3, but reduce the resistance of R to 500 ohms. This can be done by connecting another 1K-ohm resistor in parallel with the one now in series with the choke coil. When you have soldered the resistor in place, connect the tvom to the output of the voltage divider, and apply power. Adjust the potentiometer until a voltage of exactly 3 volts is applied to the coil and resistor.

Measure the ac voltage across the 500-ohm resistance; then measure the voltage across the coil. Use the 3V range for both measurements. Make a note of the readings you get, and unplug the ac power cord. .32V 2.734

To find the approximate impedance of your coil, use the formula

$$Z = \frac{E_L \times R}{E_R}$$

Multiply the voltage across the coil by 500 (the resistance of the resistor). Then divide the result by the voltage across the 500-ohm resistor. The result you get is the approximate impedance of the coil in ohms.

4.5KΩ Make a note of the value you obtained for the impedance of the coil, and then determine the dc resistance of the coil. You can use the ohmmeter section of your tvom to measure the dc resistance, but you must disconnect one lead of the coil in order to do this. Unsolder the choke coil lead from terminal 5, and connect the ground clip to one choke lead and the probe to the other lead. Reconnect the choke lead to terminal 5. Now, compare the impedance of the coil with the dc resistance, and answer the Statement.

300Ω

Statement No. 27: When I compared the dc resistance of the choke coil with its impedance, I found that the resistance was:

(1) less than
(2) approximately equal to
(3) greater than

the impedance of the coil.

EXPERIMENT 28

Purpose: to show that the voltage drop across a coil is less than 90° out-of-phase with the current flowing through it because the coil has appreciable ac resistance; and

To show that we can find the phase angle by using vectors.

Introductory Discussion: In a previous experiment, you proved that the vector sum of the voltage across a capacitor and a resistor in series is equal to the source voltage, if the drop across the capacitor is considered to be 90° out-of-phase with the resistor voltage.

In any good solid-dielectric capacitor, the ac resistance is so small that it can be ignored. Therefore, we can say that the impedance of such a capacitor is equal to its reactance. Thus, the voltage across the capacitor is 90° out-of-phase with the current through it and 90° out-of-phase with the voltage across any resistor in series with it.

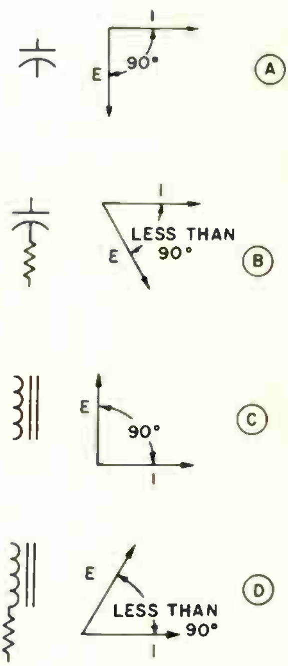


Fig. 28-1. The general phase relationship between the terminal voltage and the current when we have: (A) a pure capacitance; (B) a capacitance plus series resistance; (C) a pure inductance; (D) an inductance plus a series resistance.

However, always remember that the ac voltage we measure across any device is the voltage across the total opposition or impedance of that device. Fig. 28-1 shows the relationships. At A we have shown a device that contains only a capacitor. The phase relationship between the circuit current and the voltage across the terminals of the device is shown at the right; the voltage lags 90° behind the current because the impedance is made up solely of the reactance of the capacitor. If there is any appreciable resistance in the device, however, as shown at B, the phase angle is less than 90°. This device may be an electrolytic capacitor, since an electrolytic does have appreciable internal resistance.

If the impedance of a coil were made up of the coil reactance only, as at C, the coil voltage would *lead* the current by 90°. However, there is probably no coil that has so little resistance that it will act as a pure inductance. Every coil has some ac resistance, and it is always greater than the dc resistance because of skin effect, dielectric losses, and, in iron-core coils, core losses. The skin effect is the tendency of alternating currents to flow only along the surface of the wire rather than throughout its entire cross-section. At higher frequencies, these effects become much more noticeable. Thus, rf coils, which usually have low dc resistances, may have fairly high ac resistances.

The choke coil you will use in these experiments has a dc resistance of at least 400 ohms. Of course, its ac resistance is considerably higher. Unfortunately, there is no direct and simple method of finding its ac resistance; an ohmmeter will measure only the dc resistance.

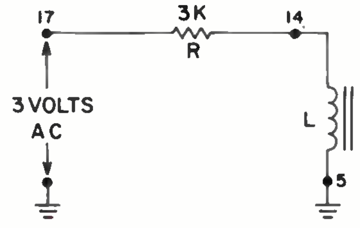


Fig. 28-2. Schematic of circuit used in Step 2.

To take this ac resistance into account, we treat the coil as though it were made up of a pure inductance in series with a resistance as in Fig. 28-1D. We can see what its total impedance is made up of with the aid of a vector diagram. The method we will use in this experiment is often called the 3-voltage vector method of finding the ac resistance and the inductive reactance of coils.

Experimental Procedure: For this experiment, you need the experimental chassis, tvom and the following:

1 3K-ohm resistor, 5%
2 .25-mfd capacitors

Set up the circuit shown in Fig. 28-2. To do this, unsolder and remove the two 1K-ohm resistors used in the last experiment and solder the 3K-ohm resistor in their place between terminals 14 and 17.

Connect the ground clip of the tvom to the chassis. Set the function switch to ac and apply power to your chassis. Touch the probe to terminal 17 and adjust the potentiometer until the voltage is exactly 3 volts, measured on the 3V range.

Step 1. To measure the ac voltage across the 3K-ohm resistor.

STEP NO.	NATURE OF MEASUREMENT	YOUR VALUE IN VOLTS	NRI VALUE IN VOLTS
1	VOLTAGE ACROSS R	1.56	1.5
2	VOLTAGE ACROSS L	2.36	2.25

Fig. 28-3. Results of Steps 1 and 2.

Connect the ground lead from the tvom to terminal 14. Apply power and touch the probe to the other end of the resistor at terminal 17. Read the voltage on the 3V ac scale. Record your reading for Step 1 in Fig. 28-3 as the voltage across R.

Step 2. To measure the ac voltage across the coil.

Clip the ground lead to the chassis and touch the probe to terminal 14. Read the voltage, and enter your reading in Fig. 28-3 as the voltage across L. Unplug the power cord.

Discussion: We are now going to show how the measurements you just made can be used to show that the phase angle between the voltage and current in the coil is less than 90°, and to compute the inductance and ac resistance of a coil. To illustrate our explanation, we will work out these characteristics for the coil on which we made measurements at NRI. In this experiment, you are to determine that the phase angle in your coil is less than 90°, but you do not have to compute the inductance and ac resistance unless you want to do so.

The NRI results for Steps 1 and 2 are given in Fig. 28-3. Yours will not necessarily be the same. If we consider the voltage drop across the coil to be exactly 90° out-of-phase with the voltage drop across the resistor, as it would be in a pure inductance, and add these values vectorially as in Fig. 28-4, our resultant is only 2.7 volts. Since this value is less than the source voltage of 3 volts, the voltage across the coil must not actually be 90° ahead of the resistor voltage. The reason is that the coil has considerable resistance. Using your readings, draw a vector diagram like that in Fig. 28-4 to show that the phase angle in your coil has to be less than 90°.

We don't know what the angle should be, and we can't calculate it without using rather complex mathematics. We can, however, use vectors to solve the problem. The method of doing so is shown in Fig. 28-5. Let's see how to use it.

We already know the three voltages for our vector diagram. What we do not know is the angle between them. To plot the angles, we start by using the voltage we measured across the series resistance

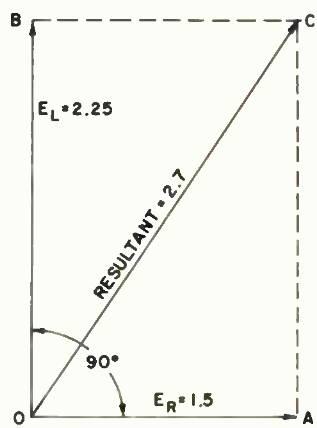


Fig. 28-4. The resultant, which is the vector sum of the voltages across the resistance and inductance, does NOT equal the source voltage.

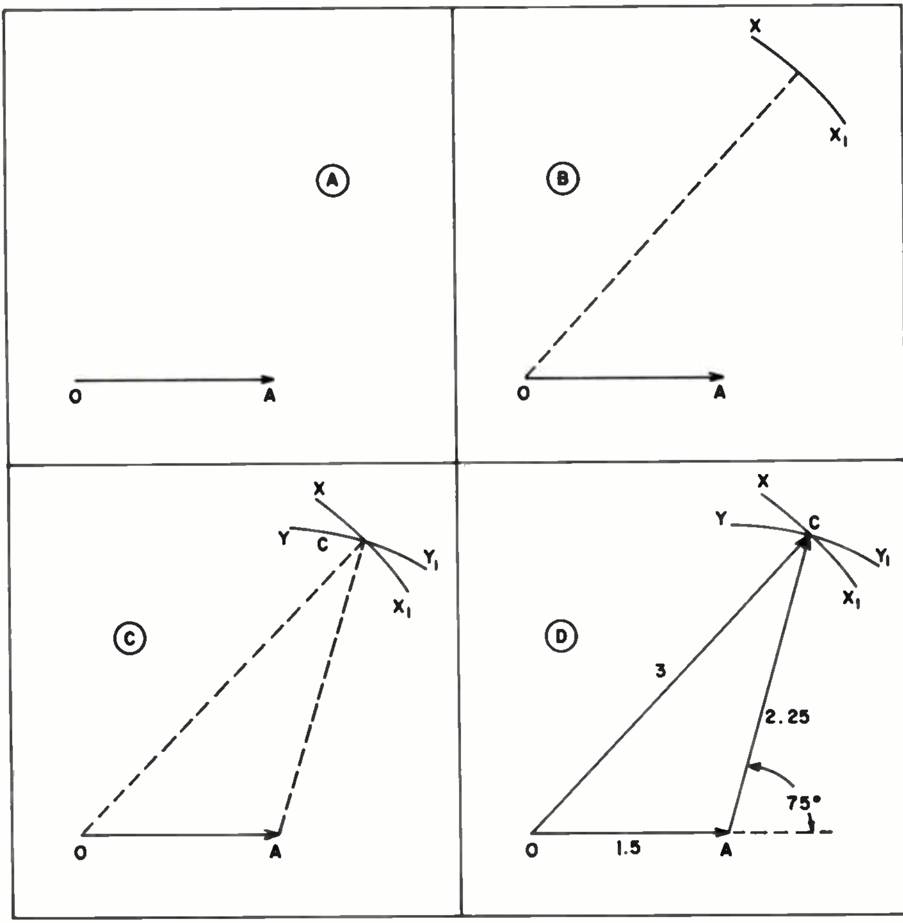


Fig. 28-5. How to use the three-voltage vector method of determining the voltage drop across the ac resistance of the coil, and the vector method of finding the voltage drop across the reactive component of the coil.

as a reference vector because it is in phase with the circuit current.

Using the figures shown in Fig. 28-3 for the coil we measured here at NRI, we plot a line, OA, to represent 1.5 volts. (The diagrams in Fig. 28-5 are *not* drawn to a scale of 1 inch equals 1 volt because of space limitations.) Now, draw your line OA to represent the voltage you measured across the 3K-ohm resistor. Use a scale of 1 inch equals 1 volt.

Using this same scale, we know that the resultant, which we have called OC in our previous vector diagrams, will be 3 inches long; it is our source voltage. It will start at point O. So the next thing we do is to use an ordinary drafting compass to draw an arc, using point O as the center, with a radius of 3 inches. This arc is called $X\text{-}X_1$ in Fig. 28-5B. Point C will fall somewhere on this arc.

As you learned earlier, line AC will be the same length and at the same angle as the other voltage vector, which we called OB in previous diagrams. In this case it is the voltage across the coil, which is 2.25 volts. Therefore, we draw another arc. This time the radius is 2.25 inches, and we use point A as the center. This is called $Y\text{-}Y_1$ in Fig. 28-5C. The point where these two arcs cross is point C. By drawing in lines OC and AC, as shown in Fig. 28-5D, we can find the phase angle between the coil voltage and the resistor voltage. In this vector diagram, the sides of the angle are made up of the line AC and the dashed line. This was explained previously in reference to Fig. 13D. For this particular coil, the angle is 75°. Since the resistor voltage and the circuit current are in phase, we know that the coil voltage is 75° ahead of the coil current.

You need not measure the angle; the important point to see is the phase angle between the current and voltage is less than 90° because the coil is not a pure inductance. This is as far as you need go in your calculations. However, we will show you how additional information can be obtained from these results.

So far, we have a vector diagram in which the sum of the voltage drops across the impedance of the coil and across the series resistance is equal to the source voltage. By using this information, we can find the voltage drops across the reactance and the ac resistance of the coil. From these, we can find the inductance and the ac resistance.

We can consider that the voltage across the coil impedance is the vector sum of two voltages 90° out-of-phase -- one across a pure inductance and one across a resistance.

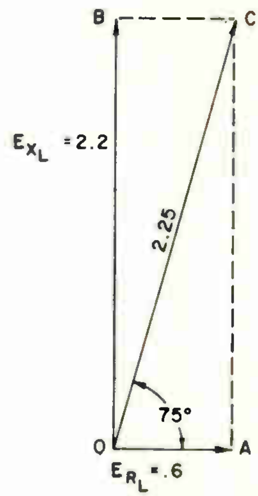


Fig. 28-6. How we find the voltage drop across the reactance and the ac resistance of the coil.

Therefore, we can draw another vector diagram using the coil voltage (line AC in Fig. 28-5D) as the resultant, as shown in Fig. 28-6. In this diagram we call this line OC. We know that it is 75° from the reference vector, and that the voltage across the coil resistance (E_{R_L}) is 90° out-of-phase with the voltage across the coil reactance (E_{X_L}). Therefore, we can draw these voltage vectors at right angles to each other.

So far, we know the angle of the two voltage vectors, but not their length. To find the length, we draw a line down from point C to form a right angle with the horizontal line, to give us point A. Then, we draw another line across from point C to form a right angle with the vertical line, to give us point B. By measuring the length of these vectors, we can find the voltage they represent. For this particular coil, the voltage across the coil resistance (E_{R_L}) equals .6 volt, and the voltage across the coil reactance (E_{X_L}) equals 2.2 volts.

To find the reactance of the coil, we divided E_{X_L} by the current. To find the current, we go back to the voltage across the 3000-ohm series resistance, which we recorded in Fig. 28-3. Our value was 1.5. Dividing this by 3, we get .0005 amperes as the circuit current. Now, dividing E_{X_L} by the current, we have 2.2 divided by .0005, which give us 4400 ohms as the inductive reactance (X_L) of the coil.

To find the inductance, we use the formula:

$$L = \frac{X_L}{2\pi f}$$

where 2π is 6.28 and f is 60, the frequency of the power line voltage. Substituting our values, we have:

$$L = \frac{4400}{6.28 \times 60} = \frac{4400}{376.8} = 11.7 \text{ henrys}$$

We can find the ac resistance of the coil by measuring the length of line OA and dividing this voltage value by the value of the circuit current. The length of line OA is .6 inches, which represents .6 volt. The ac resistance of the NRI coil works out to be $.6 \div .0005 = 1200$ ohms. Notice how much higher the ac resistance is than the dc resistance. The dc resistance of the coil we used was only 400 ohms.

You can determine the inductance and ac resistance of your coil if you wish to do so, but this is not necessary. However, be sure you understand that the ac resistance of a coil is much higher than the dc resistance, and also that the phase angle between the current and voltage in a coil is less than 90° because of the ac resistance of the coil.

Instructions for Statement No. 28: For this statement, you are to find out what happens to the circuit current when a capacitor is placed in parallel with the choke coil in a circuit like that shown in Fig. 28-7. Connecting a capacitor between the terminals of the choke coil provides another path, parallel to the one through the choke coil. Therefore, it would appear that the current through the resistor should increase.

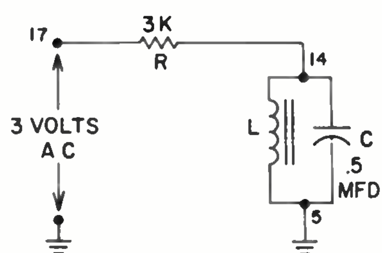


Fig. 28-7. Schematic of circuit used for Statement 28.

With the chassis connected as in Fig. 28-2, plug in the voltage divider, and adjust the potentiometer to get exactly 3 volts at the output between terminal 17 and ground. Measure the voltage across the 3K-ohm resistance and make a note of your reading in the margin of this page. 1.6V

Unplug the chassis, and set up the circuit shown in Fig. 28-7. Connect the two .25-mfd capacitors in parallel from terminal 5 to terminal 14. The two capacitors have a total capacitance of .5 mfd. Apply ac power and adjust the input to 3 volts. Note that the capacitors are in parallel with the choke coil. Now, measure the voltage across the resistor again. Compare this reading with your previous reading and answer the Statement below and on the Report Sheet.

Unplug the voltage divider; then unsolder and remove the two .25-mfd capacitors. Leave the 3K-ohm resistor connected to terminals 14 and 17.

Statement No. 28: When I connected the capacitors in parallel with the choke coil, I found that the circuit current, as indicated by the resistor voltages, was:

(1) the same as
(2) higher than
(3) lower than

it was before the capacitors were connected.

EXPERIMENT 29

Purpose: to show that when a coil and a capacitor are connected in series across a source of ac voltage, the reactance of one tends to cancel that of the other, thus causing the circuit current to increase.

Introductory Discussion: The measurements you have made so far in your ac experiments have shown only that coils and capacitors offer a definite amount of opposition to the flow of alternating currents, and that the voltage across a coil or capacitor is out-of-phase with the current flowing through the device.

We know that the voltage across the inductive reactance of a coil leads the current through the coil by 90°, and that the voltage across a capacitor lags 90° behind the current through the capacitor. Therefore, when a coil and a capacitor are connected in series so that the current flowing through one also flows through the other, the voltages across the capacitor and the inductive reactance of the coil are 180° out-of-phase. As a result, the two voltages tend to cancel each other and the net voltage across the combination of the coil and the capacitor is the difference between them.

If the voltage across the capacitor is greater than the voltage across the coil, the net reactance will be capacitive and the combination will act like a capacitor. On the other hand, if the voltage across the coil is greater, the net reactance will be inductive, and the combination will act like a coil. However, if the two voltages are equal, there will be no reactance -- the only opposition to the circuit current will consist of the ac resistance of the coil and whatever other resistance there may be in the circuit. This condition is known as resonance.

In this experiment, you will first connect a capacitor in series with a resistor and determine the opposition (impedance) the capacitor offers to the flow of ac. You will then place your choke coil in series with the capacitor and the resistor and note the effect on the circuit current. If the current increases, you know that the coil must have reduced the impedance of the circuit. This is evidence that the coil has partly cancelled the opposition of the capacitor to the flow of current.

The amount of cancellation effect any given coil has depends on the capacitance value used with it. This can be shown either mathematically or experimentally. For the experimental approach, we will connect various capacitance values in series with a given coil and measure the voltage drops across the coil and capacitor. When the voltage across the reactive component of the coil equals the voltage across the capacitor, the circuit is at resonance. You will also see that at resonance the voltage across the capacitor and the voltage across the coil may actually exceed the source voltage.

Experimental Procedure: In addition to the ac voltage source, with the 3K-ohm resistance connected to it and your tvom, you will need:

2 **.25-mfd capacitors**
1 **.1-mfd capacitor**

The 3K-ohm resistor should still be connected to terminal 17 of the ac

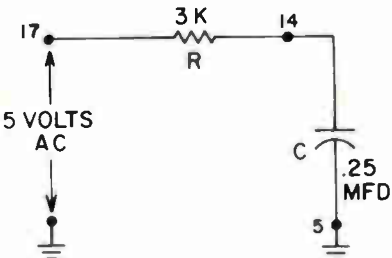


Fig. 29-1. Schematic for Step 1.

voltage source. Therefore, to form the series circuit shown in Fig. 29-1, unsolder the choke lead from terminal 14 and connect a .25-mfd capacitor from terminal 14 to terminal 5. Solder both connections. Connect the tvom test leads to terminal 17 and the chassis. Apply power to the circuit, and adjust the potentiometer to produce an output of exactly 5 volts. Use the 12-volt range of your tvom.

VOLTAGE MEASURED ACROSS	VALUE
3000 - OHM RESISTANCE	1.36
.25- MFD CAPACITOR	5.8

Fig. 29-2. Results of Step 2.

Step 1. To measure the ac voltage drops across the 3K-ohm resistor and the capacitor.

Connect the ground clip to terminal 14, and touch the probe to terminal 17 of the potentiometer. Enter your reading in Fig. 29-2. Then touch the probe to terminal 5 to measure the voltage across the capacitor, and again enter your reading in the proper space in Fig. 29-2. Unplug the power cord.

Step 2. To determine the effect of adding a coil to the series circuit.

Rewire your circuit as shown in Fig. 29-3. Move the capacitor lead from terminal 14 to terminal 6. Reconnect the free choke lead to terminal 14 and move the other choke lead from terminal 5 to terminal 6.

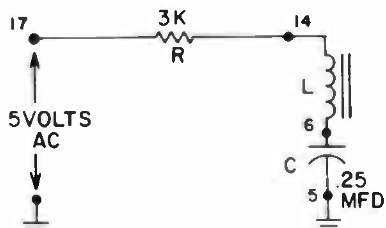


Fig. 29-3. Schematic of circuit used in Step 2. We change capacitor values in Step 3.

VOLTAGE ACROSS	VALUE	NRI VALUE
R	2.2	2.2
L	3.2	3.4
C	7 7	6.5

Fig. 29-4. Record the values found in Step 2.

When you have the circuit set up, apply power to the voltage divider, and adjust the potentiometer for a voltage of exactly 5 volts between terminal 17 and ground.

Connect the ground clip of your tvom to the junction of the resistor and the choke at terminal 14. Touch the probe to terminal 17 of the potentiometer, and measure the voltage drop across the 3K-ohm resistor. Record this reading in the first space in Fig. 29-4. Now, touch the probe to the junction of the choke and capacitor at terminal 6 and measure the voltage across the choke coil. Record your reading in Fig. 29-4.

To measure the voltage drop across the capacitor, move the ground lead of your tvom to the chassis, and touch the probe to terminal 6. Record your reading in Fig. 29-4. (Your readings may not be exactly the same as ours.)

To see if the current has increased, compare the voltage across the resistor in Fig. 29-2 with the reading you recorded in Fig. 29-4. Also, notice the voltages you have recorded for the capacitor and coil in Fig. 29-4.

Step 3. To show the effect on circuit conditions when different values of capacitance are used in combination with the coil.

Use the same circuit shown in Fig. 29-3, but change the value of the capacitor according to the values listed in the first column in Fig. 29-5. Take the measurements exactly as you did in Step 2. However, each time you connect a different value of capacitor in the circuit, make sure you connect the tvom leads from terminal 17 to ground, and set the ac source for a voltage of exactly 5 volts.

Connect a .1-mfd capacitor into the circuit and take the necessary voltage measurements. Record the values. You already have the voltage values for a .25-mfd capacitor in the circuit. Enter the values you recorded in Fig. 29-4 in the proper spaces in Fig. 29-5. You can form a .35-mfd capacitor by connecting a

CAPACITANCE	PARALLEL CAPACITOR COMBINATION	COIL VOLTAGE	CAPACITOR VOLTAGE	RESISTOR VOLTAGE
.1 MFD	ONE .1 MFD	.86	5.8	.68
.25 MFD	ONE .25 MFD	~~[illegible]~~ 3.2	7.7	2.2
.35 MFD	.25 MFD AND .1 MFD	5.0	8.2	3.2
.50 MFD	TWO .25 MFD	6.3	6.6	4.0
.60 MFD	TWO .25 MFD AND .1 MFD	6	6.6	4.2

Fig. 29-5. Results of Step 3.

.25-mfd capacitor in parallel with the .1-mfd capacitor. In a similar way, make up a .5-mfd by putting the two .25-mfd capacitors in parallel, and a .6-mfd by using the two .25-mfd capacitors and the .1-mfd capacitor in parallel. Measure the voltage across the coil, the voltage across the capacitor, and the voltage across the 3K-ohm resistance for each value of capacitance. Record your reading in Fig. 29-5.

When you have completed the readings needed for Fig. 29-5, unplug the voltage divider and unsolder and remove the capacitors and the resistors from the circuit.

Discussion: To show that the voltage drops across the coil and capacitor must in some way oppose or cancel each other, let us use the NRI values in Fig. 29-4 to draw the vector diagram in Fig. 29-6. We must take one additional measurement, however. This is the drop across the coil and the resistor. From this vector, we can determine the phase relationships, the resultant voltage differences in the circuit; and from these voltages, compute the total circuit reactance. You are not required to draw the vector or compute the reactances in this experiment. However, you may do so if you wish.

We can get a great deal of information from the vector diagram in Fig. 29-6. For example, the angle formed by lines BC and BD tells us that the voltage across a coil leads the voltage across the resistor (line OB, which is used here as the reference) by less than 90°. The line, CD, tells us that there is a voltage drop of 3.07 volts across the coil reactance (E_{X_L}), and the short line BD indicates that the voltage drop across the ac resistance of the coil is 1.45 volts.

Line DE is the voltage drop across the reactance of the capacitor (E_{X_C}). We learned in Experiment 27 that the voltage drop across a capacitor is 90° out-of-phase with the source voltage in the circuit. Thus, line DE is drawn straight downward from point D. The length of this line corresponds to 6.5 volts -- the voltage drop across the capacitor.

We now have the voltage drop across the inductive reactance (line CD) and the voltage drop across the capacitive re-

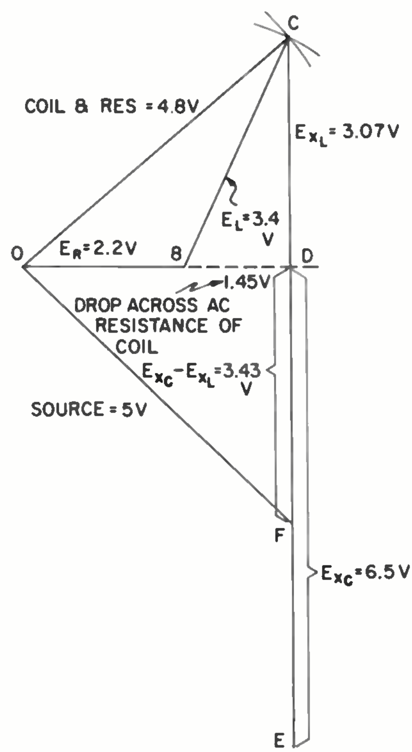


Fig. 29-6. Complete vector diagram of voltage relationship in a circuit consisting of a capacitor, a coil, and resistance connected across a source of ac voltage.

actance (line DE). As you learned in Step 2 of this experiment, these reactances oppose each other, and the net reactance or opposition to the current flow is the difference between the two voltage drops. This is shown in the diagram in Fig. 29-6. Beginning at point E, we subtract 3.07 volts, the length of line CD, from line ED. This leaves a total of 3.43 volts (line DF) as the net drop across the circuit reactance. We can prove that the length of line DF is actually the voltage drop across the net reactance by measuring the line from point F to point O. This is 5 volts -- the voltage of the source.

With this information, we can compute the circuit reactances and see that adding the coil *does* reduce the total reactance in the circuit. To compute the reactance, we divide the voltage drop across the reactance by the amount of current in the circuit, or R = E/I. The current, of course, is equal to the voltage drop across the 3000-ohm series resistor (2.2 volts) divided by 3000, or I = E/R. This works out to be approximately .0007 ampere.

Using the reactance formula, we find that the reactance of the capacitor alone is approximately 10,400 ohms. But when we compute the net reactance in the series circuit, as indicated by line DF in Fig. 29-6, we find that it is approximately 4900 ohms. (We compute the reactance by dividing the net voltage, 3.43 volts, by the circuit current, .0007 amperes.) From this we can see why the voltage drop across the components increased when we put the coil in the circuit. The voltage drops across the coil and capacitor actually opposed each other to produce a lower net reactance in the circuit, which caused an increase in the circuit current. This was indicated by the increase in the voltage drops across the circuit components.

In Step 3, you varied the capacitance value in the series circuit, and from your results that you recorded in Fig. 29-5, you should notice that the voltage drops across the components increased as you increased the value of the capacitance. You may notice that with one value of capacitance, the voltage drops reach their highest values. The fact that the higher voltage drops exist in the circuit shows that the circuit reactance must have become very low. This point is the resonance point for the coil-capacitor combination.

As you increased the capacitance further, you probably noticed that the voltage drops began to decrease. It is not necessary for you actually to reach resonance in this experiment. It is important only that you understand that the voltage drops across the coil-capacitor combination in a series circuit increase as the circuit capacitance is increased.

The resonant point of the series-resonant circuit can be shown graphically as in Fig. 29-7. Notice from the graph

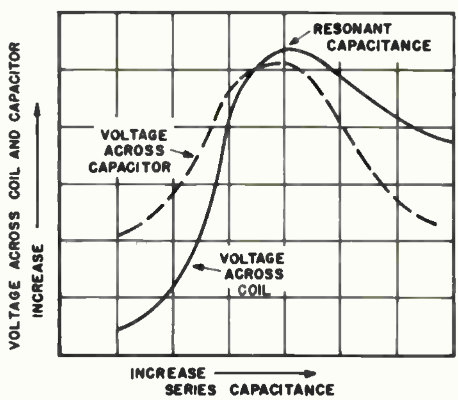


Fig. 29-7. Resonance in a series-resonant circuit.

that the voltage drops across the coil and capacitor increase with an increase in capacitance until a value is reached where both curves reach a maximum. This is the resonant point in the circuit. As the capacitor value is increased further, the voltage drops decrease, as indicated by the curves.

Instructions for Statement No. 29: You need not take any additional readings. Just examine the voltage readings you took across the capacitor in Fig. 29-5, and answer the Statement.

Statement No. 29: The highest voltage that I measured across the capacitor was:

(1) higher than
(2) lower than
(3) equal to

the source voltage.

EXPERIMENT 30

Purpose: To show that shunting a capacitor across an inductance in an ac circuit will cause the line current to decrease; and

To show that when the reactance of the coil equals the reactance of the capacitor, the line current becomes a minimum, indicating that the combination has a high impedance.

Introductory Discussion: As you demonstrated in the preceding experiment, the principal characteristic of a series-resonant circuit is that at resonance it acts like a low resistance. This, of course, produces a high current through the circuit and a high voltage drop across the coil and capacitor. There are many circuit applications, however, in which the opposite effect is desirable. One of many practical examples of this is a wave trap designed to filter out undesired frequencies at the input of a radio or television receiver.

As you learned in your lessons, a parallel-resonant circuit at resonance acts like a high resistance. You will prove this by measuring the current in a circuit in which you will connect various capacitors in parallel with the coil.

The current in this circuit must divide between the two components. Part of the current will flow through the capacitor and the remainder through the coil. The circuit acts like a high resistance because the currents of the two branches are 180° out-of-phase. (This is just the opposite of the conditions in a series-resonant circuit, in which the voltages are 180° out-of-phase.) The net circuit current, which is the difference between the currents in the two branches of the parallel circuit, is, therefore, relatively small. In fact, it is just large enough to make up for the losses in the parallel-resonant circuit. As in a series-resonant circuit, these losses are due primarily to the ac resistance of the coil.

If you had an instrument sensitive enough, you could measure the current through the coil as various capacitors were connected across it. As you approached resonance, you would find that there was an increase in the current flowing in the parallel circuit, which would be accompanied by a corresponding decrease in the current in the rest of the circuit. With the equipment we have at hand, however, you can measure only the current flowing through the entire circuit with any degree of accuracy. Therefore, we shall assume that the impedance of the parallel-connected coil and capacitor is at its maximum when the circuit current is at its minimum.

Experimental Procedure: You need the experimental chassis, tvom and the following:

- **2 .25-mfd capacitors**
- **1 .1-mfd capacitor**
- **1 1K-ohm resistor**
- **1 18K-ohm resistor**

Construct the circuit shown in Fig. 30-1. Replace the 3000-ohm resistor with a 1000-ohm resistor. Then, unsolder the choke lead from terminal 6 and solder it to terminal 5.

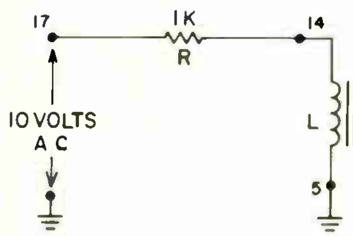


Fig. 30-1. Schematic of the circuit for Step 1.

Apply power to the circuit, and adjust it to produce a voltage of exactly 10 volts across the output of the ac voltage divider between terminal 17 and the chassis.

Step 1. To find the current through the coil and the resistor.

Measure the voltage drop across the 1K-ohm resistor by connecting the ground clip of the tvom to terminal 17 and the probe to terminal 14. Since the resistance is 1K-ohms (± 10%), the current (in milliamperes) through it is the same as the voltage across it in volts.

For example, our measurement for this step was 1.6 volts. Dividing this by 1000 to get the current in amperes gives a value of .0016, which is 1.6 milliamperes -- numerically the same as the voltage value. Record your voltage reading on the first line of Fig. 30-3. (It may not be the same as ours.) Unplug the line cord.

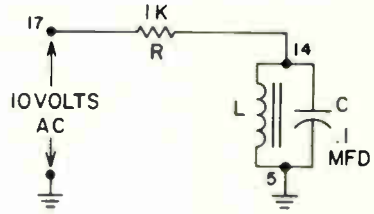


Fig. 30-2. The circuit for Step 2.

Step 2. To show that the circuit current decreases when a capacitor is connected across the choke coil.

Solder a .1-mfd capacitor across the terminals of the choke coil to form the circuit shown in Fig. 30-2, adjust the voltage between terminal 17 and ground to exactly 10 volts, and again measure the voltage drop across the 1K-ohm resistor.

STEP NO.	CAPACITANCE (IN MFDS)	VOLTAGE ACROSS RESISTOR	
		YOUR VALUE IN VOLTS	NRI VALUE IN VOLTS
1	NONE	[illegible]	1.6
2	.10	1.5	1.2
3	.25	1.0	.8
	.35	.66	.7
	.50	.25	.35
	.60	.35	.5

Fig. 30-3. Record results for Steps 1, 2, and 3.

Enter your voltage reading on the second line of Fig. 30-3.

Step 3. To show how the circuit current varies as different values of capacitance are connected across the coil.

Replace the .1-mfd capacitor in turn with each capacitance listed for Step 3 in Fig. 30-3. (These values of capacitance are the same as those you used in the previous experiment, and are formed the same way.) Each time the capacitance is changed, be sure to readjust the input voltage to exactly 10 volts, and then measure the voltage drop across the resistor. You need not measure the voltage drops across the coil and capacitor in this step. Enter your readings in Fig. 30-3.

When you have finished making the measurements, unplug the power cord.

Discussion: As in the previous experiment, you may not be able to actually go through resonance with the coil-capacitor combination. This is unimportant because from your readings in Fig. 30-3 you can see that as the capacitance increases, the circuit current decreases. From the typical values in Fig. 30-3, you can see that we reached resonance with a .5-mfd capacitor.

In a parallel-resonant circuit, then, the circuit is at resonance when the circuit current is at a minimum, as shown by the curve in Fig. 30-4. Compare this curve with the one shown in Fig. 29-7. From these you should be able to see the difference between the two resonant circuits.

Instructions for Statement No. 30: We have mentioned several times that a solid-dielectric capacitor normally has very little ac resistance. For your report on this experiment, you will place a given amount of resistance in series with the capacitor in the parallel-resonant circuit and see what happens to the circuit current.

Set up the circuit shown in Fig. 30-5,

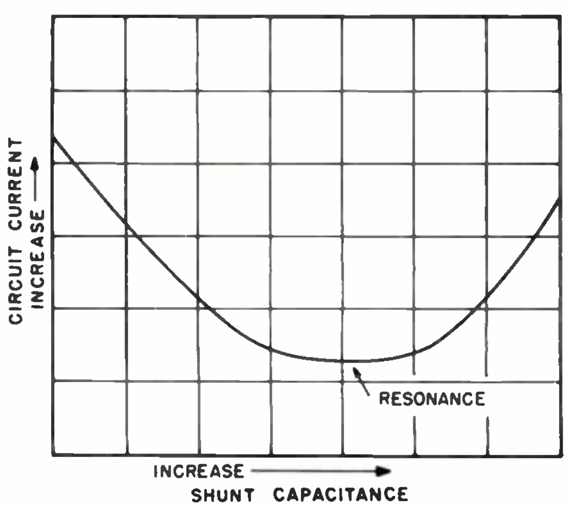


Fig. 30-4. Resonance in a parallel-resonant circuit.

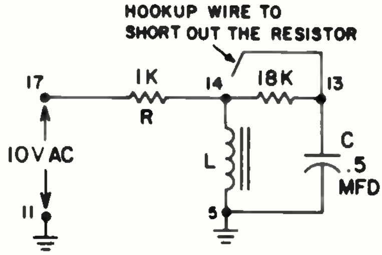


Fig. 30-5. Schematic of the circuit used in your experiment.

using .5-mfd for capacitor C. You should still have a .1-mfd and two .25-mfd capacitors connected between terminals 5 and 14. Remove the .1-mfd capacitor. You now have .5 mfd in parallel with the coil. Disconnect the leads of the two .25-mfd capacitors from terminal 14 and connect them to terminal 13. Leave the other leads of the capacitor combination connected to terminal 5. Then, connect an 18K-ohm resistor between terminals 13 and 14. You should still have a 1000-ohm resistor connected from terminal 14 to terminal 17.

Prepare a 4 or 5" length of hookup wire and solder one end to terminal 13. Arrange the other end of the piece of wire so that you can conveniently touch it to terminal 14 when you are instructed to do so. Solder all connections.

When you have the circuit set up, connect the tvom ground clip to the chassis and clip the probe to potentiometer terminal 17. Adjust the voltage to exactly 10 volts. Next, move the tvom ground clip to terminal 14 and the probe to terminal 17 and touch the short length of hookup wire that you soldered to terminal 13 to terminal 14. Measure the voltage across the 1K-ohm resistor, and make a note of the reading.

.2 YV

Disconnect the hookup wire from terminal 14 and note whether the voltage across the 1K-ohm resistor increases, decreases, or remains unchanged. When you have found out what happens, unplug the power cord. Now complete the Statement below and on the Report Sheet.

Unsolder the resistors and the capacitors from the terminals, and lay them aside for future experiments.

Statement No. 30: When I removed the short, placing an 18K-ohm resistor in series with a capacitor, the circuit current:

(1) remained unchanged.
(2) increased.
(3) decreased.

LOOKING AHEAD

Now that you have completed the experiments that demonstrate the fundamental properties of resistors, coils, and capacitors in ac and in dc circuits, you are ready to combine these components into more complex circuits. In your next group of experiments, you will demonstrate how power supplies work. A knowledge of power supply operation is important to you because power supplies are used to provide dc voltages in radio and television receivers. You will carry out experiments using solid state rectifiers as well as vacuum tube rectifiers.

After you have entered all your answers on the Report Sheet, send it to NRI for grading. While you are waiting for the next kit to arrive and the Report Sheet to be returned to you, gather all the parts you have left over from this kit and the previous kits, and put them in a safe place. The parts left over are shown in Table I.

After you have received a passing grade on your Report Sheet, you can unsolder and disconnect the choke, leads, and the connections to the potentiometer. Remove the flashlight cells, the potentiometer and the potentiometer mounting bracket. Remove the excess solder from the terminals and the parts.

1	.1 mfd tubular capacitor	2	22K-ohm resistors
2	.25 tubular capacitors	1	47K-ohm resistor
2	20 mfd, 150V electrolytic capacitors	1	82K-ohm resistor
1	1K-ohm potentiometer	3	100K-ohm resistors
1	500K-ohm potentiometer w/switch	1	220K-ohm resistor
1	Potentiometer mounting bracket	1	470K-ohm resistor
1	220-ohm resistor	1	1-megohm resistor
1	470-ohm resistor	1	1.8-megohm resistor
1	680-ohm resistor	2	10-megohm resistors
3	1K-ohm resistors	2	Silicon diodes
1	3K-ohm resistor, 5%	2	1.5V flashlight cells
1	3.3K-ohm resistor	1	Experimental chassis w/parts attached
2	4.7K-ohm resistors	1	Alligator clip
1	6.8K-ohm resistor	1	Etched circuit board w/7-pin tube socket
2	10K-ohm resistors	1	Marking crayon
1	15K-ohm resistor		Hookup wire
1	18K-ohm resistor		Solder
			Miscellaneous hardware

Table I. Leftover parts to be stored for later use.

HOW DO YOU FEEL?

A theory has been advanced (and to a large extent scientifically proven) that people feel good and feel bad in cycles.

Psychologists say that for a certain number of days you will be "sitting on top of the world." Then for a longer period of time you will feel about average. Then for a while you may be depressed – "in the dumps" -- have the "blues."

Then the cycle starts over again. It is claimed you can keep a record of the way you feel, and predict accurately about when you will be feeling grand -- or when you will be depressed. Be this as it may, we DO know that no matter how black things look at times, conditions always seem to improve. It's a very, very true saying that "every cloud has a silver lining." Perhaps this old saying is really based on the scientific theory I mentioned above.

And since you and I both know that we are bound to "snap out" of periods of depression, let's resolve never to make important decisions while feeling "low".

Don't fuss with a friend -- don't quit a good job – don't give up a worthwhile ambition just because you are in a "depressed cycle." Tomorrow, or next week you'll feel better!

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ACHIEVEMENT THROUGH ELECTRONICS

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TRAINING KIT MANUAL

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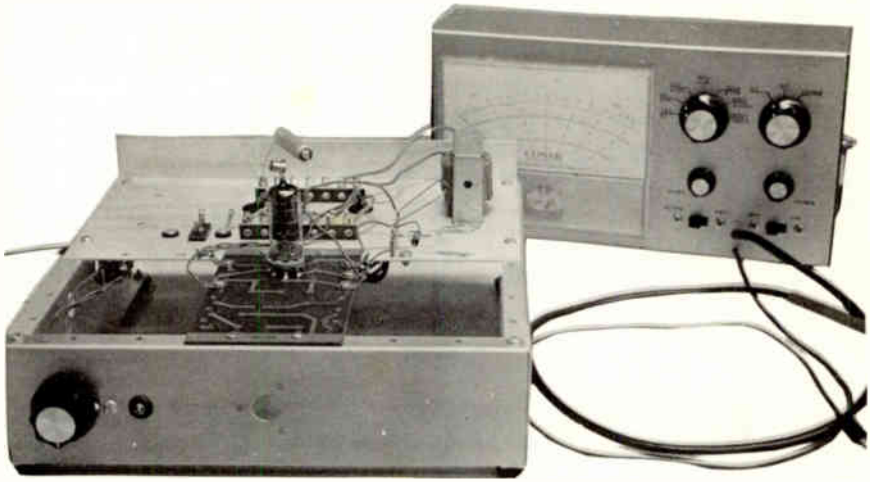
TRAINING KIT MANUAL 4T

PRACTICAL DEMONSTRATIONS OF
RADIO-TV FUNDAMENTALS



INDEX OF SECTIONS

JP1M276 1976 EDITION Litho in U.S.A.

INSTRUCTIONS FOR PERFORMING EXPERIMENTS 31 THROUGH 40

This part of your training program covers power supplies, tube fundamentals and transistor fundamentals. The experiments in this training kit are especially important because the knowledge and experience you gain will be of great value in your practical work.

You will study power supplies in some detail in this kit. You will build and investigate several types of rectifier circuits, filter networks, voltage regulators, and voltage doublers. Such broad coverage will enable you to understand nearly all of the power supply configurations currently in use and will give you self-confidence in your service work.

Following the work on power supplies, you will perform experiments on tube fundamentals and transistor fundamentals. You can see the importance of this when you realize that a tube or transistor is used in the vast majority of circuits which amplify, oscillate or perform any other active function. In addition to learning how these devices work, you will prepare yourself for work with amplifier, oscillator, mixer and other circuits which you will study in the following training kits.

HOW TO AVOID ELECTRICAL SHOCKS

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

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.

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 an external ground must not be fastened to the chassis. Unless polarized plugs and receptacles are used 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.

You can determine whether or not the chassis is at ground potential by measuring the ac voltage between a known grounded object and the chassis. If you read ac line voltage, remove the line plug, turn it over and measure the voltage again. It should be zero, which means that you can touch the chassis without being shocked.

A power line is not the only source of

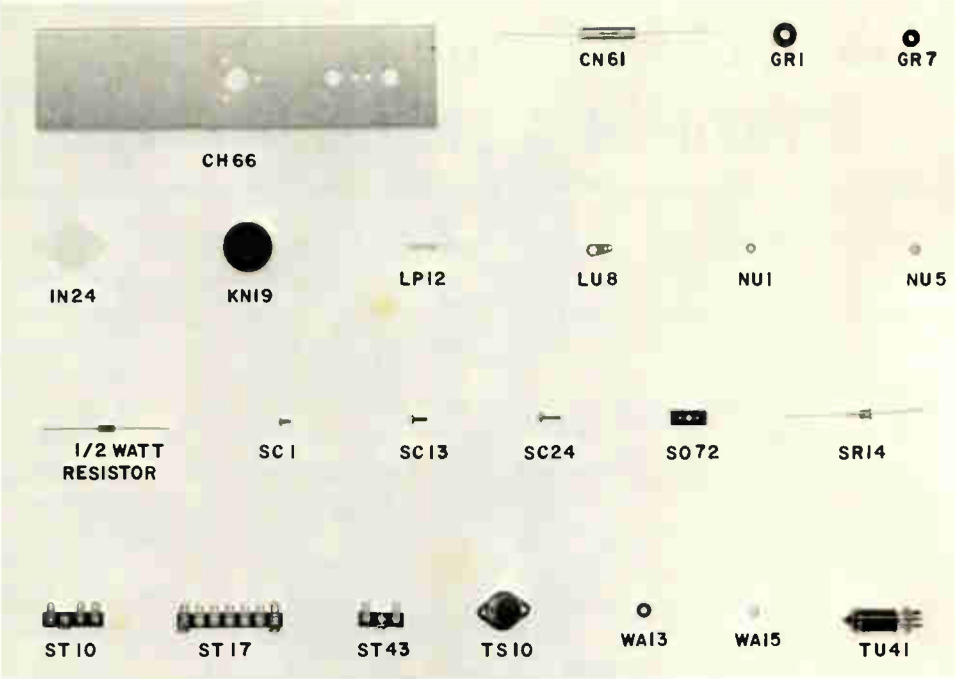


Fig. 1. The parts you received in this kit are pictured above and listed below.

Quan.	Part No.	Description	Price Each	Quan.	Part No.	Description	Price Each
2	CH66	Chassis rail	.79	9	SC6	1/4" X 4-40 screw	.15
1	CN61	20-mfd, 150V electrolytic capacitor	.65	10	SC13	3/8" X 6-32 screw	12/.15
				2	SC24	1/2" X 6-32 screw	12/.25
1	GR1	3/8" rubber grommet	12/.25	1	SO72	Transistor socket	.07
1	GR7	5/16" rubber grommet	.06	2	SR14	High voltage silicon diode	.80
1	IN24	Transistor insulator	.28				
1	KN19	Knob	.55	1	ST10	3-lug terminal strip	.05
1	LP12	Neon lamp type NE83	.26	1	ST17	7-lug terminal strip	.12
5	LU8	Terminal lug	12/.15	1	ST43	2-lug terminal strip	.06
12	NU1	6-32 hex nut	12/.15	1	TS10	Power transistor	1.08
9	NU5	4-40 hex nut	12/.15	1	TU41	12BA6 tube	1.05
1	RE26	100-ohm resistor	.15	2	WA13	Fiber shoulder washer	12/.15
1	RE58	2.2K-ohm resistor	.15	15	WA15	No. 6 lockwasher	12/.15

Resistors are 1/2 Watt, 10%

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 you do when working with a power line.

Make your work space safe. If you have provisions for an antenna and ground at your bench, the ground should be where you will not accidentally touch it. If water pipes are nearby, cover them with insulating 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. For a stool with metal legs put an insulating caster under each leg.

Do not be afraid of electricity, but respect it. Beginners almost never get shocked. Only when you grow overconfident 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 pictured in Fig. 1 and are listed 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 unless instructed to do so or until you have finished your NRI course; you will use the parts again in later experiments.

IMPORTANT: If any part of this kit is missing, look for a substitute part or special instruction sheet. 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.

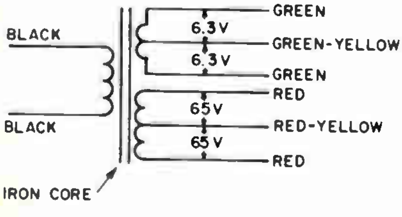


Fig. 2. Schematic symbol for power transformer.

THE POWER TRANSFORMER

The power transformer which you received in Kit 3 may be called 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. 2.

As the diagram shows, there are three separate windings on this transformer. The primary winding, which is wound for 117-volt, 60-Hz 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 power line having a frequency of 25 or 40 Hz. 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 about 6.3 volts; the voltage between the two green leads is approximately 12.6 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 voltage needed for the plates of the vacuum tubes. It is designed to have a no-load output of about 130 volts between the red leads. Variations in line voltage 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 VACUUM TUBE

You received a type 12BA6 vacuum tube in this kit. This is a miniature type pentode and its schematic symbol is shown in Fig. 3A. The labels G_1, G_2 and G_3 represent the control grid, screen grid and suppressor grid; K is the cathode; P is the plate; and H is the heater or filament.

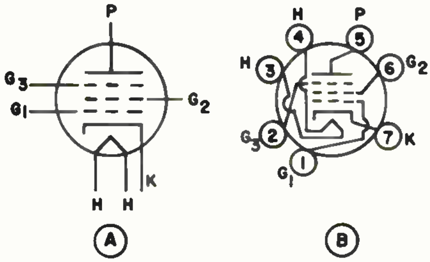


Fig. 3. (A) Schematic symbol and (B) basing diagram for a 12BA6 tube.

The 12BA6 fits a standard 7-pin tube socket, such as the socket you installed on your etched circuit board. The filament requires approximately 12.6V and the filament current is .3 amp.

Fig. 3B is a basing diagram of the 12BA6 tube. It shows the pin connections to the tube elements. The pins are numbered in a clockwise direction, counting from the open space when viewed from the bottom.

THE TRANSISTOR

You also received a power transistor in this kit. It is a germanium type PNP transistor in a TO3 case. The transistor has three elements: base, emitter and collector. The base and emitter have pin connections while the collector terminal is the transistor case. The schematic symbol for the transistor is shown in Fig. 4A and the elements are identified in Fig. 4B.

This transistor is designed to provide little amplification. However, it can pass high current. It will be mounted in such a manner that the chassis will serve as a heat sink and prevent the transistor from overheating.

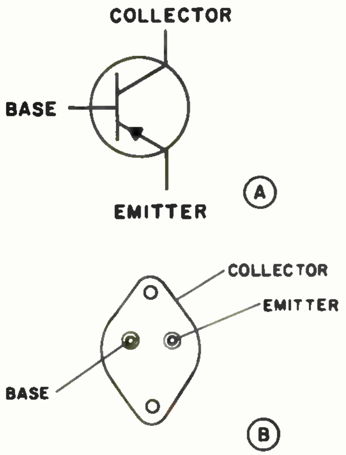


Fig. 4. (A) Schematic symbol and (B) basing of a PNP transistor with lead identification.

SILICON DIODES

You received two solid-state silicon diodes (NRI part No. SR14) in this kit. We will call them high voltage or HV diodes to distinguish them from the diodes you received in Kit 1. These HV diodes can withstand up to 400 peak volts across their terminals. These HV diodes are commonly called "top hats" because of their appearance. The actual diodes are tiny pellets of silicon inside the plastic and metal package.

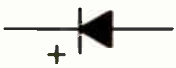


Fig. 5. The schematic symbol for a solid state diode.

Fig. 5 shows the schematic symbol for a solid-state diode. The diode has two elements – an anode represented by the arrow, and a cathode which is represented by the bar. The leads are usually identified by a + sign near the cathode lead or by a schematic symbol printed on the body of the diode. The cathode of the HV "top hat" diode is the lead that connects to the "brim" end of the case. Notice that this lead *connects directly to the metal case!* The anode lead comes from the top of the "top hat."

Preliminary Assembly

Before performing the experiments in this kit, you will have to make several changes in your experimental chassis. Most of the parts you will need are shown in Fig. 1. The others were included in the earlier kits.

PREPARING AND INSTALLING THE CHASSIS RAILS

You will need the following parts:

- 2 Chassis rails
- 1 3/8" rubber grommet
- 1 5/16" rubber grommet
- 1 3-lug terminal strip
- 1 2-lug terminal strip
- 9 3/8" X 6-32 screws
- 9 6-32 hex nuts
- 10 No. 6 lockwashers
- 1 500K-ohm potentiometer with On-Off switch

Make sure the power cord is unplugged. Unsolder and disconnect the leads of the power cord from the black leads of the power transformer. Also, unsolder the green lead from the 4-lug terminal strip.

Observe the two chassis rails which you received in this kit and the rail already attached to your chassis. Notice that the three are identical. Position one chassis rail as shown in Fig. 6, so that the two 3/8" holes are on the right, and the top and bottom lips of the rails are toward you. You will then have the inside of the rail facing you.

Install a 3/8" rubber grommet in the hole nearest the right end of the chassis rail. Squeeze the grommet into an oblong shape and push it into the hole so that the rubber completely lines the hole in the chassis.

Mount the 3-lug terminal strip on the inside of the same chassis rail. Position the terminal strip exactly as shown in Fig. 6. Pass a 6-32 screw through the rail from the outside. Place the foot of the terminal strip and a No. 6 lockwasher over the screw. Attach a hex nut and tighten the screw.

Pass the end of the power cord up through the grommet in the chassis rail. Tie an overhand knot in the cord approximately 2 inches from the end of the wire. Lay this chassis rail aside. Position the second rail as shown in Fig. 7.

Slip a control lockwasher over the shaft and bushing of the potentiometer and mount the potentiometer in the 3/8"

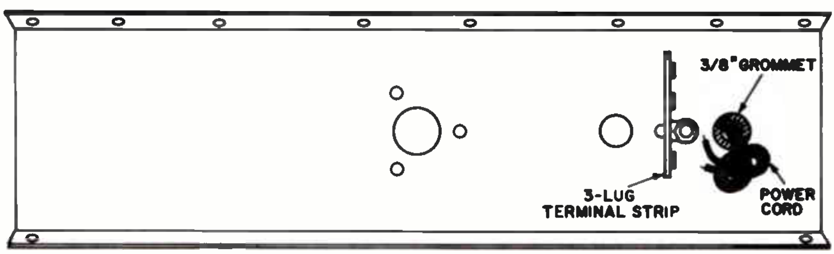


Fig. 6. The parts installed on the left chassis rail.

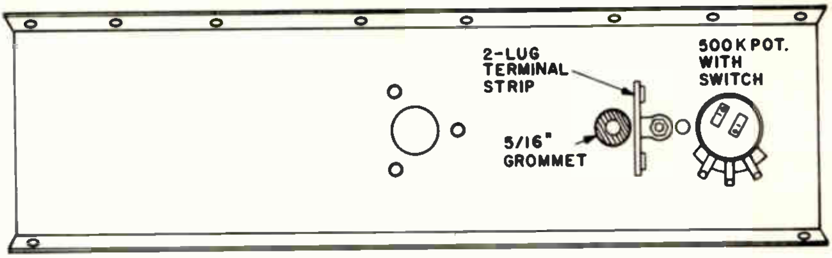


Fig. 7. Parts mounted on the front chassis rail.

hole nearest the end of the rail. Attach a control nut. Rotate the potentiometer so that the three terminals are in the positions shown in Fig. 7 and tighten the nut.

Install a 5/16" rubber grommet in the other 3/8" hole as shown in Fig. 7. This grommet will fit loosely in the hole. Mount the 2-lug terminal strip on the inside of your chassis rail near the rubber grommet. Position the terminal strip as shown in Fig. 7, and attach it securely, using a 6-32 screw, lockwasher and nut.

Next, you will fasten the chassis rails to the chassis plate. Remove the chassis rail from the front of the chassis plate. Set aside the 4-lug terminal strip. Using the same screws and nuts, mount this as the right chassis rail as shown in Fig. 8. Note that the lips are turned inward toward the center of the chassis plate and the rail extends beyond its front.

Fasten the chassis rail with the power cord and a 3-lug terminal strip to the left side of the chassis plate, as shown in Fig.

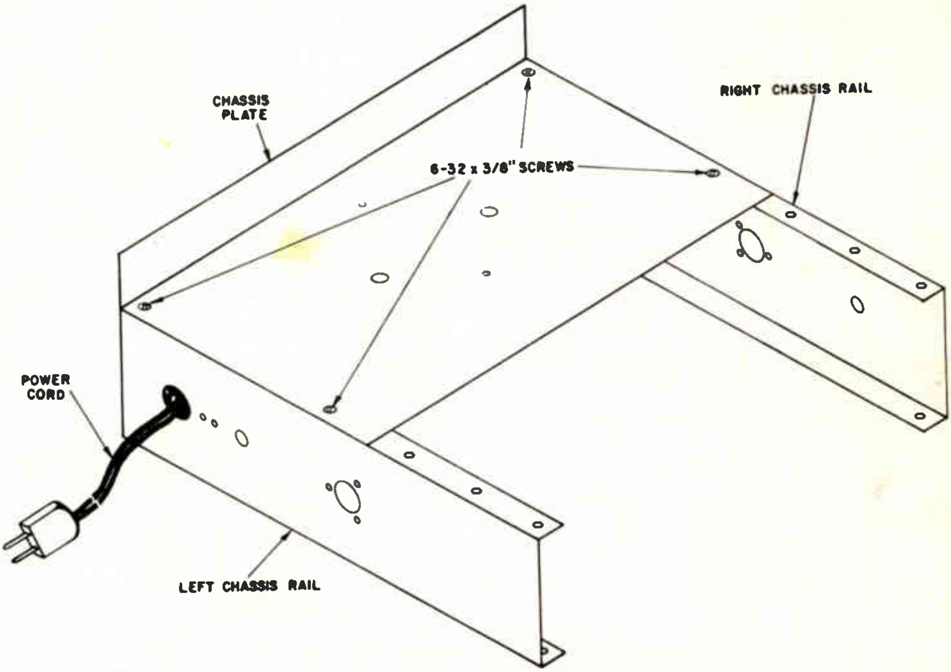


Fig. 8. Mounting the side rails on the chassis plate.

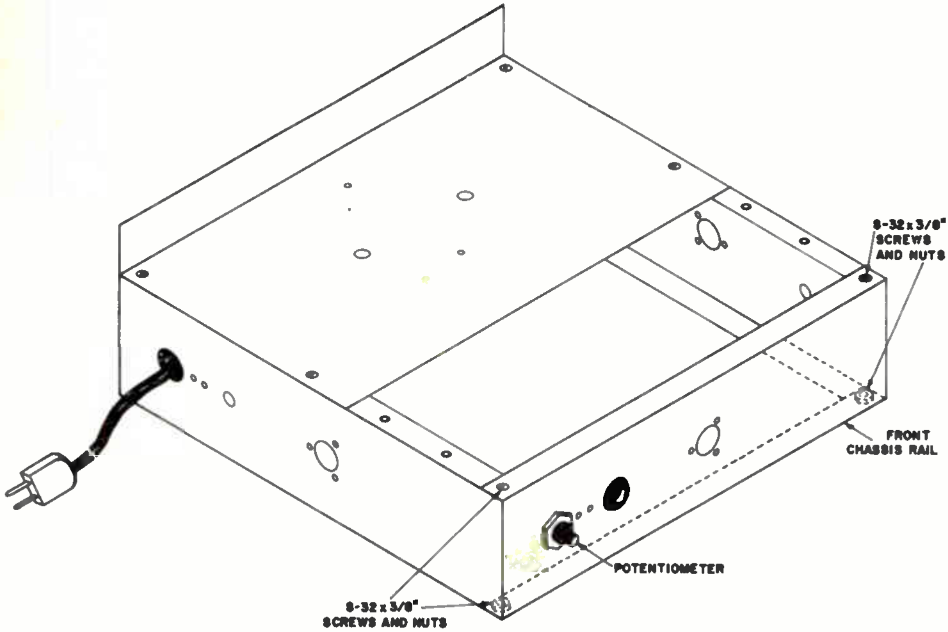


Fig. 9. Mounting the front rail on the chassis.

8. Secure with two 6-32 screws, No. 6 lockwashers and 6-32 hex nuts.

Next fasten the chassis rail with the potentiometer to the left and right side rails, to form a box as shown in Fig. 9. Notice that the top lip of the front rail fits *over* the top lips of the left and right side rails. Secure the front rail to the side rails with four 6-32 screws, No. 6 lockwashers and 6-32 hex nuts. Pass a screw through the top and bottom lip of both rails at each corner.

MOUNTING THE PARTS ON THE CHASSIS

Now, you will make changes on the chassis plate. You will need the following:

1 Power transistor
1 Transistor socket
1 7-lug terminal strip
1 3/8" × 6-32 screw
2 1/2" × 6-32 screws
1 Control knob
3 No. 6 lockwashers
3 6-32 hex nuts
2 Insulated shoulder washers
1 Transistor insulator

Remove the 3-lug terminal strip and solder lug from the left side of the chassis plate. Save the parts.

Mount the 7-lug terminal strip at holes F and I as shown in Fig. 10. Secure with the 6-32 screws and nuts just removed from the chassis. Reinstall the 4-lug terminal strip at hole U, as shown in Fig. 10. Use a 6-32 screw, No. 6 lockwasher and 6-32 hex nut.

Next, you will install the power transistor. The transistor mounts under the chassis at the location shown in Fig. 10. The transistor socket attaches to the pins which will project through holes C and C_3 in the chassis.

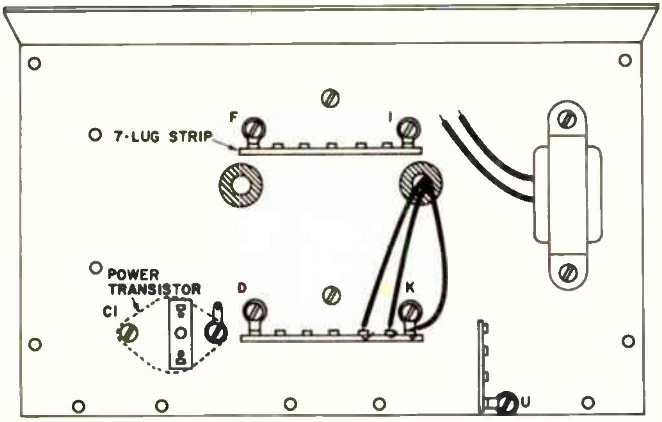


Fig. 10. Mounting the parts on the chassis.

Fig. 11 is an exploded view showing how to mount the transistor. Place the thin insulator over the transistor terminals. Place the solder lug and fiber shoulder washer over one of the two 1/2" X 6-32 screws. Slip a shoulder washer only over the other screw. Place the screw with the solder lug in transistor mounting hole C2 in the chassis and push the other screw through hole C1 so that the shoulder washers insulate the screws and the solder lug from the chassis.

Mount the transistor as shown in Figs. 10 and 11. Position the solder lug as shown in Fig. 10. Attach No. 6 lockwashers and 6-32 hex nuts and tighten the nuts just enough to compress the lockwashers.

Slip the transistor socket over the pins of the transistor. Install the control knob on the potentiometer shaft by lining up the flatted part of the shaft with the flat of the knob. Push the knob onto the shaft firmly.

WIRING THE CHASSIS

You now have a number of terminal strips and other parts mounted on the chassis plate and chassis rails. The simple terminal number system used in the earlier training kits would be a little awkward to use now that we have so many terminals. We will therefore change to a more flexible system.

If you have marked the terminal numbers on your chassis plate or a piece of tape with your crayon, you should now

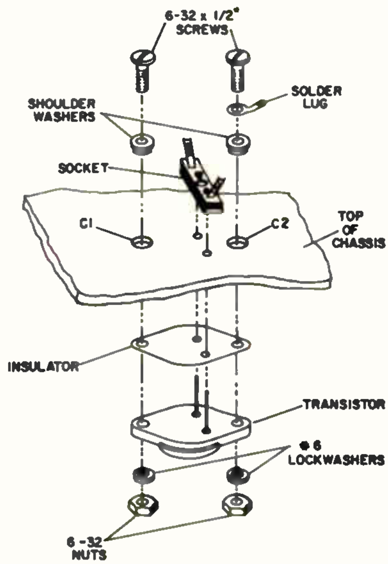


Fig. 11. Mounting the transistor on the chassis.

remove the markings. An ordinary pencil eraser or a soft cloth and a little liquid detergent will help you.

We will identify the terminals on the chassis by giving each terminal strip a letter designation. Each terminal will be completely identified by a letter and a number. Fig. 12 shows the terminals identified using this method. Notice, for example, the terminals on Strip A are called A1, A2, A3, etc., and those on Strip B are called B1, B2, B3, etc.

You will now connect the power transformer leads, the power cord and the on-off switch. Some of these connections are permanent. When instructed to make a permanent connection, remove about 1/4" of insulation from the end of the wire, bend a hook, slip the hook through the hole in the terminal and squeeze it closed with your longnose pliers.

Use only temporary connections on top of the chassis. The wiring is shown in Fig. 13.

Remove the tape from the red and red/yellow power transformer leads. Push the ends of these three leads of the power transformer up through the grommet in hole E of the chassis.

Connect one red lead to terminal B1 and solder the connection.

Connect the red/yellow transformer lead to terminal B2. Do not solder.

Connect the other red transformer lead to terminal B3.

You should have a green transformer lead connected to terminal B7 and the green/yellow lead connected to terminal B5. Move the green/yellow lead to B6 and connect the other green lead to B5 as shown in Fig. 13.

Connect the leads of the choke coil to terminals A6 and A7.

You will now perform the under-chassis wiring. Refer to Figs. 14A and B as you make the following connections. Each of these connections is to be permanent unless otherwise indicated.

Remove 1/4" of insulation from each end of the two 10" lengths of hookup wire. Twist the wires together to form a twisted pair.

At one end, connect one lead of the twisted pair to terminal D1 and connect the other lead to D2. Do not solder.

At the other end of the twisted pair connect one lead to terminal 4 of the on-off switch on the back of the potentiometer and connect the other lead to terminal 5 of the on-off switch. Solder

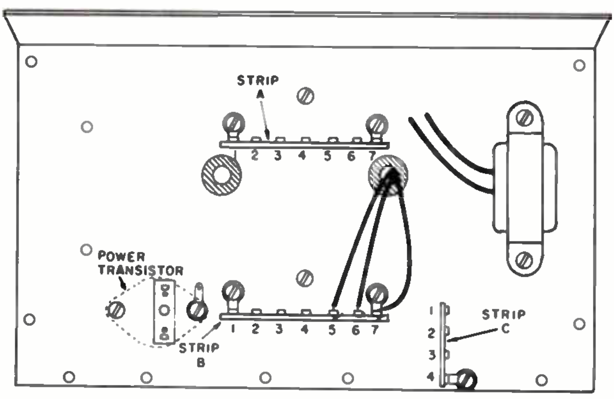


Fig. 12. Terminal identification.

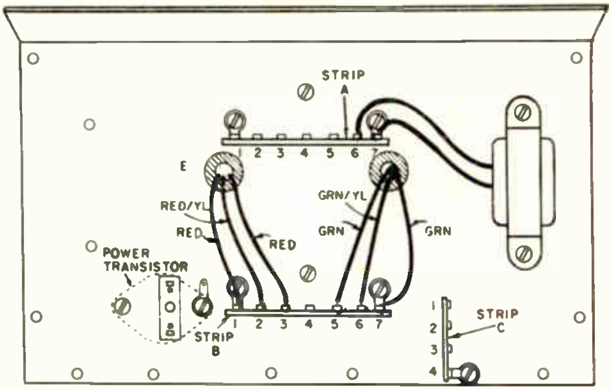


Fig. 13. Preliminary wiring on top of the chassis.

both connections and route the twisted pair along the side of the chassis rail.

Connect one black lead of the power transformer to terminal D1. Solder.

Connect the other black power transformer lead to D3. Do not solder.

Connect one lead of the power cord to D2. Solder.

Connect the other lead of the power cord to D3 and solder.

This completes your preliminary assembly and wiring. Check your work against the diagrams in Figs. 13 and 14 to see that you have done your work correctly.

At this point, your chassis is essentially complete. The space left between the chassis plate and the front rail is reserved for the circuit boards which you will mount and use in your experiments.

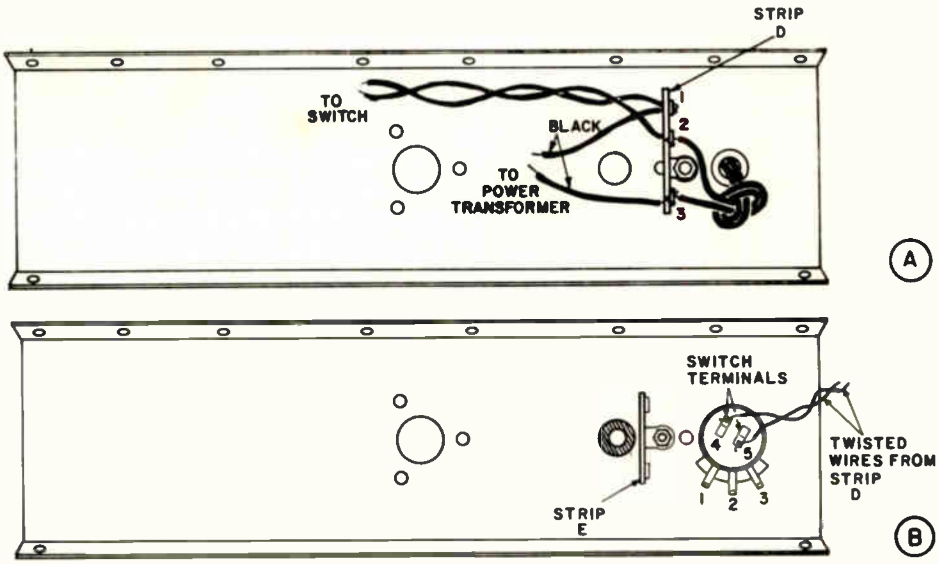


Fig. 14. (A) The wiring inside the left chassis rail. (B) Connections to the on-off switch.

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 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 B1 and B3, think of it as being across 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 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.

EXPERIMENT 31

Purpose: To show that a coil can develop a counter emf and to show that a transformer can be used to step voltage up or down while providing dc isolation.

Introductory Discussion: Coils are among the most widely used electronic components. It is therefore, desirable for you to learn how coils work and how they are used.

The most important characteristic of a coil is inductance. Inductance is the property that causes a magnetic field to be produced around a wire or coil through which current is flowing and causes a voltage to be induced in a wire or coil placed in a varying magnetic field.

Coils may be used separately, where inductance is required, or two or more coils may be wound on the same core to form a transformer. In most cases, transformers are used to inductively transfer signals or ac power from one circuit to another while providing isolation. The voltage may be "stepped" up or down, depending upon the ratio of the turns of the windings and how the transformer windings are connected.

Coils and transformers can be designed to operate at any desired frequency. In this experiment, you will use your power transformer and choke coil which are designed for use in 60-Hz power line applications.

We will use a neon lamp to indicate the presence of voltage in these steps. The tvom is unsuitable for several of these steps because the voltage will rise and fall before the meter has time to respond. The lamp, which you will use, will light when approximately 65 volts is applied to it. Thus, you will know that you have at least that voltage whenever the lamp lights. The brilliance of the glow depends upon the voltage applied to the lamp. Thus it will glow more brightly with 100 volts applied than with 65 volts applied.

Experimental Procedure: For this experiment, you will use the experimental chassis with the choke and the power transformer mounted on it and the following parts:

1 1.5 volt flashlight cell
1 Neon lamp

Make sure the chassis is unplugged from the ac receptacle.

Construct the circuit shown in the schematic diagram in Fig. 31-1. Using temporary connections, connect the neon lamp in parallel with the choke coil between terminals A6 and A7. Solder a 6" to 8" length of hookup wire to each terminal of one flashlight cell. Solder the free end of the negative battery lead to terminal C4 or to any convenient ground terminal.

Step 1: To show that an inductance can develop a counter emf.

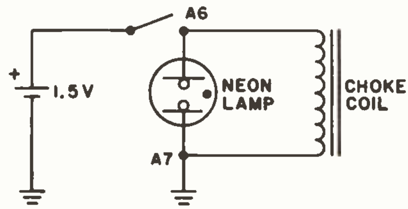


Fig. 31-1. The circuit used in Step 1.

You now have the neon lamp connected in parallel with the choke coil. Touch the positive battery lead to terminal A6. While observing the neon lamp, remove the battery lead from A6 to open the circuit. You should see the lamp flash or glow momentarily. Repeat the experiment. Touch the battery lead to A6 and hold it for a few seconds. Remove the battery lead while observing the bulb.

Now observe the bulb as you *touch* the battery lead to the terminal again. Remove the battery lead. You will find that the lamp lights only as you *open* the circuit.

Now touch the battery lead to the terminal and remove it quickly while observing the lamp. You should find that the length of time the circuit is closed has no noticeable effect on the brilliance of the flash.

Step 2: To show that the transformer windings have inductance and can produce a counter emf.

Connect the neon lamp across the 12.6 volt filament winding of the transformer. Unsolder the lamp from A6 and A7 and solder it to B5 and B7. While observing the neon lamp, touch the positive battery lead to B5. Open the connection and note the brilliance of the lamp flash.

Unsolder the lamp and connect it across the high voltage winding, terminals B1 and B3. Touch the positive battery lead to B3 and observe the lamp. As you open the battery connection, look carefully to see if the lamp flashes. Make and break the connection several times if necessary.

Step 3: To show that a transformer can step up voltage.

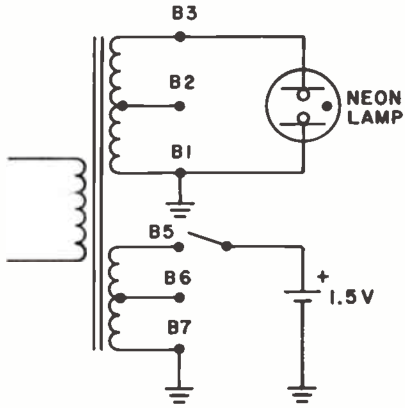


Fig. 31-2. The transformer connected to produce voltage step up.

You will use the circuit shown in Fig. 31-2. Leave the lamp across the high voltage winding of the transformer, but connect the battery across the low voltage winding between terminals B5 and B7.

Touch the battery lead to B5, then break the connection while observing the neon lamp. Note that the flash is the brightest yet obtained in this experiment, indicating the highest voltage.

Step 4: To test the transformer for continuity and isolation.

Set up your tvom for resistance measurements and measure the resistance of the high voltage winding from terminal B1 to terminal B3. The neon lamp will not affect your reading. Record the resistance reading in the chart in Fig. 31-3.

Now connect the ohmmeter across the low voltage winding, terminals B5 and B7 and measure the resistance. Place the value in the space provided in Fig. 31-3.

Next, disconnect the transformer leads from terminals B1 and B7. Make sure that the transformer and battery leads are not shorted to the chassis or to any terminals. Measure the resistance between the leads connected to terminals B3 and B5. Record the value in Fig. 31-3. You should read a very high resistance. When you have made this measurement, reconnect the red lead to B1 and the green lead to B7.

Connect the clip of your tvom to the chassis and the probe to terminal B5. Adjust the meter to read 3 volts dc. Touch the battery lead to the high voltage winding of the transformer at terminal B3.

Allow the meter a couple of seconds to settle down, then observe and jot down the reading in the margin of this page. Remove the tvom probe from terminal B5, then disconnect the positive battery lead from terminal B3.

Discussion: In this experiment, you saw that you were able to light a neon lamp, requiring about 65 volts from a 1-1/2 volt flashlight cell. The inductances of the coil and the transformer windings were responsible for the increase in voltage.

A neon lamp consists of a pair of electrodes placed in neon gas. When a high enough voltage is applied to the electrodes, the neon gas will "ionize" and begin to conduct, thus producing light. The chemical composition of the neon gas and the spacing of the electrodes establishes the voltage required to cause the gas to conduct.

H.V. WINDING	L.V. WINDING	B_3 TO B_5
200Ω	1.5Ω	∞

Fig. 31-3. Chart for recording your transformer resistance readings.

In the first step, the lamp was connected directly across the winding of the choke coil. When the flashlight cell was connected, the coil and the lamp were a parallel-connected load. However, when the battery was disconnected, the coil acted as the source of voltage. It was the voltage produced in the coil that lighted the lamp.

Now, let us review the action of an inductance. Current flowing through a conductor produces a magnetic field around the conductor. This magnetic field will vary in strength as the current in the conductor varies.

A counter emf (or voltage) is produced whenever the current in a coil changes. The amount of the counter emf is governed by the inductance and the rate at which the current changes. When you removed the battery lead from the circuit in Step 1, you caused an instantaneous change in the current from some level of current flow to 0, resulting in a very high counter emf. The fact that the lamp glowed proved that the voltage was 65 volts or more. Thus, the counter emf was at least 43 times as great as the voltage produced by the flashlight cell. Incidentally, the duration of the high voltage was less than one millisecond (1 thousandth of a second).

In Step 2 you saw that transformer windings, like the choke, also have inductance and can produce a large counter emf. Even though there are fewer turns (small inductance) on the low voltage winding than on the high voltage winding, you probably observed a brighter glow when testing the low voltage winding. A look at your readings recorded in Fig. 31-3 will give you a clue as to why you developed a greater counter emf with the low voltage winding. This winding has a very low resistance and thus will draw a large current from the battery to produce a large magnetic field. The much higher resistance of the high voltage winding draws less current and produces a smaller magnetic field than the low voltage winding. Thus, even though the inductance of the HV winding is large, the current is small and a small counter emf is produced.

You obtained the brightest flash when you used the circuit in Fig. 31-2. The lamp was connected across the high voltage winding and you applied voltage to the low voltage winding. The current supplied by the flashlight cell caused a magnetic field to be produced around the low voltage winding. When you opened the battery connection, the field collapsed and a high voltage was induced in the high voltage winding.

In Step 4, you used your tvom to make a few basic tests on the transformer. You read the continuity of the high voltage and low voltage windings and you tested the transformer for isolation.

The low dc resistances proved that the windings have continuity and are capable of passing current. The dc resistance between windings is quite high because there is no direct electrical connection between them. Also, you saw that there was no transfer of the dc voltage through the transformer. Only alternating or changing voltages are coupled from one winding to another.

Instructions for Statement No. 31: For this Report Statement, you will determine if a short circuit in one winding of a transformer affects the voltage induced in another winding.

Make sure the line cord is unplugged. The circuit of Fig. 31-2 should still be connected. Touch the battery lead to terminal B5 and quickly remove it. Make

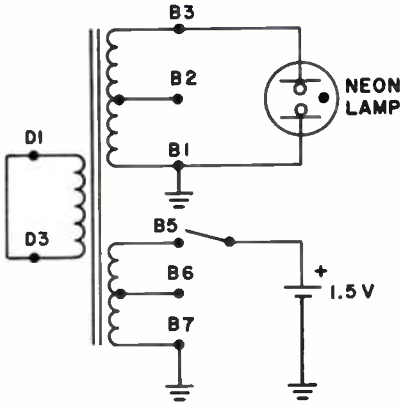


Fig. 31-4. The schematic diagram of the circuit used for Statement 31.

a mental note of the brilliance of the flash of the neon lamp across the high voltage winding.

Next, place a short circuit across the transformer primary winding. Turn the on-off switch "on" and hold both prongs of the power cord against the metal chassis. This will give you the circuit shown in the schematic diagram in Fig. 31-4. Note that you are now using all three windings of the transformer, with the low voltage winding acting as the primary.

Touch the battery lead to terminal B5 and open the connection while observing the neon lamp.

Answer the Statement here and on the Report Sheet. Unsolder and remove the neon lamp and the flashlight cell from the chassis.

Statement No. 31: When I placed a short circuit across the transformer primary winding, I found that the voltage induced in the high voltage winding was

(1) higher.
(2) unchanged.
(3) lower.

Assembling A Basic Power Supply

Before going further you will mount your etched circuit board and several other parts on your chassis and wire a simple power supply circuit. You will use the 7 pin tube socket on the circuit board and make connections to the circuit board and to the terminal strips on the chassis. You will also wire the neon lamp into the circuit so that it will show you when the circuit is energized.

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

- 1 **Etched circuit board**
- 1 **12BA6 tube**
- 9 **1/4" X 4-40 screws**
- 9 **4-40 hex nuts**
- 5 **Terminal lugs**
- 2 **100K-ohm resistors**
- 1 **Neon lamp**

First, attach the 5 terminal lugs to the circuit board at the locations shown in Fig. 15. Use 1/4" X 4-40 screws and 4-40 nuts. Position the lugs as shown, so they do not touch adjacent copper strips or terminals.

Mount the circuit board in the location shown in Fig. 15 with four 1/4" X 4-40 screws and nuts. Note that the tube socket is towards the chassis plate and the circuit board is near the center of the opening in the chassis.

Next, you will wire the circuit shown in the schematic in Fig. 16. The terminal lugs on the circuit board are numbered 1 through 5, as shown in Fig. 15. The broken line in Fig. 16 encloses the wiring on the etched circuit board itself. Note on the circuit board that the copper foil connects pins 2, 5 and 6 of the tube socket and lug 5. Pin 1 of the tube socket is connected to lug 3 and pins 3, 4 and 7 are connected to lugs 2, 1 and 4, respectively.

You can use the diagram in Fig. 15 for help in wiring the circuit shown in the schematic.

Note that lengths of hookup wire are connected from lug 3 to lug 5 on the circuit board and between terminals B2 and A2. The green lead and green/yellow lead of the power transformer, connected to terminals B6 and B7, are interchanged from their previous positions as are the red and red/yellow leads connected to terminals B1 and B2. The neon bulb is connected to A2 and A3 and a 100K-ohm resistor is connected from A3 to B3.

When you complete your wiring, check over your work and insert the 12BA6 tube in the socket.

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

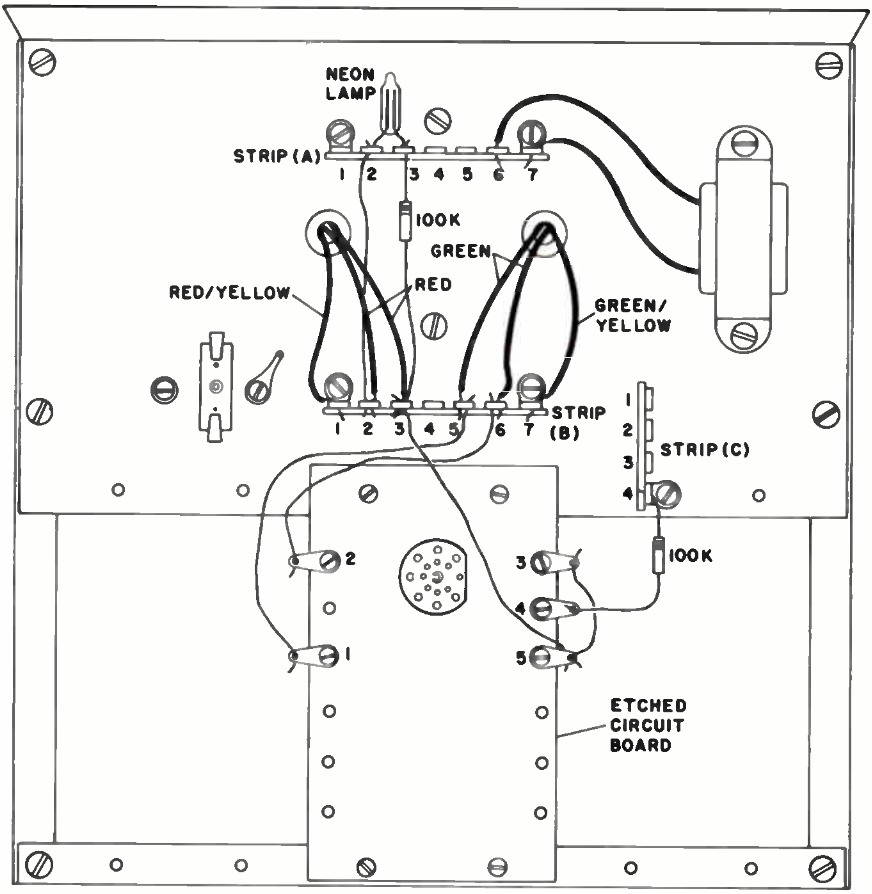


Fig. 15. Pictorial diagram of the power supply wiring.

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 tvom to carry out the continuity tests. Turn your tvom on and turn the function switch to ohms. Do not plug in the line cord of your chassis until you are instructed to do so.

First, turn off the switch on the power supply: Turn the knob on the 500K-ohm potentiometer shaft all the way in the counterclockwise direction until you hear a click. With the switch in the off position, proceed with the continuity tests.

To test the line cord, switch, and primary transformer winding, turn the range switch to the R X 10K position, and connect the ohmmeter leads 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 move to the zero position. Turn the range switch to the R X 1 position. When you do this, the meter should indicate between 20 and 40 ohms, which is the resistance of the primary power transformer winding.

Next, connect your ohmmeter leads to lugs 1 and 2 of the circuit board. These lugs connect to pins 3 and 4 of the tube socket. You should measure about 1 ohm. This is the parallel resistance of the filament winding and the 12BA6 heater.

To check half of the high voltage winding of the power transformer, connect the ground clip to the chassis and touch the probe to lug 5. With the range switch in the R X 1 or R X 10 position, your reading should be approximately 80 ohms.

Next, measure the resistance from tube cathode (lug 4) 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 117-volt, 60-Hz receptacle. 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 lug 5 of the circuit board. 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 30-volt position and measure the voltage between lugs 1 and 2 of the circuit board. You should get a reading between 12 and 13 volts.

To measure the line voltage, remove the line cord plug from the wall outlet, turn your chassis up on its back edge and connect the ground clip of your tvom to terminal D3. Turn the tvom range switch to the 300-volt range, and plug the line cord back into the wall outlet. Touch the tvom probe to terminal D2. You will get a reading of approximately 117 volts. The actual voltage in your area may be any value from 105 volts to 130 volts. Unplug the power cord and disconnect the meter ground clip.

When you have finished making these measurements and found that the continuity and the ac voltages of the power

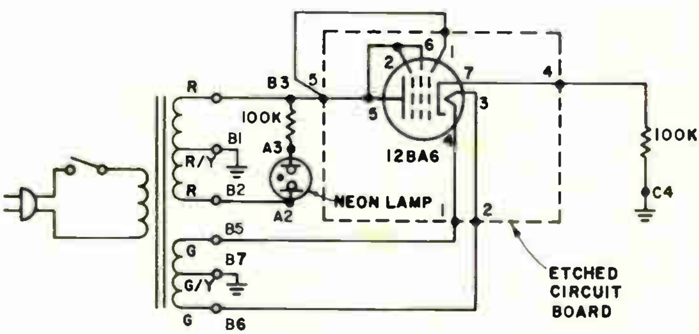


Fig. 16. The basic power supply circuit.

supply are correct, you are ready to go ahead with the next group of 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.

EXPERIMENT 32

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.

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. 32-1. This is the half-wave rectifier circuit that you built and tested earlier. To simplify the discussion, we 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 tvom will not respond to any ac voltage when the function switch is in the dc position. You will use the normal-reverse switch to indicate polarity. When the meter pointer deflects to the right (upscale), the polarity of the voltage at the terminal to which the probe is being touched is positive if the polarity switch is set to normal, and negative if the switch is in the reverse position.

We usually use diode tubes as tube-type rectifiers. As you know, a diode tube has two elements called a cathode and a plate (in addition to the heater). You will use your 12BA6 tube, which is a pentode, as a diode. By connecting the three grids to the plate externally, as shown in Fig. 32-1, we make the pentode act as a diode.

Experimental Procedure: For this experiment, in addition to the power supply circuit you have constructed, you will need:

1 HV silicon diode

Turn the tvom on and clip the ground lead to the experimental chassis. This is the same as clipping it to the 100,000-ohm resistor lead that goes to terminal C4 since C4 is grounded. Set the function switch to the dc position, the slide switch to normal, and the range

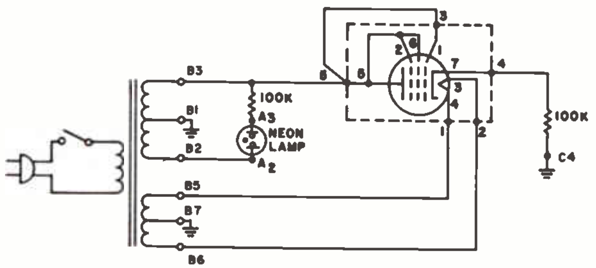


Fig. 32-1. The half-wave rectifier circuit used in Step 1.

STEP	READING
1	28.5V
3	28.5V
4	-23V

Fig. 32-2. Chart for recording your voltage readings for Experiment 32.

switch to the 120V position. You are now ready to proceed with the first step.

Step 1: To show that there is a dc voltage across the load resistor in series with a diode tube rectifier and an ac source.

Insert the plug of the power cord into an ac receptacle, and turn on the on-off switch. Allow the tube to warm up and touch the probe of your tvom to the end of the 100,000-ohm resistor that is connected to lug 4 of the circuit board. If you read less than about 25 volts, adjust the range switch to the 30V range, measure the voltage and record your reading in the first line of the table in Fig. 32-2. Turn your circuit off.

Step 2: To show forward and back resistance of a diode.

Set the function switch of your tvom to ohms on the R X 1 range and clip the ground lead to the cathode lead of the silicon diode. Touch the probe to the anode lead and measure the resistance. (The leads are identified by a diode symbol on the body of the diode.) Be sure the meter is set to normal. You should read a low resistance. Record your reading on the first line in Fig. 32-3.

7Ω

Reverse the tvom leads by placing the normal-reverse switch in the reverse position and again measure the resistance between the cathode and anode leads of the diode. Switch the ohmmeter to a higher range, if necessary, to get a reading. Record your value in the space provided in Fig. 32-3.

Step 3: To show that a silicon rectifier gives essentially the same results as a vacuum tube rectifier.

Remove the 12BA6 tube from the tube socket on the circuit board. Grasp the tube with a cloth if it is still hot. Connect and solder the silicon rectifier between lugs 4 and 5 on the circuit board as follows: Connect the cathode lead to lug 4 and connect the anode lead to lug 5.

Set your tvom to read positive dc voltage on the 120-volt range and clip the ground lead to the chassis. Turn the circuit on and measure the voltage across the 100K-ohm load resistor. Record your reading in the space provided for Step 3 in Fig. 32-2.

Step 4: To show that the polarity of the voltage across the load resistor depends on how the rectifier is connected in the circuit.

Set up the circuit shown in Fig. 32-4, in which the anode and cathode connections are the reverse of those in the circuit you just used. Interchange the diode leads: Connect the cathode lead to

DIRECTION	RESISTANCE
FORWARD	7Ω
REVERSE	3 Mego

Fig. 32-3. Chart for recording rectifier resistance values.

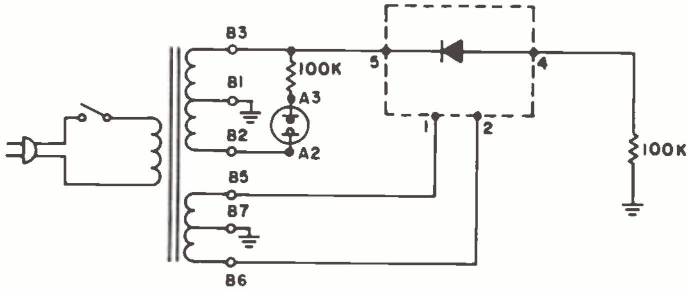


Fig. 32-4. The circuit used for Step 4.

lug 5 of the circuit board and connect the anode lead to lug 4.

To show that the polarity of the voltage drop across the load resistor has changed, turn on the experimental chassis, connect the ground clip of the tvom to the chassis, and momentarily touch the probe to lug 4. Note that with the slide switch in the normal position, you get a downscale reading.

Move the slide switch on the tvom to reverse and touch lug 4. Now you should get an upscale 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 connected. The reading you get should be just about the same as the one you got in Step 3, 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. 32-2 as a minus (–) value, and turn off the power supply.

Unsolder and remove the silicon diode from the circuit board.

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 Step 2, you used your ohmmeter to show that the effective resistance of a diode depends upon the polarity of the voltage applied to it. When the plate or anode is *positive* with respect to the cathode, the resistance is low; when the anode or plate is *negative* with respect to the cathode, the resistance is high.

Your ohmmeter is wired so that with the polarity switch set to normal, the probe is slightly positive with respect to the ground clip. Thus, when the probe was connected to the anode and the ground clip was connected to the cathode, the diode conducted readily and you measured a low value of resistance. When you reversed your ohmmeter leads, you reversed the polarity of the voltage applied to the diode, and the effective resistance of the diode became quite high.

The tube-type rectifier has similar characteristics. When the plate is positive with respect to the cathode, the effective resistance between cathode and plate is low; when the applied voltage is reversed, the effective resistance is very high.

This is a good way of checking most solid-state diodes. Measure the resistance in both directions and compare your results. In one direction, you should have a high resistance and in the other, you should obtain a low resistance. Certain special purpose diodes, such as high voltage selenium types used in color TV sets, cannot be tested in this manner as they show a high resistance in both directions.

In each of the circuits you set up in this experiment, the plate or anode 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 load, you would get a pattern somewhat like that shown in Fig. 32-5.

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 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 tvom is capable of measuring only the average of the positive pulses, which is about one-third of the peak value.

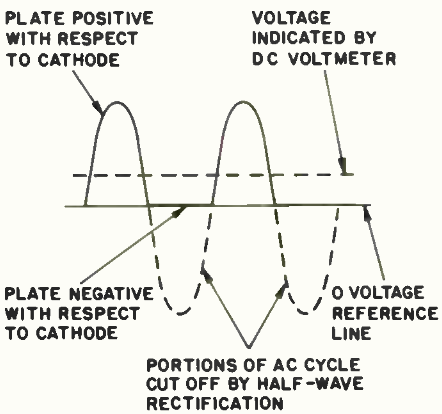


Fig. 32-5. The heavy line indicates the shape of the voltage across the load of the half-wave rectifier circuit.

Some important radio and TV servicing principles are shown by this experiment. First, as you know, you must set the polarity switch of your tvom to the proper polarity to make the instrument indicate dc voltages correctly. By the term "proper polarity" we mean that the polarity switch must be set so that the meter pointer moves to the right when you make a voltage measurement. If the meter pointer moves to the left, the switch must be moved to the opposite position.

In any device in a circuit, except the source, the terminal at which the electrons enter is the negative terminal. This fact lets you find the direction of the 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. 32: For your Report on this experiment, you will put the load between the plate of the rectifier tube and the ungrounded side of the high voltage winding. The circuit is shown in Fig. 32-6. You are to measure the dc voltage drop across the load, and compare it to the voltage drops you measured in Steps 1 and 3 of the experiment.

To change the circuit, proceed as follows: First, unsolder and remove the 100K-ohm resistor which is connected

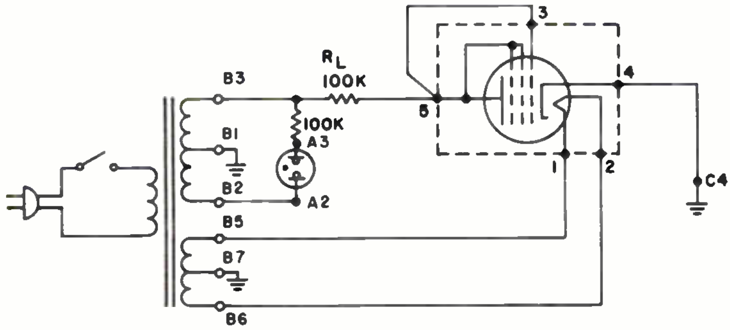


Fig. 32-6. The circuit for Statement 32.

from the circuit board to terminal C4. Unsolder and remove the length of hookup wire connecting terminal B3 to the circuit board.

Connect a length of hookup wire from lug 4 of the circuit board to terminal C4.

Connect the 100,000-ohm resistor between terminal B3 and lug 3 or 5. Solder all connections and insert the tube in the socket. Your circuit should now be like Fig. 32-6.

Connect the ground clip of your tvom to lug 5, plug the power cord into the ac outlet, and turn the circuit on. Carefully consider the direction of electron flow through the load resistor, and set your polarity switch to give an upscale reading when you touch the probe of your tvom to terminal B3. Make a note of your reading, then turn the circuit off. You now have sufficient information to complete the Statement.

Statement No. 32: 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 1 and 3.

EXPERIMENT 33

Purpose: To demonstrate the basic operation of the full-wave rectifier circuit and to show that it has better regulation than the half-wave rectifier circuit.

Introductory Discussion: A half-wave rectifier circuit has a diode connected between the ac source and the load so that current passes to the load only once during each cycle. In a full-wave rectifier circuit, two diodes are connected in such a manner that one diode conducts on each half of the ac cycle. Thus, both the negative and positive halves of the ac voltage are used and current passes to the load twice during each cycle. Because of this, the full-wave rectifier can supply greater current than can a half-wave rectifier under similar circumstances and it is better able to supply a constant voltage to varying load resistances.

Experimental Procedure: For this experiment, you will need your chassis, your tvom and the following parts:

1 HV silicon diode
1 22K-ohm resistor
1 .25-mfd capacitor

Before you begin the experiment, construct the circuit shown in the schematic diagram in Fig. 33-1. First, unsolder and remove the 100,000-ohm resistor connected from terminal B3 to the circuit board and replace it with a short length of hookup wire. Then remove the wire connected between terminal C4 and lug 4 on the circuit board and connect the 100,000-ohm resistor in its place.

Connect the HV diode between terminals B2 and B4 with the cathode lead to B4 and connect a length of hookup wire from B4 to lug 4 on the circuit board.

Check over your wiring and make sure all connections are soldered.

Step 1: To demonstrate the operation of the full-wave rectifier circuit.

Turn the circuit on, allow the tube time to warm up, and measure the voltage across the 100K-ohm load resistor. Set the tvom to measure dc voltage on the 120-volt range, clip the ground lead to the chassis and touch the probe to lug 4. Read the meter and record the value in the chart in Fig. 33-2. Switch your tvom
60V to ac and measure the voltage from terminal B3 to the chassis. Move the probe to terminal B2 and note that you read the same voltage. You should have approximately 65 volts at both terminals.
64V Turn the chassis off and unsolder the resistor lead from lug 4 of the circuit board. Connect a .25-mfd capacitor from lug 4 to terminal C4.

Step 2: To show that the full-wave rectifier will charge a capacitor to the peak value of the applied voltage.

Set the function switch of the tvom to the dc position, turn the circuit on and allow time for warm-up. Touch the probe to lug 4 and measure the voltage across the .25-mfd capacitor. Note that it is
92V much higher than the voltage across the resistor alone. Record the voltage in the space provided for Step 2 in Fig. 33-2. Turn the circuit off.

Discharge the capacitor by shorting across its leads or by grounding lug 4 to the chassis momentarily. Connect the 100K-ohm resistor in parallel with the .25-mfd capacitor by connecting the free resistor lead to lug 4 of the circuit board.

Step 3: To measure the voltage developed across a load resistor shunted by a capacitor.

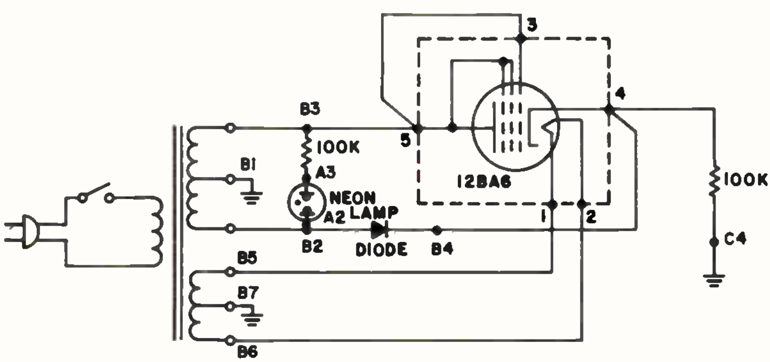


Fig. 33-1. Full-wave rectifier circuit for Experiment 34.

STEP	CIRCUIT	VALUE
1	100K Load Resistor	60V
2	.25-MFD Capacitor	92V
3	100K Resistor Shunted by .25-MFD Capacitor	82V
4	22K Resistor Shunted by .25-MFD Capacitor	67V
5	Half Wave With 22K Resistor and .25-MFD Capacitor	46V

Fig. 33-2. The chart used with this experiment.

Turn the circuit on, allow time for the tube to warm up and measure the voltage across the load. Record your voltage reading in the space for Step 3 in Fig. 33-2. Turn the circuit off and replace the 82V 100K-ohm resistor with a 22K-ohm resistor.

Step 4: To measure the output of the full-wave rectifier with a heavier load connected across it.

Turn the circuit on and measure the voltage between lug 4 of the circuit board and the chassis. Note that it is lower than the voltage you measured in the preceding step. Record the voltage in the chart in Fig. 33-2.

Step 5: To show that the full-wave rectifier circuit has better voltage regulation than the half-wave rectifier.

Remove the 12BA6 tube from the socket and turn the circuit on. Without the tube, you have a half-wave rectifier, using only one-half of the transformer winding and the silicon diode. Measure the voltage across the 22K-ohm resistor and the capacitor and place your reading in the chart in Fig. 33-2. Turn the circuit off.

Discussion: The full-wave rectifier circuit is essentially two half-wave rectifiers arranged so they operate alternately and supply current to the same load.

The fundamentals of full-wave rectification are shown in Fig. 33-3. The transformer winding is center-tapped and the center tap is our point of reference. With respect to the center tap, the ends of the

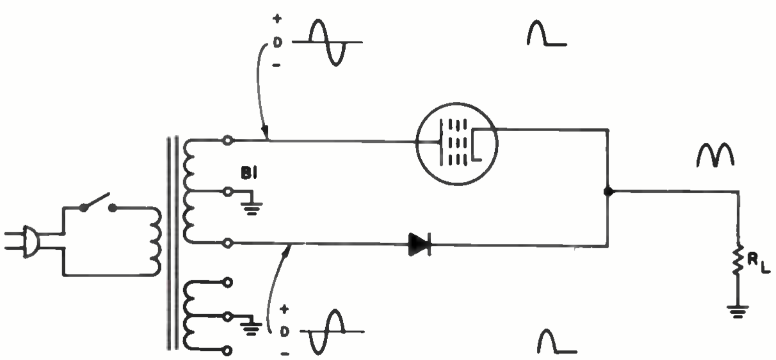


Fig. 33-3. Diagram showing the waveform in the full-wave rectifier circuit used in Step 1.

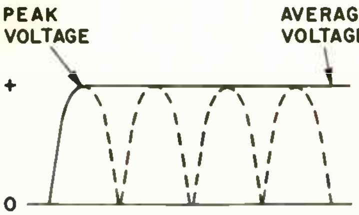


Fig. 33-4. Voltage across the capacitor in Step 2.

transformer winding are 180° out-of-phase with each other. Thus, during one half-cycle of the ac, the plate of the tube is positive, and the anode of the silicon diode is negative; during the next half cycle, the plate of the tube becomes negative and the anode of the diode becomes positive.

As you know, a diode conducts only when its plate or anode is positive with respect to its cathode. Therefore, the tube conducts and passes current through the load on one half-cycle and the silicon diode conducts and passes current on the other half-cycle. Thus, the spaces between the pulses produced by a half-wave rectifier circuit are filled in, as there are two pulses produced during each cycle.

Note that with full-wave rectification, there is always some positive voltage across the load. Therefore, the average voltage is higher. For this reason, you measured about 60 volts across the resistor in Step 1. You may remember that in the preceding experiment, you read only about 30 volts across the resistor in the half-wave rectifier circuit.

In Step 2, you should have found that the capacitor charged to approximately 90 volts, which is the peak value of the ac voltage. The peak value of a sine wave is equal to 1.4 times the rms voltage. Fig. 33-4 shows the waveform of the voltage across the capacitor. Note that the spaces between the pulses are filled in so that the average voltage is equal to the peak voltage.

When you connected the capacitor and 100K-ohm resistor in parallel across the output of the full-wave rectifier, you should have noticed some reduction in the dc output voltage. The capacitor charged each time the diode conducted and discharged through the resistor each time the rectifier output voltage passed its peak value. The waveform of the voltage across the resistor and capacitor is shown in Fig. 33-5. The effect of the capacitor was to produce a higher average voltage.

In Step 4, you increased the load on the rectifier circuit. You should have measured about 70 volts across the load. This voltage is lower than that measured in Step 3 because the capacitor discharges more quickly through the lower load resistance. As a result, the average voltage falls to a level nearer to that which you would have measured with no capacitance in the circuit.

The half-wave rectifier output voltage was much lower with the low load resistance. This is due to the fact that in the half-wave circuit, no voltage is supplied by the rectifier for a large percentage of the time. Thus, the capacitor is able to discharge almost completely between pulses as shown by the waveform in Fig. 33-6. In these last two steps, you can see

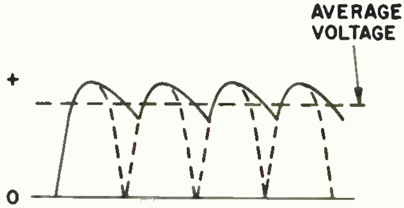


Fig. 33-5. Voltage across the capacitor and resistor in Step 3.

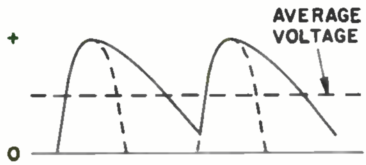


Fig. 33-6. Waveform across the capacitor and resistor in Step 5.

that the full-wave rectifier circuit has better regulation than the half-wave rectifier. Although both circuits develop about 90 volts across the capacitor alone, when a 22K resistor was connected across the capacitor, the output voltage of the full-wave rectifier fell to about 70 volts while the output of the half-wave rectifier was reduced to about 45 volts.

Instructions for Statement No. 33: For this Report Statement, you will disconnect the center tap of the transformer from the grounded terminal and measure the voltage across the load. Unsolder and disconnect the red/yellow lead from terminal B1 and push it out of the way. Put the tube back in the socket.

Turn the circuit on, measure the voltage between the chassis and lug 4 on the circuit board and answer the Statement here and on the Report Sheet. Turn your circuit off.

Statement No. 33: When I disconnected the transformer center tap lead, the voltage across the load:

(1) decreased to zero.
(2) increased slightly.
(3) decreased slightly.

EXPERIMENT 34

Purpose: To demonstrate the basic operation of the bridge rectifier circuit and to show the effects of loading the circuit.

Introductory Discussion: In the previous experiments, you studied some of the characteristics of simple half-wave and full-wave power supplies. Now, you will take up the full-wave bridge rectifier circuit.

Full-wave bridge rectifier circuits are used in both high and low power applications. They are often used in the ac voltmeter sections of multimeters. The ac voltage applied to the input section of the meter is rectified by the bridge circuit and the resulting dc voltage is applied to the meter circuit. Full-wave bridge rectifier circuits using solid state diodes are found in power supplies in many TV receivers and transmitters.

The diagram in Fig. 34-1 shows how a full-wave bridge circuit works. The semiconductor diodes are labeled W, X, Y and Z. The ac voltage is fed to the bridge circuit at points A and D, and the load, represented by resistance R_L, is connected between points B and C.

The arrows indicate the directions of current flow. When point A is negative, with respect to point D, the current shown by the solid arrows flows from

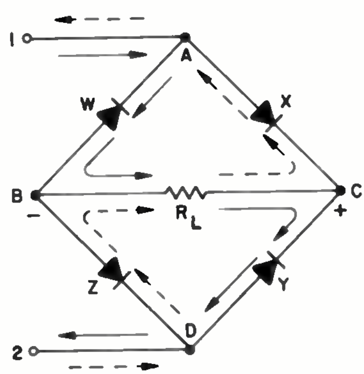


Fig. 34-1. Basic bridge rectifier circuit.

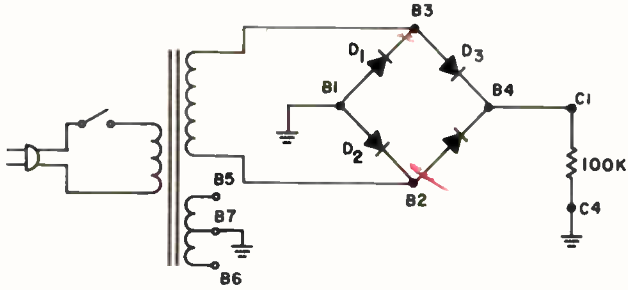


Fig. 34-2. Schematic diagram of the bridge rectifier circuit for Step 1.

point A through rectifier W, through R_L from left to right, and through rectifier Y to point D.

On the next half-cycle when point D is negative with respect to point A, the current flows as shown by the arrows drawn with broken lines. The current flows from point D through rectifier Z through the load resistor from left to right, and through rectifier X to point A.

Notice that the current flows through R_L in the same direction on both half-cycles of the applied ac voltage. Thus, point B is negative and point C is positive in the circuit in Fig. 34-1.

Experimental Procedure: For this experiment, you will need the following parts in addition to the chassis and tvom:

2 LV silicon diodes
1 HV silicon diode
1 .25-mfd capacitor

Construct the bridge rectifier circuit shown in the schematic diagram in Fig. 34-2. The wiring is shown in the pictorial diagram in Fig. 34-3. You should already have the red/yellow transformer lead disconnected from terminal B1. Also, there should be a HV silicon diode connected between terminals B2 and B4. The other HV diode is D_3. Use the LV diodes at D_1 and D_2.

When you have the circuit wired, be sure to remove the vacuum tube and then check your wiring to be sure there are no short circuits and that all connections are correct and soldered.

Step 1: To show that the bridge rectifier is a full-wave rectifier circuit and that a low dc voltage exists across each diode.

Set your tvom to measure positive 300 volts dc and clip the ground lead to the chassis. Turn the circuit on and measure the voltage across the 100K-ohm load resistor. You should read about 120 volts dc. Place your voltage reading in the chart in Fig. 34-4. 115

Touch the probe to terminal B2 and measure the dc voltage across diode D_2. Move the probe to terminal B3 and measure the dc voltage across diode D_1. Note that the two voltage readings are about the same. Jot down the voltage readings in the margin of this page.

Turn the circuit off and replace the 100K-ohm resistor with a .25-mfd capacitor. You may disconnect the resistor lead from terminal C1 and leave the other lead connected to terminal C4. Solder the capacitor leads to terminals C1 and C4.

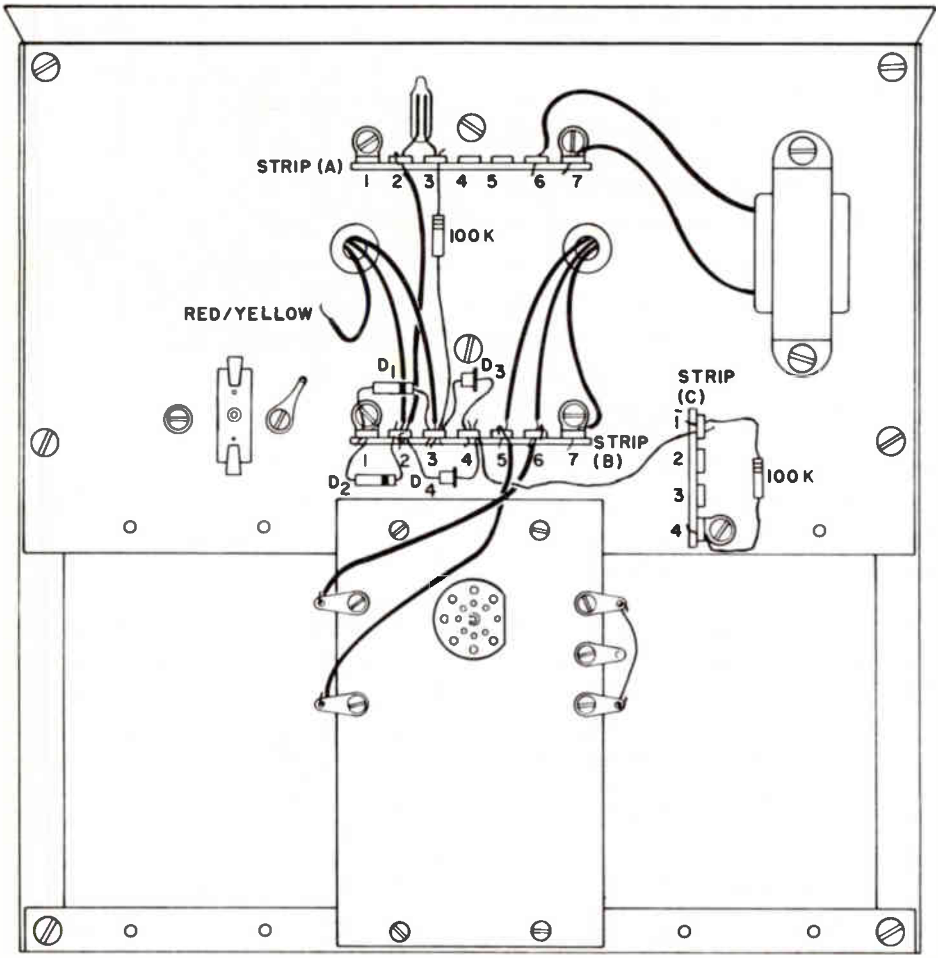


Fig. 34-3. Pictorial diagram of the circuit in Fig. 34-2.

Step 2: To show that the bridge rectifier will charge a capacitor to the peak value of the ac voltage.

Turn the circuit on and measure the voltage across the capacitor. Record the voltage in the space for Step 2 in the chart in Fig. 34-4. Turn the circuit off.

180V

Step 3: To show that the bridge rectifier will supply dc to a load shunted by a capacitor.

Connect the 100K-ohm resistor in parallel with the .25-mfd capacitor. Turn the circuit on and measure and record the voltage across the resistor and capacitor in the chart in Fig. 34-4. 160

Turn the circuit off and unsolder the resistor lead from terminal C1. Also, unsolder the lead of the LV diode, D_1, from terminal B3 and unsolder the lead of the HV diode, D_4, from terminal B2.

Step 4: To show that the bridge

rectifier can operate as a half-wave rectifier.

Energize the circuit and measure the voltage across the .25-mfd capacitor. It should read about the same as the voltage in Step 2. Record the voltage in the space for Step 4 in Fig. 34-4 and turn the circuit off. 180

Discussion: In this experiment, you operated your circuit from the full high voltage secondary winding of your transformer. Thus, the applied ac voltage was about 130 volts. This has a peak value of 130 X 1.4 or about 180 volts.

The dc voltage across the load resistor in Step 1 was about 120 volts. From previous discussions you know that this is the average value of the pulses which rise from zero to the peak voltage. The average value is about two-thirds of the peak value. Thus, you can be reasonably sure that the circuit is a full-wave rectifier, producing two positive pulses across the load during each cycle. The waveform of the output voltage is shown in Fig. 34-5A.

The rectifier circuit charged the .25-mfd capacitor to the peak value of the ac in Step 2. You should have measured about 180 volts, which is approximately the peak value of 130 volts ac.

STEP	VOLTAGE
1	115 ✓
2	180 ✓
3	160 ✓
4	180V

Fig. 34-4. Chart for use with Experiment 34.

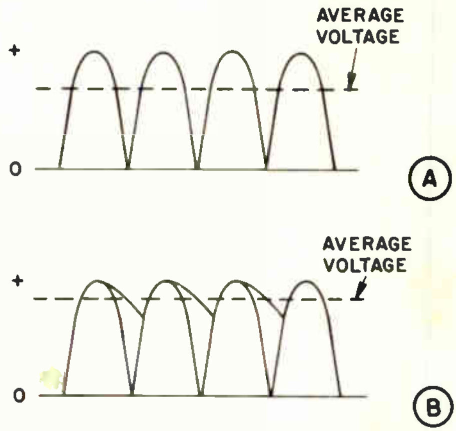


Fig. 34-5. Waveforms of voltages across (A) load resistor only in Step 1 and (B) load resistor and capacitor in Step 3.

In Step 3, you had a 100K-ohm load resistor shunted by a .25-mfd capacitor. You should have measured about 165 volts across the 100K-ohm load resistor and the capacitor. This is about an 8% drop from the voltage across the capacitor alone, and about a 40% increase over the voltage across the resistor alone. As in the previous experiment, the average voltage is higher than it was without the capacitor because the capacitor charges fully on each peak and discharges into the load between peaks producing the waveform shown in Fig. 34-5B.

You converted your bridge rectifier to a half-wave rectifier in Step 4 by disconnecting two of the diodes. A schematic diagram of the circuit used in Step 4 is shown in Fig. 34-6. The circuit should have charged the capacitor to the peak voltage of about 180 volts.

Refer to the schematic. Note that the two diodes are connected so that they pass current in the same direction and at the same time. When the polarity of the ac voltage is such that terminal B3 is

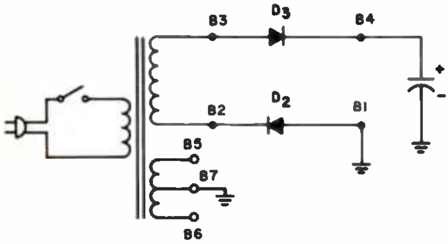


Fig. 34-6. Schematic diagram of the bridge circuit used as a half-wave rectifier.

positive with respect to terminal B2, current flows from B2 through diode D_2 to terminal B1 and ground. From ground, the current flows up to the negative plate of the capacitor. From the positive capacitor plate, current flows through diode D_3 and back to the transformer at terminal B3. On the other half-cycle of the ac voltage, the diodes do not conduct and no current flows.

Instructions for Statement No. 34: For this statement you will compare the operation of the circuit used in Step 4 with a circuit having three diodes.

Connect the 100K-ohm resistor in parallel with the .25-mfd capacitor. Turn the circuit on and measure the dc voltage across the capacitor and resistor. Jot down the value in the margin and turn the circuit off. 150V

Resolder the lead of the HV diode, D_4, to terminal B2 to form the circuit shown in the schematic in Fig. 34-7. Energize the circuit and measure the voltage across the resistor and capacitor again. Compare the results of the two tests and answer the Statement here and on the Report Sheet. Turn the circuit off. Unsolder and remove the two LV diodes and resolder the red/yellow transformer lead to terminal B1. 150V

Statement No. 34: When I connected diode D_4 into the circuit I found that the voltage across the load:

(1) increased by more than one-half.
(2) increased by about one-third.
(3) remained the same.

This proves that with three diodes, the circuit acted as a:

(1) half-wave rectifier circuit.
(2) full-wave rectifier circuit.
(3) full-wave bridge rectifier circuit.

EXPERIMENT 35

Purpose: To show that there is a ripple voltage at the rectifier output; to show that 120 Hz ripple can be filtered more easily than 60 Hz ripple; and to show that this ripple can be filtered out with a choke and a capacitor.

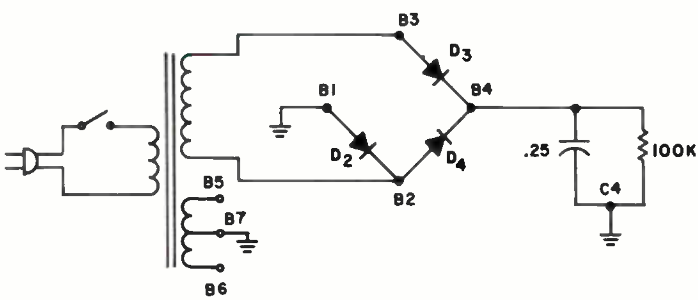


Fig. 34-7. The circuit used for Statement 34.

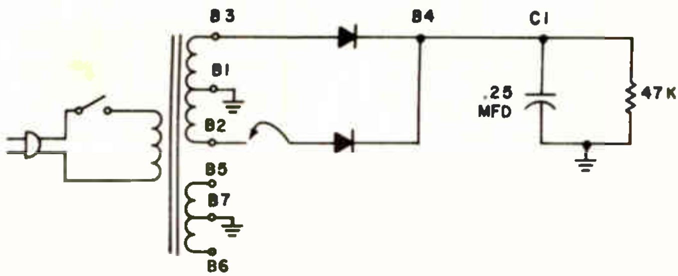


Fig. 35-1. The circuit used in Step 1.

Introductory Discussion: So far we have considered only the pure dc voltage 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 this ac component. In this experiment you will measure the ripple voltage and see how it can be reduced to a very small value so that almost pure dc can be supplied to the load.

Experimental Procedure: In addition to your tvom and the parts mounted on your chassis, you will need the following parts:

2 20-mfd, 150V electrolytic capacitors
1 47K-ohm resistor

Heat your soldering iron and carefully examine the tip. Clean and re-tin it if necessary. Also, check the calibration of your tvom.

The circuit which you will use in this experiment is shown in Fig. 35-1. You will only have to unsolder the anode lead of the diode from terminal B2 and replace the 100K-ohm resistor with a 47K-ohm resistor.

Step 1: To measure the ac ripple voltage and the dc voltage produced by a half-wave rectifier across the 47K-ohm load shunted by a .25-mfd capacitor.

Set the function switch of your tvom to ac and set the range switch to the 120-volt position. Clip the ground lead to the chassis and measure the ac voltage between terminal C1 and ground. If your reading is less than about 25 volts, set the range switch to the 30-volt position. Observe the reading and record it in the chart in Fig. 35-2. 12V

Now set the tvom to dc and measure the dc voltage across the load. Make this measurement and record your value in Fig. 35-2. Turn off the circuit.

Step 2: To show that 120-Hz ripple can be filtered more easily than 60-Hz ripple.

Convert your circuit to a full-wave rectifier by resoldering the free HV diode lead to terminal B2. Energize the circuit and measure the ac ripple voltage across the load resistor and the .25-mfd capacitor. Set the tvom to ac and touch the probe to terminal C1. Record the voltage in the space for Step 2 in Fig. 35-2.

Switch the tvom to dc, set the range switch to 120 volts, and measure the dc output voltage between terminal C1 and the chassis. Record the value and turn your circuit off.

Step 3: To measure the ac ripple voltage and the dc voltage across the load shunted by a higher capacitance.

The change to make in the circuit is shown in Fig. 35-3. Disconnect and remove the diode connected between terminals B2 and B4. Also, disconnect the lead of the .25-mfd capacitor from terminal C1. Connect a 20-mfd electrolytic capacitor from terminal C1 to terminal C4 or some other convenient ground

STEP	CIRCUIT	VOLTAGE MEASURED	
		AC	DC
1	47K Load Shunted by .25 MFD	12V	73V
2	F.W. Rectifier. 47K Load Shunted by .25 MFD	12V	73V
3	47K Load Shunted by 20 MFD	.4	86V
4	Choke and Two 20 MFD Capacitors	—	86V

Fig. 35-2. Enter your readings here for Experiment 35.

terminal. The positive lead of the electrolytic capacitor must connect to terminal C1.

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. 35-2. 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 1.2V or 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.

Set your tvom to measure the dc voltage across the load, make this measurement, and record your results in Fig. 35-2. Turn off the power supply. Notice again the change between the readings in Step 1 and Step 3. Obviously, the large capacitor in the circuit caused the increase in the dc voltage.

Step 4: 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. 35-4. Unsolder and remove the length of hookup wire connecting terminals B4 and C1. Connect a second 20-mfd electrolytic capacitor from terminal B4 to terminal B7 with the positive lead to B4. Connect one lead of the choke coil mounted on your chassis to terminal B4. Connect the other choke lead to terminal C1. Solder all connec-

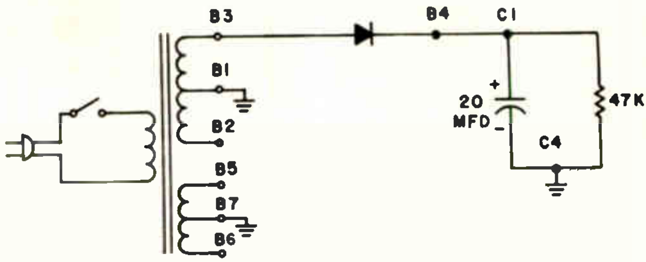


Fig. 35-3. The circuit for Step 3.

tions and recheck your wiring. You are now ready to continue making your measurements.

Set the tvom for ac measurements and measure the ac ripple voltage across the load resistor between the chassis and terminal C1. If you cannot measure any ripple voltage, simply make a dash in the space provided in Fig. 35-2. Now reset your tvom, and measure the dc voltage across the load resistor. Record your results in Fig. 35-2. Turn off the power supply.

Discussion: In this experiment, you have observed the fact that filtering the output of a rectifier increases the dc voltage and decreases the ac ripple voltage across the output.

In Steps 1 and 2, you saw that the small capacitor was better able to filter the full-wave rectifier output than the half-wave output. This is because the full-wave circuit produces two pulses of voltage during each cycle. Thus, the capacitor is recharged twice as often as it is in a half-wave circuit. The capacitor has less time to discharge between pulses and therefore, it maintains a higher average voltage.

The 20-mfd capacitor which you used in Step 3 produced a higher dc voltage with lower ripple than you obtained with the full-wave rectifier circuit and the small capacitor. Each time the rectifier conducted, the capacitor became fully charged. Because it has such a high capacity, the electrolytic capacitor stored more energy and discharged very little between pulses. Thus, the average dc voltage across it was high.

You should have measured nearly the

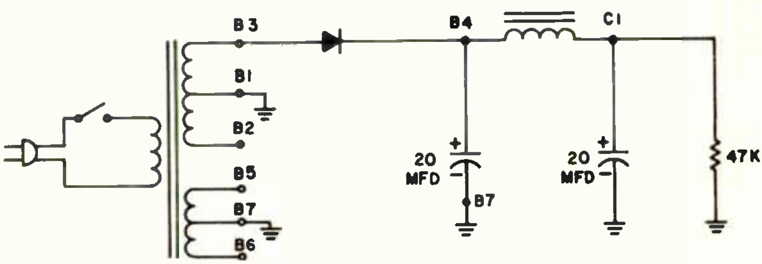


Fig. 35-4. The rectifier and π circuit for Step 4.

same dc voltage in Step 4 that you measured in Step 3, but with almost no ripple. The network which you used in Step 4 is a low pass pi filter, consisting of two capacitors and a choke. The capacitor connected between the cathode of the rectifier and ground is called the input filter capacitor and the one across the load is called the output filter capacitor.

Refer to the schematic diagram in Fig. 35-4. Notice that the choke, output filter and resistor form a load for the rectifier and input filter capacitor. The combined ac and dc voltage is applied to this load. The capacitor has low reactance to ac and high reactance to dc. On the other hand, the choke has high reactance to ac, and low reactance to dc. Thus, when applied to the choke and a capacitor, the ac and dc voltages divide differently.

Because the choke has high reactance to ac, most of the ac voltage is developed across it. The dc resistance of the choke is low compared to the dc resistance of the load resistor, resulting in little dc voltage drop across the choke. Most of the dc voltage, therefore, is developed across the output filter capacitor and the load resistor.

Pi filter networks using resistors instead of chokes are used in some low power equipment such as ac-dc receivers. The use of a resistor gives considerable savings in weight, space and cost. As long as the circuit current is not high, a circuit of this type can provide adequate filtering.

In order to provide the filtering, the value of the resistor must be high compared to the impedance of the output filter capacitor. The ripple voltage is developed across the resistor and the output filter capacitor in series. If the impedance of the capacitor is quite low, most of the ripple will appear across the resistor and little of it will appear across the load.

The dc current drawn by the load also flows through the filter resistor. Because the resistor value must be fairly high, there is a substantial voltage drop across it. This voltage drop is in series with the load, thereby making available less voltage for the load.

Instructions for Statement No. 35: For this statement, we are going to determine the ripple reduction factor of the filter circuit. To do this, we divide the amount of ripple voltage across the input filter capacitor by the amount of the ripple voltage across the output filter capacitor. For example, if you have 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. 35-5. The .25-mfd capacitor is used as the input filter capacitor, so unsolder and remove the 20-mfd electrolytic capacitor connected to terminal B4 and connect the .25-mfd capacitor from terminal B4 to terminal B7 or C4.

Set the tvom for ac voltage measurements, and turn the range switch to the 120-volt position. Measure the ac ripple voltage at the rectifier cathode, terminal B4. If necessary, adjust the range switch to a lower range. Now measure the output ripple voltage across the load by touching the probe of the tvom to terminal C1. Reduce the setting of the range switch as necessary to get a usable 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 here and on the Report Sheet.

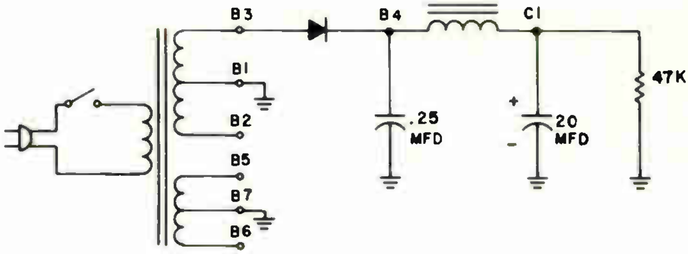


Fig. 35-5. The circuit used to answer Statement 35.

Statement No. 35: The ripple reduction factor for this experiment was:

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

EXPERIMENT 36

Purpose: To show the effect of a 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 a 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 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 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. 36-1. Fig. 36-1A shows the effect of leakage, and Fig. 36-1B 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. 36-1B 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. 36-2 to demonstrate the effects of high power factor in both the input and output filter capacitors.

Experimental Procedure: In addition to your tvom and the parts mounted on the chassis, you will need:

- 2 20-mfd, 150-volt electrolytic capacitors
- 1 3000-ohm resistor
- 2 22K-ohm resistors

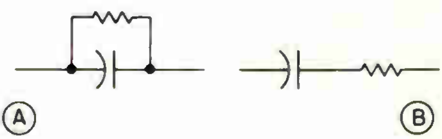


Fig. 36-1. (A) Leakage in a capacitor. (B) Power loss.

Proceed as follows: First remove the .25-mfd capacitor from terminal strip B and replace it with a 20-mfd, 150V electrolytic capacitor. Be sure to connect the positive lead to terminal B4. Disconnect the 47K-ohm lead resistor and replace it with two 22K-ohm resistors connected between terminals C1 and C4. Solder the connections.

Your circuit should now be wired as shown in Fig. 36-2. Check it over carefully, comparing it to Fig. 36-2. Examine both sides of the terminal strips 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 tvom for ohmmeter measurements with the range switch in the R X 1K position. Put the ground lead on the chassis, and touch the positive probe to the rectifier terminal, B4. 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 of the circuit shown in Fig. 36-2.

Set the function switch to dc, set the range switch to the 300-volt position and set the polarity switch to normal. Clip the tvom ground lead to the chassis, turn on the power supply and touch the positive probe to terminal C1. Record the reading as the dc output voltage for Sfep 1 in Fig. 36-3.

Now set up your tvom for ac measurements, and measure the ac voltage between terminal C1 and the chassis. If no perceptible voltage is present even on the 1.2-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 positive capacitor lead from terminal B4. Solder one end of the 3000-ohm resistor to terminal B4, and then solder the capacitor lead to the other lead of the 3000-ohm resistor, as shown in Fig. 36-4. 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 positive lead and the capacitor plates. You can consider the end of the 3000-ohm resistor

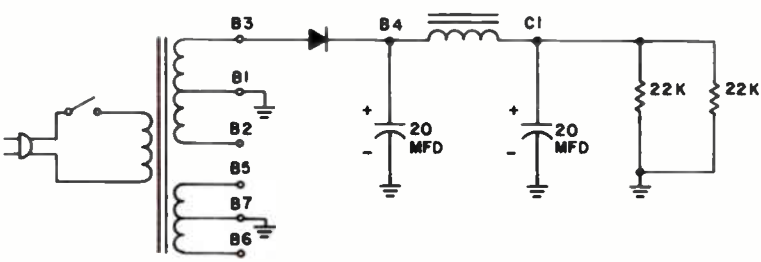


Fig. 36-2. The circuit for Step 1.

STEP	CIRCUIT CONDITIONS	OUTPUT VOLTAGE	
		DC	AC
1	Normal	80V	0
2	High Power Factor in Input Capacitor	50	.3V
3	Defective Input Capacitor Shunted by Good Capacitor	80V	0
4	High Power Factor in Output Capacitor	78V	.5V

Fig. 36-3. Enter your readings here for Experiment 36.

connected to terminal B4 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 tvom to measure dc voltages as you did before, with the switch in the 300-volt position. Measure the dc voltage between terminal C1 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 C1. 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, 36-3. 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 C1, using the slip-on alligator clip over the positive probe. Turn the power supply on, and note the voltage reading. Now pick up the third 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 terminal B4. 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. 36-3 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 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

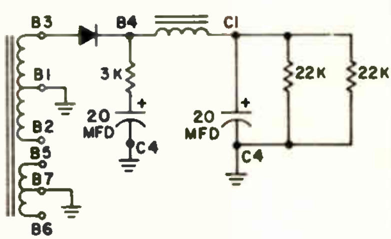


Fig. 36-4. The circuit for Step 2.

shock later. There is no danger as long as you hold the capacitor by its insulating case.

Leave your voltmeter connected to the output of the power supply, turn off the power supply, and set 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 terminal B4. Notice that when the capacitor makes contact across the defective capacitor, the ac output voltage drops to the same value as Step 1 for ac output voltage. Record this in Fig. 36-3.

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.

You have now finished the tests with the input filter capacitor; so remove the 3000-ohm resistor from the circuit, and unsolder the positive lead of the input capacitor from the resistor lead. Resolder the positive lead to terminal B4. The circuit is now the same as in Fig. 36-2.

Step 4: To show the effect of a high power factor in the output filter capacitor.

Disconnect the positive lead of the electrolytic capacitor from terminal C1. Solder one lead of the 3000-ohm resistor to lug C1. Then, solder the positive capacitor lead to the free resistor lead. Place the two leads so they cannot touch the chassis.

Connect the ground clip of the tvom to the chassis of the power supply, and connect the positive probe to terminal C1. Set your tvom to measure the dc voltage across the 11K-ohm 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. 36-3.

The voltage should be the same as that in Step 1 in Fig. 36-3. 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 the 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 in Fig. 36-3. 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 C1 or to any point in electrical contact with C1. 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 capacity, but should have a working 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. 36: You have seen the effect of a high power factor in both the input and 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 positive capacitor lead from the 3000-ohm resistor, remove the 3000-ohm resistor from the circuit, and arrange the free capacitor lead so that it cannot short to the chassis. Clip your tvom to the chassis and to terminal C1. Set your tvom for ac measurements, turn on the power supply, and note the reading. You will then be able to answer the Statement. 1V AC

Statement No. 36: When I simulated an open in the output filter capacitor, I found that the ac voltage across the load resistor was:

(1) less than
(2) more than
(3) the same as

the ac output voltage in Step 4.

EXPERIMENT 37

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 radio receivers today are designed to operate on power supply voltages of 90 to 100 volts dc. A half-wave rectifier that is capable of supplying this voltage is shown in Fig. 37-1. 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.

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

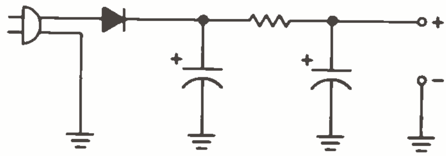


Fig. 37-1. A rectifier circuit capable of supplying about 90V dc.

reason, the study of how voltage-doubler power supplies operate is important to you.

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

The half-wave voltage doubler is often used in TV receivers which have no power transformers. The ac line is connected directly to the negative side of the doubler circuit. You may also see half-wave doublers in TV high voltage supplies because in the high voltage supply the current demands are very low. Hence, filtering is not a problem.

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 voltage used, the basic principles are the same.

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

1 20-mfd, 150-volt electrolytic capacitor
1 .25-mfd capacitor
1 12BA6 tube

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 C1 and C4. Unsolder the two choke leads, and unsolder the red/yellow transformer lead from terminal B1. Also disconnect the two 20-mfd electrolytic capacitors. Remove any excess solder on the terminal strips, and make certain that no solder has bridged from the lugs to the chassis.

Fig. 37-2A 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. 37-2B 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

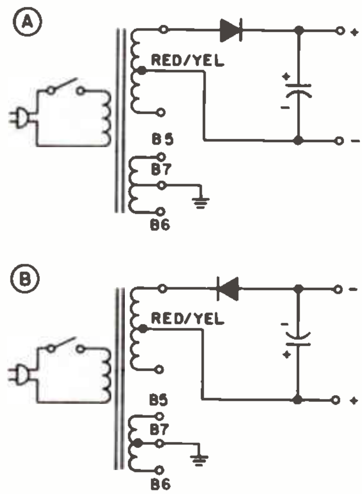


Fig. 37-2. Rectifier connected to (A) a positive supply and (B) a negative voltage with respect to the transformer center tap.

make a full-wave voltage doubler. The circuit is shown in Fig. 37-3.

Wire the circuit shown in the schematic diagram in Fig. 37-3. First, connect the red/yellow transformer lead to terminal B4. Connect a rectifier diode from terminal B3 to terminal A6; the cathode connects to A6. Connect another rectifier diode from terminal A4 to terminal B3. Connect the cathode to B3. Connect a 20-mfd, 150V electrolytic capacitor from terminal A4 to terminal B4, with the positive lead to B4. Connect another 20-mfd electrolytic capacitor from terminal B4 to terminal A6, with the positive lead to A6. Check your work against the schematic and solder all connections.

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. 37-3, and you can proceed with the experiment.

Step 1: To show that the circuit in Fig. 37-3 gives twice the voltage that a single rectifier would.

Measure the ac source voltage between terminals B4 and B3. Record your measurement in Fig. 37-4. Turn off the supply after each measurement.

65V

Now measure the dc output voltage of rectifier D_1 by measuring across capacitor 70V C_1. Connect the ground clip of the tvom to terminal B4, and the probe to terminal A6. Note the polarity marked on the electrolytic capacitor in Fig. 37-3 so you will know how to set the polarity switch on the tvom. Record your reading in Fig. 37-4.

Measure the dc voltage developed by rectifier D_2 by measuring the voltage 80V across capacitor C_2. Leave the ground clip of the tvom on terminal B4, note the polarity of the voltage to be measured as shown on the electrolytic capacitor in Fig. 37-3, and set your polarity switch accordingly. Touch the probe to terminal A4, and record the voltage you measure in Fig. 37-4.

As you can see from Fig. 37-3, capacitors C_1 and C_2 are in series, so that the voltages across them add. Measure this voltage by clipping the ground lead of the tvom to terminal A4, note the polarity so you can set the polarity switch properly, and put the range switch in the 300-volt position. Touch the probe to terminal A6, and record your voltage in Fig. 37-4 as the dc output without load. You should get approximately twice the voltage that you got across either C_1 or C_2. 180V Notice that the dc voltage is much higher than the peak of the rectified ac source

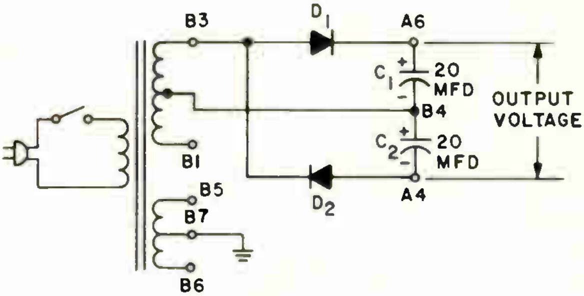


Fig. 37-3. The full-wave voltage doubler circuit.

VOLTAGE MEASURED	READING
AC Source	65V
DC Output of Diode D_1	90V
DC Output of Diode D_2	86V
DC Output Without Load	180V
DC Output Under Load	170V

Fig. 37-4. Enter your readings for Step 1 here.

voltage. Turn off the power supply. As a final measurement in this step, let us see how much the output voltage drops when a load is applied. Connect the two 22K-ohm resistors in series, and connect the outside leads of the 44K-ohm resistance between terminal A4 and terminal A6. Solder the connections. Now measure the dc voltage between terminals A4 and A6, and record the value in the space provided in Fig. 37-4. 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 chassis from the power line, and holding the wire by the insulation, short terminal A6 to terminal B4. You may see a spark as the capacitor discharges. Do this several times. Now discharge capacitor C_2 by touching the ends of the hookup wire to terminals B4 and A4. 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 voltage for the second rectifier.

The circuit that you will use is shown in Fig. 37-5. First, remove the 44K-ohm load resistor (the two 22K-ohm resistors in series) from terminals A4 and A6. Unsolder and disconnect capacitor C_2 from terminals A4 and B4. Move the red/yellow transformer lead from B4 to A4. Move the negative lead of capacitor C_1 from B4 to A4.

Move both diode leads from terminal B3 to terminal B4. Connect capacitor C_2 between terminals B3 and B4, with the positive lead to B4. Solder all connections and check your work against the schematic in Fig. 37-5.

To measure the ac source voltage, set up your tvom for ac voltage measurements, and connect the ground clip to terminal B3. Turn on the power supply, and touch the probe to terminal A4. Record the ac voltage measured in Fig. 37-6.

Now, set your tvom for positive dc voltage measurements. With the ground

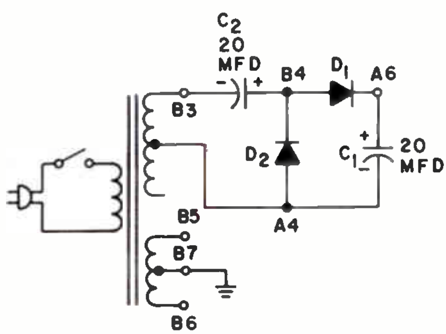


Fig. 37-5. The half-wave voltage doubler circuit.

lead connected to terminal B3, touch the probe to terminal B4. The voltage you measure is that developed across capacitor C_2, the 20-mfd, 150-volt capacitor connected between these terminals. Record the value in Fig. 37-6.

To measure the voltage at the output of rectifier D_1, turn off the power supply, connect the ground lead of the tvom to terminal A4, set the range switch to the 300-volt range, turn on the power supply, and touch the probe to terminal A6. Record the voltage you measure in Fig. 37-6. Note that it is approximately the same as the dc output voltage in Step 1 of Fig. 37-3. Turn your equipment off.

Discussion: In Fig. 37-3 the rectifiers function on alternate cycles of the power line, so the ripple voltage developed in the circuit between the output terminals (A4 and A6) is 120 Hz.

When the red transformer lead is positive with respect to the red/yellow lead in Fig. 37-3, we have current flow through rectifier D_1, which charges capacitor C_1 with the polarity shown. (Remember that the lead marked + on the rectifier is actually the cathode.) When the ac across the power transformer has this particular polarity, rectifier D_2 will not conduct. On the next half-cycle, the red/yellow lead is positive with respect to the red lead. Then rectifier D_1 will not conduct. However, rectifier D_2 does conduct, and in so doing, charges capacitor C_2 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 A4 and A6 is twice that of either capacitor.

In the half-wave voltage doubler in Fig. 37-5, there is a 60 Hz ripple between the output terminals A6 and A4. When the red lead in Fig. 37-5 is negative with respect to the red/yellow lead, rectifier D_2 will conduct, charging up capacitor C_2 to the polarity shown. This time rectifier D_1 will not conduct. On the next half-cycle, the red lead becomes positive with respect to the red/yellow lead and the voltage across C_2 is added to the transformer voltage. The polarity is incorrect for conduction through D_2, but D_1 will conduct, and its output will charge C_1 to the peak of this voltage. As you have seen, it is roughly equal to the output voltage of the full-wave doubler.

Note in Fig. 37-5 that one side of the ac source (the red/yellow lead) is connected to the negative side of the output at terminal A4. Therefore, the half-wave doubler can be used without an isolation transformer in an ac line operated receiver, since one line is common to the input and the output of the power supply.

Voltage doubler circuits, such as those in Figs. 37-3 and 37-5, 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

VOLTAGE MEASURED	READING
AC Source	64V
Voltage Across C_2	90V
Voltage Output	176V

Fig. 37-6. Enter your readings for Step 2 here.

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. 37: 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.

Insert the 12BA6 tube in the socket on the circuit board. You should still have leads connecting terminals B5 and B6 to lugs 1 and 2 of the circuit board for the 12BA6 heater voltage. Disconnect the power supply from the ac line. Run a lead from lug 4 on the circuit board to terminal B3 and solder both connections. Make certain that the connections already on terminal B3 do not come loose.

Connect a .25-mfd capacitor from lug 5 on the circuit board to terminal A4, again taking care that the leads already connected to terminal A4 do not come loose, and solder does not drip down and short to the chassis. You should have a wire connecting lugs 3 and 5 on the circuit board. The circuit should now be wired like that shown in Fig. 37-7.

Connect the ground clip of your tvom to the .25-mfd capacitor lead that goes to lug 5. Clip the positive probe of the tvom to terminal A6. 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 tube heats up, the voltage will start to rise rather rapidly, and will soon come to a stop. Record the voltage you measure on the margin of this page. You are now ready to answer the statement.

200v

Statement No. 37: The voltage I measured between the plate of the 12BA6 tube and terminal A6 was approximately:

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

that across capacitor C_2 in Step 2.

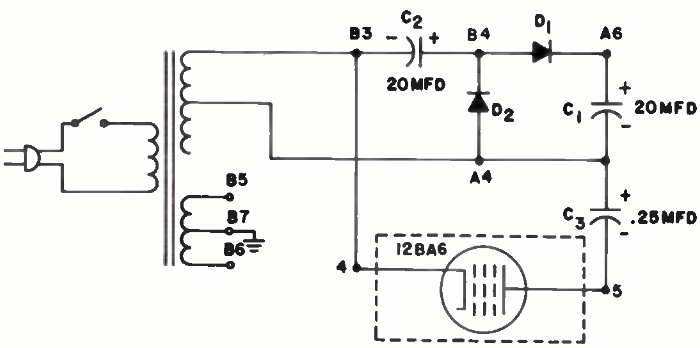


Fig. 37-7. The circuit for Statement 37.

Tube And Transistor Fundamentals

In the following experiments, you will demonstrate triode vacuum tube and transistor fundamentals. You will then use the tube and transistor in voltage regulator circuits. We will review briefly the operation of tubes and transistors before going further.

You know that a tube passes current from cathode to plate. The current is in the form of electrons which are emitted by the heated cathode. When the plate is at a positive potential, the electrons are attracted to it.

The control grid, which is an element placed near the cathode in triodes, tetrodes, pentodes, etc., controls the electron flow, and hence the amount of current reaching the plate. The cathode-to-grid voltage or bias is normally slightly negative. By varying the bias, the plate current can be increased or decreased.

As you learned from your regular lessons, a transistor is similar to a triode tube. It has three elements - a collector, base and emitter, and can be used for many of the functions served by vacuum tubes.

Bipolar transistors, which are the most widely used type of transistor, are made in either of two classifications: PNP or NPN. You received a PNP type in this kit. In a PNP transistor, current passes from collector to emitter. This conduction takes place when the base is more negative than the emitter and the collector is more negative than the base.

The amount of collector-to-emitter current is controlled by the emitter-to-base current. The collector current increases as the base-to-emitter current increases.

EXPERIMENT 38

Purpose: To show that when the plate of a triode tube is positive with respect to the cathode, the tube can complete a path for direct current and to show that grid-to-cathode voltage can control the conduction of a triode.

Introductory Discussion: In previous experiments, you have connected two or more resistors in series across the battery and have noted how the battery voltage divides between the resistors. We will repeat this experiment using the high voltage supply instead of a battery. We will first simulate the cathode-plate circuit of a tube with a resistance. Then we will substitute the cathode-to-plate path of the tube for one of the resistors. You will find that the voltage will still divide between the remaining resistor and the cathode-plate path within the tube. You will use various values of resistors in series with the tube and see that the voltage division will change when one of the resistors in the circuit changes.

Following this, you will see that the series resistor can be placed between the negative side of the power supply and the cathode of the tube or between the plate and the positive side of the supply. You will find that the tube operation is similar in either case. You will see how we can vary the cathode-plate resistance of a tube. You will use a low voltage battery to supply bias voltage and measure the resulting plate current.

In this experiment you will use your 12BA6 tube connected as a triode. Previously, you used it as a diode, with the control grid connected to the plate. Now you will have to disconnect the control grid from the plate circuit, as the control grid will be supplied separately. Always be sure to turn off the supply and discharge the capacitors before you make circuit changes to avoid being shocked.

Experimental Procedure: For this experiment, you will need the following parts in addition to the experimental chassis and your tvom:

1 100K-ohm resistor
2 22K-ohm resistors
2 1.5-volt flashlight cells

Fig. 38-1 shows the circuit you will use in the first step of this experiment. The circuit consists of a half-wave rectifier power supply and a voltage divider. The 100K-ohm resistor we will call the load resistor, R_L, and the 44K-ohm resistance will represent the cathode-to-plate resistance of the tube. Before wiring the circuit, unsolder and remove from the chassis the two rectifiers and the three capacitors used for Statement 37. Also unsolder the red/yellow power transformer lead from terminal A4 and solder it to terminal B1. Remove the lead connected between terminal B3 and lug 4 of the circuit board.

Now connect a rectifier diode between terminals B3 and B4, with the cathode lead connected to B4. Connect a 20-mfd, 150V electrolytic capacitor between terminals B4 and B1, with the positive lead to B4.

Connect a 100K-ohm resistor between terminal B4 and lug 5 of the circuit board. If necessary, solder a short length of wire to the resistor lead. Connect the series-connected 22K-ohm resistors from terminal C4 to lug 5.

If you have not already done so, remove the 12BA6 tube from the tube socket. Also, remove the wire connecting lugs 3 and 5 on the circuit board. Note that you have a series circuit connected across the high voltage power supply and you are using lug 5 of the circuit board merely as a tie point.

Step 1: To measure the voltage drop across the 44K-ohm resistance.

Connect the ground lead of your tvom to the chassis and set the meter for measuring positive dc voltage on the 120-volt range. Plug the experimental chassis power cord into an ac receptacle and turn the equipment on. Touch the probe of your tvom to lug 5 and measure the voltage. Record the measurement under "Plate-Cathode Voltage" in the space for Step 1 in the chart in Fig. 38-2.
28v
This is the voltage drop across the 44K-ohm resistance.

The voltage drop across the 100K-ohm load resistor can now be found by measuring the B supply voltage at terminal B4 and subtracting the voltage drop across the 44K-ohm resistance. For example, if the voltage across the 44K-ohm resistance

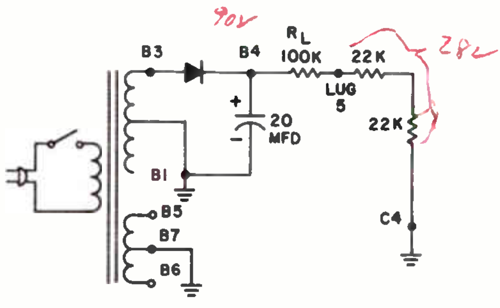


Fig. 38-1. The circuit used in Step 1.

90V 28 62 | 90 1.4 88.6 | 90.0 4.6 85.4 | 90.0 84.0 6.0 | 90 37 53

STEP	PLATE CATHODE VOLTAGE	VOLTAGE ACROSS R_L
1	28V	62V
2	1.4V	88.6V
3	4.6V	85.4V
4	6V	84.0V
5	37V	53V

Fig. 38-2. The chart you will use for Experiment 38.

is 24 volts, and your B supply voltage is 80 volts, the voltage across the 100K-ohm resistance is 56 volts. For convenience we call this resistor R_L. Enter the voltage you calculated for the drop across R_L in the proper space in Fig. 38-2.

Step 2: To measure the plate voltage of a tube with a 100K-ohm load resistor.

Change the circuit so it will be wired according to the schematic in Fig. 38-3. Unsolder and remove the 44K-ohm resistance. Connect a length of hookup wire from lug 4 on the circuit board to terminal C4. Connect a short length of hookup wire from lug 4 to lug 3 of the circuit board. Finally, insert the 12BA6 in the socket.

Connect your tvom to measure the dc voltage at the plate, pin 5, of the tube (lug 5). Turn the circuit on and notice that the voltage rises immediately to the B supply voltage. As the tube warms up, the voltage will decrease. Record the plate voltage in Fig. 38-2. Subtract it from the B supply voltage value and record the difference as the voltage across R_L. Turn off the circuit and discharge the filter capacitor of the power supply.

Step 3: To show that decreasing the plate load resistance increases the plate voltage.

Remove the 100K-ohm load resistor connected between terminal B4 and circuit board lug 5. The two 22K-ohm resistors should still be connected in series. Connect them in place of the 100K-ohm resistor.

Turn the circuit on and allow time for the tube to warm up. Then measure the voltage at the plate of the tube, lug 5. Record this as the plate voltage for Step 3 and compute the voltage drop across the load resistance R_L. Record this voltage also in Fig. 38-2.

Step 4: To show that the load resistor can be in either the plate or cathode circuit.

You will use the circuit in Fig. 38-4. After turning the circuit off and discharging the filter capacitor, unsolder and remove the 44K-ohm load resistance. Connect a piece of hookup wire in its place between lug 5 and terminal B4. Remove the length of hookup wire connected in the cathode circuit between terminal C4 and lug 4 of the circuit

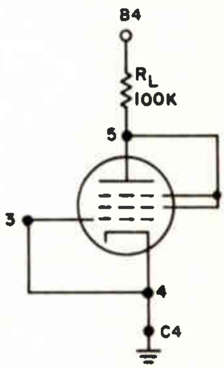


Fig. 38-3. The circuit for Step 2.

board. In its place, connect the 44K-ohm resistance.

Connect your voltmeter across the 44K-ohm resistance and turn the circuit on. Note that the voltage is zero at first and rises gradually as the tube warms up.

Because the meter is connected directly across the load resistance, you are measuring the voltage across R_L. Record this voltage in the space for R_L for Step 4 of Fig. 38-2. Subtract this voltage from the B supply voltage and enter the difference in Fig. 38-2 as the plate voltage.

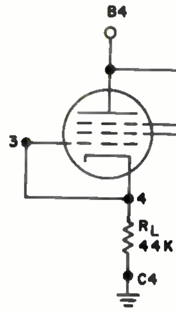


Fig. 38-4. The tube with the load resistance in the cathode circuit.

Step 5: To show that the grid voltage will vary the resistance of the cathode-plate path.

With the circuit turned off, unsolder and remove the 44K-ohm resistance and connect a length of hookup wire in its place, between terminal C4 and lug 4. Remove the length of hookup wire between lug 5 and terminal B4. Connect the 44K-ohm resistance in its place.

The two 1.5-volt D cells should be still connected in series to form a 3-volt battery. If they are not, reconnect them. Connect the battery between the cathode and grid of the tube as shown in Fig. 38-5. Solder the positive battery lead to a convenient ground terminal and the negative battery lead to lug 3. Check your work to see that the circuit is wired according to Fig. 38-5.

Connect your tvom to measure the dc voltage between the chassis and the plate of the tube at circuit board lug 5. Energize the circuit. Allow time for the tube to warm up and observe the voltage reading. Record the plate voltage for this step in Fig. 38-2. Compute the voltage across R_L and record it in the chart. Turn the equipment off.

Discussion: In this experiment you have demonstrated some of the very important facts about vacuum tube circuits. These are:

(1) The cathode-plate path inside a tube will conduct current and this path has a definite resistance.
(2) If a resistor is placed in series with either the plate or cathode, the source voltage will divide between the tube and resistor.
(3) Changing the value of the resistor will change the voltage division between the tube and the load resistor.
(4) If a voltage is applied that makes the grid of the tube negative with respect to the cathode, the tube acts as a higher resistance and it conducts less current.

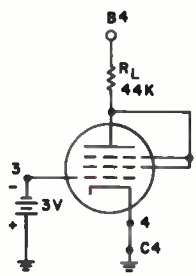


Fig. 38-5. The circuit for Step 5.

(5) When the load, R_L, is in the plate circuit, the plate voltage is equal to the supply voltage less the drop across R_L.

Instructions for Statement No. 38: For this statement, you will determine whether or not or how much current flows in the grid circuit used in the last step.

Unsolder the negative battery lead from circuit board lug 3 and connect a 100,000-ohm resistor in series between the battery lead and lug 3. Turn the circuit on and allow the tube to warm up. Measure the voltage across the 100K-ohm resistor. Using the Ohm's Law formula for current ($I = E/R$) compute the grid current. Answer the Report Statement here and on the Report Sheet. Turn the circuit off.

Unsolder and disconnect the 3-volt battery from the chassis. Unsolder and disconnect the 44K-ohm resistor. Also remove the length of hookup wire connected between lug 4 and terminal C4.

Statement No. 38: The grid current in the vacuum tube circuit with negative grid voltage was:

(1) between 5 and 15 ma.
(2) more than 20 ma.
(3) less than 1 ma.

EXPERIMENT 39

Purpose: To show that a transistor consists of two semiconductor junctions and to show that the base-emitter current can affect emitter-collector path resistance.

Introductory Discussion: You will use your power transistor in this experiment. This is a PNP-type germanium power transistor. The designation PNP refers to the characteristics of the materials which make up the emitter, base and collector elements of the transistor. The base is doped with a donor material which gives it an excess of electrons or negative characteristics. The emitter and collector are doped with an acceptor material. This material takes electrons from the germanium and leaves the emitter and collector with positive characteristics.

When a voltage is applied to a PN junction so that the negative voltage is applied to the N-type material and a positive voltage is applied to the P-type material, we say that the junction is forward biased. When the opposite polarity is applied, of course, the junction is reverse biased. For proper operation of a transistor, the base-emitter junction must be forward biased and the base-collector junction must be reverse biased.

Experimental Procedure: For this experiment, you will need the experimental chassis (with the transistor mounted), your tvom and the following:

1 100-ohm resistor
1 1,000-ohm resistor
1 47K-ohm resistor
1 10K-ohm resistor
2 1.5-volt flashlight cells

Be sure the chassis is turned off or unplugged from the power line for the first two steps of this experiment.

Step 1: To measure the dc resistance between the elements of the transistor.

You will use the ohmmeter section of your tvom to measure between the terminals of the transistor, which are identi-

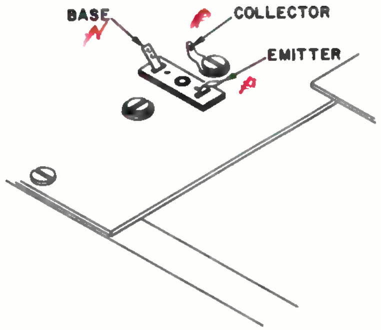


Fig. 39-1. How to identify the power transistor terminals.

fied in the sketch in Fig. 39-1. You will record your readings in the chart in Fig. 39-2.

Begin by measuring the forward resistance of the base-emitter junction. Set the tvom function switch to ohms and set the polarity switch to normal. Now the probe of the tvom is positive with respect to the clip. This is a PNP transistor so connect the tvom clip (negative) to the base and touch the probe (positive) to the emitter. Use the R X 100 range. Read the meter and record the resistance in the space for the B-E (base-emitter) forward resistance.

Switch your tvom to reverse and measure the resistance of the base-emitter junction in the reverse direction. Use the R X 1K or R X 10K range and record the resistance reading in the chart.

Now move the probe to the collector terminal, set the polarity switch to normal and measure the forward base-collector resistance. Use an appropriate ohmmeter range. Record the resistance in Fig. 39-2.

Switch the polarity to reverse, choose a convenient ohmmeter range and measure the base-collector resistance in the reverse direction. Place this value in the chart.

Now move the clip of the tvom to the emitter terminal, set the polarity to normal and measure the emitter-collector resistance. Place this value in the first column in the chart. Switch the tvom to reverse and take the final resistance reading. Touch the probe to the collector and measure the emitter-collector resistance in the opposite direction. Record this value in the chart.

Step 2: To measure the currents crossing the transistor junctions.

For this step, you will make indirect current measurements. You will measure the voltage drop across either a 100-ohm resistor or a 10,000-ohm resistor and compute the current by using the Ohm's Law formula, I = E/R. When you use the 100-ohm resistor, the current in milliamperes (ma) will be 10 times the voltage reading in volts. For example, a reading 2.4 volts across 100 ohms is 24 ma. When you use the 10,000-ohm resistor, the current in ma is 1/10 the voltage reading in volts. Thus, a reading 2.4 volts across 10,000 ohms represents a current of .24 ma or 240 microamperes (μa).

BASE-EMITTER		BASE-COLLECTOR		EMITTER-COLLECTOR	
FORWARD	REVERSE	FORWARD	REVERSE	NORMAL	REVERSE
100Ω	50K	14Ω	40K	6K	250

Fig. 39-2. Record your results for Step 1 here.

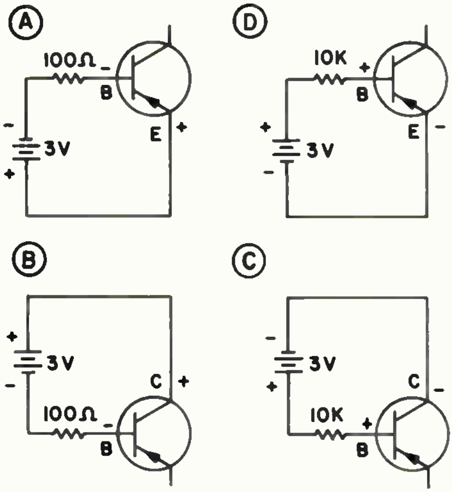


Fig. 39-3. Connections for measuring the forward and reverse currents of the two transistor junctions.

Wire the circuit shown in Fig. 39-3A. You should still have the two 1.5V flashlight cells connected in series, forming a 3-volt battery. Solder one lead of a 100-ohm resistor and a 10,000-ohm resistor to the transistor base terminal. Solder the positive lead of the 3-volt battery to the emitter terminal and solder the negative battery lead to the free lead of the 100-ohm resistor. Measure the dc voltage across the 100-ohm resistor, compute the current and record the value in the space for the base-emitter forward current in the chart in Fig. 39-4.

Change your wiring to that shown in Fig. 39-3B. Note that the negative battery lead still connects to the 100-ohm resistor and the positive battery lead is now connected to the collector terminal. Measure the voltage drop across the 100-ohm resistor and compute the forward base-collector current. Record the value in the chart in Fig. 39-4.

Modify your circuit as shown in Fig. 39-3C. Replace the 100-ohm resistor with the 10K-ohm resistor and reverse the battery polarity. Measure the voltage drop across the 10K-ohm resistor and compute the current. Record it in the space for base-collector reverse current in the chart in Fig. 39-4.

Change your circuit to that shown in Fig. 39-3D by moving the negative battery lead to the emitter terminal. Measure the voltage across the 10K-ohm resistor, compute the current and record it in the space for the base-emitter reverse current in Fig. 39-4.

Discussion of Steps 1 and 2: Thus far, you have proved two important facts about transistors:

(1) They consist of two PN junctions which act very much like semiconductor diodes, and

(2) the emitter-collector resistance is relatively high in both directions.

In Step 1, the low voltage across the ohmmeter leads biased the junction being measured. When applied in the forward direction, this caused the junction to pass current readily and, in turn, gave a low resistance reading. On the other hand, when you reversed the tvom polarity, you reversed the polarity of the voltage applied to the transistor junction. The slight reverse bias was sufficient to reduce the conduction of the junction and produce a very high resistance reading.

The diode action of the junctions was shown more clearly in Step 2 in which you used an external battery and series

	FORWARD	REVERSE
BASE-COLLECTOR	24.0mA	.01mA
BASE-EMITTER	23.4mA	.008mA

Fig. 39-4. Record your results for Step 2 here.

resistors to measure the junction currents. The resistor values were chosen to give reasonable meter indications without affecting the transistor action excessively. By comparing the forward and reverse currents in the chart in Fig. 39-4, you can see that the forward currents are many times the values of the reverse currents for both junctions.

From your regular lessons, you know that forward current across a PN junction is carried out by the majority carriers and reverse current is through minority carriers. Thus the forward and reverse currents you measured in both steps are indicative of the majority and minority carriers respectively crossing the PN junction.

The data accumulated in the chart in Fig. 39-2 can be helpful in checking transistors for condition and type (NPN or PNP). First, you found the resistances across each junction to be high in one direction and low in the other. This indicates that the junctions are neither shorted nor open. Consequently, you can assume that the transistor is not defective.

Second, you found that to forward bias the junctions a negative voltage is applied to the base. This means that the base must be N-type material and the

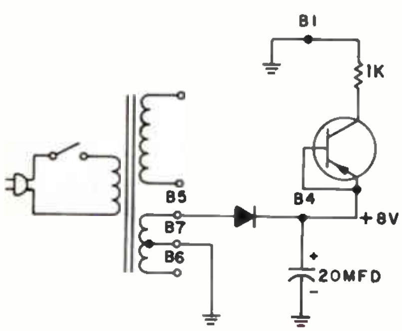


Fig. 39-5. Circuit used for Step 3.

BIAS	COLLECTOR CURRENT
0	.14MA
3V-47K	5mA
3V-10K	6.7mA

Fig. 39-6. Record your results for Step 3 here.

emitter and collector must be P-type material. Therefore, the transistor is a PNP type. It must be remembered that this is only a rough check for transistors.

Step 3: To show that base-emitter current can control the emitter-collector resistance.

Construct the circuit shown in Fig. 39-5. Move the anode lead of the silicon diode from terminal B3 to terminal B5. Connect a length of hookup wire from terminal B4 to the emitter terminal of the transistor. Connect a 1,000-ohm resistor from the collector terminal of the transistor to terminal B1. Connect a short length of hookup wire from the emitter to the base terminal.

Energize the circuit and measure the dc voltage across the 1,000-ohm resistor. Convert the reading to current. Since the resistor value is 1,000 ohms, the current in ma is equal to the voltage in volts. This is the collector or collector-emitter current. Record the current in the chart in Fig. 39-6.

Turn the circuit off and connect the 3-volt battery into the base-emitter circuit. Refer to the schematic diagram in Fig. 39-7A. Note that the positive battery lead is connected to the emitter and the negative battery lead is connected

2.6V / 10KΩ

10K ⟌ 2.600

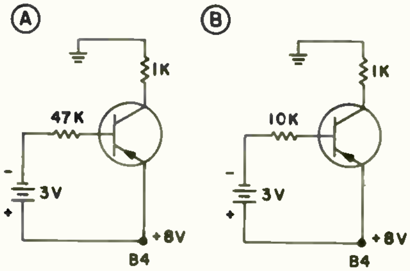


Fig. 39-7. Circuit used for Step 3 and Report Statement 39.

through a 47K-ohm resistor to the base.

When you have finished the wiring changes, energize the circuit and measure the collector current again. That is, measure the voltage across the 1,000-ohm resistor and convert it to current. Record the current value in Fig. 39-6. Turn the circuit off and replace the 47K-ohm resistor with a 10K-ohm resistor. Then, energize the circuit and measure the collector current again. Record the value in Fig. 39-6. Turn the circuit off.

Discussion of Step 3: A transistor is normally operated with a forward bias on the base-emitter junction and reverse bias on the base-collector junction. You had this condition when you connected the battery into the circuit.

Initially, with the base shorted to the emitter, the collector current was low. This indicates that the resistance between the emitter and the collector is high. By connecting the 3-volt battery and the 47K-ohm resistor between the emitter and base, you permitted about 50 μa of current to flow across the emitter-base junction. This base current resulted in a significant decrease in the resistance of the emitter-collector path of the transistor and permitted about 4 ma of collector current to flow.

When you substituted the 10K-ohm resistor for the 47K-ohm resistor, you increased the base current to about 270 μa. The increased base current caused a further reduction in the emitter-collector path resistance, resulting in a substantial increase in collector current.

Before leaving this circuit, note the directions of the currents and the polarities of voltages applied to the junctions in Fig. 39-7B. Because this is a PNP transistor, the base is slightly negative (about .2V) with respect to the emitter. Thus, current flows from the negative side of the battery, through the 10K-ohm resistor to the base. Current crosses the base-emitter junction and flows from the emitter back to the positive side of the battery.

The emitter-collector voltage is applied so that the base-collector junction is reversed biased. In a PNP transistor, this means that the collector will be negative with respect to the base. The primary current path is from the negative terminal of the power supply through the 1K-ohm resistor to the collector. Within the transistor, current crosses the collector-base and base-emitter junctions. From the emitter, the current flows back to the positive terminal of the source voltage.

Instructions for Statement No. 39: For this Report Statement, you will compare the base current and the collector current in the circuit shown in Fig. 39-7B.

Turn the circuit on and measure the current through the 1K-ohm collector load resistance. (You can use the value from Fig. 39-6 if you wish.) Now, move the voltmeter probe and ground clip and measure the voltage across the 10K-ohm base resistor. Using the procedure outlined earlier, calculate the base current.

Now, you have enough data to answer the Report Statement. Answer the State-

Collector 6.7 MA
Base .26 ma.

.3) 6.0

ment here and on the Report Sheet and turn the circuit off. Also, unsolder and disconnect the 3-volt battery.

Statement No. 39: When I compared the base and collector currents, I found that:

(1) the base and collector currents were about equal.

(2) the base current was slightly greater than the collector current.

(3) the collector current was between 20 and 30 times the base current.

EXPERIMENT 40

Purpose: To demonstrate the fundamentals of voltage regulation and to show the operation of basic shunt and series regulators.

Introductory Discussion: In many electronic applications the voltage supplied to the various circuits must be stabilized (regulated) against variations in load and input voltage. There are a number of different methods used to regulate both high and low voltages. In this experiment we will investigate simple shunt and series regulators in both high and low voltage applications. We will be primarily concerned with regulators which stabilize voltages for variations in *load* current.

The percent regulation of a power supply for load variations is expressed using the following relationship: % regulation =

$$\frac{E_{no\ load} - E_{full\ load}}{E_{full\ load}} \times 100$$

For example, if the no load output of a certain power supply were 110 volts and the full load voltage were 100 volts, the percent regulation would be: % regulation =

$$\frac{110 - 100}{100} \times 100 = \frac{10}{100} \times 100 = 10\%$$

A perfect power supply would have zero percent regulation since the no load and full load voltages would be the same. The larger the percent regulation, the poorer the power supply is said to be regulated.

The basic shunt regulator consists of a series resistance connected between the power supply and the load, and a constant-voltage variable-current device connected in parallel with the load. As the load current varies, so does the current of the shunt regulator to maintain a constant output voltage.

In the basic series regulator, a variable resistance device is connected between the power supply and the load. As the load current varies, the series resistance is changed to keep the output voltage steady. We will examine both shunt and series regulators in this experiment.

Experimental Procedure: For this experiment you will need the experimental chassis, your tvom and the following parts:

- 1 100-ohm resistor
- 1 220-ohm resistor
- 1 1K-ohm resistor
- 1 2.2K-ohm resistor
- 1 4.7K-ohm resistor
- 1 22K-ohm resistor
- 1 47K-ohm resistor
- 1 12BA6 tube
- 1 Neon lamp
- 2 HV diodes
- 2 LV diodes
- 2 20-mfd electrolytic capacitors

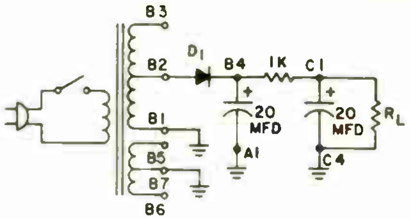


Fig. 40-1. The circuit used for Step 1 and Step 2.

By now you have worked with the experimental chassis enough that you should be familiar with the terminal strips and the schematic symbols used in the diagrams. Therefore we will not give detailed instructions for changing the wiring around for the various steps in this experiment.

Step 1: To measure the regulation of a typical half-wave high voltage power supply.

Construct the circuit shown in Fig. 40-1. Use a high voltage diode for D_1 and be sure to observe the polarity of the two electrolytic capacitors when you connect them into the circuit. The output terminal of the supply is terminal C1. Do *not* connect resistor R_L (the load resistor) yet.

When you have the circuit wired, turn on your tvom and set it to read 120 volts dc. Clip the probe to terminal C1 and the ground clip to the chassis. Turn the circuit on and read the no load output voltage. Record this reading in Fig. 40-2 under "NO LOAD VOLTAGE" for Step 1. Without disconnecting the tvom, turn the circuit off. Notice that the output voltage drops very slowly even though you have turned the power off. This is because the two 20-mfd capacitors are fully charged and are loaded only by the tvom. They would retain this charge quite a long time and if you were to start making circuit changes now you could receive a nasty shock from the "dead" circuit.

To discharge the filter capacitors, take a screwdriver and quickly short terminal C1 to the chassis. This will discharge both of the capacitors. This is *always* a good practice to follow when working with circuits operating at high voltages: With the power off, short the output filter capacitor to discharge it before working on any of the circuits.

With the power supply discharged, remove the tvom probe and solder a 22K-ohm resistor from C1 to C4. This will be your load resistor. Reconnect the tvom probe to C1, turn on the power and

STEP	NO LOAD VOLTAGE	FULL LOAD VOLTAGE	PERCENT REGULATION
1	88V	80V	10
2	83V	77V	7.8
3	47V	30V	56
4	49V	47V	4.2

$\frac{E_{NL} - E_{FL}}{E_{FL}} \times 100$

Fig. 40-2. Record your results for Steps 1 through 4 here.

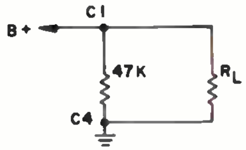


Fig. 40-3. The 47K bleeder used in Step 2.

record the FULL LOAD VOLTAGE for Step 1 in Fig. 40-2. Using the formula given previously, calculate the percent regulation and enter this value in Fig. 40-2. With the tvom still connected to terminal C1 turn the power to the circuit off. Notice that the voltage decreases rapidly to zero with the 22K-ohm load in place.

Step 2: To show that a bleeder resistor will improve the power supply regulation.

By placing a fixed load on the power supply the voltage regulation will be improved. You have demonstrated this before in an earlier Training Kit, but now you will see the bleeder resistor used in a real power supply. You will use a 47K-ohm bleeder as shown in Fig. 40-3. Solder it into the circuit, turn the power on and measure the no load output voltage. Record this in Fig. 40-2 for Step 2. Turn the power off, discharge the filter capacitors and connect the 22K-ohm load resistor as before. Turn the power on and record the full load voltage in Fig. 40-2. Calculate the percent regulation and enter it in Fig. 40-2 also.

Step 3: To show the operation of a basic shunt regulator.

With the power off, wire the neon shunt regulator shown in Fig. 40-4. Do not connect R_L yet. Turn the power on and measure the no load output voltage at terminal C3. Record this value in Fig. 40-2 for Step 3. Turn the power off and discharge the filter capacitors. Connect the 22K-ohm load resistor across the neon lamp, turn the circuit on and measure the full load output voltage. Record this in Fig. 40-2 and calculate the percent regulation. Enter this value in Fig. 40-2 also. Turn the power off and discharge the filter capacitors.

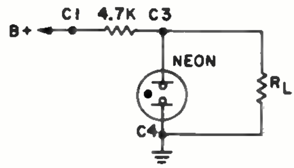


Fig. 40-4. The neon shunt regulator used in Step 3.

Step 4: To show the operation of a basic series regulator.

For this step you will use the circuit of Fig. 40-5. The neon lamp and 4.7K-ohm resistor are already connected. To construct the circuit, install the 12BA6 tube in the socket of the etched circuit board.

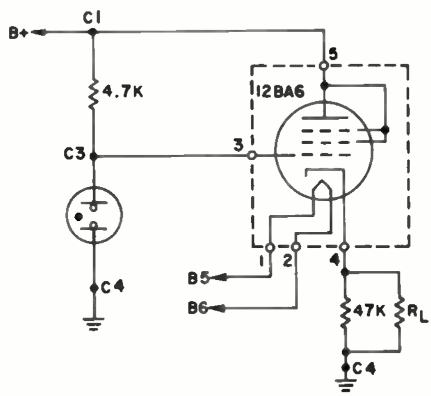


Fig. 40-5. The simple series regulator used in Step 4.

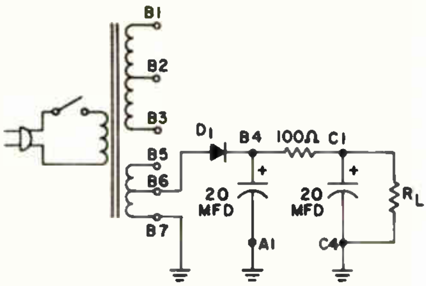


Fig. 40-6. Basic low voltage supply used in Step 5.

Lug 1 and lug 2 should still be connected to terminals B5 and B6. Be sure to remove the 22K-ohm resistor before you connect lug 3 of the circuit board to terminal C3.

When you have wired the circuit, check your connections and turn on the power. It will take a few seconds for the tube to warm up. When the tube has warmed up, read the no load output voltage at lug 4 of the circuit board. Record this value in Fig. 40-2. Turn the power off, discharge the filter capacitors and connect the 22K-ohm load resistor from lug 4 of the circuit board to terminal C4. After allowing the tube to warm up, read the full load voltage at lug 4 of the circuit board. Record this in Fig. 40-2 and calculate the percent regulation. Enter this value in Fig. 40-2 also.

Disconnect the leads and resistors from the etched circuit board and remove the etched circuit board from the chassis. Also remove the 4.7K-ohm resistor and the neon lamp.

You will perform the following steps using the basic low voltage power supply of Fig. 40-6. Disconnect the green lead from terminal B6 and the green/yellow wire from terminal B7. Reconnect the green/yellow lead to terminal B6 and the green lead to terminal B7. To construct the circuit of Fig. 40-6, move the anode lead of D_1 from terminal B2 to terminal B6 and replace the 1K-ohm resistor with a 100-ohm resistor.

Step 5: To measure the regulation of the basic low voltage power supply.

Turn the power on and measure the no load voltage at terminal C1. Use the 12 volt dc range of your tvom. Record your reading in Fig. 40-7. Connect a 2.2K-ohm load resistor from terminal C4 to terminal C1 and read the full load voltage. Record this value in Fig. 40-7 and calculate the percent regulation. Enter this value in Fig. 40-7 also.

The low voltage equivalent of the neon lamp shunt regulator used in Step 3 of this experiment is the Zener diode. We do not have such a diode, but for our purposes we can use a series of forward-biased silicon diodes to perform roughly

STEP	NO LOAD VOLTAGE	FULL LOAD VOLTAGE	PERCENT REGULATION
5	9.3	7.6	22.3
6	1.75	1.73	1.16
7	1.72	1.70	1.18

Fig. 40-7. Record your results for Steps 5 through 7 here.

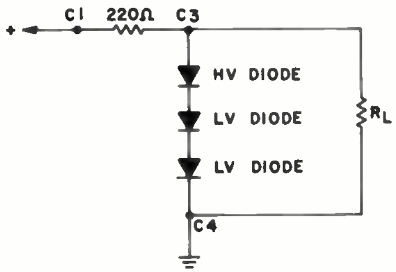


Fig. 40-8. Simple low voltage shunt regulator used in Step 6.

the same job. A forward-biased silicon diode will have a voltage drop of about 0.7 volts if we pass enough current through it. Three diodes connected in series will produce a fairly constant 2.1 volts (3 X .7). You will connect the two low voltage diodes and the remaining high voltage diode in series to make the shunt regulator of Fig. 40-8. Since we will consider the three diodes together as a circuit element, simply tack solder the diodes together: cathode lead of the HV diode to the anode lead of one LV diode; cathode lead of the LV diode to the anode lead of the other LV diode. Solder the anode lead of the diode assembly to terminal C3 and the cathode lead to terminal C4. Connect a 220-ohm resistor between terminals C1 and C3. Terminal C3 is now the output of the low voltage shunt regulated power supply.

Step 6: To see how the basic low voltage diode shunt regulator works.

Turn on the power and measure the no load output voltage at terminal C3. Record this value in Fig. 40-7. Connect the 2.2K-ohm load resistor from terminal C3 to terminal C4 and read the full load output voltage. Record this value in Fig. 40-7 as well as the calculated percent regulation.

Step 7: To show the operation of a transistor series regulator.

Without changing the basic power supply connections, wire the series regulator shown in Fig. 40-9. Notice that now the output voltage is between terminals C1 and C3, and ***not*** to the chassis. This is necessary to simplify the wiring since the PNP transistor must be placed in the ***negative*** lead of the power supply. Refer to Experiment 39 if you have forgotten which are the base and emitter terminals of the transistor. After you have completed wiring the circuit of Fig. 40-9, carefully recheck your wiring to be sure all parts and leads are correctly placed.

Clip the probe of your tvom to terminal C1 and the ground clip to terminal C3. Turn the power on and record the no load output voltage in the space provided in Fig. 40-7. Connect the 2.2K-ohm load resistor between terminals C1 and C3, record the full load voltage and percent regulation in Fig. 40-7 and turn off the power.

Discussion: In the first step you measured the regulation of a typical high voltage power supply. You saw how a bleeder resistor, while lowering the no load output voltage, improved the power

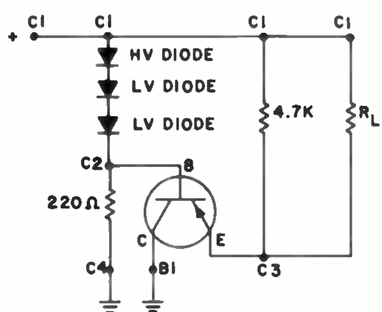


Fig. 40-9. Low voltage series regulator used in Step 7.

supply regulation. Going one step further, you saw how the neon lamp could be used to provide extremely good regulation in Step 3. Neon lamp regulators make use of the characteristics of neon gas that when the gas becomes ionized (by applying a high enough voltage), the voltage drop is very constant and independent of the current through the gas. As a shunt regulator, when the applied load draws current from the supply, the current through the neon decreases but the voltage across it remains constant.

The neon lamp was used as a stable reference voltage for the series regulator of Step 4. The 12BA6, connected as a triode, was used as a cathode follower. The tube supplied cathode current to the load and the neon acted only as a stable reference voltage to set the grid and cathode voltage.

Step 5 and Step 6 were basically similar to Steps 3 and 4 using the low voltage power supply. The series regulator of Step 7 is the transistor equivalent of the circuit used in Step 4. The forward-biased diodes provided the reference voltage while the transistor acted as a variable resistance to maintain the output voltage steady with changes in load current.

1.82

Instructions for Statement 40: For this Statement you will double the voltage applied to the transistor series regulator of Fig. 40-9 and see how well the circuit regulates input voltage variations.

Leave the 2.2K-ohm resistor connected and move the anode of the rectifier, D_1 from terminal B6 to terminal B5. Turn the power on and measure the output voltage between terminals C1 and C3. Compare this voltage with the full load voltage recorded for Step 7 in Fig. 40-7.

Answer the Report Statement below and on your Report Sheet.

Statement No. 40: When I doubled the voltage applied to the transistor series regulator I found the output voltage:

(1) did not change significantly.
(2) increased considerably.
(3) almost doubled.

WIRING THE PILOT LAMP

This completes your experimental work in this Training Kit. You will now install and wire the neon lamp in its permanent location, where it will serve as a pilot lamp. You will need a 100K-ohm resistor.

Unplug the power cord of the chassis. Push the lamp into the grommet in the front panel from the inside, as shown in Fig. 17, so that about 1/4" projects on the outside of the chassis. Connect the leads to terminals 1 and 2 of strip E but do not solder. Connect and solder a 100K-ohm resistor from terminal 1 of strip E on the front panel to terminal 4 of the on-off switch on the back of the potentiometer.

Connect a length of hookup wire from terminal 2 of strip E to terminal 3 of strip D. (Note: this terminal has a power cord and black transformer lead connected to it.) Solder the connections.

Turn the switch off and plug in the power cord. The neon lamp should not light. If it does, unplug the power cord, unsolder the resistor lead from terminal 4 and solder it to terminal 5 on the back of the switch and plug the cord in again.

Your pilot lamp should then be wired directly across the primary winding of the power transformer. Thus, it will light only when the circuit is energized.

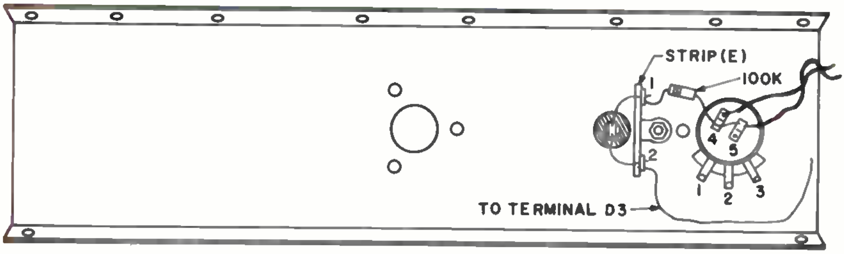


Fig. 17. Pilot light wiring.

LOOKING AHEAD

This completes your experimental work on power supplies. After you have answered all the statements on the Report Sheet, send it to NRI for grading. While you are waiting for your next kit, unsolder and remove all resistors and capacitors wired to terminal strips A, B and C and the circuit board.

Clean the terminals on top of the chassis and on the circuit board. Hold the chassis up and heat the terminals, allowing the solder to run down on the tip of your soldering iron. You should also clean and straighten the leads on your components so they will be usable in your future experiments.

Check the tip of your soldering iron. If necessary file and re-tin the tip, using the procedure given in the first group of experiments.

The parts that are left over are listed in Table I.

1	.1-mfd tubular capacitor	1	2.2K-ohm resistor
2	.25-mfd tubular capacitors	1	3K-ohm resistor
3	20-mfd electrolytic capacitors	1	3.3K-ohm resistor
2	1.5V flashlight cells	2	4.7K-ohm resistors
1	Experimental chassis w/parts attached	1	6.8K-ohm resistor
		1	10K-ohm resistor
1	Etched circuit board w/7-pin tube socket	1	15K-ohm resistor
		1	18K-ohm resistor
1	Alligator clip	2	22K-ohm resistors
2	LV silicon diodes	1	47K-ohm resistor
2	HV silicon diodes	2	100K-ohm resistors
1	1K-ohm potentiometer	1	220K-ohm resistor
1	100-ohm resistor	1	470K-ohm resistor
1	220-ohm resistor	1	1-megohm resistor
1	470-ohm resistor	1	1.8-megohm resistor
1	680-ohm resistor	2	10-megohm resistors
3	1K-ohm resistors	1	12BA6 tube

Table I. Parts left over after completing the experiments in this kit.

Cashing In On Discontent

Discontent is a good thing -- if it makes you want to do something worthwhile. If you had not been discontented, you would never have enrolled in the NRI course.

Practically everyone is discontented. But some of us are "floored" by discontent. We develop into complainers. We find fault with anything and everything. We end up as sour and dismal failures.

Those of us who are wise use our discontent as fuel for endeavor. We keep striving toward a goal we have set for ourselves. We are happy in our work. We face defeat, and we come out the victors.

At this minute you may be discontented with many things -- your progress with your course, your earning ability, yourself.

Make that discontent pay you dividends. Don't let it throw you down. If you do, you may never be able to get up again. Keep striving to remove the cause of your discontent. Remember that it's always darkest before the dawn. And a real NRI man works hardest and accomplishes most when he is face to face with the greatest discouragements.

ACHIEVEMENT THROUGH ELECTRONICS

nri

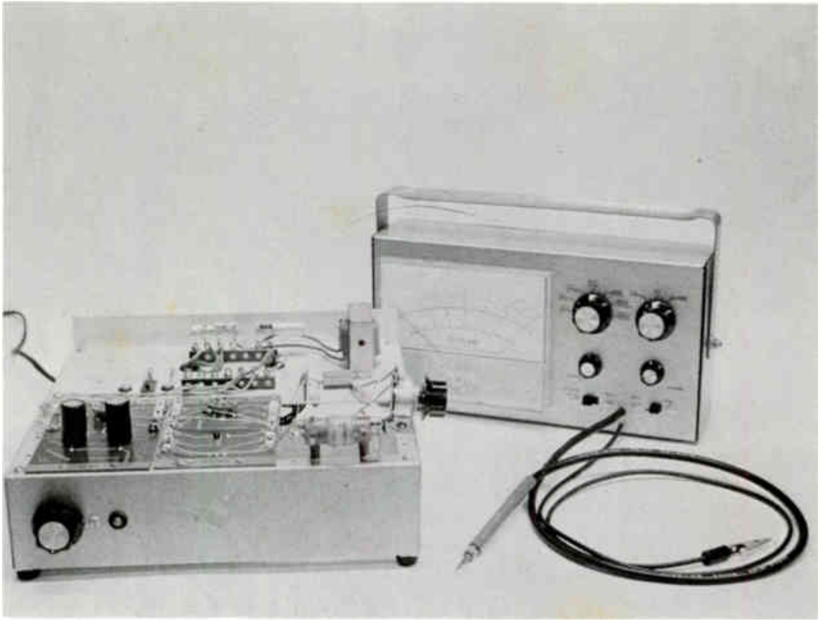
TRAINING KIT MANUAL

5T

NATIONAL RADIO INSTITUTE • WASHINGTON, D. C.

TRAINING KIT MANUAL 5T

PRACTICAL DEMONSTRATIONS OF
RADIO-TV FUNDAMENTALS



INDEX OF SECTIONS

NRI4M373 1973 EDITION Litho in U.S.A.

INSTRUCTIONS FOR PERFORMING EXPERIMENTS 41 THROUGH 50

In any modern AM/FM or TV receiver there are only a few basic parts such as resistors, capacitors, inductors (transformers and coils) and amplifying devices (tubes and transistors). You have already conducted experiments using resistors and capacitors that show how they act in ac and dc circuits. Now you are going to demonstrate the action of tube and transistor amplifiers and learn how tubes and transistors can be used in practical circuits.

Although tubes and transistors will do the same job, they work in different ways. For this reason, the basic tube and transistor experiments will be carried out separately.

The first four experiments show how a tube produces signal amplification. After completing this section, you will demonstrate how transistors work and how they can produce amplification.

In the remaining experiments, you will study oscillator circuits and cascade amplifiers. You will show that an oscillator is actually a self-excited amplifier and then you will build up and demonstrate the various types of oscillator circuits. This section includes both L-C oscillators and R-C oscillators.

You will demonstrate both R-C coupled and DC (direct coupled) cascade amplifiers in the final experiment. You will see how the individual circuits work and you will demonstrate how the amplifier stages affect each other. In this experiment you will also get valuable experience in finding defects in practical amplifier circuits.

Each experiment in this manual illustrates some important fact you will need in your servicing career. Study each experiment carefully -- make sure you understand both what you are going to show before you start, and the conclusion drawn from each experiment in the discussion.

CONTENTS OF THIS KIT

The contents of this kit are illustrated in Fig. 1 and listed below it. Check the parts you received against this list to be sure you have all of them. Some of the parts sent to you may be slightly different in appearance from those pictured in Fig. 1.

Do not discard any of these parts or the parts from previous kits until you have finished your NRI course or unless instructed to do so. Do not cut the leads of any part.

> IMPORTANT: If any part in this kit seems to be missing, look for a substitute. If any part is obviously defective, or has been damaged in shipment, return it immediately to NRI as directed on the "Packing and Returned Material" slip included with this kit.

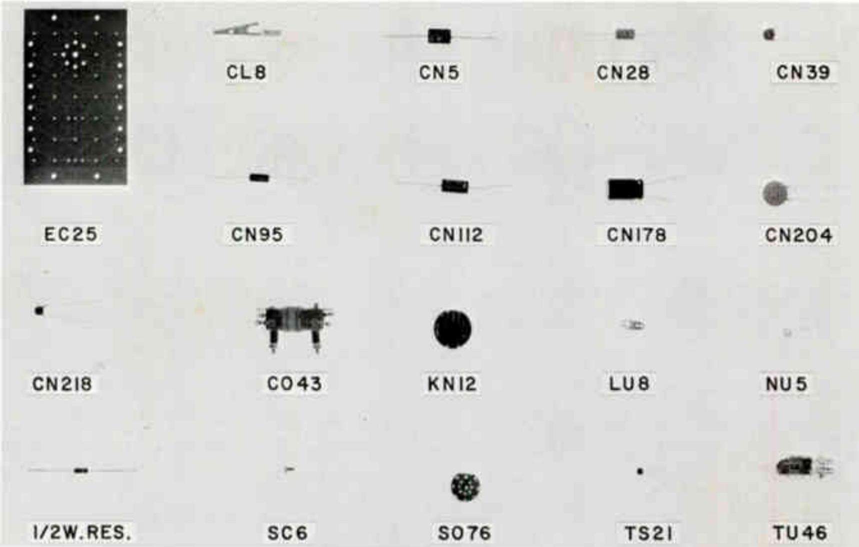


Fig. 1. Parts supplied with this kit are shown above and listed below.

Quan.	Part No.	Description	Price Each
1	CL8	Alligator clip	.07
1	CN5	250-pf mica capacitor	.24
1	CN28	10-mfd, 25V electrolytic capacitor	.59
1	CN39	.002-mfd disc ceramic capacitor	.15
1	CN95	6-mfd, 20V electrolytic capacitor	.42
1	CN112	100-mfd, electrolytic capacitor	.45
2	CN178	200-mfd, 35V electrolytic capacitors	.45
1	CN204	.05-mfd disc ceramic capacitor	.30
2	CN218	.001-mfd disc ceramic capacitors	.15
1	CO43	Oscillator coil	1.17
1	EC25	Experimental etched circuit board	1.10
1	KN12	Bar knob	.17
13	LU8	No. 4 solder lugs	12/.15
16	NU5	4-40 hex nuts	12/.15
1	RE35	47K-ohm, 10%, 1/2W resistor	.15
1	RE45	3.3K-ohm, 10%, 1/2W resistor	.15
1	RE58	2.2K-ohm, 10%, 1/2W resistor	.15
1	RE64	33K-ohm, 10%, 1/2W resistor	.15
1	RE67	68K-ohm, 10%, 1/2W resistor	.15
1	RE72	47-ohm, 10%, 1/2W resistor	.15
1	RE76	10-ohm, 10%, 1/2W resistor	.15
1	RE118	330K-ohm, 10%, 1/2W resistor	.15
1	RE140	330-ohm, 10%, 1/2W resistor	.15
16	SC6	1/4" X 4-40 machine screws	12/.15
1	SO76	7-pin miniature pc tube socket	.12
2	TS21	2N5134 NPN silicon transistors	.19
1	TU46	12AT6 vacuum tube	1.20

THE 12AT6 TUBE

The 12AT6 tube supplied in this kit is really two tubes in one. It consists of a high-gain triode section and a double diode section. The triode and the two diode plates all use the same cathode. The diodes can be used to rectify small signal voltages. Because of their small physical size and close spacing to the cathode, they could not be used to rectify high currents or high voltage as found in a receiver power supply.

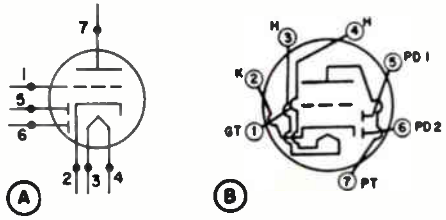


Fig. 2. Schematic symbol for a 12AT6 tube (A) and connections of the elements to the pins (B).

A diagram of a 12AT6 tube showing the elements schematically and the arrangement of the pins is shown in Fig. 2. The standard practice for numbering the tube pins has been followed in this diagram -- that is, it is assumed that you are looking at the base of the tube (or at the bottom of the tube socket). Notice that pin 1 is at the left of the space where there is no pin, and that the numbers increase as you go around the tube clockwise from this pin. This is the numbering system used for all miniature tubes.

Note that the triode grid connects to pin 1, and is marked GT. The cathode is connected to pin 2, and is marked K. The cathode is common to the triode and diode sections. The heater, marked H, connects to pins 3 and 4. The two diode plates are marked PD1 and PD2, and are connected to pins 5 and 6. The triode plate, marked PT, is connected to pin 7.

This tube heater or filament requires an operating voltage of 12 volts at a current of .15 ampere. The maximum plate voltage rating for the triode section of this tube, when it is used as an amplifier, is 300 volts, applied between the triode plate and the cathode. However, in these experiments we will use a voltage of approximately 100 volts.

TRANSISTORS

You received two small junction transistors in this kit. They are low power NPN silicon transistors. Such transistors are normally used as high gain amplifiers for small signals or as oscillators.

Each of these transistors has a base of P-type material and an emitter and collector of N-type material. This is just the opposite of the PNP transistor you used in the preceding kit.

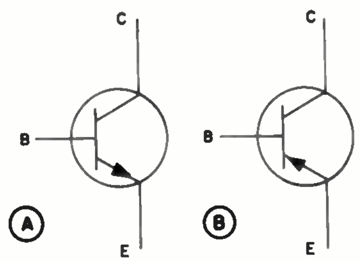


Fig. 3. The schematic symbol for (A) an NPN transistor and (B) a PNP transistor.

The schematic symbols for an NPN and PNP transistor are shown in Fig. 3. Note that the only difference between them is the direction of the arrow. In an NPN transistor symbol, the arrow points away from the base and, in a PNP transistor symbol, the arrow points toward the base.

Because a transistor can be damaged by rough handling or excessive heat, you must be careful with it. This will be discussed further when you connect the transistor into a circuit.

INSTRUCTIONS FOR PERFORMING THE EXPERIMENTS

Each of the experiments described in this manual will contribute to your knowledge of circuit action and develop your skill in handling parts, in making measurements, in adjusting circuits to resonance, and in learning how circuit defects can prevent proper operation. Do not rush through the experiments. Spend enough time on each one to make sure you not only get acceptable results, but also thoroughly understand each principle involved.

The extra practice in soldering you will get as you go through these experiments will be very helpful if you make every effort to make your soldering better each time. But if you are careless, the extra practice will make bad habits harder to break. Remember you need very little solder to make a good connection. The parts must be clean and enough heat must be applied to melt the solder into a smooth flowing liquid and burn off the rosin. If there is rosin in a joint, the poor connection may affect your experiments. After the solder has cooled, test the strength of the connection by pulling the leads gently with a pair of longnose pliers. Even an expert will have trouble soldering with an iron with a pitted, corroded, or untinned tip. A beginner will have more trouble and may not be able to tell if he has a good soldered connection even though the parts seem to be held together. Make it a habit to check the tip of your iron periodically, re-filing it when necessary and keeping it bright and tinned.

To get the greatest benefit from each experiment, make sure you understand the principles and the procedure before you set up the circuits and take your measurements. If any part of the theory involved in the experiment puzzles you, refer to the lesson texts in your course where the principles are covered, and read them carefully.

If you fail to get acceptable results from any experiment, review the instructions carefully. Make sure your tvom is properly calibrated and the 9-volt battery is in good condition. If it is weak, replace it. Make sure that you connect the tvom properly to the experimental circuit. If the ground clip is disconnected from the chassis of the experimental circuit and you touch only the probe to the circuit, you will get erratic readings, which are meaningless.

We shall not give you detailed instructions on the adjustment and use of your tvom in these experiments, so failure to get the proper readings may be caused by some error in your use of the instrument. If you are not absolutely sure that you know every detail of how to adjust and use your tvom, refer to the instructions given in Kit Manuals 2T and 3T.

Examine each experimental circuit to see that you have set it up correctly and have the correct components in the circuit. Then check for possible defective parts and for poorly soldered connections. Also make sure that the power supply furnishes the right plate and filament voltage for the experiment. Be patient and thorough in your search for any trouble that develops.

If you are unable to get the correct

results, or to locate the source of trouble, write to us for help. Use the special Consultation Blank enclosed with this kit. Describe the trouble briefly but completely. Also describe the tests you have made and the results of those tests. Be sure to include the actual values found in any measurements you have made so that we will have facts and figures on which to base our reply.

As you have done in previous kits, record your results in the charts or tables provided, as you perform each experiment. After you have completed each experiment, fill out the Statement at the end of the experiment and on the Report Sheet.

Be sure to turn your experimental equipment and tvom off when you are not performing experiments.

Preliminary Assembly

You will begin to prepare the experimental chassis for the experiments in this kit by assembling and mounting an etched circuit board. Then you will wire the HV power supply you will use throughout this kit.

The diagram in Fig. 4 shows the locations of the holes in the chassis. Refer to it as necessary.

If any resistors or capacitors are still attached to the terminals on top of your chassis, remove them at this time.

WIRING THE CIRCUIT BOARD

To prepare the etched circuit board, you will need these parts.

- 1 **Circuit board (EC25)**
- 1 **7-pin socket (SO76)**
- 13 **Terminal lugs (LU8)**
- 12 **1/4" X 4-40 screws**
- 12 **4-40 hex nuts**

Mount the tube socket on the foil side of the circuit board as shown in Fig. 5. (Fig. 5 shows the circuit board mounted on the chassis.) Line the pins up over the holes and push the socket down tightly to seat the pins. Then solder the 7 pins to the copper foil.

Attach twelve terminal lugs on the foil side of the board at the places shown in Fig. 5. Attach each lug with a 1/4" X 4-40 screw and nut. Position each terminal so that it does not short to adjacent terminals or strips on the circuit board and tighten the nuts.

Remove circuit board EC24 from the

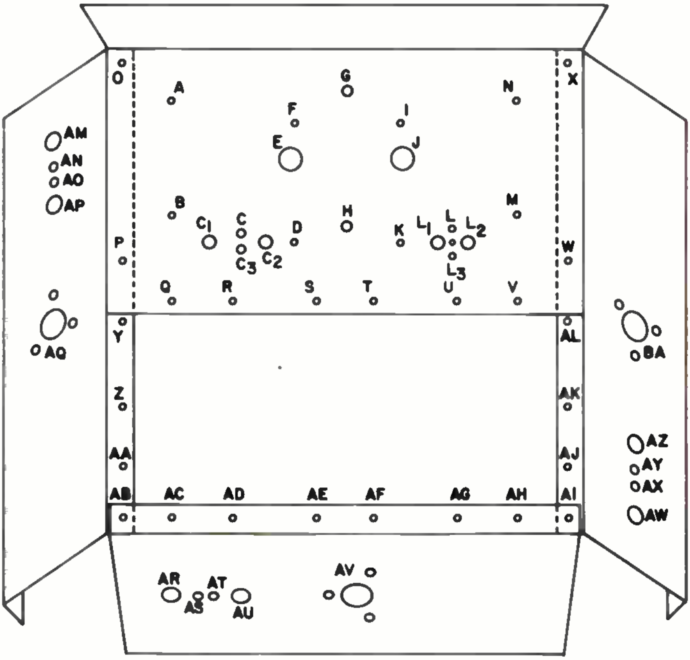


Fig. 4. How to identify the holes in the experimental chassis.

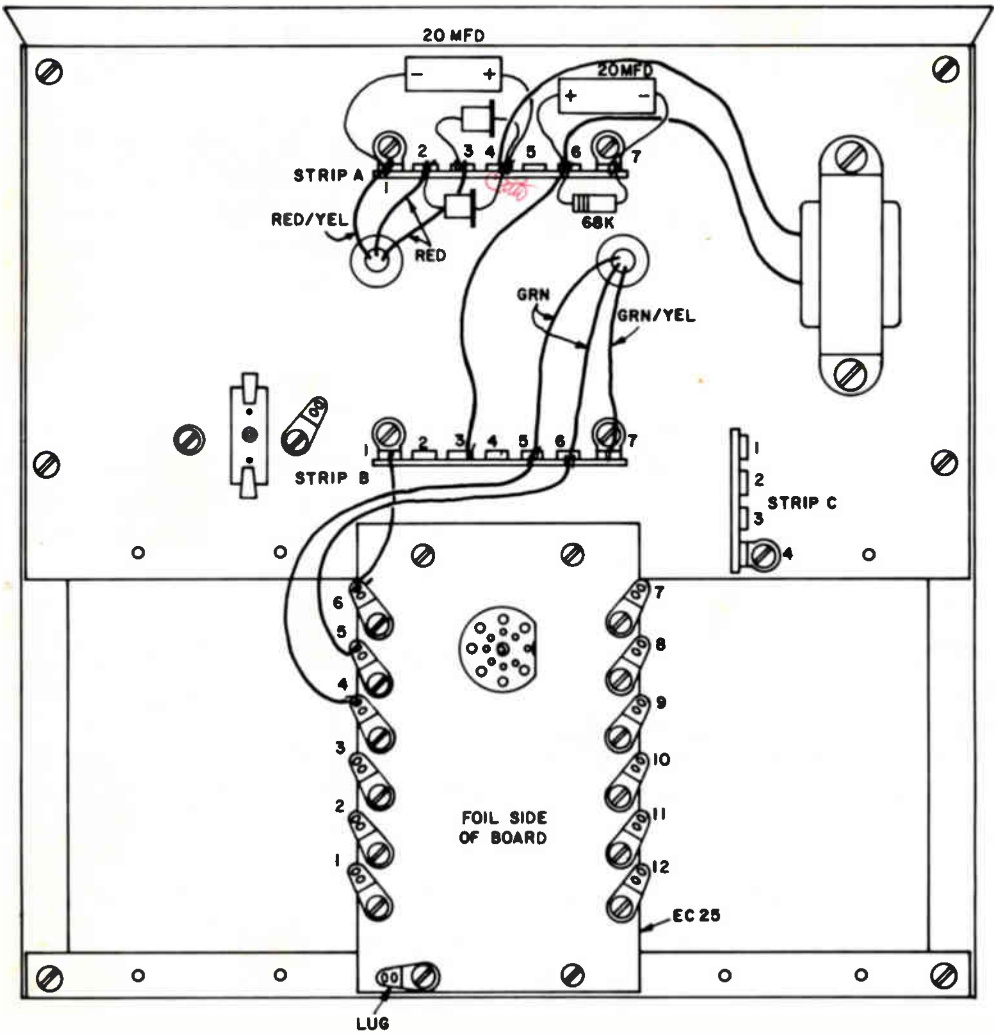


Fig. 5. Pictorial diagram of the circuit board and the preliminary wiring.

experimental chassis and mount the new board, EC25, in its place, as shown in Fig. 5. Attach this board with four 1/4" X 4-40 screws and nuts. Place a terminal lug under the mounting screw at hole AE, as shown.

Refer to Fig. 5 to identify the terminal lugs on circuit board EC25.

Connect and solder a length of hookup wire from terminal B5 to lug 4 on the circuit board.

Connect and solder a length of hookup wire from terminal B6 to lug 5 on the circuit board.

Connect and solder a length of hookup wire from lug 6 to terminal B1.

ASSEMBLING THE HV POWER SUPPLY

The HV power supply will be wired on terminal strip A. You will need the following parts:

2 HV silicon diodes
2 20-mfd, 150V electrolytic capacitors
1 68K-ohm resistor

The diodes and capacitors were left over from the previous kit.

Construct the circuit shown in the schematic diagram in Fig. 6. Fig. 5 also shows the wiring on the chassis. First, unsolder the red and red/yellow power transformer leads from terminal strip B. Connect a length of hookup wire between terminal A6 and B3.

Solder the red/yellow transformer lead to terminal A1. Connect one red transformer lead to terminal A2 and connect the other red lead to terminal A3.

Connect an HV diode between terminals A2 and A4, with the cathode lead to A4. Solder terminal A2.

Connect a second HV diode between terminals A3 and A4, with the cathode lead to A4. Solder terminal A3.

Connect one lead of the filter choke to terminal A4. Connect the other lead of the filter choke to terminal A6.

Connect and solder a 68K-ohm resistor between terminals A6 and A7.

Connect a 20-mfd, 150V electrolytic capacitor from terminal A1 to terminal A4. The positive lead connects to A4. Solder both connections.

Connect another 20-mfd, 150V electrolytic capacitor from terminal A6 to terminal A7, with the positive lead to A6. Solder both connections.

Check your wiring to be sure that the polarities of the diodes and the capacitors are correct and that there are no short circuits. Also, be sure that all connections are soldered.

To test the power supply, short terminals A4 and A6 to the chassis momentarily to discharge the electrolytic capacitors. Then, connect your ohmmeter to measure the resistance between the chassis and terminal A6. Set the range switch to R X 10K, set the polarity switch to normal and touch the probe to terminal A6. You should read at least 40,000 ohms.

If you get this reading, you are ready to test the power supply for voltage. Set the function switch on your tvom to dc and set the range switch to the 120V position. Energize the circuit and measure the voltage. You should read 80 volts or more. If the voltage is negative, the diodes are installed incorrectly; if the voltage is quite low, look for a capacitor or diode installed incorrectly, a poor connection or a resistor of too low a

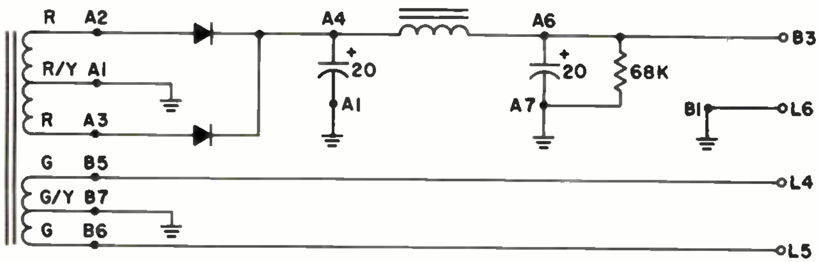


Fig. 6. Schematic of HV power supply.

value between terminals A6 and A7. If you have trouble and cannot locate it, write for help before you go on with your experiments.

You now have a full-wave rectifier circuit operated from the center-tapped high voltage winding of the power transformer. The circuit is quite conventional in all respects. The resistor connected across the output of the filter network is primarily a bleeder resistor. Its purpose is to present a constant load to the power supply and to discharge the filter capacitor slowly when the power is turned off.

Vacuum Tube Fundamentals

The primary function of a triode or other type of tube having a control grid is amplification. Amplification, as you know, is increasing the strength of a signal so it can provide a useful output. An example of this is found in a public address system. The amplifier builds up the weak signal produced by the microphone and makes it strong enough to operate a speaker.

You have already conducted experiments that show that current flows from cathode to plate in a triode and that the amount of current can be controlled by the grid voltage. In the following experiments you will demonstrate bias, biasing methods and practical amplifier circuits.

EXPERIMENT 41

Purpose: To show that a voltage applied to the control grid of a vacuum tube will control the plate current; and to show that the effect the grid voltage has on the plate current depends upon the polarity of the control grid voltage with respect to the cathode.

Introductory Discussion: In a previous experiment you saw that the cathode-plate path of a tube is conductive. When the tube was connected to the source in series with a resistor, the voltage divided between the tube and the resistor. This resistor is called the plate load of the tube, because it is usually in the plate circuit and because it translates variations in plate current into voltage variations.

In these experiments we will not actually measure the plate current flowing through the tube and the load resistor. Checking the voltage drop across the tube or across the resistor will show whether current is flowing, when the current changes, and whether it increases or decreases.

Remember that when the current increases, there will be *less* voltage across the tube and *more* voltage across the plate load resistor. When the plate current of the tube decreases, there will be more voltage across the tube, and less voltage across the plate load resistor.

In a previous experiment, you compared the plate voltage with the grid not connected to anything, and with the grid shorted to the cathode. The resultant change in plate voltage showed that the grid does affect the plate current. In this experiment, you are going to apply voltage between the control grid and the cathode. You will use the two 1.5-volt cells you received in a previous kit. You will be able to make the control grid either positive or negative.

Experimental Procedure: In conducting this experiment, you will need the parts mounted on the chassis, and the following parts:

2 1.5-volt flashlight cells
1 220-ohm resistor
1 100K-ohm resistor
1 12AT6 tube
1 Test clip

After checking your soldering iron tip to be sure it is in good condition, check the condition of the flashlight cells. You have used them in several kits, so you may need to replace them.

To test the two flashlight cells, connect them in series to form a 3-volt battery as you did in previous experiments by connecting a piece of hookup wire from the negative terminal of one cell to the positive terminal of the other. Then set your tvom for dc and measure the voltage of the series-connected cells. The results that you get for this test may show that the cells are good. However, to get a true indication of their condition, you must measure the voltage under load conditions.

To measure the cells under load, connect a 220-ohm resistor between the positive and negative terminals of the series-connected cells. Measure the voltage across the resistor; it should be at least 2.5 volts. If it is not, you will have to obtain new flashlight cells to do this experiment.

When you are sure you have good flashlight cells, unsolder the resistor from the cell terminals, but leave the cells connected in series. Then, put a rubber band or tape around the two cells to hold them together. Lay them on your work surface near the chassis. Cut off about ten inches of hookup wire, solder one end to the ends of the cells that are joined together. This is the positive terminal of one cell and the negative terminal of the other. Solder the free end of this wire to terminal B7.

Connect and solder a 100K-ohm resistor from terminal B3 to lug 8 on the circuit board.

Solder a 10-inch length of hookup wire to lug 7 on the circuit board. Remove about 1/2 inch of the insulation at the other end. The circuit is now wired as in Fig. 41-1. You are now ready to conduct the experiment.

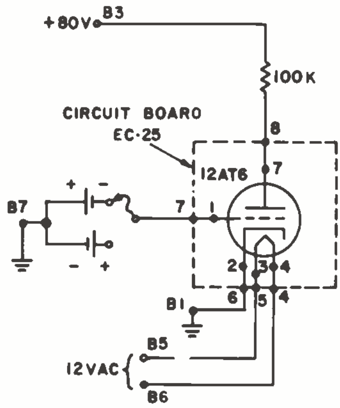


Fig. 41-1. The circuit used in Step 1.

Carefully install the 12AT6 tube in the tube socket. Do not push too hard when you install it or you may break the circuit board.

Step 1: To measure the plate voltage with zero voltage on the control grid.

Set up your tvom for dc voltage measurements; clip the ground lead to the experimental chassis. Slip the test clip which you received in Kit 2T over the probe of the tvom. Clip the probe to lug 8. Turn the circuit on and hold the free end of the tube grid lead against the chassis. This will ground the circuit.

After the tube heats up, observe the voltage reading at the plate. Record the reading in Fig. 41-2.

Step 2: To measure the plate voltage with +1.5 volts applied to the control grid of the tube.

5.00
.35
4.65

STEP	MEASUREMENT	VALUES
1	PLATE VOLTAGE WHEN GRID VOLTAGE = 0	5V
2	PLATE VOLTAGE WHEN GRID VOLTAGE = +1.5V	.35V
3	PLATE VOLTAGE WHEN GRID VOLTAGE = −1.5V	55V
4	CHANGE IN PLATE VOLTAGE WHEN GRID VOLTAGE = +1.5V	-4.65
5	CHANGE IN PLATE VOLTAGE WHEN GRID VOLTAGE = −1.5V	+50V

Fig. 41-2. Record your results for Exp. 41 here.

Connect the free lead from the control grid to the positive terminal of the 3-volt battery. This will put a positive voltage of 1.5 volts between the control grid and the cathode. Measure the plate voltage and record your reading for Step 2 in Fig. 41-2.

The plate voltage should have dropped considerably, showing that the application of a positive voltage between the control grid and the cathode of the tube has reduced the resistance in the cathode-plate path of the tube, increasing the plate current, and increasing the voltage drop across the plate load resistor.

Step 3: To show the plate voltage when −1.5 volts is applied between the control grid and the cathode.

Move the free control grid lead to the negative terminal of the 3-volt battery and measure the plate voltage. Record your reading in the space provided for Step 3 of Fig. 41-2. In this case, the negative voltage between the control grid and the cathode has increased the resistance in the path between the cathode and the plate of the tube. This reduces the plate current and sharply reduces the voltage drop across the plate load resistor.

Turn your equipment off.

Step 4: To calculate the change in plate voltage when the grid is made 1.5 volts positive.

Subtract the plate voltage in Step 2 from the value you obtained in Step 1, when the grid was at zero potential. For example, suppose the voltage measured in Step 1 was 11 volts and in Step 2, 1 volt. By subtracting 1 volt from 11 volts, we find that the voltage between the plate and cathode of the tube decreased 10 volts. Compute the change in plate voltage using your readings, and record it in the space provided in Fig. 41-2. Indicate the decrease by placing a minus sign in front of your value.

Step 5: To find the change in plate voltage when the control grid has −1.5 volts applied between it and the cathode.

In this case, subtract the voltage in Step 1 from the voltage in Step 3. Indicate this increase in plate voltage by placing a plus sign (+) in front of your value for Step 5 in Fig. 41-2.

Discussion: The results shown in Steps 4 and 5 in Fig. 41-2 show that a positive voltage applied to the control grid does not cause as much change in the plate voltage as does an equal amount of negative voltage applied to the control grid.

If we were to apply a signal such as a sine wave between the grid and the cathode of the tube under these conditions, the resultant signal across the plate load would be highly distorted, because the negative portion of the signal voltage would be amplified far more than the positive portion.

In the next experiment, we will see how the circuit can be modified to give more linear amplification. By this we mean that a change in grid voltage in a positive direction will cause the same amount of change in the plate voltage as an equal grid voltage change in the negative direction. It is these changes in voltage across the plate load that represent the amplified signal.

Instructions for Statement No. 41: For this Statement you will increase the dc voltage between the grid and the cathode to 3 volts negative, and note the effect on the plate current.

To do this, unsolder the lead that goes from the junction of the two cells to terminal B7, and connect it to the free positive terminal at the other side of one of the cells. Solder the lead from the control grid, lug 7, to the free negative terminal of the other cell. This gives the circuit shown in Fig. 41-3, with 3 volts negative between the control grid and the cathode. Leave the tvom probe clipped to circuit board terminal 8. Connect the ground lead of the tvom to the experimental chassis. Now, turn on the power supply, and give the tube time to heat up.

Note the voltage reading on the tvom in the margin of this page. Then, while looking at the meter pointer, grasp the tube lightly, and pull it straight up out of its socket. Note the change in reading when the tube is removed. A slight flicker of 1 or 2 volts can be considered as no change at all. You now have sufficient information to answer the Statement here and on the Report Sheet. Unsolder the lead from the negative battery terminal and turn your circuit and your tvom off.

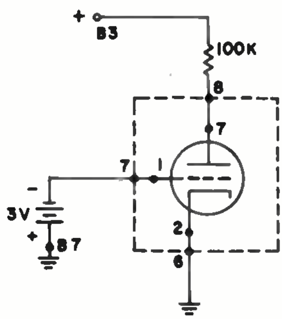


Fig. 41-3. The circuit for Statement 41.

Statement No. 41: I found that with −3 volts applied between the control grid and the cathode, the cathode-plate path of the tube became, for all practical purposes:

(1) an open circuit.
(2) a low-resistance circuit.
(3) a medium-resistance circuit.

EXPERIMENT 42

Purpose: To show that we can get linear amplification in a vacuum tube by applying a suitable negative voltage to the control grid; and

To show that the tube reverses the phase of the grid voltage 180°.

Introductory Discussion: In the last experiment, the plate voltage variation when the control grid was made 1.5 volts positive was quite different from the plate voltage variations when the grid was made 1.5 volts negative. We said the operation of the tube was nonlinear and a signal voltage amplified by such a circuit would be distorted. When the variations in plate voltage caused by applying positive and negative voltages to the control grid are approximately equal, we say that the tube operation is linear. A signal amplified by this circuit will have the same wave shape as the applied signal. Nonlinear operation of an amplifier tube, therefore, can result if incorrect voltages are applied to the electrodes.

If a negative voltage of the correct value, called a "bias", is applied to the grid, and then varied by a signal, the variations in plate current and plate voltage will be linear. That is, when the control grid is kept negative at all times, a signal that shifts the bias in a positive direction (toward zero) will cause a definite decrease in plate voltage. A signal that shifts the bias in a more negative direction (away from zero) by the same amount will cause an equal increase in plate voltage.

In this experiment, you will vary the grid voltage by using a 1K-ohm potentiometer as a voltage divider across a 3-volt battery. The midpoint of the battery will be grounded and connected to the cathode as shown in Fig. 42-1. By changing the potentiometer setting, you can then make the grid 1.5 volts negative, 1.5 volts positive, or any value in between.

In conducting the experiment, you will find that changing the grid voltage in one direction changes the plate voltage in the opposite direction. Thus, if the grid is made more negative, the plate voltage will increase (become more positive). If the grid is made less negative, the plate

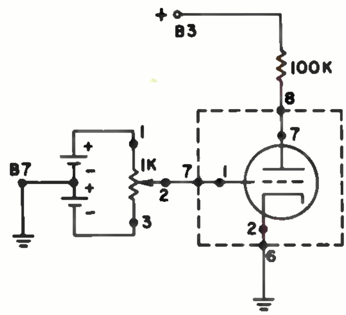


Fig. 42-1. The circuit for varying grid bias.

voltage will decrease (become less positive). When the tube is properly biased, equal grid voltage variations of opposite polarities will cause plate voltage variations that are approximately equal in magnitude.

The exact plate voltage variation that you will obtain will depend upon the characteristics of your tube, the care with which you set the grid bias values and take your readings, and the accuracy with which you have adjusted the zero set on your tvom.

Turn on your tvom a few minutes before you start your work. Then, if you make the zero adjustment just before you start taking measurements, the calibration should not drift. Observe the meter pointer zero position each time before you take measurements and, if necessary, readjust the zero so your results will be as accurate as possible.

When measuring the bias voltages, you will use the 3-volt range of the tvom. The function switch will be set for dc and you will have to switch polarities. When measuring plate voltages, be careful to change the range switch to 120 volts and to see that the polarity switch is set to normal. You can reduce the range selector setting when making plate voltage measurements if necessary.

If you forget and measure plate voltage with the range switch on the 1.2 or 3-volt range or the polarity switch at reverse, the meter pointer will slam off the scale. This may damage your meter so you should train yourself to avoid such carelessness. Always have a good idea of what you are going to measure and always check the tvom switch settings before touching your probe to the circuits.

Experimental Procedure: To conduct this experiment, you will use the tvom, the experimental chassis with the HV power supply and circuit board mounted, and the following parts:

- **1 Potentiometer mounting bracket**
- **1 3/8" X 6-32 screw**
- **1 6-32 nut**
- **1 No. 6 lockwasher**
- **1 1K-ohm potentiometer**
- **1 Pointer knob**

The 100K-ohm resistor should already be connected between terminal B3 and pin 7 of the tube. Wire should be connected from the control grid lug (lug 7) and from the positive terminal of the 3-volt battery to the chassis.

Attach the potentiometer mounting bracket to the right front corner of the chassis at hole AJ. Turn the bracket so that it faces away from the chassis. Attach the bracket with a 6-32 screw, lockwasher and nut. Now, mount the 1K-ohm potentiometer in the bracket with the shaft to the right. Position the potentiometer so that its terminals point upward and tighten the nut.

Rotate the shaft of the 1K-ohm potentiometer fully counterclockwise and attach a pointer knob. The knob is held by a setscrew. If necessary, loosen the setscrew with a small screwdriver. Install the knob in the "7 o'clock" position and tighten the setscrew.

Now you are ready to construct the circuit shown in the schematic diagram in Fig. 42-1. Connect the free end of the lead from lug 7 to the center terminal of the 1K-ohm potentiometer. Cut two pieces of hookup wire about 12 inches long and connect these leads to the two outside terminals of the 1K-ohm potentiometer. The leads will be long enough to reach the positive and negative terminals of the two cells when the cells are lying on your workbench.

The flashlight cells should still be connected in series. If you mistakenly removed the wire joining them, replace it. Connect the hookup wire from terminal B7 to the junction of the two cells. Connect the free end of the wire from one terminal on the potentiometer to the positive terminal of the 3-volt battery, and the free end of the lead from the other terminal of the potentiometer to the negative terminal of the 3-volt battery.

Plug the power cord into an ac wall outlet, and turn on the power supply and let the tube warm up.

Step 1: To measure the plate voltage with 0 volts applied to the control grid.

Connect the ground clip of the tvom to the experimental chassis, set the function switch to dc, and the range selector switch to 3 volts. Touch the probe to the control grid circuit of the tube at lug 7 of the circuit board.

With the probe in place, adjust the knob on the potentiometer until the meter registers exactly 0 volts. Remove the probe, and turn the range selector switch to the 120-volt range.

If the meter pointer is no longer at zero, readjust the zero control. For exact readings, you should check this adjustment on each measurement. In service work, the error introduced by a slight shift in the meter pointer from zero can usually be ignored.

Now touch the probe to circuit board lug 8 and read the meter. If necessary, switch to a lower range. Record the plate voltage in the space for Step 1 in Fig. 42-2.

In the previous experiment you measured the plate voltage with +1.5 and −1.5 volts applied to the grid. You will use smaller positive and negative voltages in the next two steps to see if there is any improvement in the linearity of the output (plate) voltage variations.

Step 2: To measure the plate voltage when the grid voltage is +.5 volt.

Following the same procedure as in Step 1, set the control grid voltage to +.5 volt, measure the plate voltage, and record the value in the appropriate column in Fig. 42-2.

STEP	GRID VOLTAGE	PLATE VOLTAGE	GRID VOLTAGE CHANGE	PLATE VOLTAGE CHANGE
1	0	12V		
2	+.5V	4V	+.5V	+8V
3	−.5V	28V	−.5V	+16
4	−.75V	40V		
5	−.25V	20V	+.5V	20V
6	−1.25V	60V	−.5V	20V

Fig. 42-2. Record your results for Exp. 42 here.

The change in grid voltage was +.5 volt. This has already been recorded in the table. Now, to find out how much the plate voltage changed when the bias was +.5 volt, subtract the plate voltage value you obtained in Step 2 from the value you measured in Step 1. Record it in the last space for Step 2 in Fig. 42-2. Since it is a decrease, put a minus sign in front of it.

Step 3: To measure the plate voltage when the grid voltage is −.5.

Set the grid voltage to −.5 volt, measure the plate voltage, and record it in Fig. 42-2. Be certain to set the switches on the tvom to the proper positions when making these measurements. When measuring a negative grid voltage, set the polarity switch to reverse. Set it to normal for the plate voltage measurement.

In this step, the change in grid voltage was −.5 volt. Find the difference between the plate voltage for Step 1 and the plate voltage for Step 3. Record it in the correct space in Fig. 42-2. Since it is an increase, put a plus sign in front of it.

The change in plate voltage recorded in Step 2 would be as great as the change you recorded in Step 3 if it were not for the fact that the control grid in Step 2 was positive. When the grid is made positive with respect to the cathode, some of the electrons will be attracted to the grid instead of flowing past it to the plate. This, of course, prevents as much decrease in the resistance between the cathode and plate as would be expected, and, as you noticed in Steps 2 and 3, the plate voltage does not vary in step with the grid voltage.

In the remainder of this experiment,

you will see what happens when we use a negative bias at all times, and vary it .5 volt in each direction.

Step 4: To measure the plate voltage when −.75 volt is applied to the control grid.

Adjust the potentiometer so that exactly −.75 volt is applied to the control grid. Then measure the resultant plate voltage. Record the reading in Fig. 42-2.

Step 5: To measure the change in plate voltage when the control grid is driven .5 volt positive from −.75 volt to −.25 volt.

Set the bias to −.25 volt and record the value in Fig. 42-2. Here we are using −.75 volt as the reference value. By decreasing the grid bias from −.75 volt to −.25 volt, we have made the grid less negative (more positive) by +.5 volt. For this reason, we placed a plus sign in front of the grid voltage change in Fig. 42-2. The change is in the positive direction, but the voltage actually applied to the grid is still negative.

Notice that driving the grid voltage .5 volt in a positive direction causes the plate voltage to decrease. Subtract the plate voltage in Step 5 from that in Step 4, and record it in Fig. 42-2. Put a minus sign in front of it to show that the voltage has decreased.

Step 6: To measure the plate voltage when the control grid is driven .5 volt negative, from −.75 volt to −1.25 volts.

Set the bias to −1.25 volts, measure, and record the plate voltage. To find the change in plate voltage caused by a −.5 volt change in grid voltage, subtract the plate voltage in Step 4 from that in Step 6. Record the change in Fig. 42-2. Since the plate voltage increased in this step, put a plus sign in front of it. Turn the circuit off.

Notice that the change in Step 5 is opposite in polarity to that in Step 6, and that the changes are more nearly equal in magnitude than those in Steps 2 and 3. Your readings in Steps 5 and 6 may not be exactly equal. The variations are due to the characteristics of the tube, how accurately you have read your meter, the accuracy with which you set the bias values, and the accuracy of your tvom zero set adjustment. Do not worry about small variations. The important thing is that you see that the values are nearly the same.

Discussion: You have proved in this experiment that when a suitable negative bias is applied to the control grid, the tube operation will be linear, as indicated by the values of plate voltage change in Steps 5 and 6. When you varied the bias voltage an equal amount on either side of the reference voltage value of −.75 volt, the plate voltage changed by an equal amount.

The bias applied to the grid in this experiment was a dc voltage, and the plate voltage was also dc. In a receiver, however, an ac signal is applied in series with the dc bias; the result is a pulsating dc grid voltage that never becomes positive. A large pulsating dc voltage appears in the plate circuit. Thus, the pulsating portion of the dc plate voltage is the amplified signal.

We can show the effect the grid voltage has on the plate voltage by studying the signal waveforms in the output of an amplifier stage. At A in Fig. 42-3 we have

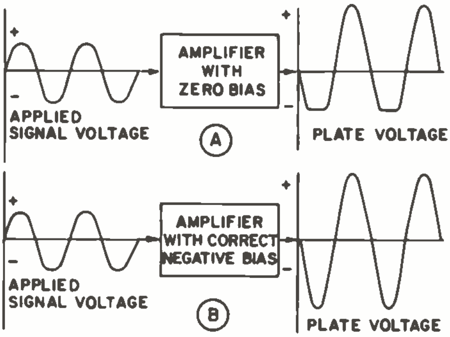


Fig. 42-3. Incorrect bias in a tube causes distortion of the signal, as shown at (A). When the bias is correct, all parts of the signal are amplified the same amount, and no distortion is introduced, (B).

shown a signal voltage applied to an amplifier with zero bias. We have not drawn the schematic of the amplifier, but have merely represented it by a box. To the right of the amplifier, we have shown the resultant variation in plate voltage. Notice that the plate-voltage swing in the negative direction is not as large as the plate-voltage swing in the positive direction. However, the signal in the plate circuit is definitely larger than the grid-voltage variations, indicating that the signal has been amplified. The wave shape at the output of the stage, as you can see, is quite different from that applied to the grid. Thus, the output signal is distorted.

At B in Fig. 42-3, we have shown the same signal voltage applied to an amplifier using the correct negative bias on the control grid. Note that again the plate-voltage variations are larger than the grid-voltage variations, showing that amplification has taken place. This time, the two halves have been amplified the same amount. The tube has amplified the signal without introducing distortion.

From this you can see that correct bias is necessary to avoid distortion. Thus, when the signal at the output of an amplifier stage is distorted, one of the first things you would look for is incorrect bias voltage. In a later kit you will actually hear the distortion introduced by incorrect bias voltage and learn the probable causes of incorrect bias in typical circuits.

In this experiment you have also proved that changing the control grid voltage in a positive direction causes the plate voltage to change in a negative direction. Changing the control-grid voltage in a negative direction drives the plate voltage in a positive direction.

Study the results that you obtained for Steps 5 and 6 in Fig. 42-2. In Step 5, with +.5 volt applied, the direction of the output voltage swing was negative. In Step 6, the grid voltage was −.5 volt. The plate-voltage swing then was in the positive direction.

Thus, a tube connected as shown in Fig. 42-1 reverses the phase of the voltage applied to the control grid by 180°.

This is of no importance as far as the amplification of the signal is concerned. However, it is of real importance in the overall design and operation of radio and TV receivers, as you will later demonstrate.

Instructions for Statement No. 42: For this Statement, you will operate the tube −2 volts on the control grid. Again change the grid voltage .5 volt positive and .5 volt negative and notice the change in plate voltage. To make the change, disconnect the ground lead from the junction of the two cells, and connect it to the positive terminal of the 3-volt battery. The lead from one terminal of the potentiometer should already be connected to this battery terminal.

Set the bias to −2 volts, and measure the plate voltage. Note the value in the margin of this page. Change the bias to −1.5 volts, and again measure the plate voltage, and make a note of the value. Finally, set the bias to −2.5 volts and measure the plate voltage. Calculate the change in plate voltages as you did previously, and answer the Statement here and on the Report Sheet.

Turn off the supply and disconnect the 3-volt battery from the circuit. The easiest way is to unsolder the leads from the terminals of the potentiometer and the lead from terminal B7. Set the battery aside for use in a later experiment. Unsolder the hookup wire from terminal 2 of the potentiometer.

Statement No. 42: With a −2 volt bias on the grid, I found that when I changed the bias .5 volt in the positive and negative directions, the resultant plate voltage variations were:

(1) more linear than
(2) less linear than
(3) about the same as

the variations with a bias of −.75 volt.

EXPERIMENT 43

Purpose: To demonstrate the methods of obtaining bias voltage without using a separate battery.

Introductory Discussion: Bias voltage is essential for any amplifier stage which must amplify without excessive distortion. However, a separate bias battery is not normally used in modern circuits, although a separate negative voltage supply is still used in some special-purpose applications. In receivers, bias is obtained from the signal, the amplifier circuit itself or from the B power supply.

The four primary biasing methods are: conduction bias, self bias (cathode bias), fixed bias, and grid-leak bias. You have studied all these methods in your regular lessons. Conduction bias relies on the random movement of electrons within the tube while self bias is produced by tube-plate current flow. Fixed bias uses a voltage divider across the B power supply. Grid-leak bias, on the other hand, is derived from the input signal to an amplifier stage.

Experimental Procedure: For this experiment, you will need the following parts in addition to those mounted on the chassis:

2 1K-ohm resistors
1 3.3K-ohm resistor
1 47K-ohm resistor
1 10-megohm resistor
1 100K-ohm resistor
1 .1-mfd capacitor
1 3-volt battery

Before starting work on the new circuits, clean the chassis wiring and remove excessive solder from the terminal lugs.

The circuit you will build for the first step in this experiment is shown in Fig. 43-1. The 100K-ohm resistor is already in the circuit, so all you need to do is

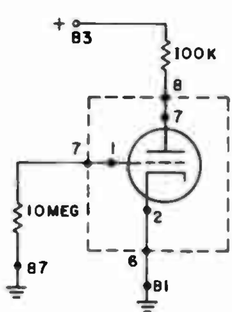


Fig. 43-1. Amplifier using conduction bias.

connect the 10-megohm resistor from the grid of the tube to ground. To do this, connect the resistor from lug 7 to terminal B7.

Step 1: To demonstrate conduction bias.

Connect the tvom ground clip to the chassis, and touch the probe to lug 7. Set the polarity switch to reverse, and the range switch to the 1.2-volt range. Turn on the power supply, and watch the meter. As the tube heats up and the space charge builds up around the cathode, the voltage across the 10-megohm resistor, which is the grid bias, will gradually rise to −1 volt or a little more.

Now, to show that the bias is independent of the B supply, you will open the plate circuit. Turn off the power supply, discharge the filter capacitor, and unsolder the 100K-ohm plate load resistor from terminal B3. Turn on the power supply again and note, when the tube warms up, the bias voltage is still there.

Still watching the meter, grasp the tube and remove it from its socket. You will see that the voltage drops to zero, showing that the bias is dependent on the presence of the tube in the circuit.

Turn off the power supply, and after discharging the filter capacitors, replace the tube in its socket. Resolder the 100K-ohm resistor to terminal B3.

Step 2: To demonstrate self bias.

The circuit used in this step is shown in Fig. 43-2. To construct the circuit, remove the 10-megohm resistor and replace it with a 47K-ohm resistor. Next, connect a 3.3K-ohm resistor in the cathode circuit. Unsolder and remove the short length of hookup wire between lug 6 on the circuit board and terminal B1 and replace it with the resistor.

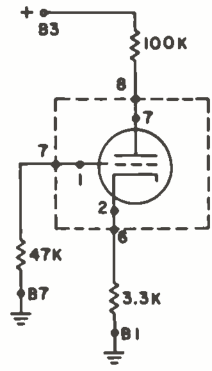


Fig. 43-2. Circuit using self bias.

Switch the tvom to the 3-volt range, connect the ground clip to the chassis and touch the probe to circuit board lug 7. The meter is connected to measure the grid voltage. Turn on the circuit, let the tube warm up and note that there is practically no voltage on the control grid.

Now, to measure the voltage drop across the 3.3K-ohm cathode resistor, touch the probe to lug 6 of the circuit board. Read the meter. Next connect the ground clip to circuit board lug 6 and touch the probe to lug 7. You are measuring grid voltage with respect to the cathode. You should get a negative reading. The voltage between the grid and cathode (pins 1 and 2 of the tube) should be approximately the same as the voltage between the chassis and the cathode lug 6.

To show that the voltage across the cathode bias resistance varies with the plate current, move the tvom ground clip to the chassis and clip the probe to lug 6. Turn the circuit on and observe the meter indication.

Next, apply +3V to the grid. Hold the

negative lead of the 3-volt battery against the chassis and touch the positive lead to lug 7 on the circuit board. Note that when you make the grid positive, the cathode bias voltage increases. Reverse the battery connections to place the negative 3 volts on the grid. Note that this reduces the cathode bias voltage to nearly zero.

Step 3: To show fixed bias.

Turn your circuit off and connect a 100K-ohm resistor between terminal B3 and lug 6. This gives you the circuit shown in Fig. 43-3.

Apply power and measure the voltage between the cathode (lug 6) and the chassis ground. Remove the tube from its socket and note that the voltage does not change significantly. Re-insert the tube. As you did in the preceding step, apply a positive 3 volts to the grid and note that there is very little change in the cathode voltage. Turn the circuit off and discharge the filter capacitors.

Step 4: To demonstrate grid-leak bias.

Unsolder and remove the 3.3K-ohm and 100K-ohm resistors connected to lug

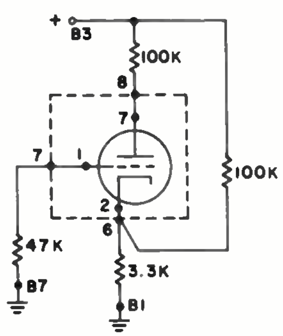


Fig. 43-3. Circuit using fixed cathode bias.

6. Connect a short length of hookup wire between lug 6 on the circuit board and terminal B1.

Connect a .1-mfd capacitor from lug 7 to terminal B6. Set the tvom to read −12V dc and apply power to the circuit. 3.5 V
Allow time for warm-up and measure the voltage between the chassis and lug 7. Jot down the value in the margin of this page.

While observing the meter, remove and re-insert the tube. You should see the bias fall to zero whenever the tube is removed from the socket.

Discussion: You have demonstrated the principal methods of obtaining bias voltages for vacuum tube circuits. In the first step, you saw that conduction bias can be produced simply by using a high-value grid resistor. The maximum bias voltage which can be developed, however, is very low, so this method is only used for small amplifier stages. Cathode bias, or self bias, is produced by connecting a resistor in series with the tube cathode. Plate current flows through the resistor and develops a voltage drop across it. This makes the cathode positive with respect to B− or ground. The grid resistor is returned to ground and this places the grid at zero or ground potential. Therefore, the grid is negative with respect to the cathode.

A bypass capacitor can be connected in parallel with the cathode bias resistor to prevent the bias level from varying widely with variations in the signal. With a suitable capacitor, the cathode will remain at an average bias level.

In Step 3, you used fixed bias on the cathode. The 3.3K and 100K-ohm resistors formed a voltage divider across the supply voltage. The voltage drop across the resistor connected between the cathode and ground was the positive cathode bias voltage. The bias level was set primarily by the ratio of the resistor values, although it was increased somewhat by the tube cathode current.

Fixed bias is sometimes applied to the control grid instead of the cathode of the tube. A negative voltage obtained from a separate power supply or by modifying the B power supply is fed to the return side of the grid resistor.

Grid-leak bias, which you demonstrated in Step 4, derives bias voltage from the signal applied to the control grid. The cathode and grid of the tube act as a diode. The grid becomes positive on the positive part of each ac cycle and draws current. This current charges the coupling capacitor connected to the grid.

When the input signal swings in a negative direction, the grid-cathode conduction ceases and the capacitor begins to discharge. Current flows down through the grid resistor to ground and back through the source to the other plate of the capacitor. A negative bias voltage is thus developed at the grid, because the capacitor charges through the low resistance cathode-grid path of the tube and discharges through the large grid resistor.

Instructions for Statement No. 43: For this Report Statement, you will reduce the level of the 60-cycle ac signal applied to the grid and note the effect on the grid-bias voltage.

Disconnect the lead of the .1-mfd capacitor from terminal B6.

Connect two 1K-ohm resistors together to form a 2,000-ohm resistor. Solder one lead to terminal B6 and solder the other lead to terminal B7. These resistors form a voltage divider with about one-half the applied voltage existing between the junction of the two resistors and ground.

Energize the circuit and connect your tvom to measure negative dc voltage at the control grid, lug 7. Touch the free lead of the .1-mfd capacitor to terminal
3.5 B6. Read the bias voltage and jot down the value in the margin.

Now move the capacitor lead from terminal B6 to the junction of the two 1K-ohm resistors. This gives you an input signal of about 3V ac. Measure the grid voltage again. Compare the bias voltage in the two cases and turn your equipment
2V ✓ off. Answer the Statement here and on the Report Sheet.

Statement No. 43: When I reduced the signal level by one-half, the grid-leak bias voltage:

(1) increased by about one-half.
(2) decreased by about one-half.
(3) remained the same.

EXPERIMENT 44

Purpose: To compare the grounded-cathode, grounded-grid and grounded-plate (cathode follower) types of vacuum tube amplifiers.

There are three different ways of applying a signal and removing the amplified signal from an amplifier stage. These are shown in Fig. 44-1.

The circuit shown at A is known as a "grounded-cathode" amplifier, the one at B a "grounded-plate"amplifier, and the one at C a "grounded-grid" amplifier.

The grounded-cathode circuit is the one most often used in radio and TV amplifier stages. The input signal is applied between the grid and ground, and

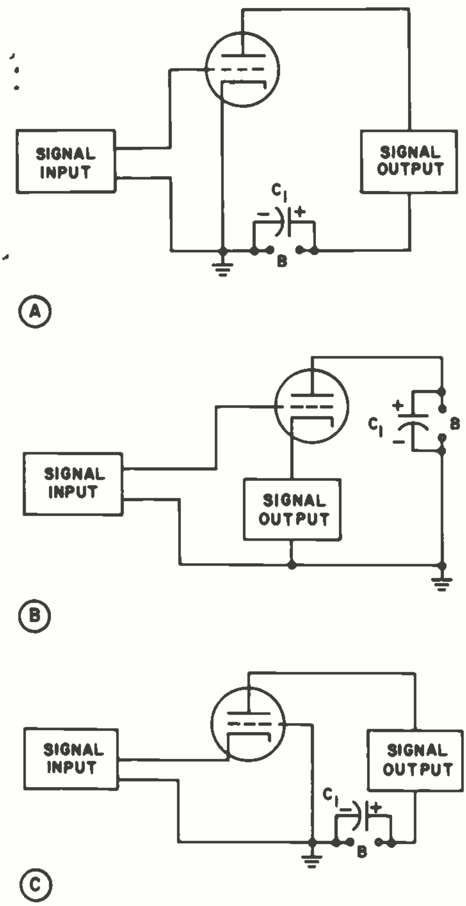


Fig. 44-1. Three types of amplifiers. (A) grounded-cathode amplifier; (B) grounded-plate amplifier; (C) grounded-grid amplifier.

the output is taken off between the plate and ground. The cathode can be connected directly to ground, or it can be grounded through a resistor. If a bias resistor is used between the cathode and ground, the resistor is generally bypassed with a capacitor. The impedance of the capacitor at the signal frequency is so low that practically no signal voltage is developed between the cathode and ground. Thus, the cathode is at ground potential as far as the signal is concerned.

In some cases, the cathode bias resistor is left unbypassed so an ac voltage is developed between the cathode and ground, which acts to reduce the signal voltage between the control grid and the cathode. The effect is the same as if a smaller signal voltage were being used, and the signal output is reduced. This effect is known as degeneration and is often deliberately introduced to stabilize amplifiers, to prevent oscillation, or to reduce distortion. However, this ac voltage is relatively low, and the circuit is still considered a grounded-cathode amplifier.

In the grounded-plate amplifier as shown at B in Fig. 44-1, the plate is kept at a high dc potential so it will attract electrons from the cathode. The plate, however, is bypassed by capacitor C_1 so that as far as the signals are concerned, the plate is at ground potential. Capacitor C_1 could be the output filter capacitor in the power supply.

The signal is applied between the grid of the tube and ground, as in the grounded-cathode type. However, the output is taken off between the cathode of the tube and ground. This type of amplifier is also called a cathode follower. Although we may call it an amplifier, it is impossible to have voltage amplification in a stage of this type. It does have some useful applications, primarily because it has a low output impedance and, therefore, can drive a low-impedance load.

The third type of amplifier is shown at C in Fig. 44-1. The signal to be amplified is applied between the cathode of the tube and ground. The output voltage is taken off between the plate of the tube and ground. If a bias resistor or supply is placed in the grid circuit, it is bypassed so the grid is at ground potential as far as signals are concerned. This circuit has gain, and the gain may exceed that of the grounded-cathode amplifier.

You will not ordinarily find an amplifier of this type in a radio receiver, but you may find it in the tuner of a television receiver.

In this experiment you will build the three types of amplifiers shown in Fig. 44-1, feed ac signals to their inputs, measure the signal voltage at their outputs and compare their gains.

Experimental Procedure: For this experiment, you will need the experimental chassis with the circuit board and wiring on it, your tvom and the following:

1 3.3K-ohm resistor
1 4.7K-ohm resistor
1 22K-ohm resistor
1 470K-ohm resistor
1 1-megohm resistor
1 .25-mfd capacitor
1 20-mfd, 150V electrolytic capacitor

Begin by constructing the grounded-cathode circuit shown in the schematic diagram in Fig. 44-2. The 1K-ohm potentiometer should still be mounted on the right front corner of the chassis with its terminals upward. The center terminal is terminal 2, the terminal nearest the front of the chassis is terminal 1, and the terminal toward the rear of the chassis is terminal 3.

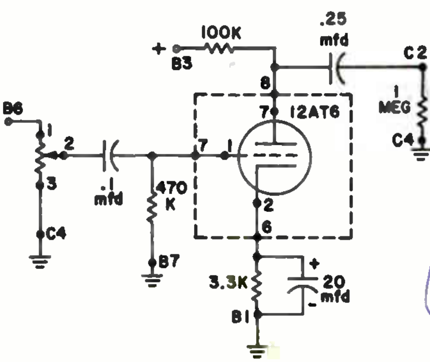


Fig. 44-2. The grounded-cathode amplifier circuit.

14V

Remove the jumper wire from terminal B1 to lug 6 and replace it with a 3.3K-ohm resistor.

Connect a 20-mfd electrolytic capacitor in parallel with the 3.3K-ohm resistor, with the polarity shown. Replace the 47K-ohm resistor between terminal B7 and lug 7 with a 470K-ohm resistor.

Complete the wiring using Fig. 44-2 and be sure to check all connections. You should now be ready to begin taking measurements.

Step 1: To determine the gain of a grounded-cathode amplifier.

Energize the circuit and let the tube warm up. Then adjust the input signal to the amplifier as follows. Set the tvom to measure ac voltage and connect the ground clip to the chassis. Adjust the 1K-ohm potentiometer for .2 volt ac at its center terminal. Switch your tvom to the low range for greater accuracy in adjusting the potentiometer. Move the tvom probe to circuit board lug 7 and notice that you have about the same voltage at the grid of the tube.

Set the tvom range switch to the 30-volt position and measure the ac signal in the plate circuit. Touch the probe to circuit board lug 8 and read the meter carefully. Record this value in the space for the output voltage in Fig. 44-3.

The .25-mfd capacitor and the 1-megohm resistor represent a fairly typical load on a voltage amplifier. Move the

,24),1800 .2)4.0 .2)14.0

STEP	GROUNDED ELEMENT	INPUT	OUTPUT	GAIN
1	CATHODE	.2V	14V	70
2	PLATE	.2V	4V	.7
3	GRID	.2	20V	100

Fig. 44-3. The chart for Experiment 44.

tvom probe to terminal C2 and measure the voltage across the 1-megohm resistor. As you can see, it is about the same as the voltage at the plate of the tube.

Next, compute the gain of the amplifier from the information in the chart. To do this, divide the input voltage of .2 volt into the output voltage you just measured. Record the gain for this circuit in the chart in Fig. 44-3.

Move the probe to lug 6. Note that there is no appreciable ac voltage at the tube cathode.

To show that a lower value of load resistor will reduce the output voltage, turn the circuit off, and replace the 1-megohm resistor with a 22K-ohm resistor. Energize the circuit and measure the plate signal again at lug 8 of the circuit board. Jot down the value in the margin of this page.

14V

Step 2: To measure the gain of a grounded-plate amplifier.

Turn the power off and unsolder the lead of the 20-mfd electrolytic capacitor from terminal 6 of the circuit board and push it out of the way. Unsolder the lead of the .25-mfd capacitor from lug 8 and move it to lug 6 of the circuit board. Also, unsolder and remove the 100K-ohm plate-load resistor. Connect a short length of hookup wire in its place between circuit board lug 8 and terminal B3. You should now have the circuit shown in the schematic in Fig. 44-4. This circuit is generally called a cathode follower or grounded-plate amplifier.

Energize the circuit and set the 1K-ohm potentiometer for .2 volt ac at the grid of the tube. Move the probe to the plate circuit, terminal 8 of the circuit board, and note the absence of an ac signal.

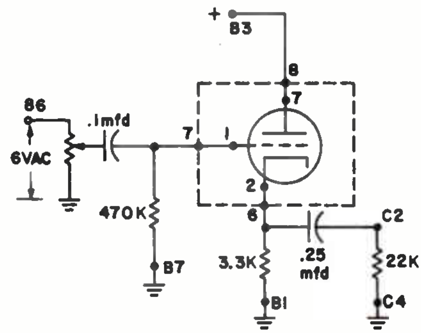


Fig. 44-4. The grounded-plate amplifier circuit.

The output signal appears in the cathode circuit. Touch the probe to circuit board lug 6 and measure the output voltage. Record your reading in the space provided in Fig. 44-3. Compute the "gain" by dividing the input signal of .2 volt into the output signal level. The gain should be somewhere between .5 and .1.

Replace the 22K-ohm resistor in the output circuit with a 4.7K-ohm resistor. Apply power to the circuit and note that the output voltage changes very little with the change in the load.

Step 3: To show gain in a grounded-grid circuit.

Turn the circuit off and wire the circuit shown in Fig. 44-5. Remove the

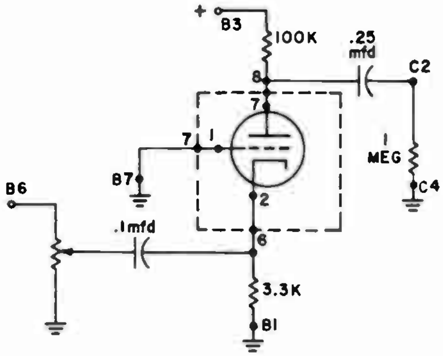


Fig. 44-5. The grounded-grid amplifier used in Step 3.

hookup wire between the plate terminal, lug 8, and terminal B3. Connect a 100K-ohm resistor in its place. Move the .1-mfd capacitor lead from lug 7 to lug 6 of the circuit board. Ground the grid by connecting a short length of hookup wire from lug 7 to terminal B7. Move the lead of the .25-mfd capacitor from lug 6 to lug 8. Replace the 4.7K-ohm resistor with a 1-megohm resistor.

Turn the circuit on and adjust for .2 volt ac at the tube cathode terminal, circuit board lug 6. If you cannot get .2 volt, set the potentiometer for maximum, then measure and record the voltage at the cathode in Fig. 44-3. Move the tvom probe to the center terminal of the potentiometer and measure the voltage there. Note that it is much higher than the voltage at the cathode.

2d Measure the output voltage at the plate terminal, lug 8 of the circuit board. Record the output voltage in Fig. 44-3, then compute the gain of the amplifier. Record the gain in the space provided in the chart.

Discussion: In this experiment you demonstrated amplifier circuits. You saw that when an ac signal is applied to a tube along with sufficient bias voltage, an input signal is produced. In all three circuits you used cathode bias. Cathode-to-plate current flowing from ground up through the 3.3K-ohm resistor made the cathode positive. Since the grid was returned to ground and remained at about ground potential, the grid-to-cathode voltage was negative.

From your chart in Fig. 44-3, you can see that the grounded cathode amplifier, which is a conventional amplifier circuit, has high voltage gain, with a gain of about 40. In carrying out Step 1, you should have found that there was little if any loss in the signal voltage across the .1-mfd input coupling capacitor. This is due to the fact that the grid circuit has a relatively high input impedance. Because no current flows, no signal power is dissipated in the grid circuit. The grid signal has only to vary the potential between the grid and cathode in order to control the tube plate current.

The grounded-cathode amplifier also has high output impedance. This means that the load resistance must be high if the tube is to have high amplification. As you demonstrated, connecting a low-resistance load caused a substantial reduction in the signal voltage at the plate.

The larger capacitor across the cathode resistance prevented the cathode bias voltage from varying with plate current. Therefore, the variations in plate current were proportional to the variations in grid voltage and high gain was realized.

The grounded-plate amplifier, which is called a cathode follower, has no voltage gain. A "gain" of .8 to .9 is typical of the circuit you used in Step 2. As you have already learned, a cathode follower is used primarily for matching a high impedance source to a low impedance load.

The input impedance is high as illustrated by the absence of signal voltage drop across the input coupling capacitor, and the output impedance is quite low.

The output impedance of a cathode follower is lower than the value of the cathode resistor. When you reduced the output load resistance to 4700 ohms, you should have observed very little reduction in the level of the signal at the cathode. This indicates that this load resistance is high compared to the amplifier output impedance.

In general, the characteristics of the grounded-grid amplifier are opposite to those of the cathode follower. The grounded-grid circuit, which you used in Step 3, has relatively high gain, low input impedance and high output impedance. Thus, it is useful for matching the impedance of a low impedance source to a high impedance load. In Step 3, you should have measured a gain of about 40.

Grounded-grid amplifiers are most often used to couple cathode followers to conventional amplifier stages. The fact that the grid is grounded makes the grid act as a shield between the cathode and plate. Consequently, it provides shielding between the amplifier input and output circuits and prevents signal energy from being coupled back through the tube.

The low impedance of the grounded-grid amplifier is largely due to the low value of resistance across which the input signal is developed. Voltage divider action results in most of the signal being dropped across the coupling capacitor between the signal source and the tube.

In this experiment, the word ground refers to signal ground. This may be dc ground, such as a connection to the chassis or B–. It may also be a point having a capacitor connected between it and B– (ground) such that no signal is developed at that point. Thus, in Step 2, the plate was at signal ground while having a potential of +80V applied.

From this experiment, we can make the following conclusions:

1. The conventional (grounded-cathode) amplifier has high gain, high input impedance and high output impedance;

2. The grounded-plate (cathode follower) amplifier has no gain, high input impedance and low output impedance; and

3. The grounded-grid amplifier has high gain, low input impedance and high output impedance.

Instructions for Statement No. 44: For this Statement, you will change the grid circuit of a grounded-grid amplifier and determine the effect of the gain. With the circuit turned off, unsolder and remove the length of hookup wire connecting circuit board lug 7 and terminal B7. Connect a 470K-ohm resistor and a 20-mfd electrolytic capacitor in parallel between these terminals, as shown in the schematic diagram in Fig. 44-6.

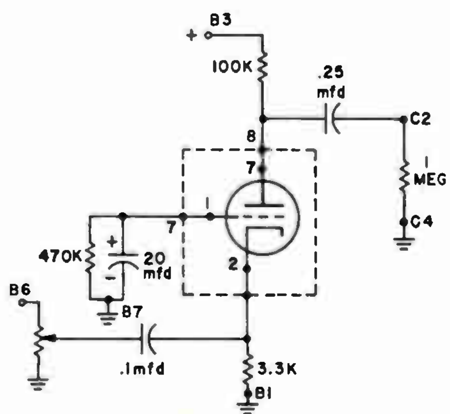


Fig. 44-6. The circuit for Statement 44.

Energize the circuit, measure the input and output signal voltages as before. Turn your equipment off and compute the gain.

Compare the gain with the gain for Step 3, which you recorded in the chart in Fig. 44-3. You are now ready to answer the Statement.

100

.2)20.0

Statement No. 44: When I installed the capacitor and resistor in the grid circuit of the grounded-grid amplifier circuit, I found that the gain of the stage:

(1) did not change appreciably.

(2) increased considerably.

(3) decreased considerably.

Transistor Fundamentals

In the first four experiments you have seen how a tube works and how it amplifies the signal. In the next six experiments you will see how a transistor works, how it is biased, how it amplifies signals and the various ways in which signals are applied to and removed from transistor circuits.

In these experiments, you will use the low power NPN transistor. This transistor is just the opposite of the transistor used in the preceding kit. It is a silicon NPN transistor, made of a piece of silicon which has been doped with impurities which give the base a P characteristic and the emitter and collector N characteristics. The transistor cannot safely pass high currents. The base current should not exceed a few milliamperes and the collector current should be limited to about 20 ma. The transistor has high gain. This means that small changes in base-emitter current can produce relatively large changes in the collector current.

A transistor is normally operated with forward bias on the base-emitter junction and reverse bias on the base-collector junction. Because we will be using an NPN transistor, the base should be positive with respect to the emitter and the collector should be positive with respect to the base. Note that this makes the emitter the least positive (or most negative) element of the transistor.

PRELIMINARY CONSTRUCTION

First you will assemble the low voltage power supply. This supply will be constructed on the circuit board which you received in Kit 1T. You will need the following parts:

1 Circuit board (EC24)
2 LV silicon diodes
2 200-mfd, 35V electrolytic capacitors
1 100-ohm resistor
1 1K-ohm resistor
4 1/4" X 4-40 screws
4 4-40 hex nuts

Mount circuit board EC24 on the left side of the chassis over the 500K-ohm potentiometer and the neon lamp. Secure the board with four 4-40 screws and nuts.

Fig. 7 shows the circuit board, EC24, with the complete power supply assembled and mounted on the chassis. Refer to this figure as you mount the parts.

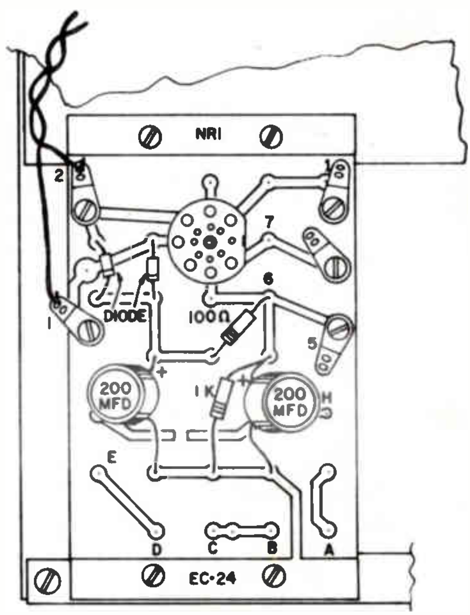


Fig. 7. Assembling the LV power supply.

You received the circuit board and the diodes in Kit 1T. In wiring EC24, push the parts down against the board and cut off the excess lead lengths.

Identify the anode and cathode leads of the two low voltage silicon diodes. Install each on the foil side of the board as shown, with the cathode lead toward hole D on the circuit board. Solder the leads.

Identify the leads of the two 200-mfd electrolytic capacitors and mount them as shown in the diagram. Note that the positive lead of each capacitor is toward the tube socket. Solder their leads to the foil.

Position the 100-ohm resistor as shown and install it on the board. Solder the leads.

Connect a 1K-ohm resistor to the foil as shown. Electrically, the resistor is between lug 5 and ground.

Check your work against the drawing very carefully.

Connect lengths of hookup wire between terminals B5 and B6 and terminal lugs 1 and 2 on the circuit board.

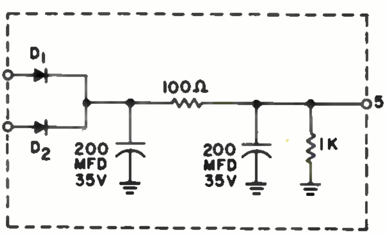


Fig. 8. Schematic diagram of the LV power supply on circuit board EC24.

Before you turn the circuit on, check the wiring against the schematic diagram in Fig. 8. Note that you have a full-wave rectifier operating off the center-tapped low voltage winding of the power transformer. The two 200-mfd capacitors and the 100-ohm resistor form a pi type filter network, producing filtered dc at lug 5 of the circuit board.

To test your low voltage power supply wiring, apply power to your chassis and measure the dc voltage between circuit board lug 5 and the chassis. You should read approximately 8 volts dc. Turn the power off.

Next, you will install an NPN transistor (TS21) on circuit board EC25. The transistor should not be subjected to physical strain or excessive heat on the leads. Therefore you should use the following procedure to install it: Identify the leads and bend them to fit the connections; grasp each lead with your longnose pliers and hold it in the molten solder. The pliers will serve as a heat sink and carry away the excess heat.

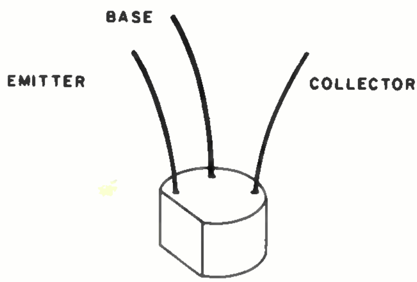


Fig. 9. Identifying the leads of the 2N5134 transistor.

Refer to Fig. 9 to identify the transistor leads. This is a bottom view. Note that there is a flat spot on the transistor case next to the emitter lead. Fig. 10 shows how to position the leads. Bend

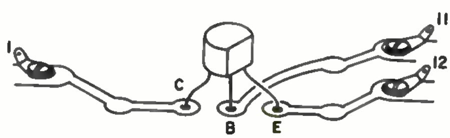


Fig. 10. Mounting the transistor on the experimental circuit board.

the leads and install the transistor as shown.

Unsolder and disconnect the filament leads to lugs 4 and 5 of EC25. Also unsolder and remove the lead between terminals A6 and B3. Unsolder and remove the parts connected to lugs 6, 7, and 8, terminals C2 and C4 and the 1K-ohm potentiometer.

EXPERIMENT 45

Purpose: To show the need for bias current in transistors; to show that a transistor can provide amplification and to show that the collector load resistance will affect the gain of a transistor amplifier.

Introductory Discussion: In an earlier experiment, you found that the current flowing in the collector circuit of a transistor can be controlled by placing a potential across the base-emitter junction. Now you will demonstrate the operation of a practical amplifier circuit and plot the relationship between base current and collector current.

In parts of this experiment, you will have to determine and compare currents. You will use the indirect method which you have used before to determine the current in these circuits: measure the voltage drop across a series resistor and divide the voltage by the resistance value. To simplify these computations, remember that in a 1,000-ohm resistor, the current in ma is equal to the voltage across the resistor in volts.

That is, if you measured 3.6 volts across a 1,000-ohm resistor, the current would be 3.6 ma. In measuring the current in a 10,000-ohm resistor, the current in microamperes is equal to the voltage across the resistor multiplied by 100. For example, if you measured 0.36

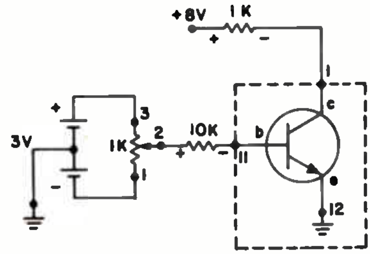


Fig. 45-1. The circuit for Step 1 and Step 2.

volts across a 10,000-ohm resistor, the current would be 36 microamperes.

Experimental Procedure: In order to perform this experiment, you will need the experimental chassis with two circuit boards mounted, the tvom, and the following parts:

- 1 1,000-ohm resistor
- 1 4,700-ohm resistor
- 1 10K-ohm resistor
- 2 Flashlight cells

You should already have a 1K-ohm potentiometer and two circuit boards mounted on the experimental chassis. The low voltage power supply is wired on circuit board EC24 and the NPN transistor is mounted on circuit board EC25.

Construct the circuit shown in the schematic in Fig. 45-1 and in the diagram in Fig. 45-2. The dashed line in the schematic of Fig. 45-1 encloses the wiring

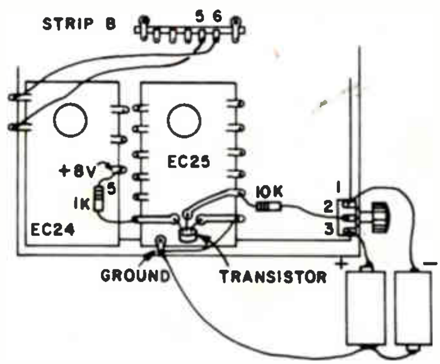


Fig. 45-2. Wiring layout for Step 1.

on circuit board EC25. When you complete your wiring, you will be ready to proceed with the experiment.

Step 1: To show that the base-emitter junction of a transistor must be forward biased for the transistor to operate and pass collector current.

Connect the tvom to measure the voltage between the chassis and the center terminal of the 1K-ohm potentiometer on the right side of the chassis. Set the potentiometer for −1 volt at terminal 2. Move the tvom leads to measure the voltage dropped across the 1K-ohm collector load resistor connected between lug 1 on circuit board EC25 and the +8V dc supply at lug 5 of EC24. With the tvom polarity switch set to "normal," connect the ground clip to lug 1 of EC25 and the probe to lug 5 of EC24.

Turn the circuit on and measure the voltage across the 1K-ohm resistor. Compute the current in the collector circuit. Record the current on the first line in the collector-current column in Fig. 45-3. The value should be close to zero.

BASE VOLTAGE	COLLECTOR CURRENT
−1 −.6	0
0	0
+1 +.6	1 mA.

Fig. 45-3. The chart for use with Step 1.

Using the same procedure, set the potentiometer for zero volts at terminal 2 of the 1K-ohm potentiometer and measure the corresponding collector current. Record the value in the chart in Fig. 45-3. Repeat the measurement with the potentiometer set to provide +1 volt at terminal 2. Record your results and turn off the power.

Step 2: To show that a transistor can amplify signal current.

Connect the tvom across the 10,000-ohm resistor which is connected in series with the base of the transistor. Observe the polarity of the voltage shown in Fig. 45-1 and connect your tvom leads accordingly. With the circuit turned on, adjust the 1K-ohm potentiometer for a voltage of .3 volt across the resistor. This reading corresponds to a base current (I_b) of .030 ma or 30 μa.

Without changing the adjustment of the 1K-ohm potentiometer move the tvom leads to the 1K-ohm collector load resistor and measure the collector current. Record this current in the collector current column of Fig. 45-4. Next, measure the collector voltage between the collector and the chassis and record it in Fig. 45-4.

Following the same procedure, set the base current to 20 microamperes (0.2 volt) and measure and record the collector current and the collector voltage. Finally adjust the base current to 40

BASE CURRENT	COLLECTOR CURRENT	COLLECTOR VOLTAGE
.03 ma	.8 MA	6.8V
.02 ma	.34 MA	7.4V
.04 ma	1.16 MA	6.4V

Fig. 45-4. The chart for Step 2.

microamperes (0.4 volt) and record the collector current and voltage measurements.

Step 3: To show that the collector load resistance affects the voltage gain.

Turn your circuit off and replace the 1,000-ohm collector load resistance with a 4700-ohm resistor. Fig. 45-5 shows a schematic diagram of this circuit.

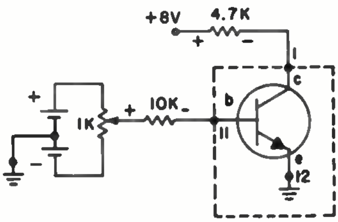


Fig. 45-5. The circuit used for Step 3.

Turn the circuit on and adjust the 1K-ohm potentiometer for a base current of 30 microamperes (0.3 volt across the 10,000-ohm resistor). Next measure the voltage between the collector terminal, lug 1, and ground. Record your reading in Fig. 45-6. Repeat the measurements using base currents of 20 microamperes and 40 microamperes and record the base current and collector voltage readings in Fig. 45-6. When you finish these measurements, turn the circuit off.

BASE CURRENT	COLLECTOR VOLTAGE
.03 ma	4.4V
.02 ma	6.2V
.04 ma	3.6V

Fig. 45-6. The chart for Step 3.

Discussion: In Step 1, you measured the collector current with different voltages applied to the base circuit. The base-emitter current is commonly called base current. You should have read close to zero collector current with both −1 volt and 0 volt applied to the base circuit.

Forward base current is required for conduction in a transistor. This is an NPN transistor, so when the base-emitter junction was reverse biased or when no voltage was applied, you had only "leakage" current through the emitter-collector path. Conduction took place when you forward biased the base-emitter junction by applying a positive voltage.

Assuming that we wanted to amplify a signal which varies in both the positive and negative directions, we needed a forward bias current so the negative portion of the signal would not reverse bias the transistor.

In Step 2 you measured the collector current with three values of base current. If you assume from the information in the chart in Fig. 45-4 that the bias current is 30 microamperes, you should see that the collector current variations are almost proportional to the changes in base current. If we use 30 microamperes of base current as a reference, we find an increase or decrease of 10 microamperes of base current causes about a .5 ma variation in collector current.

For linear amplification, a base bias current is needed. The signal causes the base current to vary above and below the bias level. This bias must be high enough so that, as the signal varies, the base current never reaches the cutoff level, which is near zero, because this would distort the amplified signal.

The only thing you changed in the circuit for Step 3 was the collector load

.1V / 10KΩ = 10K) .10000 .01 m

resistance. By comparing the collector voltage readings for Steps 2 and 3 in the charts in Figs. 45-4 and 45-6, you can see that the variations in collector voltage are much greater with the higher value collector load resistor. This means that the voltage amplification is greater since the input signal variations were unchanged.

Notice the phase relationship between input and output voltages in this circuit. An increase in base voltage causes an increase in base current. This increases the collector current, producing a greater voltage drop across the collector load resistor. When we measure the collector voltage with respect to ground, we find that the voltage has decreased. The phase of the signal is reversed between input and output, just as it is in the conventional vacuum-tube amplifier circuit.

Instructions for Statement No. 45: For this Statement you will determine the amount of base current at which the transistor reaches saturation. (Saturation occurs when an increase in the input current produces no appreciable change in the output.) Connect your tvom to measure the voltage between the collector and ground, and turn the power on. Increase the base voltage until the collector reaches its minimum or saturation value. Then measure the voltage across the 10,000-ohm base resistor and determine the base current. Answer the Statement, turn the circuit off, and disconnect the 3-volt battery.

Statement No. 45: As I increased the base current, I found that the transistor became saturated with a base current of:

(1) less than 1 ma.
(2) approximately 3 ma.
(3) between 6 and 10 ma.

EXPERIMENT 46

Purpose: To compare the characteristics of the common base, common emitter, and common collector transistor amplifier circuits.

Introductory Discussion: The three configurations for a transistor amplifier are common emitter, common base, and common collector. In many ways, they are similar to the three vacuum tube amplifier configurations which you have already seen. You have already worked with the common emitter transistor amplifier.

In each transistor amplifier configuration, as shown in Fig. 46-1, the input and output signals share one common element. In the common base circuit, the input is applied between the emitter and base and the output is taken between the collector and the base. In the common

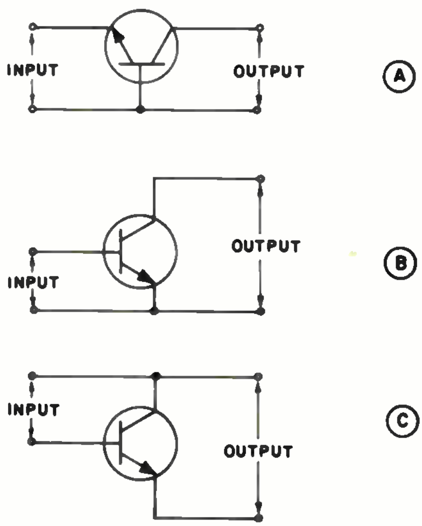


Fig. 46-1. The signal input and output terminals for the (A) common base, (B) common emitter and (C) common collector transistor amplifier configurations.

emitter circuit, the input is applied between the base and emitter and the output is taken between the collector and emitter. In the common collector circuit, the input is applied between the base and collector and the output is taken between the emitter and collector.

The connections shown in Fig. 46-1 refer to the ac signal connections. Due to the forward and reverse bias requirements, the common element may be at some dc level other than ground. However, the common element is held at signal ground by a bypass capacitor or by the low impedance of the dc source.

In this experiment, you will apply ac signals to the amplifier configurations and measure the voltage and current gain of each to compare the circuit characteristics.

Experimental Procedure: In order to carry out this experiment you will need the experimental chassis, your tvom, and the following parts:

1 10-ohm resistor
2 1K-ohm resistors
1 4.7K-ohm resistor
2 10K-ohm resistors
1 47K-ohm resistor
2 100K-ohm resistors
1 100-mfd electrolytic capacitor
1 Alligator clip

You will begin by constructing the circuit shown in the schematic diagram in Fig. 46-2. This is an adjustable voltage divider for supplying the proper level of ac signal voltage to the amplifier and the common base amplifier circuit which you will use for Step 1. The adjustable voltage divider will be used in all of the steps.

Loosen the screw at hole U and turn terminal strip C around so that terminal C1 is toward the front of the chassis. Retighten the screw. This will make the wiring easier.

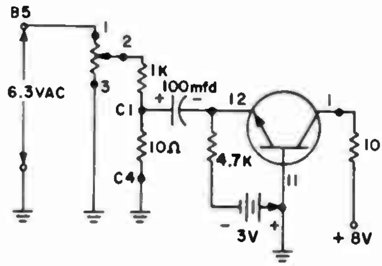


Fig. 46-2. The voltage divider and common base amplifier circuit you use for Step 1.

Construct the voltage divider portion of the circuit first. Connect and solder lengths of hookup wire between terminal B5 and terminal 1 of the 1K-ohm potentiometer and between terminal C4 and terminal 3 of the potentiometer. Connect a 1K-ohm resistor from terminal 2 of the potentiometer to terminal C1. Connect a 10-ohm resistor between terminals C1 and C4. Solder the positive lead of a 100-mfd capacitor to terminal C1. Solder the negative lead of the capacitor to lug 12 of circuit board EC25.

Next, wire the amplifier. Move the short ground wire from lug 12 to lug 11 on EC25. Solder a 10K-ohm resistor between lug 1 of EC25 and lug 5 of EC24. Solder a 4.7K-ohm resistor to lug 12 of EC25. Leave the other lead free.

You should still have two flashlight cells connected in series, forming a 3-volt battery. Solder a test clip to the positive battery lead. This will simplify your work a little later. Solder the negative battery lead to the free lead of the 4.7K-ohm resistor soldered to lug 12.

Check your wiring against the schematic and be sure all connections are soldered. To complete the 3-volt battery circuit, you will clip the positive battery lead to the chassis.

Step 1: To show that the common base amplifier has voltage gain.

Energize the circuit, connect the clip from the 3-volt battery to the chassis, and set your tvom to measure ac voltage. Measure the voltage between terminal 2 (the center terminal) of the 1K-ohm potentiometer and the chassis. Adjust the potentiometer for a reading of 2.5 volts. Use the 3-volt range. The 1K-ohm resistor and 10-ohm resistor connected between potentiometer terminal 2 and ground form a 100:1 voltage divider. With the potentiometer set for 2.5 volts, about .025 volts is being applied to the transistor amplifier circuit at terminal C1.

After you have adjusted the input voltage, measure the ac output voltage between ground and the collector of the transistor. Record this value as the output voltage for Step 1 on the first line of the chart in Fig. 46-3. Note that the input voltage has been written in.

Now that you have both the input and output voltage levels, compute the amplifier voltage gain using the formula:

$$V_G = \frac{V_{out}}{V_{in}}$$

STEP	INPUT	OUTPUT	GAIN
1	.025V	2.[illegible] V	≃ 100
2	.285[illegible]	.25 ma	≃ <1

Fig. 46-3. Record your results for Steps 1 and 2 here.

and record the gain for Step 1 in the chart.

Turn the circuit off. Be sure to disconnect the battery clip.

Step 2: To show that the common base amplifier has a current gain of less than 1.

Modify your circuit as shown in Fig. 46-4. Solder a 10K-ohm resistor to terminal 2 of the potentiometer. Unsolder the capacitor lead from terminal C1 and solder it to the free lead of the 10K-ohm resistor.

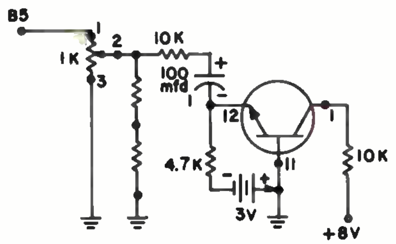


Fig. 46-4. The circuit for Step 2.

To determine the current gain, you will use the following procedure: First set the potentiometer for a given amplifier output voltage. This will give you the output signal current through the load resistor. Then measure the signal voltage drop across a resistor in series with the amplifier input. Use this value to compute the input signal current. Finally, divide the output current by the input current to find the current gain.

Now you can proceed with this step. Energize the circuit and connect the 3-volt battery clip. Set the 1K-ohm potentiometer for an output of 2.5 volts between the collector, lug 1, and ground. This corresponds to the output current of .25 ma, as recorded in the chart in Fig. 46-3.

Measure the ac voltage between ground and the resistor lead connected to the potentiometer. Jot down the value for reference. Now measure the signal voltage between ground and the resistor lead connected to the coupling capacitor. The difference between these two readings is the signal voltage across the 10K-ohm series resistor.

Now that you know the voltage across the resistor, you can find the input signal current. Divide the voltage reading by 10,000. You can do this simply if you remember that the current through the resistor in ma is 1/10 the voltage across the resistor in volts. Record the input current in the space provided in the chart in Fig. 46-3.

Compute the current gain of the amplifier. Use the formula:

$$I_G = \frac{I_{out}}{I_{in}}$$

Your answer should be some number between .7 and 1. Record the value in the chart in Fig. 46-3 and turn the circuit off.

Step 3: To show that the common emitter amplifier has voltage gain.

Construct the circuit shown in Fig. 46-5. Unsolder and disconnect the leads from lug 12 of the circuit board. Unsolder the ground wire from lug 11. Solder the free end of this wire to lug 12.

Unsolder and remove the 4.7K-ohm resistor. Solder the negative lead of the 3-volt battery to a convenient ground point. Solder one lead of a 47K-ohm resistor and the positive lead of the 100-mfd capacitor to lug 11. Solder the negative capacitor lead to terminal C1. Check your wiring and be sure all connections are soldered.

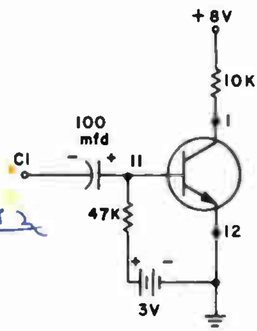


Fig. 46-5. The common emitter amplifier circuit for Step 3.

To produce an input of .025V ac between the base and emitter of the transistor, energize the circuit, clip the positive battery lead to the 47K-ohm resistor and set the potentiometer for 2.5V ac across the voltage divider.

Move the tvom probe to lug 1 and measure the output signal between the collector of the transistor and ground. Record the output voltage in the space provided in Fig. 46-6. Compute the voltage gain of the circuit by dividing the output voltage you just recorded by the input voltage of .025V. Record the voltage gain in the chart.

Turn your circuit off.

Step 4: To show that the common emitter amplifier has current gain.

Connect two 100K-ohm resistors in parallel. Solder one end of this parallel

STEP	INPUT	OUTPUT	GAIN
3	.025V	2.56	150
4	.06 A	.25 ma	4

Fig. 46-6. Record your results for Steps 3 and 4 here.

combination to terminal 2 of the potentiometer. Unsolder the capacitor lead from terminal C1 and solder it to the free leads of the two 100K-ohm resistors.

Turn your circuit on and adjust the potentiometer for an output of 2.5 volts between ground and the collector of the transistor at lug 1. This corresponds to a collector output signal current of .25 ma, as shown in the chart in Fig. 46-6. Without readjusting the potentiometer, determine the input current. Measure the ac voltage across the 50K-ohm input series resistance formed by the two parallel-connected 100K-ohm resistors. Use the technique described earlier: measure the voltage between ground and each end of the resistance and take the difference. Divide this difference voltage by 50 to find the input signal current in ma. Record the current value in the space provided in Fig. 46-6.

To find the current gain, divide the output signal current by the input current recorded in Fig. 46-6. Record the current gain in the space provided in the chart.

Turn the circuit off and disconnect the battery clip.

Step 5: To show that the common collector amplifier has a voltage gain of less than 1.

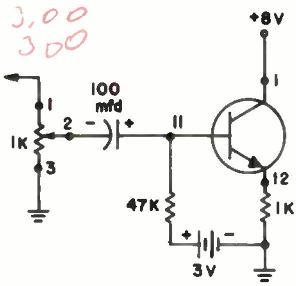


Fig. 46-7. The common collector circuit for use in Step 5.

Construct the circuit shown in the schematic diagram in Fig. 46-7. Remove the length of hookup wire connected between lug 12 and ground and replace it with a 1K-ohm resistor. Unsolder and remove the 10K-ohm resistor connected to lug 1. Solder a length of hookup wire between lug 1 of EC25 and lug 5 of EC24. Unsolder and remove the two 100K-ohm resistors from the circuit. Unsolder the capacitor lead from the 50K-ohm resistance and solder it to terminal 2 of the potentiometer.

Turn the circuit on and adjust the 1K-ohm potentiometer for .25V ac between the base of the transistor (lug 11) and ground. Move the probe of the tvom to lug 12 and measure the ac output voltage across the 1K-ohm emitter load resistor. Record this value for the output voltage in Fig. 46-8. We have already indicated the input voltage of .25V.

STEP	INPUT	OUTPUT	GAIN
5	.25V	.25	1
6	15.8µ	250 µa.	16

Fig. 46-8. Record your results for Steps 5 and 6 here.

Compute the voltage "gain" by dividing the output voltage by the input voltage of .25V. The result should be between .9 and 1. Record the gain in the space provided in the chart in Fig. 46-8.

Turn the circuit off and disconnect the battery clip.

Step 6: To show that the common collector amplifier has current gain.

Unsolder the capacitor lead from terminal 2 of the 1K-ohm potentiometer.

1.80
.25
1.55

.0155
100K) 1.55

Separate the leads of the 100K-ohm resistors and connect the capacitor in series with one of the 100K-ohm resistors.

Turn the circuit on, connect the battery, and adjust the potentiometer for an output of .25V ac across the 1K-ohm emitter load resistor. This corresponds to an output signal current of .25 ma or 250 μa. Now determine the input current flowing into the base circuit. Measure the ac voltage across the 100K-ohm series resistor using the technique outlined in Steps 2 and 4. Divide the voltage across the resistor by 100,000 to find the input current. The current in μa is equal to 10 times the voltage across the resistor in volts. For example, a voltage of .8V corresponds to 8 μa. Record the input current in the chart in Fig. 46-8.

15.5 μa

Compute the current gain by dividing the output signal current by the input signal current as you have done previously. Record the current gain in the chart in Fig. 46-8.

Turn the equipment off.

Discussion: In this experiment, you demonstrated the voltage and current gain characteristics of the three basic transistor amplifier configurations. In all three, the base, emitter and collector currents are fixed largely by the characteristics of the transistor: a small current flowing across the forward biased base-emitter junction causes a much larger current to flow from the emitter across the base to the reverse biased base-collector junction. The levels of the input and output currents are primarily due to whether they are the emitter, base or collector current or a combination.

The voltage gain of any amplifier configuration is generally determined by the current gain of the transistor and the input and output resistances.

The important facts of this experiment are summarized in Fig. 46-3, Fig. 46-6, and Fig. 46-8. You can see that the common base amplifier has the highest voltage gain but the lowest current "gain." A voltage gain of 100 and a current gain of .8 are typical. The common collector stage has the lowest voltage gain and the highest current gain. Typical values are a voltage gain of .95 and a current gain of 30. The common emitter amplifier has medium voltage and current gains. Typical values are a voltage gain of 90 and a current gain of 4.

From basic transistor theory, you know that the emitter current is the sum of the base and collector currents. You also know that the collector current is many times the value of the base current. You know that normally the base-emitter junction is forward biased and that it acts like a forward biased diode and has a low resistance. Conversely, the base-collector junction is reverse biased and hence has a much higher resistance.

With this information you can see that each amplifier configuration has different input and output impedances. The common base circuit has low input impedance and high output impedance. The input signal is applied to the emitter-base junction and the emitter current flows in the input signal circuit. On the other hand, the output impedance is roughly equal to the load resistance.

The common emitter circuit used in Steps 3 and 4 has moderate input impedance and high output impedance. The input is applied to the base-emitter junction, but only the base current flows in the input signal circuit. The output, taken across the emitter-base and base-collector junctions connected in series, is nearly equal to the resistance of the load resistor.

The common collector circuit, which you used for the last two steps, has very high input impedance. The input signal is applied across the base-collector junction, which is reverse biased and acts somewhat like an open circuit. Even with an input voltage of .25V, the input current was probably less than 10 μa (.01 ma).

From the work in this experiment you can see that the choice of an amplifier configuration must be based on the voltage and current gain requirements and input and output impedances. You will learn more about these configurations in your regular lessons.

One of the characteristics of the common base amplifier is that it does not reverse the phase of the applied signal: a positive-going change in the input signal produces a positive-going change in the output. For this Report Statement, you will determine whether or not the other amplifier configurations reverse the phase of the signal.

Instructions for Statement No. 46: Unsolder and remove the 100-mfd capacitor and the 100K-ohm resistor from the circuit and lay them aside. Solder a 100K-ohm resistor to lug 5 of EC24 and position the resistor so you can touch the other lead to lug 11 of EC25. You should now have the common collector circuit shown in Fig. 46-7, but without the ac input circuit.

Turn your circuit on, connect the battery clip, and measure the dc voltage across the 1K-ohm output load resistor. Touch the 100K-ohm resistor lead to the transistor base to represent a positive dc signal voltage and note the direction of the change in dc output voltage. (The direction of the change depends on whether the emitter voltage increases or decreases when a positive signal is applied to the base.)

1.65

+

When you have made this measurement, turn the circuit off and change the amplifier to a common emitter configuration. Replace the 1K-ohm resistor with a length of wire and replace the wire connected between lug 1 and lug 5 of EC24 with a 10K-ohm resistor. The circuit will then be similar to the circuit shown in Fig. 46-5.

Connect the 3-volt battery, energize the circuit and measure the output voltage between the collector at lug 1 and ground. Touch the lead of the 100K-ohm resistor to the transistor base circuit and note the direction in which the collector voltage changes. You now have enough data to answer the Report Statement. Turn your equipment off.

Statement No. 46: **When I applied a positive input voltage to the common collector amplifier, I found that the amplifier**

(1) reversed
(2) did not reverse

the phase of the signal and when I applied a positive input voltage to the common emitter amplifier, I found that the amplifier

(1) reversed
(2) did not reverse

the phase of the signal.

EXPERIMENT 47

Purpose: To demonstrate and compare several methods of biasing a transistor using a single source of dc voltage.

Introductory Discussion: You already know that transistors are normally operated with forward bias on the base-emitter junction and reverse bias on the base-collector junction. Now you will see how both of these bias requirements can be obtained from a single source of dc voltage.

A simple bias arrangement using one dc source is shown in Fig. 47-1. A relatively high positive voltage is applied to the collector through a load resistor. This is an NPN transistor, so the collector voltage is positive with respect to the emitter. The base resistor is connected between the base and the collector supply voltage, thereby making the base positive. This causes a current to flow from the emitter across the base-emitter junction and through the base resistor to the positive source. Most of the voltage is dropped across the resistor, making the base slightly positive with respect to the emitter, and the collector highly positive with respect to the base. The bias requirements, therefore, are satisfied.

The base bias current in the circuit in Fig. 47-1 is totally dependent on the value of the bias resistor and the resistance of the base-emitter junction of the transistor. Any change in either will shift the transistor from the desired point on its characteristic curve. This may cause distortion in the output signal (if it is used as an amplifier) or damage to the transistor due to excessive current.

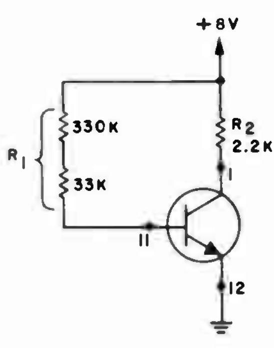


Fig. 47-1. The circuit for Step 1.

The basic bias circuit can be modified to make it more stable. By stable, we mean the transistor can be made to operate satisfactorily despite normal variations in resistor values, transistor characteristics, ambient temperature, etc. You will demonstrate this by reducing the value of a resistor and observing the effect on the output voltage.

Experimental Procedure: For this experiment, you will need the chassis, your tvom and the following parts:

- **1 1K-ohm resistor**
- **2 2.2K-ohm resistors**
- **1 4.7K-ohm resistor**
- **1 22K-ohm resistor**
- **1 33K-ohm resistor**
- **1 47K-ohm resistor**
- **1 220K-ohm resistor**
- **1 330K-ohm resistor**
- **1 10-mfd capacitor**
- **1 100-mfd capacitor**

Begin by constructing the circuit shown in Fig. 47-1. Unsolder and remove all parts and hookup wires from lugs 1, 11 and 12 of circuit board EC25. Do not remove the ac voltage divider wired on terminal strip C and the 1K-ohm potentiometer.

Connect a 2.2K-ohm resistor from lug 1 of EC25 to lug 5 of EC24. Connect together a 330K-ohm resistor and a 33K-ohm resistor and solder this resistor combination between lug 5 of EC24 and lug 11 of EC25. Connect a length of hookup wire between lug 12 of EC25 and any convenient ground point. Check over your work and solder all connections.

Your circuit is a common emitter amplifier stage having base bias supplied by a dropping resistor, R_1, of approximately 360K-ohms. Changes in collector current will be reflected in a variation in the voltage drop across the collector load resistor, R_2.

7.40

Step 1: To demonstrate simple bias.

.064
2.76

Set your tvom to measure positive dc voltage on the 12V range and energize your circuit. Measure the voltage between ground and the collector of the transistor at lug 1. Record the reading in the space for V_C on the top line of the chart in Fig. 47-2. This is the output voltage. Note that the voltage you just measured is also the voltage across the transistor (between the collector and emitter). Then record the same reading for V_{CE} in the chart.

17.8 μA

Determine the base current by the indirect method. Measure the dc voltage across the base resistance, R_1, and divide the voltage reading by 360K. Jot down the base current in the margin. The current should be about 20 μa (.02 ma).

Measure the bias voltage between the emitter and the base. About .6V is typical. Record this value in the margin also.

To check for stability, short out the 33K-ohm resistor with a piece of wire or a screwdriver and measure the collector voltage again. The voltage should be noticeably lower. Record the new value for V_C and V_{CE} on the second line in the chart.

52

Now that you have the output voltages for base bias resistances of 360K and 330K-ohms, you can determine the change in collector voltage, ΔV_C. This is equal to the difference in the V_C readings. Record the change in the space provided in the last column. Turn the circuit off.

STEP	R_1	V_C	V_{CE}	ΔVC
1	360K	6.3	6.9	[illegible]
	330K	[illegible] 2	5.2	
2	240K	5.7	4.9	.1
	220K	5.6	4.7	
3	52K	4.2	2.8	.3
	47K	4.0	2.4	
4	24K	4.40	2.9	.05
	22K	4.85	2.8	

Fig. 47-2. Chart for this experiment.

Step 2: To demonstrate simple bias with emitter stabilization.

Modify your circuit to that shown in Fig. 47-3. Replace the series-connected base resistors with a 220K-ohm resistor and a 22K-ohm resistor connected in series. Also, replace the ground wire in the emitter circuit with a 1K-ohm resistor.

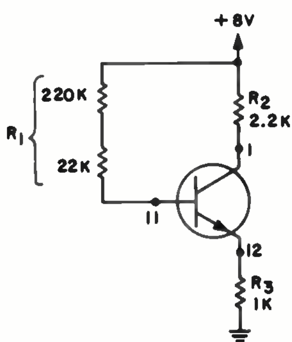


Fig. 47-3. The circuit used in Step 2.

Energize the circuit and measure the collector voltage, V_C. It should be close to the value you measured in Step 1. Record this voltage on the third line of the chart in Fig. 47-2. Move the ground clip of your tvom to lug 12 and measure the voltage across the transistor, V_{CE}. Record this voltage in the chart also.

Next, measure the voltage across the emitter resistor, R_3. The voltage drop across this resistor is equal to the difference between the collector voltage and the collector-emitter voltage. .81

Test the circuit for stability. Short out the 22K-ohm resistor and measure the collector and collector emitter voltages again. Record your readings on the fourth line of the chart. Determine the change in the output voltage and record it in the last column.

Connect your tvom across the emitter resistor again and open and close the short across the 22K-ohm resistor. Note that when you short the resistor, the emitter voltage increases, thus counteracting the change in base current. Turn the circuit off.

Step 3: To show a bias method which uses base stabilization.

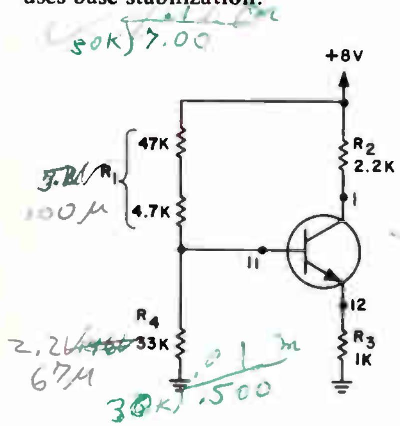


Fig. 47-4. The circuit for Step 3.

Wire the circuit shown in Fig. 47-4. Connect a 47K-ohm resistor and a 4.7K-ohm resistor in place of the base bias resistors used in the last step. Also, connect a 33K-ohm resistor between lug 11 and a ground point. Check your wiring against the schematic.

Energize the circuit and measure and record the collector and collector emitter voltages on the fifth line of the chart in Fig. 47-2. Check for stability by shorting out the 4.7K-ohm resistor and taking these voltage readings again. Record the values and determine the change in collector voltage. Record this value also.

Now, find the base current in the circuit. Note that part of the current through R_1 flows through R_4. Therefore, the base current is the difference between the R_1 and R_4 currents. First measure the voltage across R_1 and divide the voltage reading by the resistance value. Use 52K for the resistance of R_1 to make the computations easier. Next, measure the voltage across R_4 and find the current I_{R_4}. When you have found the currents, use the formula:

$$I_b = I_{R_1} - I_{R_4} = 33\,\mu$$

137.2 μ
13.9 μ
123.1 μ = I_b

The value should be in the vicinity of 20 μa. Turn the circuit off.

100 μ
67 μ
33 μ

Step 4: To show a bias network using voltage feedback.

Unsolder and remove the 47K and 4.7K-ohm resistors. Connect a 2.2K-ohm resistor and a 22K-ohm resistor in series between lug 1 and lug 11 of the circuit board. The wiring of the circuit in Fig. 47-5 should now be complete.

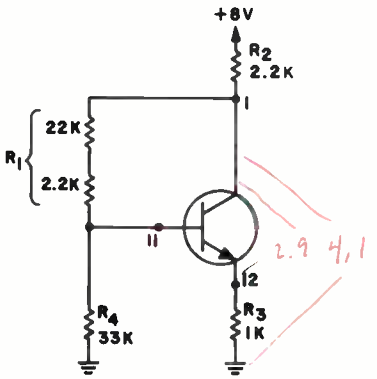


Fig. 47-5. The circuit used in Step 4.

Turn the circuit on and measure and record the voltages for V_C and V_{CE} with a bias resistance of 24K-ohms. Record your results in Fig. 47-2. Short out the 2.2K-ohm resistor and repeat the test to demonstrate the stability of this circuit. Record the change in collector voltage, ΔV_C, for this step. The change may be too small to observe on your meter. If it is, mark a dash in Fig. 47-2 for ΔV_C.

Turn the equipment off.

Discussion: You have demonstrated the four principal transistor biasing arrangements. In all four, forward bias for the base-emitter junction was obtained from the collector supply voltage. This eliminates the need for a second power source.

In Step 1, you used simple bias, which has the poorest stability. As you saw, the change in collector voltage was proportional to the change in the base resistor value. The change in the resistor value increased the base current and collector current by about 10 per cent.

In Step 2, emitter stabilization was used. Emitter current produced a voltage drop across the emitter resistor. This is reverse bias voltage for the base-emitter junction which opposes the forward bias and tends to decrease the base and collector currents. Thus, the base-emitter bias voltage was equal to the voltage directly across the terminals rather than between ground and the base. The stability of this circuit is better than the circuit shown in Fig. 47-1, as you found out.

The circuit in Step 3 combined emitter stabilization and base stabilization. As such, it was more stable than the preceding circuits. In addition to the emitter stabilization, the change in the base bias resistor value was offset by the bleeder resistor action of resistor R_4 in Fig. 47-4. Since part of the current through the forward bias resistor flowed through the bleeder resistor, the bias voltage at the base varied very little when the resistor value was decreased.

When you computed the bias current, you should have found a current of about 100 μa through R_1 and about 80 μa through R_4. Thus, the base current was approximately 20 μa.

The circuit used in Step 4 has the best stability. It uses the stabilization methods discussed earlier plus voltage feedback. Because the base bias network is supplied from the collector voltage, any change in collector voltage is reflected in a corresponding change in base voltage. Due to the 180° phase shift between the input and output, this minimizes the effect of the initial change, which was a reduction in the forward bias resistor value. You should have found that the collector emitter voltage varied by less than .1V.

Instructions for Statement No. 47: For this Report Statement, you will compare the amplification and collector voltages of the circuit in Fig. 47-5 with and without a bypass capacitor across the emitter resistor.

Use the ac voltage divider from Experiment 46 as a signal source. Connect a 100-mfd electrolytic capacitor between terminal C1 and lug 11 of the circuit board with the positive lead to lug 11 to form the circuit of Fig. 47-6. Energize the circuit and adjust the 1K-ohm potentiometer for 3V ac across the 100:1 voltage divider made up of the 1K-ohm and 10-ohm resistors. This voltage reading corresponds to an input signal of .03V ac.

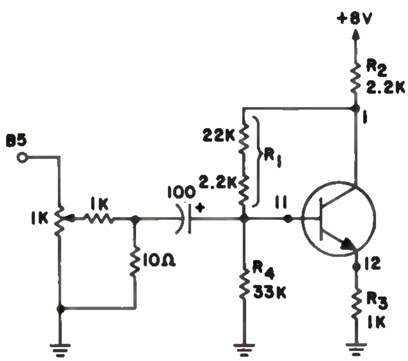


Fig. 47-6. The circuit used for the Report Statement.

Measure the ac voltage between the collector and ground. Also measure the
.15 dc collector voltage. Jot down the readings in the margin. Now, connect a
4.2 10-mfd capacitor across the 1K-ohm
DC, emitter resistor with the positive lead to lug 12 and measure the ac and dc output
4.5 voltages again. Turn the equipment off
DC and answer the Statement.
.34 AC

Statement No. 47: When I connected a bypass capacitor across the emitter resistor, the

(1) gain increased and the dc voltage remained the same.

(2) gain decreased and the dc voltage was unchanged.

(3) gain increased and the dc voltage increased.

EXPERIMENT 48

Purpose: To demonstrate L-C oscillator circuits.

Introductory Discussion: Oscillator circuits are used in nearly all types of electronic apparatus to generate ac signals. These oscillator circuits can be divided according to the frequency of operation (audio or rf) and according to what is used to establish the frequency. In an L-C oscillator, a resonant circuit made up of inductance and capacitance determines the output frequency. In an R-C oscillator of the type you will study later, the frequency is determined by R-C time constants.

All oscillator circuits are basically amplifier circuits in which some of the energy from the output of the stage is fed back to the input. If we place a resonant circuit between the output and the input of an amplifier stage, and the circuit is excited by the amplifier, an ac signal will be produced across the resonant circuit. If some path is provided so that a portion of the output energy can be fed back to the input of the amplifier stage, oscillation will be produced. The stage will continue to oscillate because the energy in the resonant circuit will be constantly reinforced by the amplified output voltage variations. This is illustrated in Fig. 48-1. Fig. 48-1A shows an rf amplifier. The signal across the resonant circuit is fed to the base and the amplified current

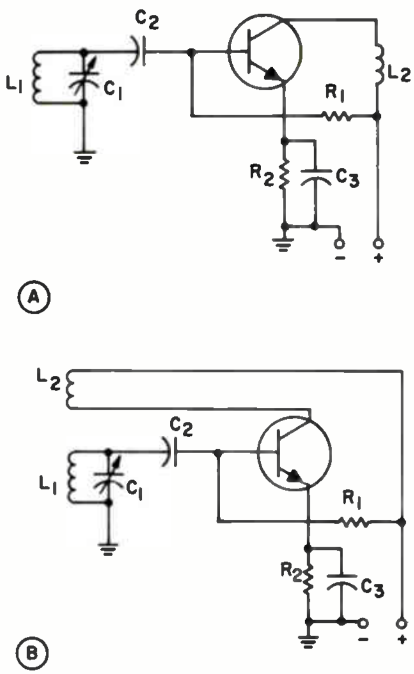


Fig. 48-1. An rf amplifier with coil L_1 in the base circuit and coil L_2 in the collector circuit, (A); an rf oscillator obtained by coupling the collector coil to the base coil, (B).

produces a larger signal voltage across the collector load inductance L_2. If no signal is present across the resonant circuit there will be no variation in collector current and no signal voltage across the collector load.

If, however, the collector load inductance is placed so its magnetic field cuts the turns in the tank inductance, the tank circuit will be shock-excited and will go into oscillation at its resonant frequency. A voltage at this frequency will be set up across the tank. Ordinarily, only a few cycles of voltage would be produced and the oscillation would quickly die out. But in this case the signal is applied to the transistor and the amplified signal current flowing in the collector load induces more voltage into the tank and the circuit continues to oscillate. Fig. 48-1B shows a practical oscillator circuit such as we have described.

As you already know and will prove in this experiment, the feedback must be of the correct phase to reinforce the signal in the tank circuit. If the feedback connections are reversed, oscillation will cease.

In this experiment you will build and test several widely used rf oscillator circuits. You will begin with circuits using inductive feedback and then work with circuits using capacitive feedback.

Experimental Procedure: For this experiment, you will need the experimental chassis, your tvom and the following parts:

- 1 Oscillator coil (CO43)
- 1 470-ohm resistor
- 1 1K-ohm resistor
- 1 2.2K-ohm resistor
- 1 100K-ohm resistor
- 2 .001-mfd disc capacitors
- 1 .002-mfd disc capacitor
- 1 250-pf mica capacitor

Prepare the chassis for this experiment by removing the resistors and capacitors attached to circuit board EC25. Also, disassemble the ac voltage divider connected to terminal strip C. Loosen the screw at hole U, turn the terminal strip around to its previous position and retighten the screw. Remove the 1K-ohm potentiometer and mounting bracket from the chassis.

Mount the oscillator coil on top of the front chassis rail at holes AG and AH as

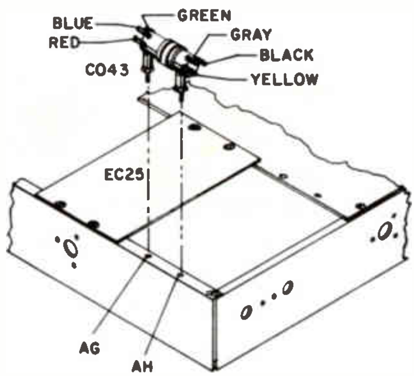


Fig. 48-2. Mounting the oscillator coil.

shown in Fig. 48-2. Remove one nut from each mounting screw on the coil, position the coil so that the terminals color-coded green, blue and red are toward the circuit board and slip the mounting screws through the holes. Attach and tighten the nuts you just removed.

When making connections to the coil, be careful to avoid touching the windings with your soldering iron, as the coil will be damaged.

Construct the circuit shown in the schematic in Fig. 48-3. Connect a 2.2K-ohm resistor from lug 12 of the circuit

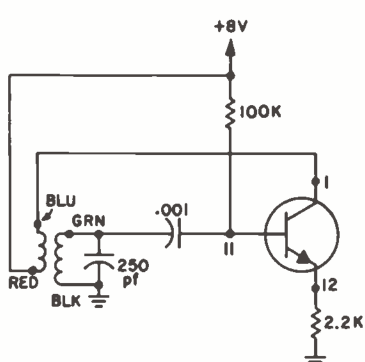


Fig. 48-3. An oscillator circuit using a tickler coil for feedback.

board to a convenient ground point. Connect a 100K-ohm resistor from lug 11 of EC25 to lug 5 of EC24. Connect a length of hookup wire from lug 1 of EC25 to the terminal color-coded blue on the oscillator coil. Connect a length of hookup wire from the red terminal of the oscillator coil to lug 5 of EC24. Connect a .001-mfd disc capacitor from the green terminal of the oscillator coil to lug 11. Connect a 250-pf mica capacitor between the green and black terminals of the coil. Connect a length of hookup wire from the black terminal of the oscillator coil to ground. Check your wiring against the schematic and make sure all connections are soldered.

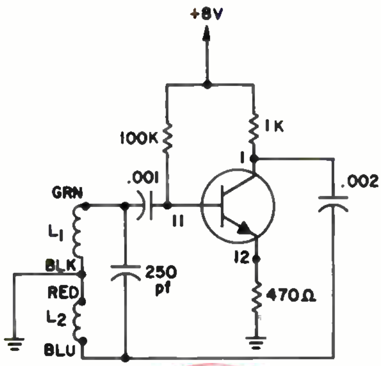
Step 1: To demonstrate a simple L-C oscillator circuit.

Energize the circuit and check to see if it is oscillating. To do this, measure the ac voltage between the collector of the transistor, lug 1, and ground. Any reading greater than about .5V is a pretty good indication that the circuit is oscillating.

Move the probe of your tvom to the green terminal of the oscillator coil and read the ac voltage across the resonant circuit. A reading of 4 to 6 volts ac is normal. Note that this is the voltage across the resonant circuit formed by the green-black winding and the 250-pf capacitor.

Step 2: To prove that in-phase feedback is necessary to sustain oscillations.

Turn the circuit off and unsolder and reverse the connections to the red and blue terminals of the oscillator coil. This change will reverse the phase of the voltage induced into the base circuit



Hartley

Fig. 48-4. The circuit used for Step 3.

winding from the collector. Energize the circuit and check for ac voltage between the collector and ground. Your reading should be zero. Turn the circuit off.

Step 3: To demonstrate an oscillator circuit having feedback through a tapped inductance.

For this step, you will construct a Hartley oscillator circuit. Wire the circuit shown in Fig. 48-4. Unsolder and disconnect the lengths of wire from the red and blue terminals of the oscillator coil. Unsolder and remove the 2.2K-ohm resistor and replace it with a 470-ohm resistor. Connect a 1K-ohm resistor between lug 1 of EC25 and lug 5 of EC24. Connect the red and black terminals of the coil together using a short length of wire.

Move the lead of the 250-pf capacitor from the black terminal to the blue terminal of the coil. Solder a .002-mfd capacitor between lug 1 of EC25 and the blue coil terminal. If necessary, connect a piece of wire to the capacitor lead. Check over your wiring to be sure it is correct.

Energize the circuit and measure the ac output voltage at the collector. Record the value in the chart in Fig. 48-5. You should read 1 volt or more, indicating that the circuit is oscillating.

Next, measure the voltage across the resonant circuit, L_1 and L_2: clip the tvom ground lead to the blue terminal and touch the probe to the green lead of the oscillator coil. Record your reading in the chart. Measure and record the feedback voltage. This is the voltage across the blue-red winding, L_2, of the rf transformer. Then measure and record the voltage across L_1, the green-black winding. Note that the two voltages add, producing approximately 4 volts across the entire resonant circuit which consists of the two windings and the 250-pf capacitor.

Turn the circuit off.

MEASUREMENT	VOLTAGE
OUTPUT	.7
ACROSS L_1 AND L_2	3.5
ACROSS L_2	.38
ACROSS L_1	3.0

Fig. 48-5. Chart for Step 3.

Step 4: To demonstrate an oscillator circuit using capacitive feedback.

You will now construct the Colpitts oscillator circuit shown in the schematic in Fig. 48-6. Unsolder and remove the .002-mfd and 250-pf capacitors and the lengths of wire connected to the red, blue and black terminals of the oscillator coil. Connect a .002-mfd capacitor between the green terminal of the coil and ground. Connect a .001-mfd capacitor between

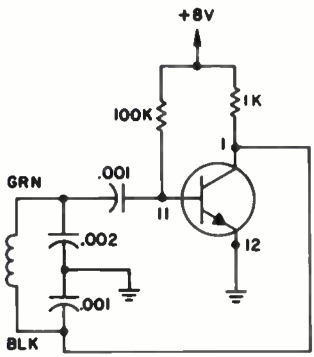


Fig. 48-6. The Colpitts oscillator for Step 4.

the black terminal of the coil and ground. Complete the wiring according to the schematic. Check your work carefully and solder all connections.

Energize the circuit and check for oscillation. You should measure about 1V ac between the collector and ground. Measure the ac voltage across the oscillator coil. A reading of 4V is normal. Now measure the ac voltage at the input to the transistor, between lug 11 and ground. Notice that it is lower than the signal at the collector.

Turn the equipment off.

Discussion: When you reversed the connections to the feedback coil, you found that the oscillator did not work. The feedback was out-of-phase with the voltage across the resonant circuit and cancellation occurred. In-phase feedback is necessary for any oscillator to work.

In Step 3, you built and tested a Hartley oscillator which uses a "tapped" inductance for feedback. By connecting the two windings of the coil in series, you simulated a single-tapped coil. The feedback signal was developed across the blue-red winding. This induced a larger voltage in the green-black winding. The two voltages are in series and add, as you can see in your chart in Fig. 48-5. The total voltage was applied to the base of the transistor.

The circuit in Fig. 48-4 is called a shunt-fed Hartley oscillator. This simply means that the ac and dc circuits of the oscillator are separated so that no dc flows in the oscillator coil, L_1 and L_2.

In Step 4, you experimented with a conventional Colpitts oscillator. The circuit uses "tapped" capacitance in its feedback path. The tapped capacitance consists of two capacitors connected in series, with the center point grounded. The feedback signal is applied through the coil and series capacitors to the base circuit to sustain oscillations. The capacitors are series-connected, and, as you already know, the net value of series-connected capacitors is less than the value of the smaller capacitor. This equivalent capacitance resonates with the coil to establish the oscillator frequency.

You can expect to find variations of these oscillator circuits in electronic equipment. For example, here we used common emitter amplifier configurations. You are sure to find both common base and common collector circuits.

Instructions for Statement No. 48: For this Report Statement, you will take dc voltage readings in the circuit you used in Step 4, first with the oscillator operating and then with it stopped. No additional wiring will be needed.

Turn the circuit on and measure the dc +5.4
collector voltage and the dc base voltage. DC
Note your readings in the margin. Then, -.02
turn the circuit off and unsolder one lead DC
of the .001-mfd capacitor from the green +5.2
terminal of the coil. Energize the circuit
and repeat the voltage measurements +6.6

You should now have enough information to answer the Statement. Turn the equipment off and answer the Statement here and on the Report Sheet.

Statement No. 48: When I stopped the oscillator circuit in Fig. 48-6 by disconnecting the .001-mfd capacitor, I found that the base voltage:

(1) became more positive
(2) became less positive
(3) did not change appreciably

and the collector voltage

(1) became more positive.
(2) became less positive
(3) did not change appreciably.

EXPERIMENT 49

Purpose: To show that two amplifier stages can be connected to form an R-C oscillator; to show how feedback controls the stages and to observe the voltage variations.

Introductory Discussion: In the previous experiments, we examined current flow in transistors and examined bias arrangements in amplifier stages. We also demonstrated the operation of L-C oscillator circuits. We will now construct two amplifier stages and connect them to form an oscillator circuit called an "astable" or "free running" multivibrator. The two amplifiers are connected so that they conduct alternately and each one controls the other. As one transistor cuts off, it turns on the other so that the second transistor conducts heavily.

The circuit you will use is the emitter-

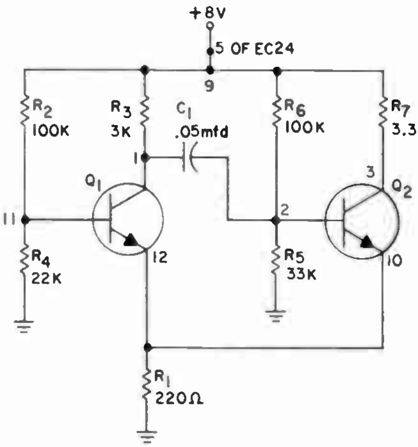


Fig. 49-1. The emitter-coupled multivibrator circuit used in Step 1.

coupled multivibrator circuit shown in the schematic in Fig. 49-1. Let's briefly describe how the circuit works. When power is first applied to the circuit, both transistors begin to conduct. Initially, however, one will always conduct more heavily than the other.

Let's assume that transistor Q_2 conducts more heavily. Current flows from ground through resistor R_1 to both emitters. In each transistor, the current divides, with part going to the base and through the base bias resistor (R_2 or R_6) and the remainder flowing into the collector circuit and through the collector load resistor (R_3 or R_7) to the positive voltage supply. The current through R_1 produces a voltage drop which makes the emitters positive and tends to reverse bias the base-emitter junctions of both transistors. As the total current increases, the emitter voltage increases. The emitter voltage reaches a level where transistor Q_1 begins to cut off as its base becomes less positive with respect to its emitter. The Q_1 collector voltage rises toward the supply voltage, causing capacitor C_1 to charge.

The charge path is through the Q_2 base circuit, causing current flow from ground up through resistor R_5. This makes the base of Q_2 more positive and Q_2 conducts even more. As C_1 becomes fully charged, the current through R_5 decreases and the voltage drop across R_5 decreases. Therefore, the bias on Q_2 decreases and it conducts less, producing a smaller voltage drop across R_1.

When the R_1 voltage drop falls below a certain level, Q_1 will begin to conduct and its collector voltage will begin to drop. C_1, which has charged to the high Q_1 collector voltage, will then begin to discharge. It discharges through R_5 and R_6 to ground and +8, through R_1 and the emitter-collector path of Q_1. Note that now the current through R_5 and R_6 makes the base of Q_2 negative. Hence, Q_2 is cut off.

After C_1 has discharged enough, the reduced discharge current will allow Q_2 to conduct again. As before, the forward bias is supplied by R_6. Q_2 will begin to conduct and the next cycle will begin.

The multivibrator is one of the most useful circuits in electronics. It is used in the horizontal and vertical deflection circuits of TV receivers, in transmitter control equipment, in test equipment and in computers. Frequency of operation can be as low as a few Hertz or as high as several megahertz. The circuits you will build have a maximum frequency of slightly less than 1 kHz.

Experimental Procedure: For this experiment you will need your tvom, the experimental chassis and the following parts:

1 220-ohm resistor
1 470-ohm resistor
1 3K-ohm resistor
1 3.3K-ohm resistor
1 22K-ohm resistor
1 33K-ohm resistor
2 100K-ohm resistors
1 .05-mfd capacitor
1 100-mfd, 10V elect. capacitor

Before proceeding with this experiment, you will construct the multivibrator circuit shown in Fig. 49-1. First unwire the circuit used in Experiment 48 but leave the transistor on the circuit board. Remove the coil from the chassis.

You will need two transistors for this experiment. Locate a second NPN transistor among the parts you received in this kit and identify the leads. Refer to the sketch in Fig. 49-2. Mount the transistor on the circuit board (EC25) at the location shown in Fig. 49-2. Mount it in the same manner as the transistor already on the board. Melt a little solder for each connection, use your pliers as a heat sink and solder each lead carefully. Check carefully to see that the collector con-

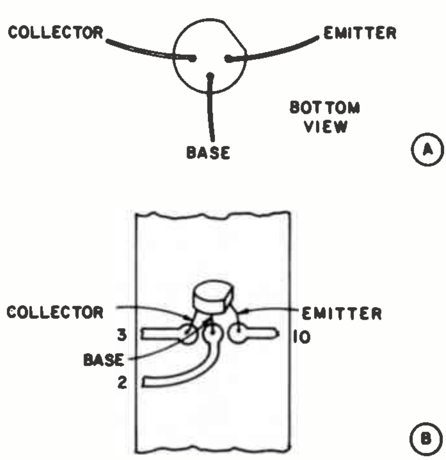


Fig. 49-2. Mounting the second NPN transistor on the circuit board.

nects to lug 3, the base connects to lug 2, and the emitter connects to lug 10.

In wiring the multivibrator circuit, the leads of the component parts can either be soldered to the terminal lugs or to the copper foil strips, as mentioned earlier. Do not cut the leads of the components, but bend the leads as necessary to make the connections.

Wire the circuit shown in Fig. 49-1. You can use lug 9 of EC25 as a tie point for some of the connections to the +8V source. Connect a 22K-ohm resistor between lug 11 and ground; connect a 220-ohm resistor between lug 12 and ground; and connect a 33K-ohm resistor between lug 2 and ground.

Connect a 100K-ohm resistor between lugs 9 and 11; connect a 3.3K-ohm resistor between lugs 3 and 9; connect a 100K-ohm resistor between lug 2 of EC25 and lug 5 of EC24; and connect a 3K-ohm resistor between lug 1 of EC25 and lug 5 of EC24.

Connect a .05-mfd disc capacitor between lugs 1 and 2; connect a length of hookup wire between lugs 10 and 12; and connect a length of wire between lug 9 of EC25 and lug 5 of EC24. Check your wiring and solder all connections. Bend the leads of the parts so that there are no short circuits.

Step 1: To show that the multivibrator circuit produces oscillations.

Set your tvom to measure 3 volts ac and turn the circuit on. Connect the tvom ground clip to the chassis, touch the probe to lug 3 and measure the ac voltage at the collector of transistor Q_2. Record the value in the space provided for Q_2 in the chart in Fig. 49-3. If you read no ac voltage, recheck your circuit to be sure it is wired correctly.

	AC	DC
Q_1 COLLECTOR	.5V	5.4
Q_1 BASE	.14V	.95
Q_2 COLLECTOR	2.[illegible]V	5.2
Q_2 BASE	.44V	.63
EMITTERS	.15V	.32

Fig. 49-3. The chart for use in Step 1.

Move the tvom probe to lug 1 and measure the ac voltage at the collector of Q_1. Record this value in the chart also. Measure and record the ac voltages at each of the points listed in the chart in Fig. 49-3.

When you complete your ac readings, go back and take the dc voltage readings at each of the 5 points in the circuit and record your readings.

Step 2: To show voltage variations in the multivibrator circuit.

Turn the circuit off and connect a 100-mfd, 10V electrolytic capacitor in place of the .05-mfd capacitor in your circuit. Connect the positive lead to lug 1 and the negative lead to lug 2. Turn the circuit on and measure the dc voltage at the collector of transistor Q_2.

You will notice first that the voltage varies from the supply voltage of about +8 volts to 0 and back again. By increasing the value of the coupling capacitor (C_1 in Fig. 49-1), you have slowed down the operation of the oscillator to the point where the dc voltmeter is nearly able to follow the voltage variations.

Note that the voltage rises sharply, remains at its maximum value for a time, falls sharply and stays near zero for a while. If you were to graph this voltage variation with respect to time, you would have a voltage waveform similar to the one shown in Fig. 49-4A.

Move the probe to the collector of Q_1 and observe the dc voltage there. You will see that this voltage varies at the same rate as the Q_2 collector voltage, but over a very narrow range. The nominal variation is from 3.5 to 5.5 volts. The transitions are not as sharp as those at the collector of Q_2. However, the waveform is said to be a rectangular wave. It is shown in Fig. 49-4B.

Set the range switch to 3V and touch the probe to the base of Q_2 (lug 2). You will see that the voltage varies by about 1 volt. Actually, it swings positive and negative. The voltage goes slightly negative and becomes positive again so quickly that the meter may not show it. Consequently you may not see the pointer move to the left of zero. The Q_2 base waveform is shown in Fig. 49-4C.

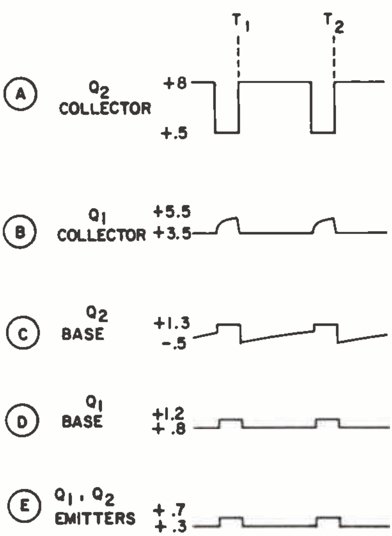


Fig. 49-4. Waveforms in the multivibrator circuit.

With your voltmeter, verify that the waveforms shown in Figs. 49-4D and E occur at the base of transistor Q_1 and at the emitters at both transistors. Note that these voltages vary over a very narrow range and that they are in step with the other voltages.

Step 3: To demonstrate the feedback paths in the multivibrator circuit.

Turn the circuit off and replace the 100-mfd capacitor with the .05-mfd capacitor shown in Fig. 49-1. Turn the circuit on and check for ac voltage at lug 3. The ac voltage will tell you that the circuit is oscillating.

Solder the negative lead of the 100-mfd electrolytic capacitor to a ground point near lug 12. While observing the ac voltage at lug 3, touch the positive lead of the electrolytic capacitor to lug 12. The capacitor places lug 12 at ac ground. Note its effect on the oscillation. Remove the 100-mfd capacitor.

Turn the circuit off and unsolder one lead of the .05-mfd coupling capacitor. Energize the circuit and measure the ac voltage at lug 3. There should be none, indicating that the circuit is not oscillating. Turn the circuit off. Replace the .05-mfd capacitor with the 100-mfd capacitor. Be sure to connect the positive lead to lug 1.

Discussion: In this experiment you demonstrated that two transistor amplifiers can be coupled together to form an oscillator. This is termed an R-C oscillator to distinguish its general type from the L-C oscillators you used in the previous experiment.

In Step 1 you proved that the circuit was oscillating by the fact that you were able to measure ac voltages in the circuit.

The ac voltages are actually the ac components of pulsating dc voltages, with the exception of the voltage at the base of transistor Q_2 which goes negative during each cycle.

Refer to your chart in Fig. 49-3. The ac voltage at the collector of Q_2 should be higher than the ac voltage anywhere else in the circuit. The ac at the collector of Q_1 should be between one third and one half of the Q_2 collector ac voltage. Typically, the ac at the base of Q_2 is under .5V and the ac at the base of Q_1 and at the emitters was too low to measure.

Now look at the dc voltages. The Q_1 collector voltage should be about 6V and the Q_2 collector voltage should be about 4V. The average conduction of Q_1 is higher than that of Q_2. Thus the average voltage drop across its collector load resistor (R_3) is higher. Similarly, the Q_1 base voltage should be more positive than the Q_2 base voltage. Both should be between .5V and 1V. It may appear that there is insufficient forward bias on the transistors. This is an illusion created by the fact that the meter gives average voltage indications.

In Step 2 you observed the wave shapes in the circuit with the oscillator operating at a very low frequency. Your observations should be very similar to the waveforms shown in the graph in Fig. 49-4.

You should have found that transistor Q_2 is alternately cut off and saturated. Cutoff is indicated by high collector voltage when there is hardly any voltage drop across the collector load resistor. When the transistor is saturated, the collector voltage is nearly zero due to the large current through the collector load and the large voltage drop across it.

This variation in collector voltage is caused primarily by the base voltage. You saw that the base was reversed biased during part of the cycle and highly forward biased during the remainder of the cycle. Thus the transistor conduction varied widely.

Transistor Q_1 acted basically as a common base amplifier as the input signal was applied to its emitter and the output was taken from its collector. As you saw, the Q_1 collector voltage varied by only 2 volts or so. This, however, was sufficient to initiate the charging and discharging of the coupling capacitor.

As we mentioned earlier, the charging and discharging of the coupling capacitor establishes the voltage drop across resistors $\mathbf{R_5}$ and $\mathbf{R_6}$ and, consequently, the voltage at the base of Q_2. Thus when we increased the amount of capacity, we increased the period of each cycle proportionately.

From earlier studies you know that the frequency of a signal is equal to the reciprocal of its period: $F = 1/P$. Then, if we increase the time required for the capacitor to charge and discharge, we decrease the frequency. To determine the frequency, count the number of complete cycles which occur in a given unit of time. If each cycle takes longer than a second, it is most convenient to express the frequency in cycles-per-minute.

In Step 3 you should have found that the oscillations stopped when you placed the capacitor across the emitter resistor and when you disconnected the coupling capacitor. In both cases you disabled the feedback. It is necessary for both feedback loops to pass signals so that each amplifier will be controlled and will be able to control the other.

In connecting the capacitor across the

emitter resistor, you placed the emitters at signal or ac ground potential. Thus variations in the conduction of Q_2 were not applied to the emitter of Q_1 so Q_1 could not cause C_1 to charge and discharge. When you opened the coupling capacitor, you prevented any voltage variations at the Q_1 collector from reaching the base of Q_2.

Instructions for Statement No. 49: For this Statement you will increase the value of the emitter resistor and note its effect on the oscillator frequency. With the 100-mfd coupling capacitor in the circuit, observe the Q_2 collector voltage and determine the frequency of the oscillations. To do this, count the number of oscillations taking place in 1 minute. One cycle is the period, for example, between T_1 and T_2 of the collector waveform in Fig. 49-4A. Watch your voltmeter and note the number of times the collector voltage jumps to +8 volts (T_1). The voltage will then drop. Use a watch or clock having a sweep second hand to measure the time accurately.

Turn the circuit off, disconnect the 220-ohm resistor from lug 12 and connect a 470-ohm resistor in its place.

14 Turn the circuit on, connect the voltmeter to lug 3 and again determine the frequency of oscillation. Compare this frequency with the frequency produced with the 220-ohm emitter resistor. Answer the Statement here and on the Report Sheet and turn your equipment off. 11

Statement No. 49: When I increased the emitter resistor value from 220 ohms to 470 ohms, the oscillator frequency:

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

EXPERIMENT 50

Purpose: To show that the gain of a cascade amplifier is greater than the gain of a single amplifier stage and to compare AC and DC coupling in cascade amplifier stages.

Introductory Discussion: There are very few applications where a single stage of amplification is used. Usually amplifier stages are connected in cascade to increase the overall gain or amplification which the signal receives. Typical examples are the audio, i-f and video sections of a TV receiver and the audio section of a radio receiver. Each of these amplifier sections consists of from 2 to 4 stages cascaded together.

Amplifier stages may be coupled together by several different methods. In this experiment, we will concern ourselves with common emitter stages, resistance-capacitance (R-C) coupling and direct current (DC) coupling. As the names imply, R-C coupling consists of a coupling capacitor connected between the stages in such a way that only the ac component signal is transferred. In DC coupling, usually a direct wire or a resistor is connected between the two stages. However, diodes can also be used. As such, the dc reference level, as well as the signal, is coupled from the first stage to the second. Of the two methods, R-C coupling is more widely used, and DC coupling is used for special purposes.

In this experiment, you will first construct a two-stage amplifier with R-C coupling. After measuring gain and dc voltages, you will rewire the circuit for DC coupling and carry out additional steps.

Experimental Procedure: For this experiment, you will need the experimental chassis with the two circuit boards mounted, your tvom, and the following parts:

- 1 10-ohm resistor
- 1 220-ohm resistor
- 1 330-ohm resistor
- 1 470-ohm resistor
- 1 2.2K-ohm resistor
- 1 3.3K-ohm resistor
- 1 4.7K-ohm resistor
- 1 15K-ohm resistor
- 1 18K-ohm resistor
- 2 100K-ohm resistors
- 1 10-mfd electrolytic capacitor
- 1 6-mfd electrolytic capacitor
- 2 HV silicon diodes

The HV diodes are in the HV power supply circuit. Temporarily remove them from terminal strip A on your chassis.

Dismantle the circuit used for Statement 49, but leave the two transistors on the circuit board. Also leave the 3.3K-ohm resistor connected between lugs 3 and 9, leave the 100K-ohm resistors in place, and leave the length of hookup wire between lug 9 and lug 5 of EC24.

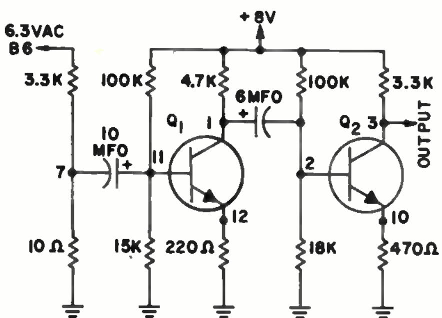


Fig. 50-1. The ac voltage divider and R-C coupled amplifier.

Wire the ac voltage divider and 2-stage amplifier circuit shown in the schematic diagram in Fig. 50-1. Connect a 3.3K-ohm resistor between terminal B6 and lug 7 of EC25. Connect a 10-ohm resistor from lug 7 to ground. Connect a 10-mfd electrolytic capacitor from lug 7 to lug 11. The positive lead connects to lug 11. Connect a 15K-ohm resistor between lug 11 and ground. Connect a 220-ohm resistor from lug 12 to ground. Connect a 470-ohm resistor from lug 10 to ground. Connect an 18K-ohm resistor between lug 2 and ground.

Connect a 4.7K-ohm resistor from lug 1 of EC25 to lug 5 of EC24. Connect a 6-mfd electrolytic from lug 1 to lug 2, with the positive lead going to lug 1.

Your circuit should now be wired according to the schematic in Fig. 50-1. Check your work and make sure all connections are soldered.

Step 1: To measure the voltage gains in an R-C coupled amplifier circuit.

As in previous work, you will use the 60 Hz ac filament voltage as your signal. The voltage divider, consisting of the 3300-ohm resistor and the 10-ohm resistor, gives an output of approximately .02V. We will use the value .02V in the discussion as the input signal voltage throughout this experiment.

With your tvom set to read ac voltage, touch the probe to lug 11 and note that the input voltage is too low to read on your meter. Move the probe to lug 1 and read the ac output voltage of the first stage at the collector. Record your reading in the space for the "stage 1 output" in the chart in Fig. 50-2.

.24

Now measure the input to stage 2 at the base connection, lug 2. The reading

.24

12.
.02) .24
2
4

should be very close to the previous reading, as the large coupling capacitor has extremely low impedance at the signal frequency. Record this value in the space for the "stage 2 input" in Fig. 50-2.

Measure the stage 2 output voltage at lug 3. This point is the collector of transistor Q_2. Record the output in the chart.

	INPUT	OUTPUT	GAIN
STAGE 1 Q_1	.02	.24	12
STAGE 2 Q_2	.24	1.6	≃7

.24) 1.60

Fig. 50-2. Chart for Step 1.

Using the information in the chart, compute the voltage gain of each stage and record it in the proper place in the chart. Use the formula,

80.
.02) 1.600

$$\text{voltage gain} = \frac{\text{output voltage}}{\text{input voltage}}$$

Now compute the overall gain of the two-stage amplifier. Use the same formula, but divide the Q_2 output by the Q_1 input of .02 volts. Jot down the results of this computation in the margin and compare it with the individual stage gains. You can readily see that the overall gain is the product of the individual stage gains.

Step 2: To show that the amplifier does not provide DC coupling.

Measure the dc voltage at the base of transistor Q_1 and record it in the chart in Fig. 50-3A. In a similar manner, measure and record the dc voltages at the other three points listed in Fig. 50-3A.

TEST POINT	Q_1	Q_2
BASE	.36	1.0
COLLECTOR	5.6	5.1

Ⓐ

TEST POINT	Q_1	Q_2
BASE	0	1.1
COLLECTOR	2.9	5.2

Ⓑ

Fig. 50-3. Chart for dc voltages (A) with signal and (B) with input shorted.

Solder a length of wire between ground and lug 11 and repeat the dc voltage measurements. Record the reading in Fig.50-3B. The short-circuited input represents a negative change in the dc voltage at the input to the amplifier. You should find that some of the voltage readings change very little if at all. Remove the short from the input.

Step 3: To measure the gain of a DC coupled cascade amplifier.

Turn the circuit off and wire the circuit shown in the schematic in Fig. 50-4. Remove the 6-mfd capacitor. Remove the 18K-ohm and 100K-ohm resis-

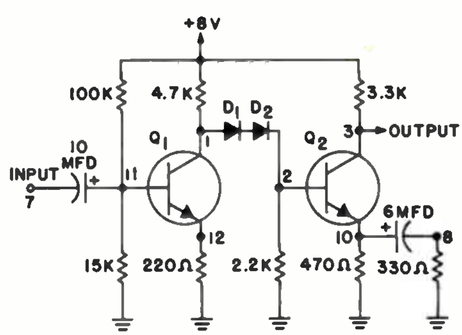


Fig. 50-4. The direct coupled amplifier circuit for Step 3.

tors connected to lug 2. Connect a 2.2K-ohm resistor between lug 2 and ground.

Connect the 2 HV silicon diodes with the anode lead of one soldered to the cathode lead of the other. Now solder the free *anode* lead to lug 1 and solder the free *cathode* lead to lug 2. Connect a 330-ohm resistor between lug 8 and ground. Connect the 6 mfd capacitor from lug 10 to lug 8 with the polarity shown in Fig. 50-4. Note in Fig. 50-4 that the forward bias as well as the signal for the base of Q_2 comes from the Q_1 collector circuit.

Energize the circuit and measure the ac voltages at the collector of Q_1 and at the base and collector of Q_2. Record your readings in the chart in Fig. 50-5. The input signal voltage remains unchanged at .02V.

	INPUT	OUTPUT	GAIN
STAGE 1 Q_1	.02	.04	2
STAGE 2 Q_2 1500	.04	.63	1500

.04).6300.

Fig. 50-5. The chart for Step 3.

Compute the gain of each stage and record your results in the chart. Also compute the overall gain of the cascade amplifier. Note this value in the margin.

Step 4: To show DC coupling between amplifier stages.

As you did in Step 2, measure the dc voltages at the points in the circuit listed in the chart in Fig. 50-6A, and record them. Then short the input, lug 11, to ground and repeat the measurements with the input shorted. Record your voltage readings in Fig. 50-6B. Turn the equipment off and remove the short from lug 11.

(A)

TEST POINT	Q_1	Q_2
BASE	.72	1.4
COLLECTOR	2.2	1.5

(B)

TEST POINT	Q_1	Q_2
BASE	0	1.6
COLLECTOR	2.5	1

Fig. 50-6. The chart for dc voltages in Step 4 (A) with signal and (B) with input shorted.

Discussion: The essential facts demonstrated in this experiment are (1) the gain of a cascade amplifier is equal to the product of the individual stage gain, and (2) a DC amplifier passes the dc as well as the ac component of the input signal.

In the first two steps, you used conventional RC coupling between the stages. The voltage variations at the collector of transistor Q_1 caused the coupling capacitor to charge and discharge through the Q_2 base circuit. This caused the current through the 18K-ohm resistor in the Q_2 base circuit to vary, and thus a varying voltage was applied to Q_2. Q_2 amplified this signal voltage.

The diodes provided the coupling in Steps 3 and 4. As you have learned, a forward biased silicon diode has a voltage drop of about .6V across itself. The two series connected diodes, therefore, have a net voltage drop of slightly more than 1V. The diodes, therefore, couple both ac and dc voltage from the collector of Q_1

to the base of Q_2. The resistor between the base of Q_2 and ground helps provide the proper bias for the transistor.

In the NRI Laboratory, we realized stage gains of 10 for Q_1 and 8 for Q_2 in Step 1. The product of the two is 80. Our overall gain measurement was equal to 1.6V/.02V which is also 80. In Step 3, the stage 1 gain was 5 and the stage 2 gain was 15, giving a computed overall amplification of about 75. The overall gain was approximately 1.5/.02 or 75.

You saw how both amplifier circuits responded to changes in dc level at the input in Steps 2 and 4. With R-C coupling, only the ac component of the signal is transferred through the amplifier circuit. This is because the coupling capacitor provides dc isolation between stages. In Step 4, however, you found that both stages were affected when you removed the forward bias on Q_1 by shorting its base to ground. The reduction in forward bias cut off Q_1 and caused its collector voltage to rise. This appeared to Q_2 as a positive-going signal, increasing the forward bias on Q_2. The resulting increase in Q_2 collector current produced a greater voltage drop across the Q_2 collector load resistor. Thus, it reduced the output dc level.

Instructions for Statement No. 50: For this Statement, you will simulate a defect in the coupling between the two amplifier stages and note its effect on the gain of the first stage.

Energize the circuit, measure the ac voltage at the collector of Q_1 and compute the gain of the stage. (The input is approximately .02V.) Then turn the circuit off and unsolder the anode lead of D_1 from lug 1.

Turn the circuit on again and measure the ac voltage at the collector of Q_1. Again compute the gain, compare it with the gain before you disconnected the diode, and answer the Statement here and on the Report Sheet.

Turn all equipment off. Remove the HV diodes from the circuit board and reinstall them in the HV power supply circuit as shown in Figs. 5 and 6.

Statement No. 50: When I opened the circuit between the two amplifier stages, I found that the gain of the first amplifier stage:

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

CONCLUSION

You have completed the final experiment in this Training Kit. Let's review the important points which you have learned. In the first four experiments, you studied vacuum tubes and vacuum-tube circuits. You learned that a Class A vacuum-tube amplifier requires a bias voltage applied between the grid and cathode. The bias voltage makes the grid negative with respect to the cathode so that both the negative and positive portions of the input signal will control the tube current and be amplified. You also saw that bias voltage can be supplied by a separate bias source, or it can be derived from the signal or from the B+ supply by one of several methods. Finally, you compared the three vacuum-tube amplifier configurations: common cathode, common plate and common grid.

In the latter part of the kit, you worked with transistor circuits. You began with bias and biasing methods and amplifier configurations. Then you constructed and performed experiments on L-C and R-C oscillators and cascade amplifiers.

You learned that in a transistor, the base-emitter junction must be forward biased in order for current to flow from the emitter across both junctions to the collector. Also, the bias voltage can be obtained from an external bias source or from the collector supply voltage in the circuit. In the experiment on transistor amplifier configurations, you constructed and compared the gain and impedance characteristics of the three amplifier configurations: common emitter, common base and common collector.

L-C and R-C oscillators were taken up after the work with amplifier fundamentals. You learned that an oscillator must have amplification and feedback. Also, you learned that in an L-C oscillator, the frequency is established by the resonant frequency of a resonant circuit while in an R-C oscillator, the frequency is set by the time constant of an R-C network.

In the final experiment, you built a cascade amplifier and saw that its overall gain is the product of the individual stage gains and that either R-C or DC coupling can be used.

LOOKING AHEAD

In the next Training Kit, you will continue your study of practical circuits and electronics fundamentals. You will

1	.1-mfd tubular capacitor	2	2.2K-ohm resistors
2	.25-mfd tubular capacitors	1	3K-ohm resistor
1	20-mfd electrolytic capacitor	2	3.3K-ohm resistors
2	.001-mfd disc capacitors	2	4.7K-ohm resistors
1	.002-mfd disc capacitor	1	6.8K-ohm resistor
1	.05-mfd disc capacitor	1	10K-ohm resistors
1	250-pf mica capacitor	1	15K-ohm resistor
1	6-mfd electrolytic capacitor	1	18K-ohm resistor
1	100-mfd electrolytic capacitor	2	22K-ohm resistors
1	Experimental chassis w/2 etched circuit boards	1	33K-ohm resistor
2	Alligator clips	2	47K-ohm resistors
1	1K-ohm potentiometer	2	100K-ohm resistors
1	10-ohm resistor	1	220K-ohm resistor
1	47-ohm resistor	1	330K-ohm resistor
1	220-ohm resistor	1	470K-ohm resistor
1	330-ohm resistor	1	1-megohm resistor
1	470-ohm resistor	1	1.8-megohm resistor
1	680-ohm resistor	2	10-megohm resistors
2	1K-ohm resistors	1	12BA6 tube
		1	12AT6 tube

Table I. Leftover parts to be stored for later use.

take up modulation, detection, rf amplification and other principles related to radio transmission and reception.

Be sure to complete your Report Sheet and send it in for grading. While you are waiting for your grade, prepare the chassis for the next kit. Remove all resistors and capacitors from the experimental circuit board (EC25). Leave the low-voltage power supply wired up on circuit board EC24, and leave the two transistors in place on EC25. Clean off all leads and terminals, using the technique which you learned earlier.

Table I lists the parts you should have left over. It does not include the parts mounted on the experimental chassis or on the two circuit boards.

WHEN YOU WORK FOR A MAN

Here are some words of advice written by Elbert Hubbard. Whether you are an employer or employee, I believe you'll want to read this over several times:

"If you work for a man, in heavens's name work for him. If he pays wages that supply you your bread and butter, work for him, speak well of him, think well of him, stand by him, and stand by the institution he represents. I think if I worked for a man, I would work for him, I would not work for him a part of his time, but all of his time. I would give an undivided service or none. If put to a pinch, an ounce of loyalty is worth a pound of cleverness. If you must vilify, condemn, and eternally disparage, why, resign your position, and when you are outside, damn to your heart's content. But, I pray you, so long as you are a part of an institution, do not condemn it. Not that you will injure the institution – not that – but when you disparage the concern of which you are a part, you disparage yourself."

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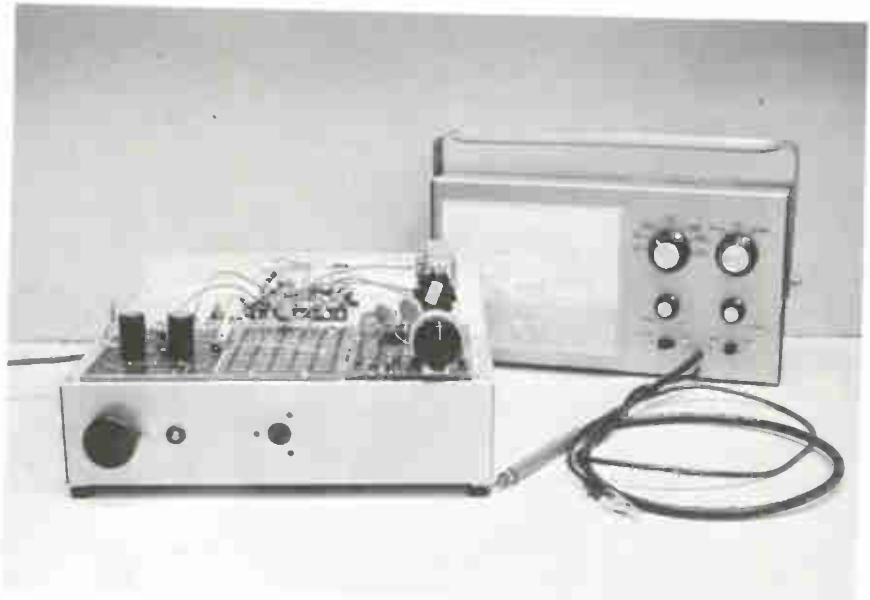

INDEX OF SECTIONS

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INSTRUCTIONS FOR PERFORMING EXPERIMENTS 51 THROUGH 60

In your last series of experiments, you conducted experiments with transistor and vacuum tube amplifiers and oscillators. You are now ready to conduct experiments on typical circuits which you will encounter in future training kits and in your work as a technician. You will continue work with amplifiers and oscillators and we will show you how these circuits are used in electronic equipment for home entertainment.

This kit is divided basically into two parts: Audio Frequency and Radio Frequency. In the Audio Frequency section, you will begin with loudspeakers and audio amplifiers. In these experiments, you will learn how loudspeakers work and you will study typical audio amplifier circuits. Then you will perform an experiment using the field-effect transistor. Following this, you will perform an experiment on a stereo indicator circuit.

In the rf section of the kit, you will construct an rf oscillator circuit and use it to demonstrate i-f amplifier and limiter stages and AM and FM demodulator circuits.

Be careful as you construct the circuits for these experiments to avoid short-circuits and wiring errors. Locating such troubles can be time-consuming and it is usually unnecessary. Extra care is needed because the circuits are more complex, containing many parts and wires.

Wiring from the schematic diagrams usually works best. However, some help is given in the form of sketches and written instructions. Use the extra help if you need it. Remember, however, a good technician should be able to work from the schematic diagram alone.

If you have trouble with any experiment, look the circuit over carefully to make sure there are no poorly soldered connections or wiring errors. Make voltage and resistance measurements and, if you need help, write, telling us what tests you have made and your test results. Use the special kit consultation blank enclosed for all questions concerning the experiments in your practical demonstration course.

CONTENTS OF THIS KIT

The contents of this kit are shown in Fig. 1 and listed below the figure. Check the parts you received against this list to be sure you have all the listed parts. Do not discard any of these parts or the parts from previous kits until you have finished your NRI course.

IMPORTANT: If any part in this kit seems to be missing, look for a substitute. If any part is obviously defective, or has been damaged in shipment, return it immediately to NRI as directed on the "Packing and Returned Material" slip included with this kit.

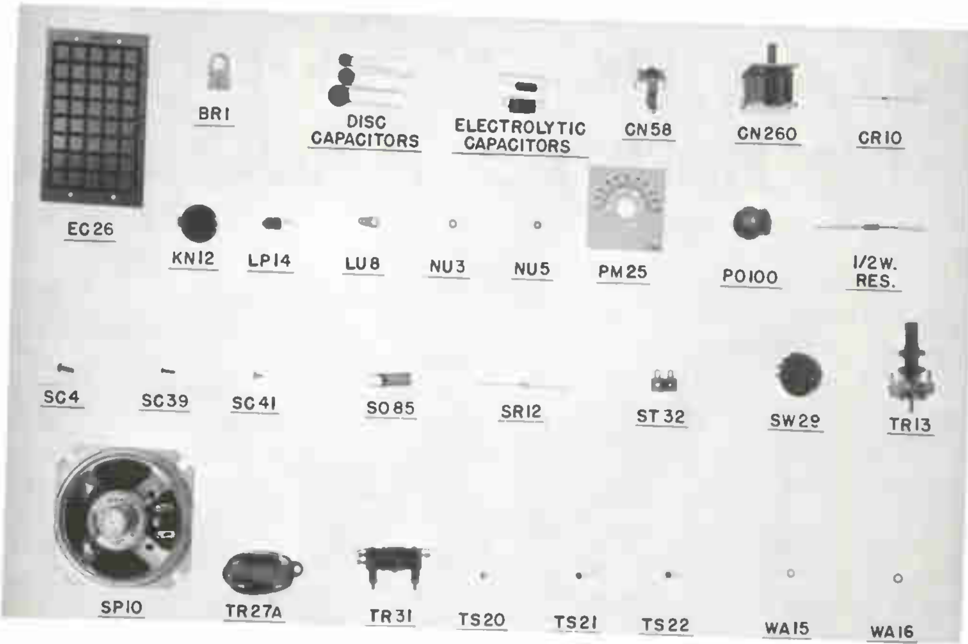

Fig. 1. The parts in this kit are shown above and listed below.

Quan.	Part No.	Description	Price Each
3	BR1	Pot. mounting brackets	.05
4	CN34	.001 mfd disc capacitors	.15
1	CN58	80-480 pf trimmer capacitor	.40
2	CN85	.01 mfd disc capacitors	.16
2	CN95	6 mfd, 20V electrolytic capacitors	.42
3	CN104	0.1-mfd disc capacitors	.36
1	CN202	18 pf disc capacitor	.15
1	CN204	0.05-mfd disc capacitor	.30
2	CN223	470 pf disc capacitor	.15
3	CN245	0.005-mfd disc capacitors	.22
1	CN112	100 mfd, 10V electrolytic capacitor	.45
1	CN260	Variable tuning capacitor	2.46
2	CR10	Silicon signal diodes	.40
2	EC26	Etched circuit boards	1.10
1	KN12	Control knob	.17
1	LP14	No. 49 pilot lamp	.40
2	LU8	Solder lugs	12/.15
2	NU3	8-32 hex nuts	12/.15
8	NU5	4-40 hex nuts	12/.15
1	PM25	Dial scale	.10
1	PO100	50k-ohm pot. w/nut & lockwasher	1.02
2	RE26	100-ohm, 10%, 1/2W resistors	.15
7	RE31	10k-ohm, 10%, 1/2W resistors	.15
1	RE47	150-ohm, 10%, 1/2W resistor	.15

Quan.	Part No.	Description	Price Each
2	RE29	4.7k-ohm, 10%, 1/2W resistors	.15
1	RE50	6.8k-ohm, 10%, 1/2W resistor	.15
2	RE68	150k-ohm, 10%, 1/2W resistors	.15
1	RE72	47-ohm, 10%, 1/2W resistor	.15
2	SC4	3/8" X 8-32 screws	12/.15
5	SC39	3/8" X 4-40 screws	12/.15
3	SC41	3/16" X 6-32 screws	12/.25
1	SP10	Loudspeaker	1.59
1	SO85	Pilot lamp socket	.71
2	SR12	Low voltage silicon rectifiers	.67
1	ST32	2-lug terminal strip	.05
1	SW29	3-position rotary switch	.94
1	TR13	I-F transformer	1.23
1	TR27A	Output transformer	1.25
1	TR31	RF transformer	1.10
1	TS20	Field effect transistor	1.00
1	TS21	NPN silicon transistor (2N5134)	.19
3	TS22	PNP silicon transistors (2N5138)	.19
3	WA15	No. 6 lockwashers	12/.15
2	WA16	No. 8 lockwashers	12/.15

PARTS DATA

The following information should help you to understand some of the special characteristics of certain parts supplied in this kit.

PNP Transistor. You received three small PNP transistors (TS22) in this kit. These are small signal silicon transistors which have high gain and are designed for amplifying weak signals. As you already know, the polarities of the voltages applied to the elements of a PNP transistor are the reverse of those for an NPN transistor. With respect to the emitter, the collector is operated highly negative and the base is slightly negative.

The schematic symbol for the transistor is shown in Fig. 2A. This symbol is different from the NPN symbol only in the direction of the arrow representing the emitter. Fig. 2A also shows the lead identification for the PNP transistor.

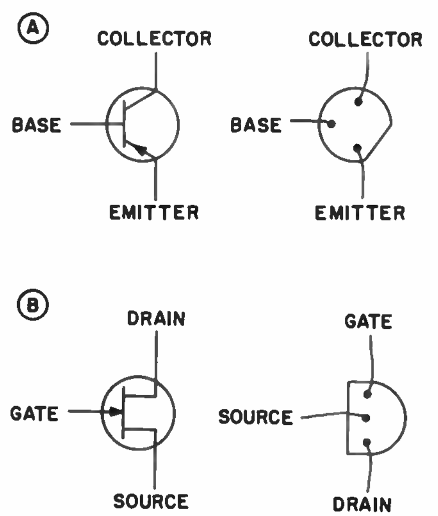

Fig. 2. Schematic symbols and lead identification for (A), the PNP transistor, and (B), the field-effect transistor you will use in this kit.

Field Effect Transistor. This transistor is a silicon N-channel type, solid-state device which physically resembles a transistor, but behaves more nearly like a vacuum tube. You will work with this transistor to discover some of its characteristics. The schematic symbol and lead identification are given in Fig. 2B.

The Tuning Capacitor. The tuning capacitor you received in this kit is a standard receiver type. It has two sets of multiple plates and uses an air-dielectric. The stator plates connect to the insulated terminals on the capacitor and the rotor is grounded to the capacitor frame.

As the shaft is turned counterclockwise, the plates mesh. This increases the total surface area between the two sets of plates and increases the total capacity.

When handling the capacitor, care must be taken to keep from bending the plates. The capacitor is shorted if any adjacent plates touch each other. Similarly, all four terminals on the capacitor are connected to the stator. Thus, if any of the terminals is shorted to the frame, the capacitor is shorted.

As you will see in the following experiments, the tuning capacitor will be connected into the resonant circuit of an rf oscillator. You will be able to change the total capacity in the circuit by rotating the shaft of the tuning capacitor. Therefore, the tuning capacitor will vary the frequency of the oscillator output signal.

Trimmer Capacitor. The trimmer capacitor also has multiple plates. It is called a compression type since the capacity is adjusted by turning the screw which changes the spacing between the plates. Tightening the screw squeezes the plates closer, thereby increasing the capacity.

RF Transformer. Transformer TR31 is an rf transformer with one tapped winding. The inductances of the two windings are about the same, so either winding can be tuned to the frequency of the rf oscillator by using the trimmer capacitor.

Physically, the rf transformer resembles the oscillator coil you used in the last kit. The rf transformer also has its own mounting hardware and mounts on top of the chassis.

I-F Transformer. As you will learn in the sixth experiment of this kit, the degree of coupling between the primary and secondary windings of an i-f transformer has a marked effect on the frequency response of the transformer, as well as on the rf voltage output. So that you can demonstrate the effects of different degrees of coupling, one coil of the i-f transformer supplied in this kit has been constructed so that it can be moved back and forth along the coil form.

This transformer was designed especially for NRI. If you should damage it in carrying out the experiments, you can get a replacement only from NRI. Do not write to the manufacturer or try to buy one from a parts jobber.

In other respects, the i-f transformer is just like any other standard 456 kHz interstage or output i-f transformer that is tuned by compression trimmers. Although output voltage will be maximum when the frequency is between 425 and 485 kHz, there will be a certain amount of output throughout the range from approximately 390 kHz with the trimmers tight to nearly 600 kHz with the trimmers at minimum capacity.

Output Transformer. The audio output transformer is used to couple and match the output of an amplifier to a loudspeaker. The transformer matches the high impedance of the amplifier, which is frequently several thousand ohms, to the four-to-eight ohms impedance of a loudspeaker. Be careful not to pull on any of the transformer leads; you might rip the paper wrapped around the coil windings and pull the leads loose from the windings.

Loudspeaker. The loudspeaker which you received is a PM or permanent magnet type. It is typical of those used in table model radio and TV receivers. The audio frequency signal is applied to the terminals, which connect to the voice coil. Signal current through the speaker causes the speaker to reproduce the signal.

Circuit Boards. Two printed circuit boards are included in this kit. These boards are labeled EC26. The boards are laid out in a pattern of squares which are numbered as shown in Fig. 3. The squares are located by a number and letter. For example, square 5H is at the intersection of the fifth column and row H.

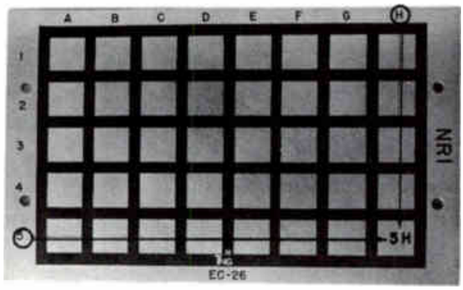

Fig. 3. Circuit board EC26.

When soldering leads to the squares on these boards, use the following technique: Melt a small pool of solder on the foil. Place the leads on top of the solder and heat until the lead penetrates the solder to the foil.

Preliminary Construction

In this section, you will prepare the experimental chassis for the following experiments. You will modify your low voltage power supply, build an audio oscillator, and build part of an audio frequency amplifier. First, you will mount the parts on the chassis. You will then wire and test your circuits.

MOUNTING THE PARTS

Gather the following parts:

2 Circuit boards (EC26)
1 2-lug terminal strip
1 Audio output transformer
3 Potentiometer mounting brackets
1 1k-ohm potentiometer
1 3-position rotary switch
2 3/8" X 8-32 screws
2 8-32 hex nuts
5 3/8" X 4-40 screws
8 4-40 hex nuts

Fig. 4 shows the parts mounted on top of the chassis. Refer to this figure as you perform the following steps.

Remove circuit board EC25 and the

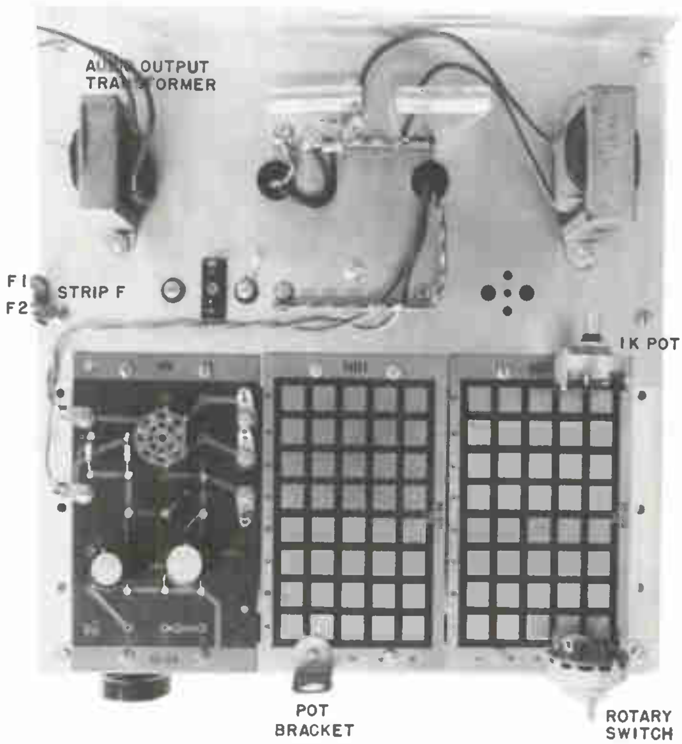

Fig. 4. Refer to this diagram as you install the parts on the chassis.

solder lug from the experimental chassis. Lay the circuit board aside, but keep the 4-40 screws and nuts handy.

Prepare a new circuit board, EC26, for mounting as follows: Secure potentiometer mounting brackets (BR1) to the board at the holes near squares 4A and 4H, using 3/8" X 4-40 screws and nuts. Position the brackets so they are facing away from the circuit board, and tighten the nuts. Place 3/8" X 4-40 screws in the remaining two mounting holes in the board and attach nuts and tighten.

Position the board over the chassis so that the potentiometer mounting brackets are over holes V and AH. (The numbers inscribed along the end of the circuit board should be over the front chassis rail.)

Mount a 1k-ohm potentiometer in the bracket at hole V. Place a lockwasher over the bushing, slip the potentiometer bushing through the hole and attach a control nut. Position the terminals upward and tighten the nut.

Next you will mount the rotary switch in the potentiometer mounting bracket at hole AH. First rotate the shaft of the switch fully clockwise. Slip a knob on the shaft temporarily or use a pair of pliers to grasp the shaft. Slip a control lockwasher over the shaft and bushing of the switch. Slip the bushing through the mounting hole in the bracket and rotate the switch so that the flat on the shaft is downward, pointing toward the circuit board.

Attach a nut and tighten.

Mount another circuit board, EC26, on the chassis at holes AE, AF, S, and T. Turn the board so that the numbers are over the front edge of the chassis rail. Secure with three 1/4" X 4-40 screws through holes AF, S, and T. Attach nuts and tighten.

Attach a potentiometer mounting bracket at hole AE, using a 3/8" X 4-40 screw and nut.

Install the audio output transformer on top of the chassis at holes A and B. Position the transformer so that the blue and red leads are toward the right and secure with 8-32 screws, lockwashers, and nuts. Position these leads so they will not touch any of the circuitry, as you will not use the transformer immediately.

Mount a two-lug terminal strip (strip F) at hole P. Secure the strip using the hardware in hole P. Position the strip as shown in Fig. 4 and tighten the screw.

One of the thin secondary leads of the audio output transformer is tinned with solder throughout its length. Solder this lead to terminal F2. Solder the enamel-covered secondary lead of the transformer to terminal F1.

WIRING THE CIRCUITS

You are now ready to construct the circuits for Experiment 51. The circuits will be constructed on the boards you just installed on your chassis.

Low Voltage Power Supply. You will convert your low voltage power supply on EC24 into a bridge rectifier circuit, using an L-C filter which will supply about +12V to your experimental circuits. You will need the following:

2 LV silicon diodes (SR12)

The schematic diagram of the power supply is shown in Fig. 5. Unsolder and disconnect the green/yellow lead of the power transformer from terminal B7. Push the lead aside and tape it to be sure it does not make contact with the chassis, terminals or other leads.

Solder the cathode lead of a silicon diode to lug 1 of circuit board EC24. Solder the cathode lead of the other

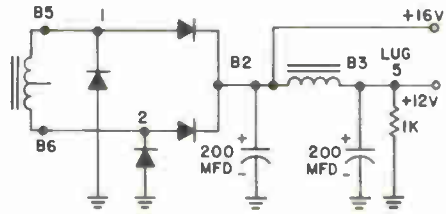

Fig. 5. The low voltage power supply circuit.

diode to lug 2 of EC24. Solder the free (anode) lead of each diode to the ground foil near the end of the circuit board.

Unsolder and disconnect the leads of the filter choke from terminals A4 and A6. Unsolder and disconnect one lead of the 100-ohm resistor from circuit board EC24. Connect the filter choke in place of the 100-ohm resistor as follows. Connect the choke leads to terminals B2 and B3. Connect a length of hookup wire from terminal B2 to the foil connecting the diodes to the input filter capacitor of the power supply circuit. Connect another length of hookup wire from terminal B3 to the foil which connects to lug 5 of EC24.

Your +12V output terminal will be lug 5 of circuit board EC24.

Audio Frequency Oscillator. You will construct a three-frequency phase-shift oscillator circuit on the circuit board on the right side of your chassis. This is the board with the switch and potentiometer attached to it.

The circuit is shown in the schematic diagram in Fig. 6. As you can see, three separate phase shift networks are used

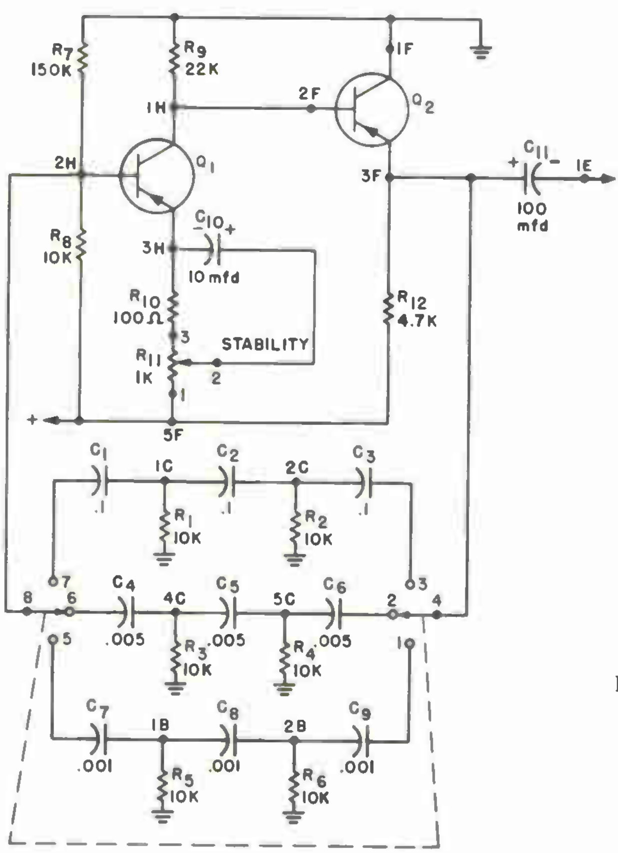

Fig. 6. Schematic diagram of the audio oscillator circuit.

and you select the desired frequency by switching in the appropriate feedback network. Capacitors C_1, C_2 and C_3 and resistors R_1 and R_2 are used in switch position 1 to produce 100 Hz. In position 2, C_4, C_5, C_6, R_3 and R_4 are used for 1 kHz. When the switch is in position 3, the R-C network made up of C_7, C_8, C_9, R_5 and R_6 is used and the oscillator frequency is 10 kHz.

To wire the oscillator circuit, you will need the following parts:

1 100-ohm resistor
1 4.7k-ohm resistor
7 10k-ohm resistors
1 22k-ohm resistor
1 150k-ohm resistor
3 .001-mfd disc capacitors
3 .005-mfd disc capacitors
3 .1-mfd disc capacitors
1 10-mfd electrolytic capacitor
1 100-mfd electrolytic capacitor
2 PNP transistors (TS22), 2N5138
1 Pointer knob

All wiring except for the connections to the 1k-ohm potentiometer will be permanent. Therefore, you will cut off the excess lead lengths as you solder the parts in the circuit.

The connections will be made by soldering the component leads to the squares of copper foil on the circuit board. In each case, you will have two or more leads soldered to a square. To avoid having one lead pull loose while you solder the next, do not leave the soldering iron on the connections too long. You may find it worthwhile to solder each lead to a different corner of the square. Cut the leads and bend them so they will stay in place even if the solder is melted.

You will build the oscillator in two parts. First you will wire the R-C phase shift network. Then you will construct the transistor amplifier section.

Begin by soldering the 10k-ohm resistors to the board near the rotary switch. Shorten one lead of six 10k-ohm resistors to 1/2-inch and bend the short lead downward slightly. Lay a resistor on the circuit board with the short lead on square 4C, as shown in Fig. 7A. Solder the lead to square 4C. Bend the free lead of the resistor so it is touching the ground foil at the end of the board. Solder the

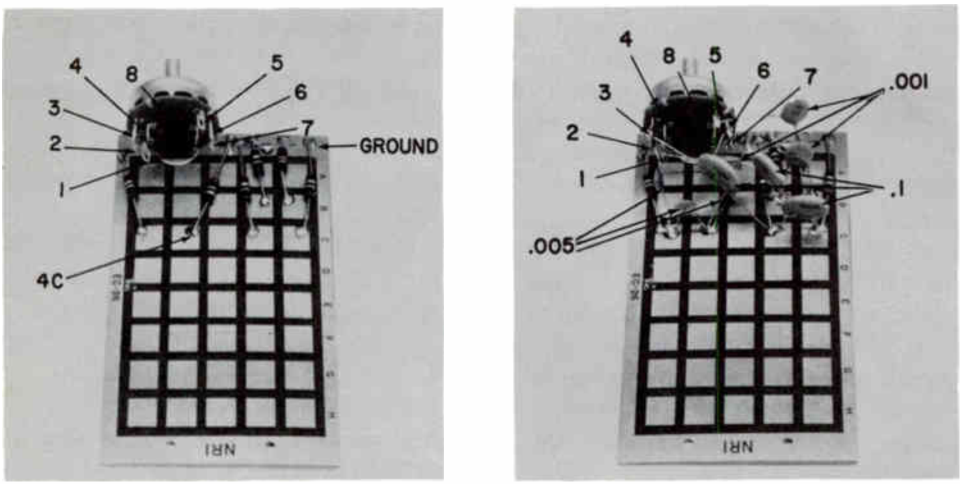

Fig. 7. (A) Mounting the resistors; (B) mounting the capacitors in the oscillator phase-shift network.

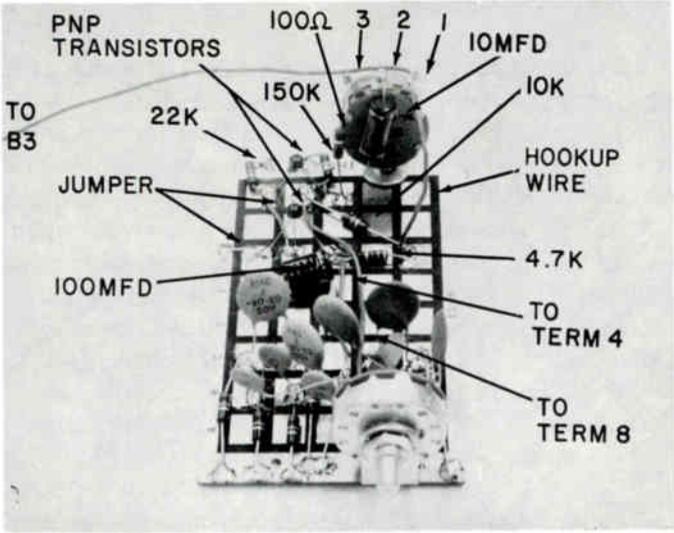

Fig. 7C. The complete audio frequency oscillator.

free lead to the foil and cut off the excess lead length.

In a similar manner, solder the short lead of another 10k-ohm resistor to square 5C, bend the leads so the free lead touches the ground foil and solder it at the end of the board.

Use the same procedure to install and solder the four remaining 10k-ohm resistors between squares 1C, 2C, 1B and 2B and the ground foil at the end of the board.

Now install the nine disc capacitors at the same end of the circuit board. When making connections to the switch, push each lead about 1/16 to 1/8-inch through the hole of the switch terminal and solder. The switch terminals are numbered in Figs. 7A and 7B.

Proceed as follows: Shorten both leads of two .001-mfd capacitors to 1 inch. Refer to Fig. 7B. Solder one lead of a .001-mfd capacitor to terminal 5 of the switch. Bend the leads so the free lead touches square 1B and solder. Solder another .001-mfd capacitor to terminal 1, bend the leads as necessary and solder the free lead to square 2B. Shorten the leads of the remaining .001-mfd capacitor to 1/2-inch and solder this capacitor between squares 1B and 2B.

Shorten the leads of two .1-mfd capacitors to 1 inch. Solder one capacitor between terminal 7 and square 1C. Solder the other .1-mfd capacitor between terminal 3 and square 2C. Shorten the leads of the third .1-mfd capacitor to 1/2-inch and solder it between squares 1C and 2C.

Shorten the leads of two .005-mfd capacitors to 3/4". Solder one capacitor between terminal 6 of the switch and square 4C. Solder the other capacitor between terminal 2 and square 5C. Shorten the leads of the remaining .005-mfd capacitor to 1/2-inch and solder it between squares 4C and 5C.

Take a break and check over your work. You should have six 10k-ohm resistors, three .001-mfd capacitors, three .005-mfd capacitors and three .1-mfd capacitors installed on your circuit board. All leads should be soldered. You will next wire the transistor amplifier section.

Refer to Fig. 7C as you perform the

following steps. Shorten the leads of a 22k-ohm resistor and a 150k-ohm resistor to 3/8-inch and bend the leads of each resistor downward at right angles. Solder the 22k-ohm resistor between square 1H and the ground foil at the end of the board. Similarly, solder the 150k-ohm resistor between square 2H and the ground foil.

Shorten the leads of a 100-ohm resistor to 1/2-inch and solder the resistor from square 3H to terminal 3 of the 1k-ohm potentiometer. Shorten the leads of a 10k-ohm resistor to 3/4-inch and solder the resistor between squares 2H and 5F.

Shorten the leads of a 4.7k-ohm resistor to 1/2-inch. Solder the resistor between squares 3F and 5F.

Shorten the leads of a 10-mfd electrolytic capacitor to 3/4-inch. Solder the positive lead to terminal 2 (the center terminal) of the 1k-ohm potentiometer. Solder the negative lead of the capacitor to square 3H.

Solder a short length of wire between terminal 1 of the 1k-ohm potentiometer and square 5F.

Solder a short length of hookup wire between squares 1H and 2F. Solder a short length of bare wire from square 1F to the ground foil at the edge of the board.

Shorten the leads of a 100-mfd electrolytic capacitor to 1/2-inch. Solder the positive lead to square 3F and solder the negative lead to square 1E.

Connect and solder a length of hookup wire from terminal 4 of the switch to square 3F. Connect and solder another length of hookup wire from terminal 8 of the switch to square 2H.

Identify the leads on the two PNP transistors (2N5138), by referring to Fig. 2A. Spread the leads of one transistor and mount it on the board. Solder the collector, base and emitter leads to squares 1H, 2H and 3H, respectively. Be careful to keep the other leads from coming loose.

In a similar manner, solder the collector, base and emitter leads of the other PNP transistor to squares 1F, 2F and 3F, respectively.

Inspect the board for short circuits and wiring errors. You can check it against Figs. 6 and 7. Also, test each solder connection by pulling each wire gently.

Finally, solder a length of hookup wire between terminal 1 of the 1k-ohm potentiometer and terminal B3 on the chassis.

Install a pointer knob on the switch shaft. Loosen the setscrew in the knob with a small screwdriver, slip the knob on the shaft and tighten the screw against the flat on the shaft.

When you complete the work, test the oscillator. Rotate the 1k-ohm stability control potentiometer fully counterclockwise and energize your circuit. Connect your tvom to measure the ac voltage between the chassis and square 1E. Adjust the 1k-ohm stability control for a reading. You should read 1.5V ac or more. Try all three switch positions and readjust the stability control slightly, as necessary. The ac output voltage at 1E should be approximately the same on all three frequencies.

If your oscillator does not work, check your wiring carefully and trace out each connection. Measure the dc bias voltage on both transistors. You should measure about −.6V between the emitter and base of each transistor. If the voltages are incorrect, look for an open in the ground or collector circuit or for trouble in the positive supply voltage. If you have trouble which you cannot locate, write for help before you attempt to perform the experiments.

WIRING THE AUDIO AMPLIFIER

You will now wire the audio amplifier circuit shown on the schematic in Fig. 8.

You will need the following:

1 47-ohm resistor
1 100-ohm resistor
1 10K-ohm resistor
1 6-mfd electrolytic capacitor
1 100-mfd electrolytic capacitor
1 NPN transistor (TS21), 2N5134

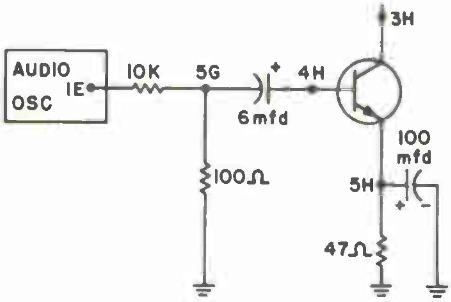

Fig. 8. The voltage divider and amplifier wiring.

The amplifier and voltage divider circuit will be assembled mainly on the center circuit board, which we will call the "experimental circuit board".

To wire the voltage divider, solder a 10k-ohm resistor between square 1E of the oscillator circuit board and square 5G of the experimental circuit board. Solder a 100-ohm resistor between square 5G of the experimental board and the ground foil at the outer edge of the board.

Solder a 6-mfd electrolytic capacitor between squares 4H and 5G of the experimental board, with the positive lead to 4H.

Solder a 47-ohm resistor and a 100-mfd capacitor in parallel between square 5H and the ground foil of the experimental board. The positive lead of the capacitor goes to square 5H.

Solder an NPN transistor to the experimental board. Be sure you can identify the leads and solder the emitter, base and collector leads to squares 5H, 4H and 3H, respectively.

As shown in Fig. 8, your amplifier is not complete. You will add parts in performing the following experiment.

EXPERIMENT 51

Purpose: To show how a loudspeaker converts electrical signals into sound and to show how a loudspeaker can be coupled to an audio amplifier.

Introductory Discussion: In this experiment, you will learn something about how the loudspeaker is constructed and how it works. You will then connect the loudspeaker to an audio amplifier and use it to reproduce a signal. You will also experiment with various methods of driving the loudspeaker. For Steps 2, 3, and 4 you will use your audio frequency oscillator as a signal source and you will use a single stage amplifier to drive the speaker. The amplifier consists of an NPN transistor. Initially, it will be operated in the common emitter mode, with the signal applied to the base and taken from the collector.

Experimental Procedure: For this experiment, you will need the experimental chassis with the oscillator and amplifier circuits wired, your tvom and the following:

1 Loudspeaker
1 1k-ohm resistor
1 3.3k-ohm resistor
1 4.7k-ohm resistor
1 10k-ohm resistor
1 150k-ohm resistor
1 6-mfd electrolytic capacitor
1 Test clip

Step 1: To demonstrate how the permanent magnet loudspeaker works.

Place the loudspeaker on your work surface so that you can reach its terminals. Set your tvom to measure resistance on the R X 1 range, and measure the resistance between the terminals of the loudspeaker. You should read quite a low resistance, probably less than 3 ohms.

Note that as you make the connection to the terminals, you hear a cracking noise in the loudspeaker. This is due to a sudden change in current passing through the coil and it causes the cone of the speaker to move. Touch the speaker cone with your fingers while you make and break the ohmmeter connection to the speaker terminals. You should feel the cone move slightly as the connection is opened. Move the polarity switch on the tvom to reverse and repeat the test. This time the cone of the speaker should move in the opposite direction.

Prepare two lengths of hookup wire about 12 inches long. Connect them between the speaker terminals and terminals 1 and 2 of strip F, the two-lug terminal strip near the audio output transformer.

Slip the test clip on the tvom probe. Switch the tvom to read ac voltage on the 1.2V range and clip the ground lead and probe to the blue and red leads of the audio output transformer. This will leave both hands free. Move the cone of the loudspeaker in and out rapidly with your fingers while observing the meter. You should see an indication on the meter.

Place the speaker near the speaker of a radio or whistle into it and observe that the tvom indicates an ac voltage.

Discussion: As you can see, the loudspeaker is made of a paper cone, a voice coil and a permanent magnet which are held together by a metal frame. The voice coil is physically attached to, and drives the cone. The permanent magnet is placed behind the voice coil. A pole piece conducts the magnetic field to the voice coil.

The voice coil is energized by a signal applied to the loudspeaker terminals. Current passes through the voice coil and sets up a magnetic field. This field interacts with the field of the permanent magnet. When current passes in one direction, the voice coil and the permanent magnet attract each other. Thus, the voice coil and the cone move in one direction. When the current is reversed, the two fields repel each other and the cone moves in the opposite direction. The frequency and strength of the signal current control the rate and the distance that the cone moves.

The voice coil in your speaker has a nominal impedance of 3 to 4 ohms. This was confirmed by your dc resistance measurement. When you connected your ohmmeter across the voice coil a current of about 100 ma flowed and caused the voice coil to move, producing the sound in the speaker. The current, produced by the 1.5-volt cell in the ohmmeter, was limited by the 10-ohm resistor in the ohmmeter circuit and the impedance of the speaker. The click in the loudspeaker was due to the sudden change in current.

You were able to reverse the direction of current through the voice coil simply by moving the polarity switch on the tvom. As you know, the polarity switch reverses the connections to the probe and ground lead.

In the latter part of this step, you found that the speaker can act as an ac generator. By moving the cone, you caused the voice coil to move within the field of the permanent magnet. The winding of the voice coil cut the magnetic lines of force and a voltage was generated in the coil. With suitable coupling, a loudspeaker can be used as a microphone to convert sound waves into an electrical signal.

Step 2: To show the loudspeaker transformer-coupled to the output of an audio amplifier.

You will use the circuit shown in the schematic in Fig. 51-1. Solder the red lead of the audio output transformer to lug 5 of EC24 and solder the blue lead to square 3H on your circuit board. Solder a 150k-ohm resistor between square 4H and lug 5 of EC24. Solder a 10k-ohm resistor between square 4H and the outer ground foil on the circuit board.

Set the frequency selector switch on your oscillator to position 2, turn the power on and listen for a tone in the loudspeaker. The tone, which is produced by a phase-shift oscillator, has a frequency of about 1000 Hz. This is one of the standard audio test frequencies.

Set your tvom to measure ac voltage on the 12-volt range and measure the

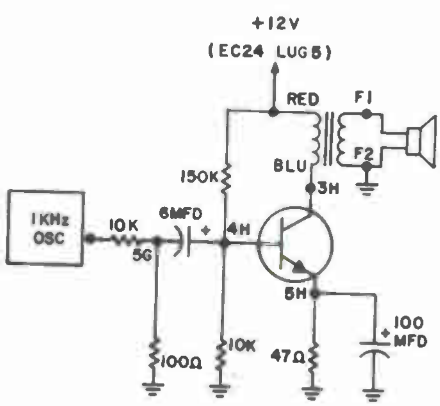

Fig. 51-1. The circuit used for Step 2.

STEP NO.	MEASUREMENT	VALUE
2	Voltage across primary	2V
	Current in primary	.4 ma
	Voltage across speaker	—
3	Voltage across speaker	—
	Voltage at collector	—

Fig. 51-2. Use this chart for recording data in Steps 2, 3 and 4.

voltage across the primary winding of the audio output transformer. Clip the ground lead to the chassis and touch the probe to the blue transformer lead. Read the ac voltage and record the value in the space provided on the first line on the chart in Fig. 51-2.

Next find the signal current through the collector and the transformer primary circuit. You can assume that the impedance of the transformer winding is 5000 ohms. Thus, you can use the Ohm's Law formula, I = E/Z, where Z is the primary impedance value of 5000 ohms. Compute the current and record it in the space provided in Fig. 51-2.

Now measure and record the voltage across the speaker terminals. The voltage may be too low to measure. If so, place a dash (–) in the space provided in the chart. Turn the circuit off.

Step 3: To show the speaker shunt-connected to the amplifier. Next, you will use the circuit shown in the schematic in Fig. 51-3.

.0004
5000)2.0000
2 0000

.4 ma

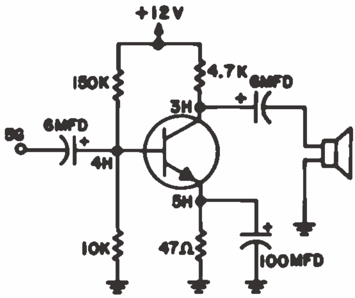

Fig. 51-3. The loudspeaker connected in shunt with the amplifier.

Unsolder and disconnect the blue and red audio output transformer leads. Connect a 4.7k-ohm resistor between square 3H and lug 5 of EC24. Solder the positive lead of a 6-mfd electrolytic capacitor to square 3H. Unsolder the speaker lead from terminal F1 and solder it to the free lead of the 6-mfd capacitor. Check your wiring carefully against the schematic.

Turn the circuit on and note the level of the sound from the speaker. Measure the ac voltage across the speaker terminals. The voltage should be less than .1V. Record the value in Fig. 51-2. Move the probe to the collector side of the 6-mfd coupling capacitor at square 3H and note that the voltage is low there also. Unsolder the speaker lead from the capacitor and note the large increase in the ac voltage at the collector of the transistor. Record the value in the chart. The increase in voltage indicates that the speaker was severely loading the transistor amplifier.

Step 4: To show that power amplification is necessary to drive the speaker.

Construct the power amplifier circuit shown in Fig. 51-4. Connect a length of hookup wire from the collector terminal (the solder lug) of the power transistor mounted at hole C to a ground terminal. Connect a 3.3k-ohm resistor between the base and emitter terminals of the transistor. The emitter terminal is nearest to circuit board EC24. Solder the free speaker lead to the emitter terminal. Replace the 4.7k-ohm resistor with a 1k-ohm resistor. Disconnect the capacitor lead from square 3H. Solder the positive lead of the 6-mfd capacitor to the base terminal of the power transistor and solder the negative lead of the capacitor to square 3H. Unsolder the other speaker lead from terminal F2 and connect it to terminal B2.

Check your wiring very carefully against the schematic diagram and be sure all connections are soldered.

Energize the circuit and note that the volume has increased significantly. Now measure the ac voltage between ground and the collector of transistor Q_1 at square 3H. Record the value in Fig. 51-5. Similarly, measure and record the ac voltages between ground and the base of Q_2 and across the speaker terminals.

Turn the equipment off.

Discussion: Typically, a loudspeaker is

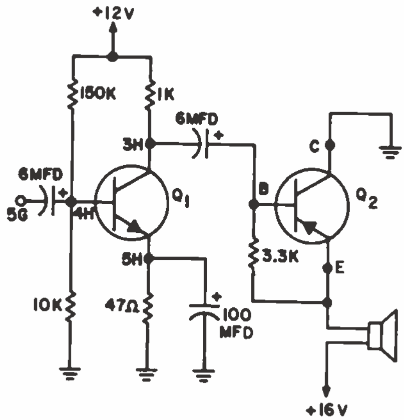

Fig. 51-4. Two-stage amplifier using the power transistor.

VOLTAGE MEASUREMENT	VALUE
Q_1 Collector	—
Q_2 Base	1.3V
Across speaker	—

Fig. 51-5. Use this chart for Step 4.

a low impedance current-operated device. Therefore, a stepdown transformer is frequently used with a speaker operated from a high impedance source, as was the case in Step 2. The amplifier output impedance was several thousand ohms and the speaker impedance was about 4 ohms. The transformer has a step-down ratio (turns-ratio) of approximately 40 to 1. The impedance ratio of a transformer is the square of the turns-ratio, or about 1,600 to 1 for the transformer you are using. Thus the transformer can match the low impedance speaker to the high impedance amplifier circuit.

You should be able to see the transformer action from the data for Step 2 in Fig. 51-2. The ac voltage across the speaker was much less than the voltage across the primary of the transformer. You should have found that the signal current in the primary was quite low, on the order of .5 to .6 ma. Because the transformer steps up the current in the same proportion as it steps down the voltage, the speaker current was about 40 X .6 ma or about 24 ma.

The speaker loaded the amplifier badly in Step 3. The coupling capacitor acted as a short circuit at the signal frequency and the speaker impedance is quite low. Thus, the transistor had approximately 4 ohms shunted across it. The amplification of the transistor was held to a minimum and little output was obtained. As you saw, when the speaker was disconnected, the ac voltage at the collector increased sharply.

In Step 4, you used the power transistor as a power amplifier stage. The transistor was connected as an emitter follower, with the speaker as the emitter load. You should have noticed the increase in sound volume and the increase in the values of ac voltages at each of the three test points listed in Fig. 51-5.

The power amplifier presented a relatively light load to transistor Q_1, while acting as a low impedance source for the speaker. You will note that the signal voltage at the emitter of the power transistor was lower than the signal voltage at the base. Thus, the stage provided an increase in the signal current, with no signal voltage gain. There are cases, however, where a power amplifier provides voltage amplification as well.

Instructions for Statement 51: For this Statement, you will connect the speaker into the collector circuit of transistor Q_2 through the audio output transformer. You will then take measurements and determine whether or not the output stage is amplifying the signal voltage.

Use the circuit shown in Fig. 51-6.

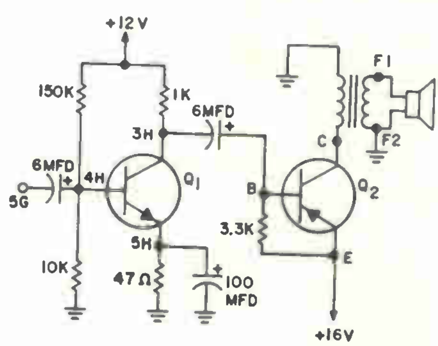

Fig. 51-6. The circuit for Statement 51.

Disconnect the speaker leads from the emitter terminal of the power transistor and terminal B2. Solder a length of hookup wire between these two points. Solder one speaker lead to terminal 1, and solder the other speaker lead to terminal 2 of strip F. Unsolder and disconnect the length of hookup wire between the collector terminal and the power transistor and ground. Solder the blue lead of the audio output transformer to the collector terminal and solder the red lead of the transformer to a ground terminal. Check your work against the schematic.

Energize the circuit and listen to the sound to be sure the circuit is working. Measure the ac voltage across the primary winding of the audio output transformer. Jot down the readings in the margin and answer the Statement.

,34V

Statement No. 51: When I measured the ac voltage at the collector and base of transistor Q_2, I found that the ac voltage at the collector was:

(1) less than
(2) equal to
(3) greater than

the ac voltage at the base. Therefore, the power transistor provided:

(1) voltage gain.
(2) no voltage gain.

EXPERIMENT 52

Purpose: To demonstrate how tone controls work.

Introductory Discussion: Tone controls are provided on an audio amplifier to enable the listener to adjust for the most pleasing sound. This is done by varying the relative amplification which the low, middle and high frequencies receive. As an example, for heavy or strong bass, the low frequencies are amplified more than the middle and high frequencies; for more brilliant sound, the highs are amplified more than the middle and low frequencies.

You will use three audio frequencies to demonstrate how tone controls work. You will apply each frequency to the input of your amplifier separately and observe their relative output levels. Then, you will see how the controls affect the amplifier frequency response.

Experimental Procedure: For this experiment, you will need your chassis, your tvom and the following parts:

1 .01-mfd disc capacitor
1 .1-mfd tubular capacitor
1 .25-mfd tubular capacitor
1 50k-ohm potentiometer (PO100)
1 Pointer knob

Mount a 50k-ohm potentiometer in the potentiometer mounting bracket at hole AE. Place a control lockwasher over the bushing. Position the potentiometer in the bracket so the terminals are upward, attach a control nut and tighten. Install a pointer knob on the shaft of the potentiometer.

You will use the phase-shift oscillator, which is wired on one of your circuit boards, and the two-stage amplifier from the last experiment. The circuit is shown in Fig. 52-1. If you find that the sound is too loud or too weak, you may substitute a 22k or 4.7k-ohm resistor for the 10k-ohm resistor connected to square 5G.

Step 1: To determine the frequency response of the amplifier.

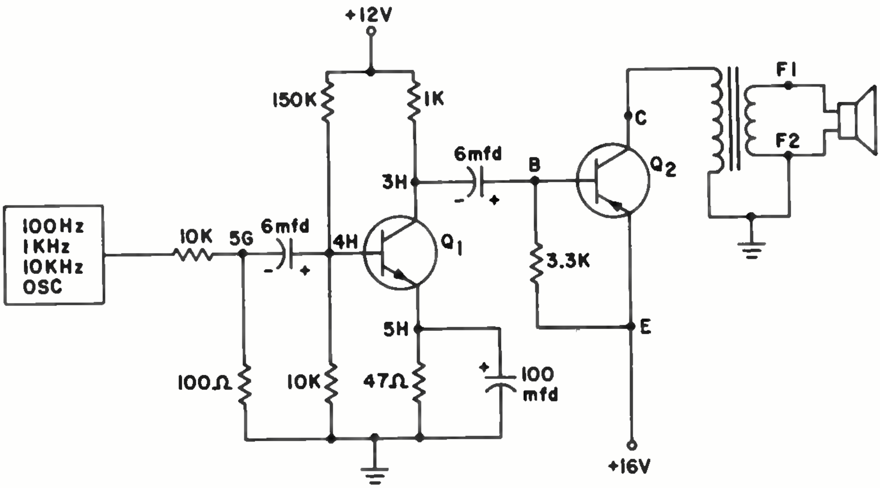

Fig. 52-1. The circuit used in Step 1.

Energize your circuit and set the frequency selector switch on the oscillator circuit board fully counterclockwise to position 1. In this position, your oscillator produces a 100 Hz tone, which should sound like a low rumble in the loudspeaker. Measure the ac voltage between the chassis and square 1E of the oscillator board. This is the oscillator output signal voltage which is applied to the amplifier through the 100:1 voltage divider. Therefore, divide your reading by 100 and record the result as the input signal in Fig. 52-2. Similarly, measure and record the signal voltage at the collector of transistor Q_1 (square 3H), the collector of transistor Q_2 and across the speaker.

Switch the frequency selector to position 2 for a 1 kHz signal. Repeat the four voltage measurements and record your readings in Fig. 52-2.

Switch the oscillator switch to the 10 kHz position (position 3) and take the measurements at this frequency to complete the chart for Step 1, in Fig. 52-2.

Step 2: To show the effect of reducing the value of the capacitor coupling the signal between stages.

Turn off the equipment and disconnect the electrolytic capacitor connected between square 3H and the base terminal

FREQUENCY	INPUT	Q_1 COLLECTOR	Q_2 COLLECTOR	SPEAKER
100 Hz	~~8~~ .023 .5	.07	~~0~~V	0.1
1000 Hz	.02	.09	12.5	.09
10 kHz	.02	.08	13.5	.12

Fig. 52-2. The chart for Step 1.

2.38

STEP	FREQ.	OUTPUT
2A (.1 MFD)	100 Hz	4.8V
	1000 Hz	12.8V
	10 kHz	13.5V
2B (.01 MFD)	100 Hz	0V
	1000 Hz	8.2
	10 kHz	12.6

Fig. 52-3. Record results of Step 2 here.

of the power transistor and replace it with a .1-mfd tubular capacitor. Connect the tvom across the speaker terminals (terminals F1 and F2) and turn the circuit on.

Turn the frequency selector switch to positions 1, 2 and 3 and measure the output voltages for 100, 1,000 and 10,000 Hz. You should find that the output increases as you switch to higher frequencies. Record your readings in the chart in Fig. 52-3.

Replace the .1-mfd capacitor with a .01-mfd disc capacitor. Repeat the test, measuring the output at each frequency. Record your results in Fig. 52-3 and turn off the equipment.

Step 3: To show the effect of connecting an R-C feedback network between the input and output of the first amplifier stage.

Make the circuit changes shown in Fig. 52-4. Remove the .01-mfd capacitor used in Step 2 and replace it with the 6-mfd electrolytic capacitor you used originally. Now, connect one lead of a .25-mfd tubular capacitor to terminal 2 (the center terminal) of the 50k-ohm potentiometer. Connect the free lead of the capacitor to the collector of transistor Q_1 at square 3H. Prepare about an 8-inch length of hookup wire and connect it to terminal 3 (the right terminal) of the 50k-ohm potentiometer. Solder the other lead to the Q_1 base terminal, square 4H.

Turn the circuit on and measure the output voltage across the speaker terminals at 100 Hz. Rotate the potentiometer

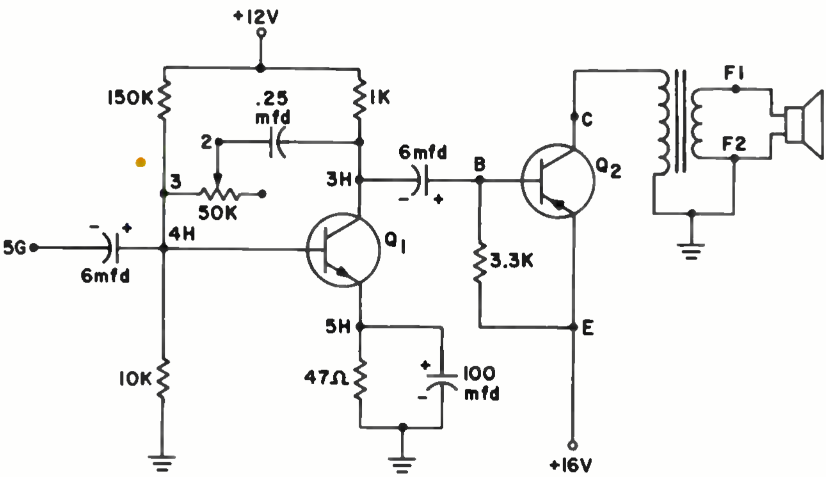

Fig. 52-4. The circuit for Step 3.

STEP	FREQ.	OUTPUT	
		CONTROL CCW	CONTROL CW
3	100 Hz	8.2	9.0
	1000 Hz	6.2	12.5
	10 kHz	7.4	13.5
4	100 Hz	9.2	.9
	1000 Hz	12.2	8.0
	10 kHz	13.6	12.5
5	100 Hz	4.7	5.0
	1000 Hz	5	8
	10 kHz	4.5	7

Q2 Collector

Fig. 52-5. Use this chart for Steps 3, 4 and 5.

throughout its range and notice how the sound level varies. Record both the voltage levels with the potentiometer fully counterclockwise and fully clockwise in the chart in Fig. 52-5. Similarly, measure and record the output for frequencies of 1000 Hz and 10 kHz with the potentiometer fully counterclockwise and fully clockwise.

Step 4: To show how low-frequency response can be varied by shunting a small coupling capacitor with an R-C network.

Change your wiring to the circuit shown in Fig. 52-6. Unsolder and remove the .25-mfd capacitor. Remove the 6-mfd coupling capacitor lead from the base terminal of the power transistor and solder it to terminal 2 of the 50k-ohm potentiometer. Solder a .01-mfd capacitor between square 3H and the power transistor base terminal. Connect the series-connected 6-mfd capacitor and 50k-ohm potentiometer across the .01-mfd coupling capacitor. Unsolder the potentiometer lead from square 4H and solder it to the power transistor base terminal.

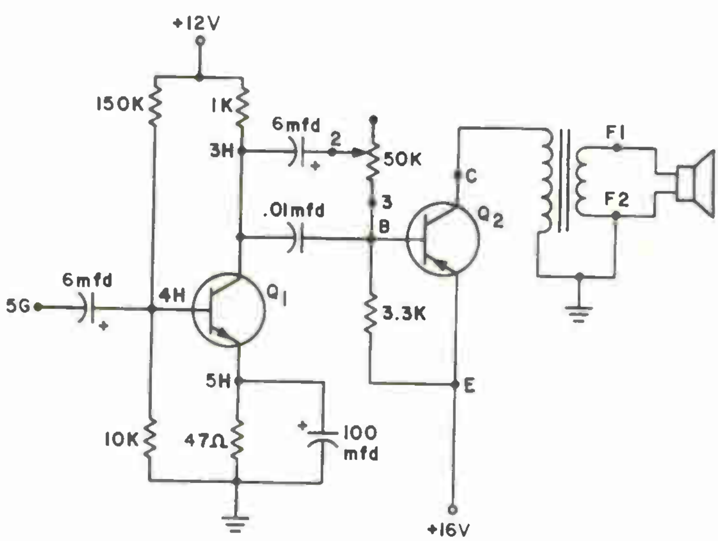

Fig. 52-6. The circuit for Step 4.

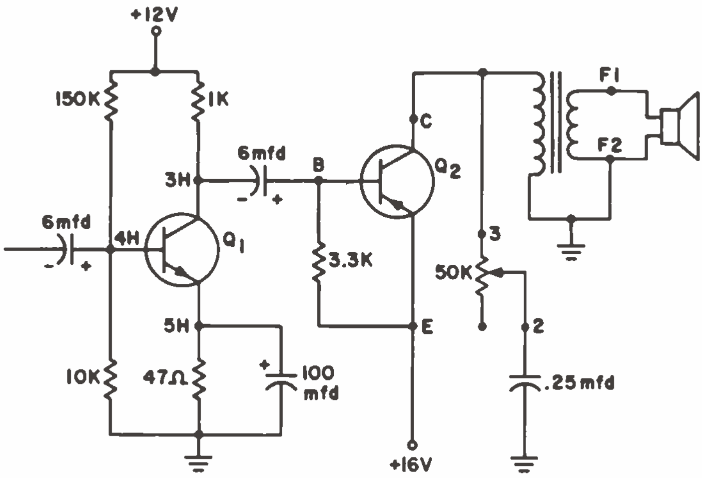

Fig. 52-7. The circuit used for Step 5.

Energize the circuit and vary the potentiometer while listening to each of the three tones. Note that the low tone is affected more than the high when you rotate the potentiometer. Measure the output level for each frequency with the potentiometer fully counterclockwise and fully clockwise, and record the values in the chart in Fig. 52-5.

Step 5: To show the effect of shunting the primary winding of the output transformer with an R-C network.

Change the circuit as shown in Fig. 52-7. Remove the .01-mfd capacitor and reconnect the 6-mfd capacitor between the base of the power transistor and square 3H. Be sure to connect the positive capacitor lead to the power transistor base. Connect the .25-mfd capacitor between terminal 2 of the potentiometer and the ground foil. Unsolder the potentiometer lead from the base terminal of the power transistor and solder it to the collector terminal of the power transistor.

Turn the circuit on and note how the 50k-ohm potentiometer affects the output sound at each of the three frequencies. Record the voltage levels for each frequency in Fig. 52-5 with the potentiometer at each extreme. Turn the equipment off.

Discussion: In this experiment, you measured the signal levels in an audio amplifier and demonstrated several methods of changing the amplifier frequency response. In Step 1, you measured the signal levels at various points in the amplifier to determine the normal amplifier response. You should have found that the three frequencies were amplified nearly equally by each of the amplifier stages. Thus, we can say that the amplifier frequency response is nearly "flat" over the range of 100 to 10,000 Hz.

Capacitance was used in each of the following steps to alter the frequency response of the amplifier. The reactance of a capacitor is inversely proportional to frequency. This can be seen from the formula for capacitive reactance:

$$X_C = \frac{1}{2\pi FC}$$

In Step 2, lower values of coupling capacitor were connected between the two stages. The smaller capacitor passed the high frequencies with less attenuation than the low frequencies. Thus, in the output, the high frequencies were emphasized. In any R-C coupling network, the coupling capacitor and the input resistance of the following stage form a signal voltage divider.

Normally the capacitance value is chosen so that it has negligible reactance at the signal frequency. Therefore, little or no signal voltage is dropped across the coupling capacitor. However, if the capacitance is small and has appreciable reactance at the signal frequency, reduced signal will be available at the input of the following stage. In this step, the capacitors were small enough so that the middle and low frequencies were highly attenuated. However, the 10 kHz signal was passed readily.

Inverse feedback was used in Step 3. The capacitor was used to couple the signal from the collector of Q_1 back to the base. This is degenerative feedback, which is 180° out-of-phase with the input, and it was used to reduce the effective input signal level. The capacitive reactance to the high frequencies was low. Thus, it coupled back more of the high frequency signal voltage. As a result, the overall gain of the stage was highest at the lowest frequency.

The 50k-ohm potentiometer varied the effect of the capacitive feedback. Increasing the resistance decreased the amount of signal coupled through the network at each frequency. Thus it reduced the difference in gain for the various frequencies.

For Step 4, you used an R-C network in parallel with a small coupling capacitor. The small coupling capacitor attenuates middle and low frequencies severely, as you saw in Step 2. The 6-mfd capacitor passed the low frequencies more readily. Therefore, as the resistance of the potentiometer was decreased, the low and middle frequencies were attenuated less and, consequently, received more overall amplification.

An R-C network was connected in

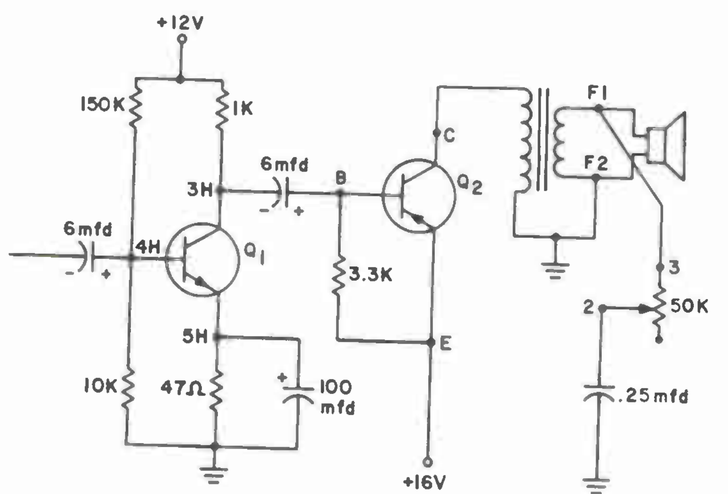

Fig. 52-8. The circuit for Statement 52.

parallel with the output of transistor Q_2 in Step 5. The capacitor filtered out the high frequencies, just as any filter capacitor would do. It has a high reactance to low frequencies. Therefore, the low frequencies were affected very little by the filtering action. The 50k-ohm potentiometer varied the amount of filtering which the capacitor could produce. Thus it varied the attenuation of the high and middle frequencies. As a result, the low frequencies would seem to be emphasized.

In Steps 2 through 5, you saw several methods of altering the amplifier frequency response. All of the methods employ R-C filtering and they either emphasize or attenuate a band of frequencies. As a general rule, 1,000 Hz is taken as the center frequency. Then the lows are frequencies less than 1,000 Hz and the highs are frequencies greater than 1,000 Hz. The effect of tone controls is gradual: The higher or lower the frequency, the more it is affected by the control.

Instructions for Statement 52: For this Report Statement, you will connect the series-connected potentiometer and the .25-mfd capacitor across the speaker terminals and determine the effect. Unsolder the lead of the 50k-ohm potentiometer from the collector terminal of power transistor and solder it to terminal F1. You now have the circuit shown in Fig. 52-8.

Energize the circuit and observe the amplifier output level at each frequency with the potentiometer set at each extreme. Answer the Statement here and on the Report Sheet and turn your equipment off.

Statement No. 52: When I varied the resistance in series with the capacitor across the speaker, I found that:

(1) the low frequencies were most affected.

(2) the middle frequencies were most affected.

(3) there was no noticeable effect.

EXPERIMENT 53

Purpose: To show some of the techniques used to control audio volume and to compare their advantages and disadvantages.

Introductory Discussion: The volume control in a radio or television receiver enables the user to vary the audio output level without changing the tone or distorting the output signal. Many different systems are used. The volume control device itself is almost always a potentiometer and it can be connected to vary either the gain of an amplifier stage or the attenuation of the signal. In rare cases the gain of two or more stages is adjusted by the volume control.

In this experiment, you will demonstrate several volume control methods. You will use your audio frequency oscillator set to 1 kHz as a signal source and, by observing the ac output voltage on your tvom and listening to the sound, you will be able to see how the volume control methods affect the sound output.

Experimental Procedure: You will need the experimental chassis with the audio oscillator and amplifier circuits and the 50k-ohm potentiometer, your tvom and the following:

1 3.3k-ohm resistor

You will begin the experiment with the

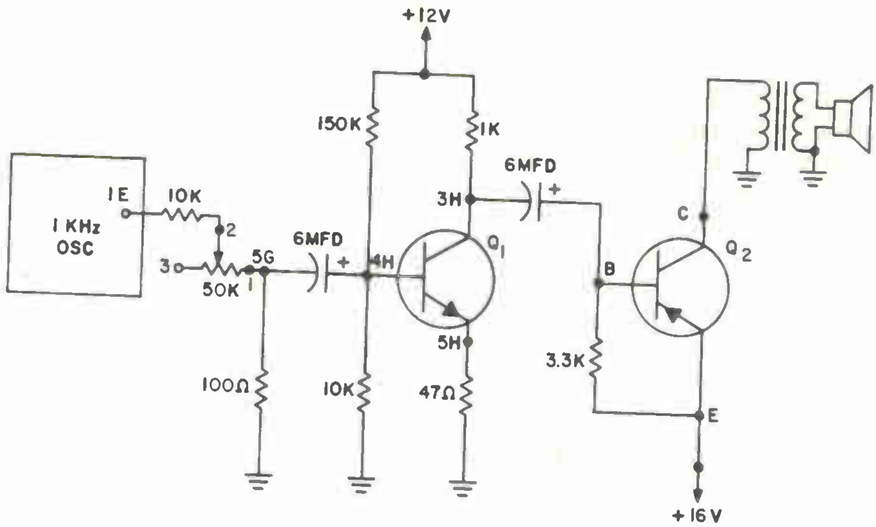

Fig. 53-1. The circuit for Step 1.

circuit shown in the schematic diagram in Fig. 53-1. To prepare for the experiment, unsolder and remove the 100-mfd capacitor from the Q_1 emitter circuit.

Unsolder the .25-mfd capacitor connected to the 50k-ohm potentiometer, and lay it aside; also, disconnect the hookup wire attached to the potentiometer.

Unsolder the 10k-ohm resistor lead from square 5G of the experimental circuit board and connect it to terminal 2 (the center terminal) of the 50k-ohm potentiometer. (You will have to solder a short length of hookup wire to the resistor lead.) Solder a length of hookup wire between terminal 1 (the left terminal) of the 50k-ohm potentiometer and square 5G. Check your wiring against the schematic and be sure all connections are soldered.

Step 1: To show that increasing or decreasing a resistance in series with a signal source will vary the signal amplitude.

Connect your tvom between ground and the collector terminal of the power transistor. Set the meter to read 12 volts ac and turn the circuit on. Set the oscillator for 1 kHz (position 2). Adjust the volume control (the 50k-ohm potentiometer) until maximum signal is indicated on the tvom.

Turn the volume control throughout its range while listening to the sound from the speaker. Also, observe the meter. The volume and the meter indication should vary. Note that the potentiometer cannot completely cut off the sound. Turn off the power.

Step 2: To show that the volume can be controlled by varying the amplifier load impedance.

You will place the potentiometer across the primary winding of the audio output transformer in the collector circuit of the power transistor. Disconnect the potentiometer lead from square 5G. Unsolder the 10k-ohm resistor lead from the center

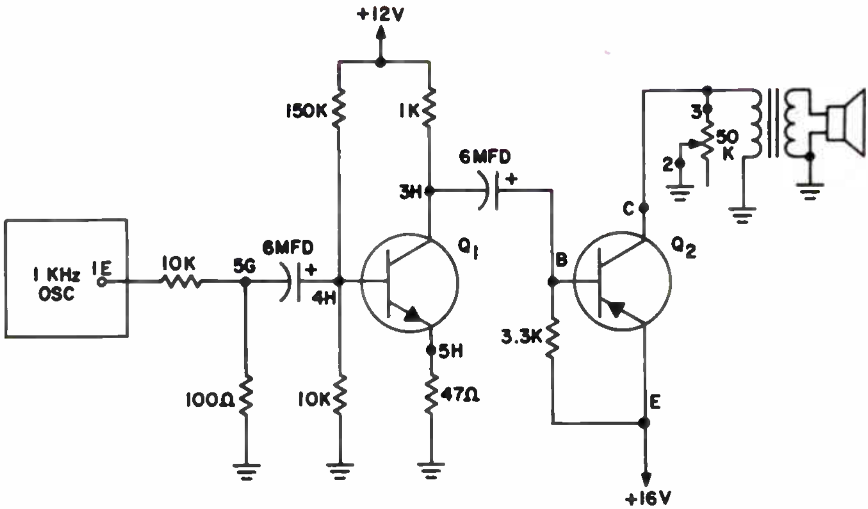

Fig. 53-2. The circuit for Step 2.

terminal of the potentiometer and solder it to square 5G. Now connect terminal 2 of the potentiometer to ground.

Connect a length of hookup wire from terminal 3 of the potentiometer to the collector of the power transistor. You should now have the potentiometer connected as shown in the schematic in Fig. 53-2.

Turn on the power and rotate the volume control. Observe the meter indication while listening to the sound. The output should vary smoothly from one extreme of the volume control setting to the other.

Step 3: To show that volume can be controlled by varying the bias on an amplifier stage.

Disconnect the potentiometer lead

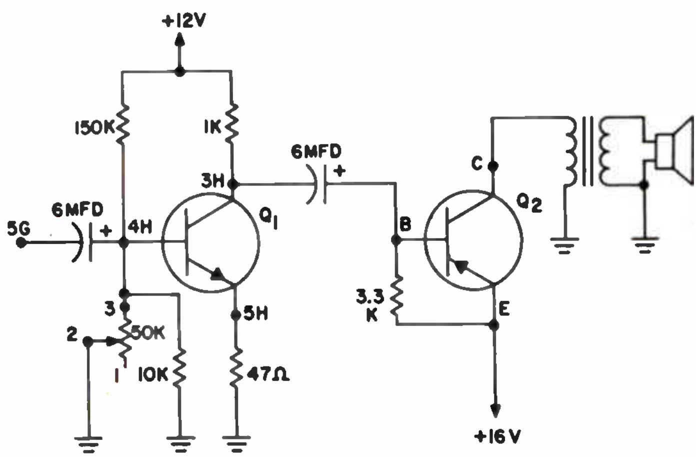

Fig. 53-3. The circuit for Step 3.

from the collector of transistor Q_2 and connect it to square 4H. You now have the circuit shown in Fig. 53-3.

Turn on the power and vary the potentiometer throughout its range while listening to the sound and observing the meter indication. Note that as the resistance is decreased, the volume decreases.

Step 4: To demonstrate a volume control method using a potentiometer as a signal voltage divider.

The circuit for this step is shown in Fig. 53-4. Note that the potentiometer is connected in shunt with the 100-ohm resistor. Wire the circuit as shown. Unsolder the lead of the 6-mfd capacitor from square 5G. Disconnect both potentiometer leads from the circuit. Connect a length of hookup wire from terminal 1 of the potentiometer to square 5G. Solder the lead from terminal 2 of the potentiometer to the free lead of the 6-mfd capacitor. Solder the lead from terminal 3 of the potentiometer to ground. Check over your work.

Turn the equipment on and vary the setting of the volume control while observing the output voltage reading on your tvom and listening for the sound. You should have full output at one extreme and no volume at the other extreme of the volume control rotation. Further, the variation in output level should be smooth. Turn the equipment off.

Discussion: In volume controls, three factors are important: The control should operate smoothly, it should not introduce distortion and the control should dissipate little if any power. The first two factors are fairly obvious. It is annoying to have the volume change suddenly from low to high as the volume control knob is rotated. You expect and prefer that the level be continuously variable from one extreme to the other.

From the preceding experiment, you know that the volume can be varied by varying the level of the high or low tones in the audio frequency output. This is a form of distortion, however. Varying the highs or the lows only would make the reproduction of the speech or music less pleasing.

Most potentiometers used in volume

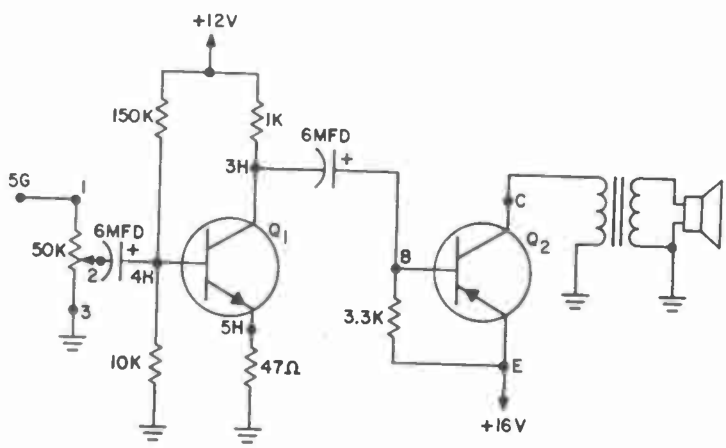

Fig. 53-4. The circuit for Step 4.

control circuits have low wattage ratings. Like fixed resistors, they become overheated and damaged by excessive current. Carbon potentiometers, such as those you have on your experimental chassis, consist of a circular resistive element connected to the end terminals and a sliding contact connected to the center terminal. As the shaft is rotated, the contact slides along the surface of the resistive element. Excessive current will frequently cause the surface of the resistive element to burn where it contacts the slider. This produces intermittent connections and popping or cracking noises in the audio.

Now let us look at the results of the experiment. In Step 1, you connected the potentiometer as a variable resistor between the source and the amplifier circuit. The potentiometer varied the attenuation of the signal applied to the amplifier input stage.

You know from previous experiments that the 10k-ohm resistor and the 100-ohm resistor form a signal voltage divider. By placing the 50k-ohm potentiometer in series with the 10k-ohm resistor, you were able to vary the voltage divider ratio. Consequently the potentiometer made it possible to reduce by approximately 80% the signal voltage applied to the amplifier circuit.

In Step 2, you connected the potentiometer across the primary winding of the audio output transformer. The primary winding and the associated impedances reflected from the secondary and the loudspeaker form the load for this stage.

Changing the resistance parallel with the primary winding altered the impedance and the path of the collector current. With the volume control set for maximum volume, the resistance was high when compared to the impedance of the primary winding. Therefore, most of the current flows through the primary winding and the loudspeaker and produced normal volume.

The volume control was connected so that rotating the shaft counterclockwise reduced the total resistance in shunt with the primary. This reduced the amplifier load resistance, and also reduced the amount of signal coupled into the speaker. At any setting except maximum volume, a heavy current flows through the volume control. Under some circumstances, the current would be great enough to require a higher wattage (and more expensive) potentiometer. Over a long period of time, the current can cause potentiometers of the type you are using to become noisy.

The volume control in this step is able to cut off the sound, or at least reduce it to inaudibility. This is because the minimum resistance of the potentiometer is quite low when compared to the impedance of the primary winding.

In Step 3, you used a volume control arrangement which varied the bias on the first amplifier stage. The potentiometer was connected between the base of the transistor and ground. Note that forward bias on the stage is developed by the voltage drop across the 150k-ohm resistor connected between the positive supply voltage and the base. The potentiometer was connected so that it affected the forward bias.

As the resistance of the potentiometer was reduced, the forward bias on the base of the transistor was lowered. Eventually, a point was reached where the transistor was cut off. Within limits, the gain of the transistor is proportional to the collector current. Thus, with this arrangement you were able to vary the output signal and amplitude.

The primary drawback of this volume

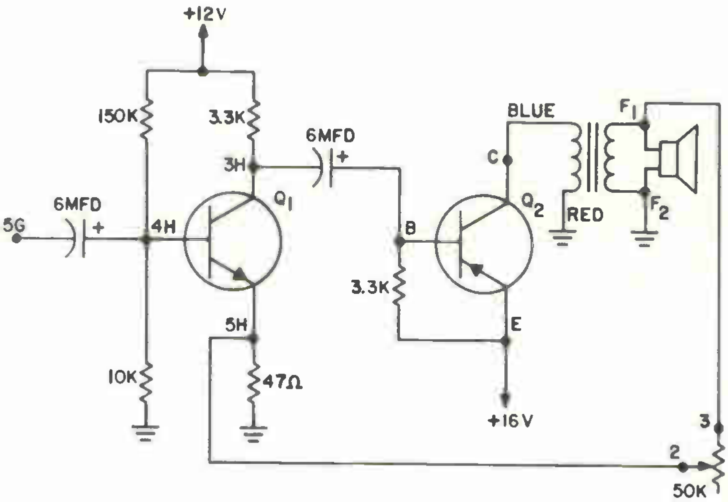

Fig. 53-5. The circuit for Statement 53.

control is the fact that it is prone to produce amplitude distortion. When the control is set for low levels, the bias is very low and negative excursions of the signal can drive the transistor into cutoff. Similarly, high positive peaks would receive more amplification than lower positive peaks. Thus the gain varies with the signal level.

In Step 4 you demonstrated one of the most common volume control circuits. In your circuit, the junction of the 10k-ohm and 100-ohm resistors was for all practical purposes the source of a low level signal. The volume control, then, was across the low level signal source.

For maximum volume, the resistance between the source (square 5G) and the slider on the volume control is at minimum. The full 50,000-ohms is between the slider and ground. As the volume is decreased, the resistance between square 5G and the slider increases while the resistance between the slider and ground decreases. As you already know, the resistance of the transistor input circuit is quite low. Therefore, the signal voltage will be dropped across the portion of the potentiometer between the slider and square 5G.

Further rotation of the potentiometer increases the resistance between the source and the slider and the voltage actually reaching the transistor becomes too low to drive the stage. This, of course, results in no audible output.

Note in Fig. 53-4 that the volume control is connected on the input side of the coupling capacitor. This arrangement prevents the volume control from affecting the bias voltage on the transistor. If the potentiometer were placed so that the slider was connected to the base, the signal reaching the transistor as well as the transistor forward bias would be reduced whenever you turned the volume down. Depending on the level of the input signal, this may produce distortion in the audio, as mentioned earlier.

Instructions for Statement 53: For this Statement, you will connect the potentiometer between the Q_1 emitter circuit and the secondary winding of the audio output transformer and determine the effect of varying the resistance. Change your circuit according to the schematic diagram shown in Fig. 53-5.

Unsolder and remove the length of wire connected between square 5G and terminal 1 of the potentiometer. Unsolder the potentiometer lead connected to ground and solder it to terminal F1. Unsolder the lead of the 6-mfd capacitor from the center potentiometer lead and solder the capacitor lead to square 5G. Solder the free end of the center potentiometer lead to square 5H. Replace the 1k-ohm resistor in the Q_1 collector circuit with a 3.3k-ohm resistor. Check your circuit against the schematic diagram.

Turn your circuit on and vary the setting of the volume control while listening to the sound and observing the output on the tvom. Observe the effect of rotating the volume control in the counterclockwise direction. If your circuit is wired correctly, this will decrease the resistance between the leads of the potentiometer. Make whatever tests are necessary and answer the Statement here and on the Report Sheet.

Statement No. 53: **When I decreased the resistance by rotating the volume control counterclockwise, the overall amplifier gain:**

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

EXPERIMENT 54

Purpose: To show how the field effect transistor works and to show that it can be used as an audio frequency amplifier.

Introductory Discussion: The field effect transistor (or FET) is a solid-state device with characteristics very similar to those of a vacuum tube. Some of its characteristics, however, are unique. An understanding of the FET is important to the service technician because FET's are being more widely used in radio and TV receivers. Thus, you will be faced with troubleshooting circuits containing them.

An FET has three terminals called the drain, source, and gate. The schematic symbol shown in Fig. 2B should be familiar to you, as FET's are used in your tvom. A resistive current path or channel exists between the drain and source terminals.

In the FET supplied with this kit, this path consists of a small bar of N-type silicon material. Thus, the device is called an N-channel FET. The gate consists of a piece of P-type material surrounding the N channel. The application of the negative voltage to the gate causes the channel to become less conductive, thus exhibiting a higher resistance.

In this experiment, you will see how the gate voltage affects the current through the channel, you will see how bias voltage is obtained and you will construct and demonstrate a basic amplifier using your FET.

Experimental Procedure: For this experiment, you will need the experimental chassis with the oscillator, power supply and experimental circuit boards, your tvom and the following:

2 1.5V flashlight cells
1 FET (TS20)
1 470-ohm resistor
1 1k-ohm resistor
1 10k-ohm resistor
1 47k-ohm resistor
1 100k-ohm resistor
1 .1-mfd tubular capacitor
1 6-mfd electrolytic capacitor

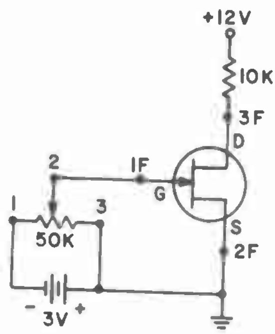

Fig. 54-1. The circuit for Step 1.

You will use the circuit shown in Fig. 54-1. Before wiring the circuit, dismantle the circuit from the previous experiment. Remove the resistors and capacitors connected to squares 3H, 4H and 5H. Leave the signal voltage divider connected to square 5G and ground and leave the transistors in place. Remove the resistor and the emitter lead from the power transistor.

Unsolder and disconnect all 4 leads and remove the audio output transformer.

To wire the battery and potentiometer, prepare two lengths of hookup wire about 8 inches long. Your two flashlight cells should still be connected in series, forming a 3-volt battery. Solder lengths of wire to the positive and negative terminals of the 3-volt battery. Solder the negative battery lead to terminal 1 (the left terminal) of the 50k-ohm bias potentiometer. Solder the positive battery lead to terminal 3 (the right terminal) of the potentiometer. Solder a short length of wire between terminal 3 of the potentiometer and ground (the chassis).

Connect a 10k-ohm resistor between square 3F and lug 5 of circuit board EC24. Connect a short length of hookup wire between ground and square 2F. Connect another length of hookup wire from the center terminal of the 50k-ohm bias potentiometer to square 1F.

Be sure you can identify the leads of the FET. This information is given in Fig. 2B. Then solder the gate, source, and drain leads to squares 1F, 2F and 3F, respectively. Use the same precautions as instructed for handling your other transistors: do not apply excessive heat or physical strain to the leads.

This completes your wiring. Check your work to be sure the circuit is wired according to the schematic diagram.

Step 1: To show that the channel current in an FET can be controlled by applying a negative voltage to the gate.

Turn the circuit on and measure the dc voltage across the 10k-ohm resistor connected between the drain terminal of the FET at square 3F and the positive supply voltage. Vary the 50k-ohm bias control potentiometer and note that the meter reading varies.

Set your tvom to measure negative voltage on the 3-volt range. Move the ground clip to the chassis and measure the voltage between ground and the gate of the FET. Adjust the bias control for 0V. Then switch the tvom to the 12-volt range and move the ground clip to the positive terminal, lug 5 of EC24. Measure the voltage across the 10k-ohm resistor and record it on the first line in Fig. 54-2.

In a similar manner, set the gate voltage to −1V, −2V, and −3V and measure and record the corresponding voltage drops across the 10k-ohm drain resistor.

When you complete these readings, compute the drain current for each entry. The current in ma is equal to 1/10th the voltage across the 10k-ohm resistor in volts. For example, a voltage of 12V corresponds to 1.2 ma.

GATE VOLTAGE	VOLTAGE ACROSS 10K	DRAIN CURRENT
0	11.5	1.18
−1	[illegible]	1.2
−2	12.2	1.22
−3	12.2	1.22

See Page 32

Fig. 54-2. The chart for Step 1.

Step 2: To show that the source and drain are interchangeable.

Turn the circuit off and unsolder and interchange the resistor lead and the ground lead to squares 2F and 3F.

Connect the tvom across the 10k-ohm resistor, turn the circuit on and vary the potentiometer. Note that the voltage drop across the 10k-ohm resistor varies just as it did in Step 1, although the current now flows through the FET from drain to source.

Step 3: To show another method of biasing an FET.

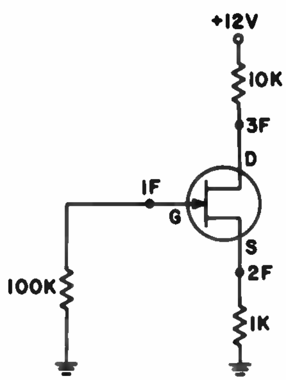

Fig. 54-3. The circuit for Step 3.

You have already used negative fixed bias applied to the gate. Now you will demonstrate self-bias. Turn the circuit off and change it to that shown in the schematic in Fig. 54-3. Disconnect the leads from the battery and the 50k-ohm potentiometer. Unsolder and remove the hookup wire from square 3F. Solder a 100k-ohm resistor between square 1F and the ground foil. Unsolder the 10k-ohm resistor lead from square 2F and solder it to 3F. Solder a 1k-ohm resistor between the ground foil and square 2F. You now have the gate grounded through a 100k-ohm resistor, the 10k-ohm resistor connected in the drain circuit and the 1k-ohm resistor connected between ground and the source.

Turn the circuit on and measure the voltage between ground and the gate terminal at square 1F. You should read zero. Now measure the voltage across the 1k-ohm source resistor. This is the gate bias voltage, as it is equal to the voltage between the gate and source.

0.5 Turn the circuit off and replace the 1k-ohm source resistor with a 47k-ohm resistor. Energize the circuit and determine the bias voltage, as before. Also,
1.0 measure the voltage across the 10k-ohm resistor and determine the drain current.
.02 ma. Jot down the current in the margin.

Step 4: To show that the FET can be used to amplify ac signals.

Wire the circuit shown in Fig. 54-4. Replace the 10k-ohm drain resistor with a 100k-ohm resistor. Connect a .1 mfd-tubular capacitor between squares 5G and 1F. Replace the 100-ohm resistor connected between square 5G and ground with a 470-ohm resistor. Check your wiring.

(A) Energize the circuit, set the oscil-

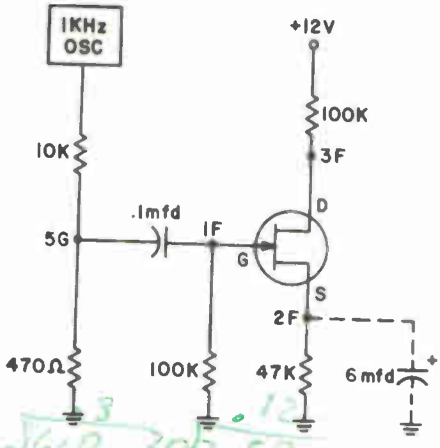

Fig. 54-4. Basic amplifier circuit in Step 4.

lator switch to position 2 and measure the ac voltage between ground and square 1E of the oscillator board. This is the oscillator output applied to the voltage divider. The voltage divider has a ratio of about 20 to 1. Thus the signal applied to the FET is about 1/20th of the voltage reading at the oscillator output.

Perform this computation and record the input voltage in the first column of Fig. 54-5. Move the probe of your tvom to square 3F and measure and record the output voltage. Compute the stage gain, using the formula,

$$\text{gain} = \frac{E_{out}}{E_{in}}$$

and record it in Fig. 54-5.

STEP	INPUT	OUTPUT	GAIN
4A	.12V	.12	0
4B	.12V	3.5V	29

Fig. 54-5. The chart for Step 4.

(B) Solder a 6-mfd capacitor between ground and the source terminal at square 2F. Note that the positive capacitor lead goes to square 2F. Turn the circuit on and measure and again record the output voltage at 3F. The input voltage has not changed. Therefore, you can use the same value as in Step 4A. Compute and record the stage gain for this step. Turn the equipment off.

Discussion: The field effect transistor you used is called a junction FET which is sometimes abbreviated JFET. This means that the gate is in physical and electrical contact with the channel. The P-type gate material must never be made positive with respect to the channel or it will act as a forward-biased diode and will pass excessive current and become damaged.

In Step 1, you recorded the gate input voltage and the resulting drain current. From the data you recorded in Fig. 54-2, you can see that the current was highest when the gate voltage was at zero and the current decreased as you made the gate more negative. This is very similar to what happens to the plate current in a vacuum tube as the grid voltage is varied. In an FET, if you continue to make the gate more negative, you reach a point known as "pinch-off", which corresponds to plate current cutoff in a vacuum tube or collector current cutoff in a bipolar transistor.

The voltage drop across the load resistor in the drain circuit varied with drain current. Therefore, the variation in the voltage at the gate produced larger changes in the voltage across the FET itself.

As stated earlier, the channel in an FET is simply a resistive current path. Thus, like a resistor, it will pass current in either direction. You should have found that the FET acted in exactly the same manner in Step 2 when you interchanged the source and drain connections as in Step 1.

In Step 3, you demonstrated the most common method of biasing an FET. The gate is returned to the negative side of the power supply and a resistor is placed between the negative supply and the source terminal of the transistor. Current flow through the source resistor makes the source positive with respect to ground. The gate, therefore, is negative with respect to the source. This method eliminates the need of a separate bias supply and also makes it possible to use FET's with widely varying internal resistances in an amplifier circuit.

You constructed an amplifier stage in Step 4. This circuit is called a common source amplifier. In Step 4A, the gain was about 2 and the output level was too low to measure accurately. The unbypassed source resistance was responsible for the low gain. Input signal variations caused variations in the source as well as drain current. The voltage drop across the source resistor opposed the signal variations and reduced the effective input signal to an extremely low level.

When you bypassed the source resistor, you found that the gain increased significantly. The bias was held stable so that the input signal variations produced proportional changes in channel current and in the voltage drop across the load resistor.

The signal across the drain resistor is 180° out-of-phase with the input signal; a positive going excursion of the signal increases the source-drain current and produces an increase in the voltage drop across the drain resistor. If the source resistor is left unbypassed, the voltage across it will be in-phase with the applied signal voltage.

Any JFET such as the one you used in this experiment can be handled safely if you heed the same precautions that you do for regular bipolar transistors. Take care not to subject the device to excessive heat, voltage or physical strain.

Another type of FET, called the insulated gate FET, (IGFET, or MOSFET) requires much more care in handling. Although it resembles the JFET, this type of FET has a thin layer of insulation between the gate and channel. This insulation can be broken down by ac voltage pickup on the leads. Therefore, the leads must be kept grounded until the FET is installed in a circuit.

Instructions for Statement 54: For this Report Statement, you will convert your FET stage to a source-follower amplifier, in which the signal is applied to the gate and the output is taken at the source.

Wire the circuit shown in Fig. 54-6. Unsolder and remove the 100k-ohm drain resistor, which is connected between square 3F and lug 5 of EC24. Connect a length of hookup wire in its place. Unsolder and remove the electrolytic capacitor in parallel with the 47k-ohm source resistor. Remove the 470-ohm resistor in the signal voltage divider.

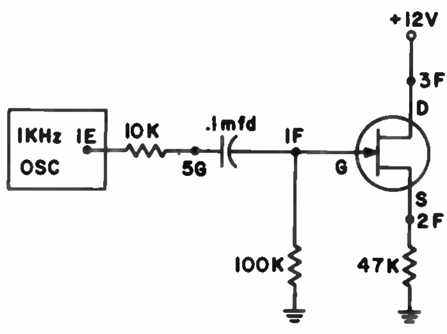

Fig. 54-6. The circuit for Statement 54.

Energize the circuit and measure the input signal voltage at the gate and at the output, which is the source terminal. Turn the equipment off. Compare the two voltage readings and answer the Statement.

Statement No. 54: When I measured the input and output voltages of the FET source follower circuit, I found that the gain was:

(1) less than .1.
(2) between .5 and 1.
(3) greater than 5.

EXPERIMENT 55

Purpose: To demonstrate how the stereo indicator on an FM receiver works and to show the effects of common circuit defects in stereo indicator circuits.

Introductory Discussion: Many FM receivers feature an indicator light which glows whenever a stereo transmission is being received. In some receivers, the circuit which operates the light also switches in the stereo detector circuitry. Otherwise, the signal passes through the simpler monophonic circuitry only.

The stereo indicator consists of a sensing circuit in addition to the indicator device. In most sets, the 19 kHz pilot carrier, which is part of the stereo multiplex signal, is monitored. When the pilot carrier is present with sufficient strength, the circuit is actuated. In order to discriminate against other signals, such as audio, a tuned circuit is often placed in the indicator circuit to pass the 19 kHz signal only.

In this experiment, you will use the 10 kHz output of your phase-shift oscillator to represent the 19 kHz pilot carrier. As an indicator, you will use an incandescent pilot lamp. This lamp requires 2V at 60 ma for full brilliance. Therefore, you will operate the lamp from the +16V supply at the input to the L-C filter in the power supply.

Experimental Procedure: For this experiment, you will need the experimental chassis, your tvom, and the following:

1 PNP transistor (TS22)
1 No. 49 pilot lamp
1 Lamp socket
1 1-megohm resistor
1 6.8k-ohm resistor
1 4.7k-ohm resistor
1 220-ohm resistor
1 150-ohm resistor
1 250 pf mica capacitor
1 Signal diode (CR10)

You will begin the experiment with the circuit shown in the schematic diagram in Fig. 55-1. First, disassemble the circuitry on the center circuit board. Leave the

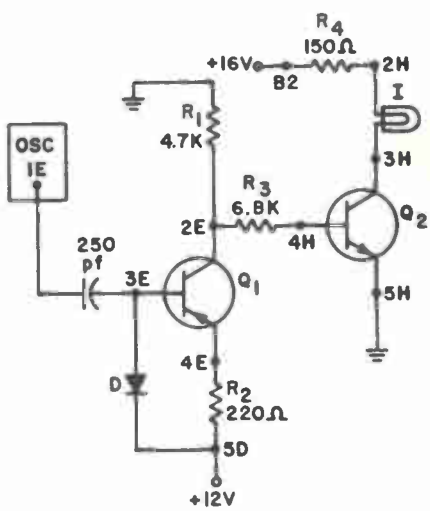

Fig. 55-1. The circuit you use for Step 1.

NPN transistor used in Experiment 53.

Connect square 5H to the outer ground foil, using a short length of wire. Solder a 150-ohm resistor between square 2H and terminal B2. Prepare the lamp socket for mounting as follows: Bend each terminal outward at a 90° angle about 1/8 inch from the end. Also, tin each terminal with solder. Solder the terminals of the lamp socket to squares 2H and 3H. Insert the lamp into the socket.

Solder a 6.8k-ohm resistor between squares 4H and 2E. Solder a 4.7k-ohm resistor between the ground foil and square 2E.

Solder a 220-ohm resistor between squares 5D and 4E. Solder a signal diode between square 3E and square 5D, with the cathode lead to 5D.

Solder a 250 pf capacitor between square 3E of the experimental board and square 1E of the oscillator board. Solder a length of hookup wire from square 5D to lug 5 of circuit board EC24.

Mount the PNP transistor on the experimental circuit board, using Fig. 2A as a guide. Identify the leads and bend them to fit. Solder the collector to square 2E, the base to square 3E, and the emitter to square 4E. Check your work carefully, making sure there are no unsoldered connections, no short-circuits, and that the circuit is wired according to the schematic.

Step 1: To demonstrate the basic circuit operation.

Set the frequency selector switch to position 3 (10 kHz) and energize the circuit. The lamp should light. If necessary, readjust the 1k-ohm potentiometer on the oscillator circuit board slightly. Switch the oscillator frequency to 1 kHz and 100 Hz and observe the lamp. Note that it glows only on the high frequency signal.

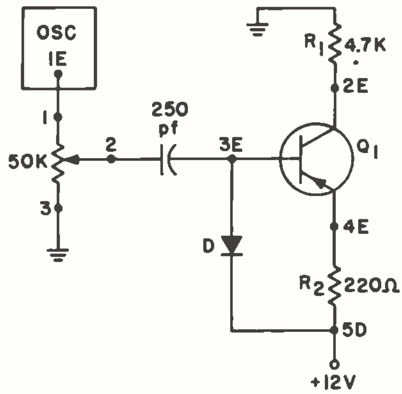

Fig. 55-2. Input circuit using the 50k-ohm pot.

Turn the circuit off and wire the 50k-ohm potentiometer, which is mounted on the front of your circuit board, into the circuit as shown on the schematic in Fig. 55-2. The terminals of the potentiometer are numbered clockwise when looking at the shaft end.

Unsolder the lead of the 250 pf capacitor from the oscillator board and solder it to terminal 2 of the potentiometer. Solder a length of hookup wire from terminal 3 of the potentiometer to ground. Solder a length of wire between terminal 1 of the potentiometer and square 1E of the oscillator circuit board.

Step 2: To show that the circuit responds to variations in signal strength.

Turn the circuit on, set the frequency to 10 kHz and vary the 50k-ohm potentiometer. Note that the brilliance of the lamp varies with the potentiometer adjustment.

Connect the ground clip of your tvom to lug 5 of EC24 and set the tvom to measure ac voltage on the 3-volt range. Touch the probe to square 3E to measure

VOLTAGE	MINIMUM	MAXIMUM
AC	.52	.6
DC	.4	.47

Fig. 55-3. Chart for input voltage measurements.

the ac voltage applied to the base of transistor Q_1. Notice the voltage variation as you rotate the potentiometer. Record the maximum value of ac voltage in Fig. 55-3. Reduce the signal strength with the potentiometer as you observe the lamp's brilliance. When the lamp just goes out, read the value of ac voltage at the base of Q_1. Record this as the minimum value of ac in Fig. 55-3.

Set your tvom to measure negative dc on the 3V range and measure the dc voltage corresponding to the minimum and maximum values of ac voltage. Record these values in the chart in Fig. 55-3.

Set the polarity switch on the tvom to normal, move the ground clip to the chassis and measure the Q_1 dc base voltage again. Record your reading in the chart in Fig. 55-4. Measure and record the voltages (with respect to the chassis) at the collector of Q_1 at square 2E; the base of Q_2 at square 4H; and the collector of Q_2 at square 3H with the minimum and maximum ac signal voltages applied.

Step 3: To show the effect of typical circuit defects. You will simulate defects

(A) To simulate a shorted diode, carefully short the signal diode lead with a screwdriver or a length of wire. Energize the circuit, vary the potentiometer and note that the bulb does not light. Measure the dc voltage at the base of transistor Q_1. The voltage should be approximately +12V. Remove the short circuit across the diode. 14.1

(B) To show the effect of a shorted transistor, Q_1. Connect a 1-megohm resistor between the ground foil and square 3E. When you energize the circuit, the lamp should light. Vary the signal level and change frequencies. The lamp should remain lighted and steady. Measure the voltages at the collector of Q_1 and the base and collector of Q_2 and compare them with the values recorded in the chart in Fig. 55-4. Remove the 1-megohm resistor.

(C) To show how a defective lamp affects the circuit voltages. Check to see that the lamp lights, and remove the lamp

MEASUREMENT	VALUE	
	MIN. SIGNAL	MAX. SIGNAL
Q_1 Base	12.9	13.2
Q_1 Collector	2	3.2
Q_2 Base	.30	.37
Q_2 Collector	16.0	14.5

Fig. 55-4. The chart for Step 2.

from the socket. Measure the voltage at the collector of Q_1 and at the base and collector of Q_2. You should find that the Q_2 collector voltage falls to zero while the Q_1 collector and Q_2 base voltages rise slightly. Turn the circuit off and replace the lamp.

(D) To show the effect of a base-emitter short-circuit in transistor Q_2. Connect a short length of hookup wire from ground to the base of transistor Q_2 at square 4H. Energize the circuit, vary the signal level and switch frequencies, and notice that the lamp remains off. Measure the Q_1 and Q_2 collector voltages. The Q_2 voltage should be abnormally high while the Q_1 voltage is normal.

Turn your equipment off and remove the short between the base of Q_2 and ground.

Discussion: In this experiment, you demonstrated a simple stereo indicator circuit. The circuit lighted the lamp whenever the proper signal voltage was applied to it.

The circuit consists of a shunt detector, diode D, and a two-stage direct-coupled amplifier with a lamp as part of the collector load of the output transistor. Transistor Q_1 is a PNP type while Q_2 is an NPN type. Normally, both transistors are turned off and little current flows through the lamp. When a signal is applied, Q_1 conducts and turns on Q_2, which causes current to flow through the lamp.

Diode D rectifies the ac signal voltage applied to it and makes the base of Q_1 negative with respect to the emitter. Because Q_1 is a PNP transistor, this negative voltage causes it to conduct. Current flows from ground through R_1 to the collector and from the emitter through resistor R_2, to the positive supply voltage terminal.

The collector of Q_1 becomes positive with respect to ground and this voltage is coupled through resistor R_3 and applied to the base of Q_2. Q_2 is an NPN transistor and the positive voltage fed to the base makes it conduct heavily. A large collector current flows through the lamp and the 150-ohm resistor to the positive supply voltage.

The information which you recorded in the chart in Fig. 55-4 confirms the preceding discussion of how the circuit works.

In Steps 1 and 2, you found that the circuit responds only to a moderately high amplitude 10 kHz signal. It does not work on 1 kHz or 100 Hz because the value of the coupling capacitor is too small to pass these frequencies without severe attenuation. The threshold or minimum required signal level is established primarily by the base cutoff characteristic of the input transistor, the reverse bias developed across the emitter resistor and the impedance of the coupling capacitor at the signal frequency. The threshold level of your circuit should be about .45V ac at the base of transistor Q_1.

In Step 3, you saw the effects of several common circuit defects. A shorted diode will not rectify the applied ac signal. Therefore, Q_1 will not become forward-biased and the lamp will not light. The circuit becomes completely inoperative.

A short in transistor Q_1, which you represented by applying a high forward bias, will keep the lamp turned on in the absence of signal. Q_1 will conduct continuously and the positive voltage dropped across the 4.7k-ohm collector load resistor, R_1, will keep Q_2 conducting heavily.

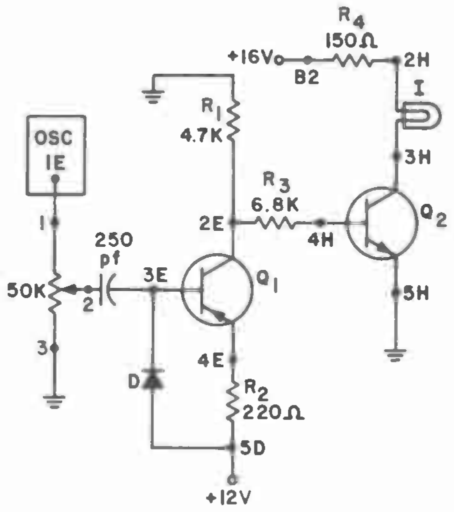

Fig. 55-5. The circuit for Statement 55.

In Step 3C, you found that a burned-out bulb will result in normal voltages throughout the circuit except at the collector of Q_2. The lamp is in series with the supply voltage and any break in that circuit removes the Q_2 collector voltage.

A shorted base-emitter in transistor Q_2 cuts Q_2 off and causes the lamp to remain turned off. The Q_2 collector voltage increases. Q_2 does not conduct so there is not enough collector current to light the lamp.

Instructions for Statement 55: For this Report Statement, you will reverse the connections of the diode as shown in Fig. 55-5 and determine how it affects the circuit operation.

Remove diode D from the circuit and reinstall it with the cathode lead to the base of Q_1 and the anode lead to the emitter supply voltage at square 5D. Turn the circuit on, test its operation on all three frequencies and answer the Statement. Be sure to place your answer on the answer sheet.

Turn your equipment off.

Statement No. 55: When I reversed the connections to the diode, I found that the circuit:

(1) worked normally.
(2) responded to all frequencies.
(3) did not respond to signals.

This concludes the experiments on audio circuits. Dismantle your circuits to prepare for the new circuits which you will build for the next group of experiments.

Unsolder and disconnect the hookup wire connecting the 1k-ohm potentiometer and terminal B3. Also, unsolder and remove the 250 pf mica capacitor. Remove the oscillator circuit board along with the three-position switch and the potentiometer brackets from the top of the chassis.

Unsolder and remove all parts and leads (including the transistors) from the center circuit board. Remove the 50k-ohm potentiometer. Remove the board and the potentiometer mounting bracket.

Unsolder and remove both leads connecting terminals B2 and B3 to the low voltage supply.

Building An RF Oscillator And I-F Amplifier

In the next group of experiments, you will work with rf and i-f circuits. Thus, you will need a source of rf voltage. You will also work with a vacuum tube amplifier so you will need a circuit board having a tube socket mounted on it.

At this time, you should have terminal strips A, B, and F mounted on your chassis. The low voltage power supply is wired on circuit board EC24 and the high voltage supply is wired on terminal strip A. The green filament leads of the power transformer are connected to terminals B5 and B6. You will install one circuit board, modify your power supplies and wire the rf oscillator and i-f amplifier circuit for the next experiment.

MOUNTING THE PARTS

Refer to Fig. 9 as you carry out the following assembly steps. First, gather the following parts:

- 1 Oscillator coil with mtg. hardware (CO43)
- 1 I-F transformer with mtg. hardware (TR13)
- 1 Tuning capacitor
- 1 1k-ohm potentiometer with mtg. hardware
- 1 Paper dial scale
- 1 Terminal lug
- 2 Knobs
- 4 No. 6 lockwashers
- 3 3/16" 6-32 screws
- 4 4-40 screws
- 4 4-40 nuts
- 1 Circuit Board (EC25)

First, remove the 1k-ohm potentiometer from the audio oscillator board.

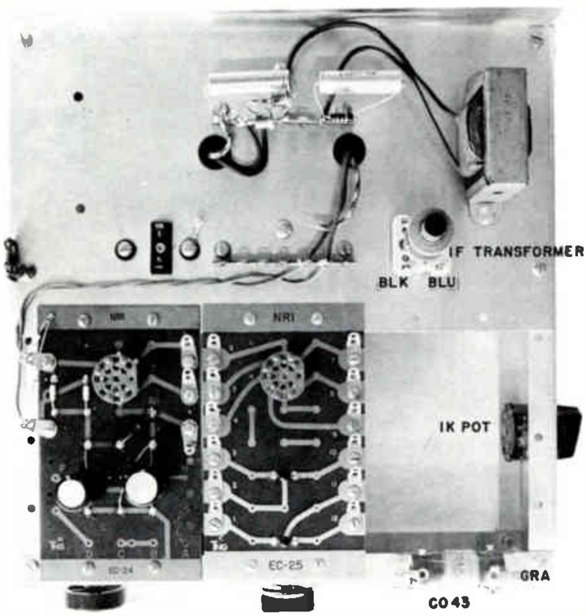

Fig. 9. The parts mounted on the chassis.

Unsolder the connections carefully. Also, remove the knob from the rotary switch on the oscillator board.

Mount circuit board EC25 on the chassis. Mount the board over holes S, T, AE, and AF, using four 4-40 screws and nuts.

Mount the rf oscillator coil, CO43, on top of the chassis at holes AG and AH. Position the coil so that the terminals color-coded yellow, gray and black are toward the right. Place a terminal lug over the screw at hole AH. Attach 4-40 nuts and tighten.

Mount the 1k-ohm potentiometer in hole AZ from the inside of the chassis. Use a control lockwasher and nut. Position the potentiometer so that the terminals are toward the top of the chassis rail.

Mount the i-f transformer on top of the chassis at hole L. Remove one of the nuts from the mounting screw of the transformer. Slip the mounting screw through the hole and rotate the transformer so that the terminals color-coded blue and black are toward the front rail of the chassis. Attach a lockwasher and the nut you removed from the screw and tighten securely.

Install the tuning capacitor at the front on the inside of the chassis at hole AV. At the same time, install the paper dial scale outside the chassis, using the same mounting screws. Refer to Fig. 10. Place No. 6 lockwashers over three 3/16" X 6-32 screws. Push the screws through the small holes in the dial scale and the three holes in the front of the chassis. Run these screws into the threaded holes in the front of the frame of the tuning capacitor. Rotate the shaft of the capacitor fully counterclockwise and place a pointer knob on the shaft. Position the knob so it points to zero on the scale and tighten the setscrew.

In a similar manner, install a pointer knob on the shaft of the 1k-ohm potentiometer. Rotate the shaft fully counter-

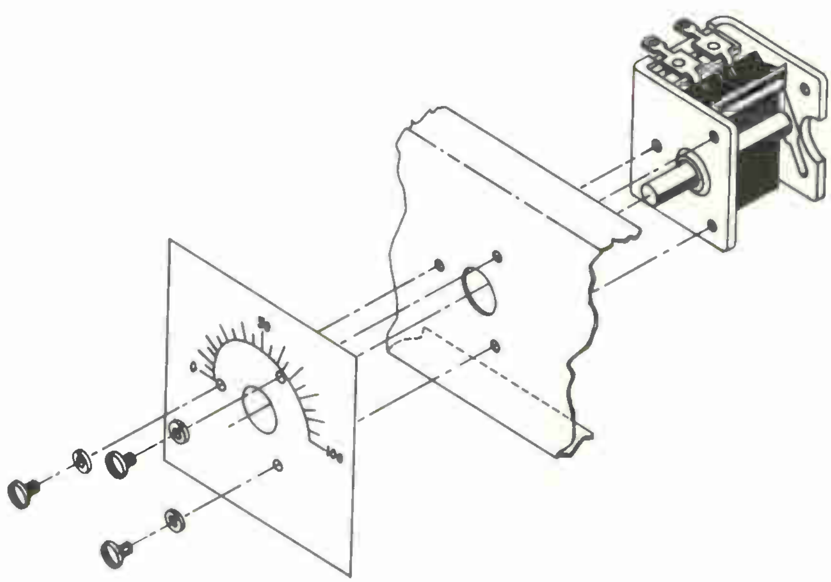

Fig. 10. Mounting the tuning capacitor on the front panel.

clockwise and install the knob in the 7 o'clock position.

WIRING THE CIRCUITS

You will begin your wiring by modifying the high and low voltage power supplies. Then you will wire the i-f oscillator and i-f amplifier circuits.

Gather the following parts:

- 1 12BA6 tube
- 1 1-megohm resistor
- 2 10k-ohm resistors
- 1 3.3k-ohm resistor
- 1 470-ohm resistor
- 1 .1-mfd tubular capacitor
- 2 .01-mfd disc capacitors
- 1 .001-mfd disc capacitor
- 1 470 pf disc capacitor

Power Supplies. The power supply circuits are shown in the schematic diagram in Fig. 11. First short terminal A4 to ground with a screwdriver to discharge the filter capacitor. Then unsolder and disconnect the red and red/yellow power transformer leads from terminals A1 and A2. Also disconnect and remove the rectifier connected between terminals A2 and A4. Solder the red transformer lead to terminal A1 and the red/yellow lead to terminal A2.

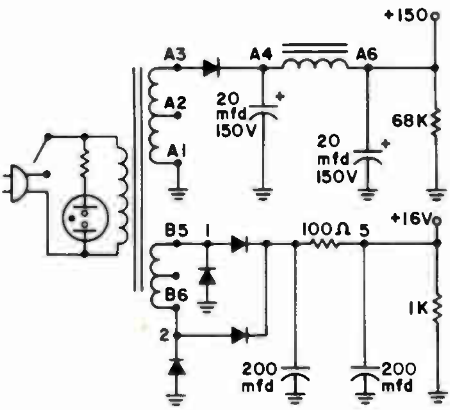

Fig. 11. High and low voltage power supplies.

Next, unsolder and disconnect the leads of the filter choke from terminals B2 and B3 and reconnect them to terminals A4 and A6. Terminal A6 is the +150V source (B+).

Reconnect the 100-ohm resistor between the positive leads of the input and output filter capacitors on circuit board EC24. Lug 5 of EC24 is the +16V terminal.

RF Circuits. To wire the rf oscillator and i-f amplifier circuits follow the schematic diagram in Fig. 12. The terminals are identified in the parts layout diagram in Fig. 9. The tuning capacitor is grounded through its frame and mounting to the chassis. The coil windings shown in the transistor circuit are windings of the oscillator coil on the front of the chassis. The windings shown in the plate circuit of the tube are the windings of the i-f transformer mounted at hole L.

All wiring, unless otherwise indicated, is on circuit board EC25. Where a ground is indicated, use a grounded terminal or solder directly to the foil at the end of the printed circuit board.

To wire the circuit, proceed as follows:

Connect a 10k-ohm resistor and a .01-mfd capacitor in parallel between lug 11 and ground. Connect a 10k-ohm resistor between lug 11 of EC25 and lug 5 of EC24.

Connect a 3.3k-ohm resistor and a .001-mfd capacitor in parallel between lug 12 and ground. Connect a 470 pf capacitor between lugs 1 and 12.

Connect a length of hookup wire from lug 1 to the green terminal of the oscillator coil.

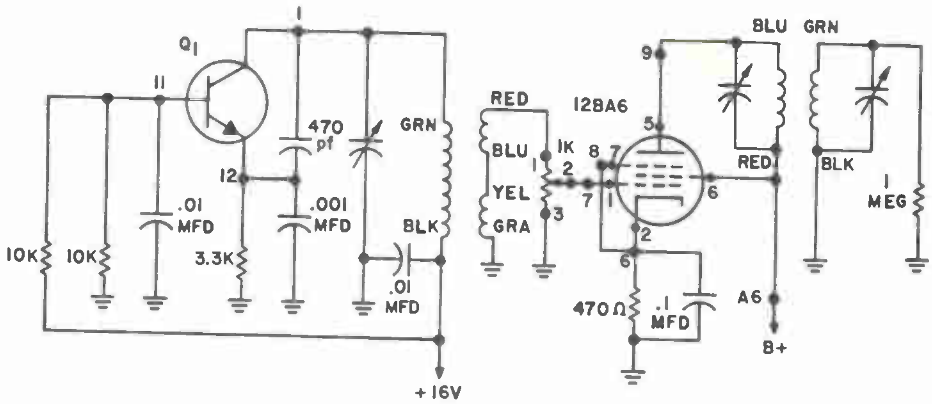

Fig. 12. The rf oscillator and amplifier circuit.

Prepare a 3-inch length of hookup wire. Push one end through the hole near lug 1 of the circuit board from the phenolic side of the board and solder. Solder the other end to the terminal at the lower rear corner of the tuning capacitor.

Connect a length of hookup wire from the black terminal of the oscillator coil, CO43, to lug 5 of EC24. Solder a .01-mfd capacitor between the black terminal and the ground lug. Connect a short length of wire between the gray terminal and the ground lug.

Solder a length of wire between the blue and yellow terminals of the oscillator coil. Solder a length of wire between the red terminal of the coil and terminal 1 of the 1k-ohm potentiometer mounted on the right side of the chassis. (The terminals are numbered clockwise from the shaft end of the potentiometer.) Solder a length of wire between terminal 2 of the potentiometer and lug 7 of the EC25 circuit board. Connect and solder a wire from terminal 3 of the potentiometer to ground.

Connect a length of wire between lugs 6 and 8 of EC25. Connect a 470-ohm resistor and a .1-mfd tubular capacitor in parallel between lug 6 and ground.

Connect a length of wire from the red terminal of the i-f transformer to terminal A6. Notice that pin 6 of the tube does not connect to any of the lugs on EC25. There are two holes in the foil instead. Solder a length of wire from one of these holes to the red terminal of the i-f transformer. Connect a wire from lug 9 to the blue terminal of the i-f transformer.

Connect a short length of wire from the black terminal of the i-f transformer to ground. Connect a 1-megohm resistor from the green terminal of the transformer to ground.

To wire the filament circuit, solder a length of wire from terminal B5 to lug 4 and solder a length of hookup wire from terminal B6 to lug 5. Be sure the wires already connected do not come loose from terminals B5 and B6. Insert the 12BA6 tube in the socket on the experimental circuit board.

When you complete the wiring, check your work carefully, then energize the circuit and observe that the filament in the tube lights up.

To test your circuit, measure the oscillator output voltage. Set your tvom to measure 3V ac and measure the voltage between the red terminal of the oscillator coil and the chassis. You should read

1V or more. If not, check for +16V at lug 5 of EC24 and check the oscillator wiring. Assuming that the oscillator is working, measure the ac voltage at the plate of the amplifier. Turn the shaft of the 1k-ohm potentiometer fully clockwise. While measuring the voltage, rotate the shaft of the tuning capacitor throughout its range. If you get a reading of over 5 volts, you can assume that the oscillator and amplifier are both working correctly.

Turn your equipment off.

HOW THE CIRCUITS WORK

At present you have a high voltage power supply supplying about +150V dc to the plate and screen circuits of the vacuum tube. From the schematic in Fig. 11, you can see that it is a half-wave supply with a pi-type filter network. The full HV secondary winding of the power transformer is used for maximum output voltage.

The low voltage supply is also a bridge type with a pi-filter network. The filter uses two capacitors and a small series resistor instead of a choke.

The rf oscillator is a Colpitts, using an NPN transistor. The transistor is connected in a grounded base configuration. The base is held at ac ground by the .01-mfd capacitor in shunt with the base bias resistors.

The resonant circuit for the oscillator consists of the primary winding of the oscillator coil in parallel with the 470 pf and .001-mfd capacitors and the tuning capacitor. The .01-mfd capacitor at the black transformer terminal has such a low reactance at the signal frequency that this end of the coil winding is at signal ground. The 470 pf and the .001-mfd capacitors form a capacitive voltage divider. This divider taps off and feeds back part of the collector output signal voltage to the emitter to sustain oscillations.

Combination bias is used. Forward bias voltage is supplied by the voltage divider across the base circuit and the resistor connected between ground and the emitter provides reverse bias.

The tuning capacitor varies the frequency of the oscillator by varying the total capacitance in shunt with the oscillator coil. The output signal is coupled inductively from the primary to the secondary winding. Note that the two secondary windings are series-connected for greatest output. This voltage is developed across the 1k-ohm potentiometer which will serve as an oscillator output level control.

The rf amplifier uses the 12BA6 tube connected as a pentode. The amplifier uses cathode bias, developed by cathode current flowing through the 470-ohm resistor. The i-f transformer in the plate circuit can be tuned to resonance by the trimmer capacitors connected across the windings.

EXPERIMENT 56

Purpose: To show that in a double-tuned circuit: (a) loose coupling gives low output and a sharp response; (b) there is a degree of coupling – called critical coupling – that gives maximum output voltage; and (c) overcoupling gives a broad double-peaked response; and to show that loading the secondary of a double-tuned transformer reduces the output and flattens the response.

Introductory Discussion: The output of an amplifier stage is of no practical use unless it can be effectively coupled to a load. This coupling can be accomplished in a variety of ways, as you have learned in your regular lessons and in previous experiments.

The i-f amplifier stages of almost all superheterodyne AM and FM sound receivers are coupled through a transformer having both the primary and secondary windings tuned to resonance at the intermediate frequency. A winding can be tuned by changing the setting of a variable capacitor connected across it, or by varying the position of a powdered-iron slug inside the winding, thus varying its inductance.

When a given voltage is applied across the primary winding of a coupling transformer, the amount of voltage developed across the secondary winding depends upon a number of factors, the most important of which are: (a) the degree of coupling between the two coils; (b) the Q of the transformer; and (c) the accuracy with which the primary and secondary coils are adjusted to resonance with the frequency of the input voltage.

In this experiment, you will vary the degree of coupling between the coils and note the effect upon the output voltage and upon the response over a wide range of frequencies.

The i-f transformer is designed to operate most effectively within the frequency range from 400 to 500 kHz.

The tuning range of the rf oscillator is from about 380 kHz to about 570 kHz, as shown in the graph in Fig. 56-1. From this graph, you can see that if you set the variable capacitor to 50 on its reference dial scale, the frequency produced by the oscillator will be very close to the 456 kHz frequency at which the i-f transformer was intended to be operated.

The response curve of a circuit is a graph in which output voltage is plotted against frequency. Normally, the frequency is varied in even steps and the voltage is plotted at each point. A smooth curve is then drawn connecting these points.

To get the response curves for a given degree of coupling, you will set the pointer knob on the tuning capacitor shaft to 50 on the dial scale, and adjust both i-f transformer trimmers for maximum output voltage at that frequency. Then, without touching the settings of

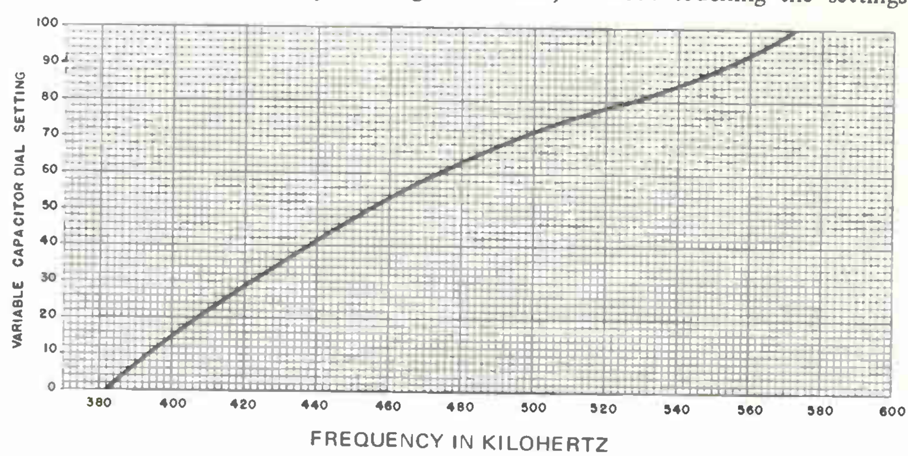

Fig. 56-1. Tuning range of the rf oscillator with .001-mfd capacitor and 470 pf capacitor across oscillator coil and tuning capacitor.

the i-f trimmers, you will tune the oscillator throughout its range and measure the rf output voltage as you do so. To show the effect of loading on the circuit response, you will connect a smaller resistor across the transformer output winding. You will again measure the rf output voltage. By comparing the results of the two steps, you will be able to see the circuit response for the two circuit conditions.

Experimental Procedure: For this experiment, you will need your tvom, your chassis and the following parts:

1 47k-ohm resistor
1 Test clip (CL8)

In this experiment, you will use the oscillator and amplifier circuits which you constructed earlier. The circuit is shown in Fig. 12.

To align the i-f transformer to approximately 456 kHz, proceed as follows:

First set the coils of the i-f transformer as far apart as you can to get minimum coupling. Only the coil at the open end of the fiber form is movable. Pull this coil gently and carefully toward the open end of the form until the distance between the two coils, measured between the inside faces of the coils, is 1-1/16 inches. This is distance D in Fig. 56-2. The open end of the fiber form is flared outward slightly to keep the coil from falling off. Don't pull the coil beyond this flare. If it does not reach 1-1/16 inches, use the maximum distance you can get as minimum coupling.

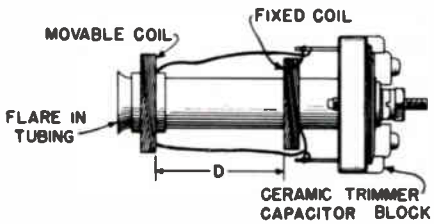

Fig. 56-2. Measure distance D when adjusting the i-f coils for different degrees of coupling.

Set the knob pointer on the variable capacitor that controls the rf oscillator frequency to exactly 50 on the calibrated scale. Use a small screwdriver through chassis holes L_1 from the bottom and L_2, and turn both trimmers of the i-f transformer as far as they will go easily in the clockwise direction. Then back each one off 1/4 turn. Turn the rf oscillator output control (the 1k-ohm potentiometer) for full output – all the way clockwise.

Slip the test clip on the probe of your tvom. Then you can clip the probe to the test point and have both hands free.

Connect the ground clip of the tvom to the chassis, and the probe to the green terminal of the i-f transformer which is the output terminal. Turn on the power.

Turn the trimmer adjustment screw through chassis hole L_2. Turn this adjustment in the direction that gives an increased voltage. Switch to higher voltage ranges of the tvom, when necessary, to keep the meter pointer from going off scale. If you find the meter pointer tends to go off scale when the 120-volt range is used, readjust the 1k-ohm potentiometer to reduce the output from the oscillator so that you will stay on this voltage range. Continue adjusting the trimmer through hole L_2 until you find the maximum reading.

Adjust the trimmer through chassis hole L_1 for maximum output; then readjust the trimmer through hole L_2 for maximum output. This is necessary to compensate for the interaction between the coils of the i-f transformer. If the output exceeds 120V, set the 1k-ohm potentiometer for a lower input. Now, make a final touchup adjustment of both trimmers to be sure that you have them set at the positions that give the maximum meter reading.

The adjustments you have made tune the i-f transformer to resonance with the frequency produced by the rf oscillator. For the rest of the experiment, the tuning of the i-f transformer will remain essentially the same as you have it now.

Step 1: To determine the frequency response of the rf amplifier stage.

Proceed as follows:

First, set the variable tuning capacitor at zero (0) on the calibrated scale (maximum capacity), so that the rf oscillator will produce its lowest frequency.

Set the rf oscillator output control (the 1k-ohm potentiometer) to apply exactly 1 volt (measured on the 3V range) to the control grid, pin 1, of the 12BA6 tube. If you make this adjustment accurately, you will not need to recheck it during any one set of frequency measurements at a particular coil spacing. The tuning range of the oscillator will be restricted to the low frequencies, at which the output of the oscillator is essentially constant.

Reconnect the probe of your tvom to the 1-megohm load resistor at the green transformer terminal, set the range switch to 12V, and measure the rf voltage. Enter your reading for the 0 dial setting in the first space in the first column of Fig. 56-3. If this voltage is less than 1 volt on the 12V scale, estimate the value as well as you can. *Don't switch to a lower range – take as many measurements as possible on the same scale.*

Set the oscillator tuning control to 30, 40, 50, 60, 70, and 100, and record the output voltage for each setting in the first column of Fig. 56-3. As the frequency of the oscillator approaches that to which the i-f transformer has been tuned, the output voltage should become high enough to make it possible to use the 120V range. The highest voltage you get should be when the oscillator frequency control is set at 50, the frequency to which the i-f transformer was adjusted.

DIAL SETTING	STEP 1 1-1/16"	STEP 2 5/8"
0	.82	5.2
30	.52	5.2
40	.94	7
50	.92	5
60	.56	5.4
70	0	5.5
100	0	2.2

Fig. 56-3. The chart for Steps 1 and 2 with a 1 megohm load on the transformer.

When you have finished this frequency run, return the oscillator tuning control to 0, and turn off the power supply.

The fixed coil of the i-f transformer is the primary winding, which is in the plate circuit of the amplifier stage, and is above ground potential by an amount equal to the dc plate voltage. For safety's sake, therefore, **ALWAYS TURN OFF THE POWER SUPPLY** before touching the coils to change the coupling.

Step 2: To show that closer spacing produces greater output.

Turn off the power and set the coils 5/8 inch apart. Rotate the tuning knob smoothly from zero to 100 on the dial scale and observe how the output varies. You should see the voltage rise to a peak at a dial setting of 50 and fall to a low value, as in Step 1. However, the peak rf voltage should be much higher than that obtained in Step 1. Record the voltages at zero, 30, 40, 50, 60, 70 and 100 on the dial scale in the second column of the chart in Fig. 56-3.

Step 3: To show the effects of over-coupling.

Set the coils 3/8 inch apart, and, after checking the rf input voltage to see that it is still 1 volt, repeat the frequency run: Rotate the tuning knob smoothly from zero to 100 while observing the rf output voltage. This time there should be two voltage peaks, with one below and one above the resonant frequency of the i-f transformer.

Repeat the test and record the frequency settings for the two peaks. These peaks may or may not be of equal value and may or may not be spaced an equal distance away from the resonant frequency setting of 50 at which the previous signal peaks were obtained. Furthermore, the peaks may not occur at one of the main scale divisions. Record the frequencies at which the peaks occur and the peak voltages in the chart in Fig. 56-4. Also, record the voltage with the dial set to 50.

	LOW PEAK	CENTER	HIGH PEAK
DIAL SETTING			
VOLTAGE			

not obtained

Fig. 56-4. The chart for Step 3.

	LOW PEAK	CENTER	HIGH PEAK
DIAL SETTING			
VOLTAGE			

only one pk.

Fig. 56-5. The chart for use with Step 4.

Step 4: To show the effect of loading an overcoupled circuit.

Remove the 1-megohm resistor across the transformer secondary and replace it with a 47k-ohm resistor. This increase in the load increases the current drawn from the transformer. Repeat the frequency run with the coil spacing still at 3/8 inch.

Again, you should find two voltage peaks, but now the maximum voltages should be much less than those you measured in Step 3. The difference between the maximum voltages and the voltage at resonance, 50 on the scale, should be much less than it was in Step 3, when the load was much less. The actual peak voltage on each side of resonance may not occur at a main scale division.

Find and record the actual positions and the peak voltages as in the previous step. Record your readings in Fig. 56-5. Also, record the voltage at the dial setting of 50.

Turn your equipment off.

Discussion: You have observed the output of an i-f amplifier with a double-tuned output transformer under various conditions. In Step 1, you had maximum spacing between the transformer coils, and hence minimum coupling. The response curve of the transformer is represented by curve 1 in Fig. 56-6.

The curve shows that the transformer passes little signal voltage at the dial setting of zero. The voltage rises to a maximum at 50, decreasing again as the oscillator is tuned higher. We can see that the transformer is resonant at 50 or that its center frequency is at a dial setting of 50.

Note that at dial settings of about 45 and 55 the voltage is about 70% of its maximum value. These points on the graph are called the half power points, in that the voltage and current are about 70% of the voltage and current at resonance. Thus, the transformer bandpass, the band of frequencies between the half power points, is about 20 kHz, as determined from the chart in Fig. 56-1.

In Step 2, closer spacing of the i-f transformer coils was used. This change produced a higher peak voltage and a slightly broader bandpass, as shown by curve 2 in Fig. 56-6. Note that the peak still occurred at the same frequency, with a dial setting of 50. The coil spacing was very close to "critical" coupling, which is the spacing that produces maximum output at the center frequency.

With a coil spacing of 3/8 inch in Step 3 you should have obtained a double peak response as in curve 3 in Fig. 56-6. The coils were overcoupled and they interacted with each other. You will note that the output at the center frequency was lower than in Step 2. The resonant frequency of one coil became lower, and the resonant frequency of the other became higher than their natural frequencies. This resulted in the peaks on either side of the center frequency. Because of the two peaks, the bandwidth of the overcoupled transformer is greater than it is with critical coupling.

In Step 4, if you plotted the points, you would have found a response curve similar to the graph in Fig. 56-7. Comparing this with curve 3 of Fig. 56-6, you can see that loading the output of the transformer lowered the output voltage at the peaks and broadened the bandwidth.

Loading in this manner is a technique used frequently to increase the bandwidth of a resonant circuit. It reduces the output voltage and makes the bandpass curve more gradual.

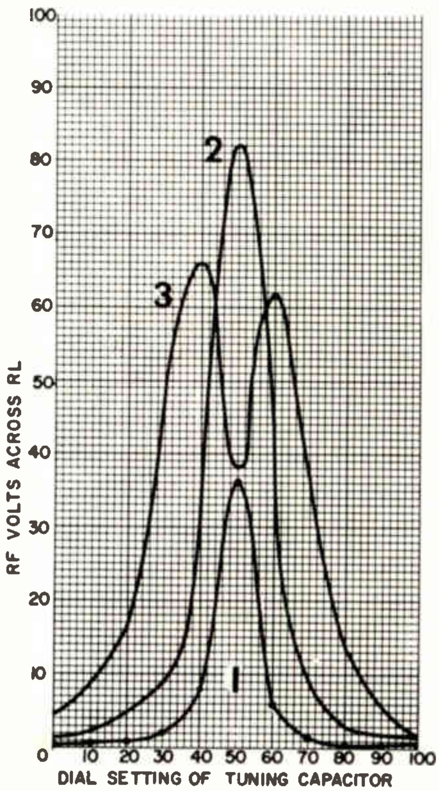

Fig. 56-6. Curves plotted from typical values for different degrees of coupling with a 1-megohm load resistor.

Instructions for Statement 56: For this Statement, you will determine the effect of loading the transformer when there is wide spacing between the coils.

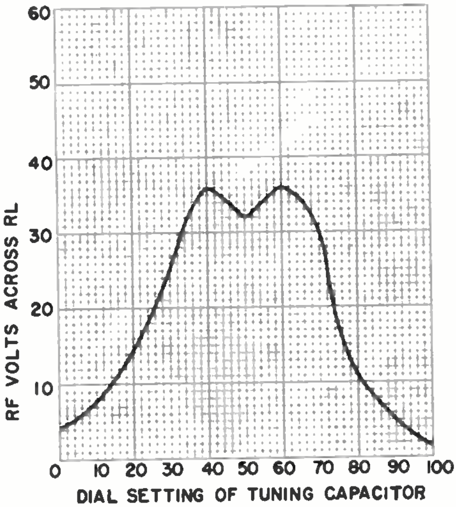

Fig. 56-7. Typical curves for a 47k-ohm load resistor and 3/8-inch spacing.

Set the coils 5/8 inch apart. At this spacing, you should have a single-peak response curve. With the 47k-ohm resistor in the circuit, run the frequency test and note the voltage across the load resistor. Note the voltage at dial settings of 10, 40, 50, 60 and 90.

Compare these voltage readings with those you recorded for Step 2 in Fig. 56-3 and answer the Report Statement.

Statement No. 56: When I loaded the secondary winding I found that the output voltage was:

(1) lower than
(2) higher than
(3) the same as

the voltage I obtained for the same coupling but with a higher load resistance in Step 2 and the bandpass was

(1) wider than
(2) narrower than
(3) the same as

the bandpass of the circuit in Step 2.

EXPERIMENT 57

Purpose: To show that an amplifier stage can provide both gain and amplitude limiting of an rf signal and to show diode limiting.

Introductory Discussion: A limiter is a special type of i-f amplifier stage used in many FM receivers. Its function is to limit the amplitude of the FM i-f signal, thereby removing the variations in the strength or amplitude of the signal reaching the demodulator. The block diagram in Fig. 57-1 shows the location of the limiter in the signal path of a typical FM receiver.

An FM signal has the intelligence in the variations in the frequency of the carrier wave about the assigned center frequency. The transmitted signal has uniform amplitude. Along the transmission path between the transmitting and receiving antennas, the signal picks up noise from vehicle ignition, static, etc. The noise takes the form of variations in the amplitude of the FM signal.

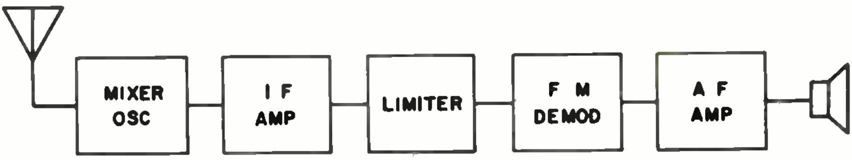

Fig. 57-1. Block diagram of a basic FM receiver.

For noise-free reception, it is necessary to either remove the noise before the signal is demodulated, or to use a demodulator which is not sensitive to amplitude variations. As you will see, both methods are used.

Limiting is usually accomplished in one of two ways:

One or two limiter stages are connected into the signal path between the i-f amplifier stages and the demodulator or diodes are placed across the secondary winding of one or more i-f transformers.

Experimental **Procedure**: For this experiment, you will need the experimental chassis, your tvom and the following parts:

- 1 **100k-ohm resistor**
- 1 **47k-ohm resistor**
- 2 **22k-ohm resistors**
- 1 **6.8k-ohm resistor**
- 2 **4.7k-ohm resistors**
- 1 **100-mfd electrolytic capacitor**
- 1 **.1-mfd tubular capacitor**
- 2 **Signal diodes (CR10)**

You should have circuit board EC25 on your chassis and the board should have 2 NPN transistors mounted on it. You should also have the 1k-ohm potentiometer mounted inside the right side of the chassis at hole AZ.

Unsolder and remove all parts and leads connected to lugs 6, 7, 8 and 9 of the circuit board. Also, unsolder all connections to the i-f transformer and remove the transformer from the chassis. Remove the 12BA6 tube from the socket.

Construct the transistor amplifier circuit shown in the schematic in Fig. 57-2. Note that the oscillator circuit is unchanged. The amplifier transistor (Q_2) is

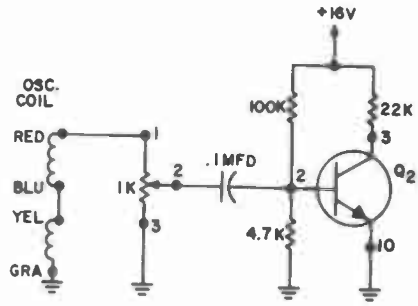

Fig. 57-2. The limiter-amplifier circuit diagram.

already on the circuit board. Its base, collector and emitter leads are connected to lugs 2, 3 and 10, respectively. Ground lug 10 with a short length of wire. Connect a 4.7k-ohm resistor between lug 2 and ground.

Connect a 100k-ohm resistor between lug 2 of EC25 and lug 5 of EC24. Connect a 22K-ohm resistor between lug 3 of EC25 and lug 5 of EC24.

Connect one end of a .1-mfd tubular capacitor to terminal 2 of the 1k-ohm potentiometer. Notice that there are two solder pads in the foil strip connecting the base of Q_2 to lug 2. Place the .1-mfd capacitor in such a position, ***under the board***, that the lead is near the hole next to the base of Q_2. Poke the lead of the capacitor through the hole in EC25 near the base of Q_2 and solder.

Be sure to check your work carefully against the schematic diagram.

Step 1: To show that the amplifier gain varies with the input signal level.

Energize the circuit and check it as follows: Rotate the knob on the 1k-ohm potentiometer fully clockwise and measure the ac voltage at the base and collector of the rf amplifier, Q_2. You should have at least .2V at the base (lug 2) and 2V at the collector (lug 3).

INPUT VOLTAGE	OUTPUT VOLTAGE	GAIN
.05V	1.14	22.8
.1	1.18	11.8
.2	1.21	6.05
.4	1.28	3.2
.6	1.35	2.25
.8	1.41	1.7625
1.0	1.45	1.45

Fig. 57-3. Chart for Step 1.

Now move the tvom probe to terminal 2 of the 1k-ohm potentiometer. Adjust the potentiometer for an input signal of .05V. Measure the collector voltage and record it on the chart in Fig. 57-3. Readjust the input to the base to .1V and measure and record the corresponding collector signal voltage. In a similar manner, set the input to each of the voltage levels given in the first column in Fig. 57-3 and measure and record the resulting ac output voltages at the collector.

When you complete the chart, compute the gain of the amplifier at the various input levels. Record the gain for each input voltage in the third column.

Step 2: To demonstrate how low supply voltage affects limiter action.

For this step, you will use the circuit shown in Fig. 57-4. Unsolder the lead of the 22k-ohm resistor from lug 3 of EC25 and connect it to lug 4 of EC24. Connect a 6.8k-ohm resistor and a 100-mfd electrolytic capacitor between lug 4 of EC24 and ground. Note that the positive capacitor lead goes to lug 4. Connect a 4.7k-ohm resistor between lug 4 of EC24 and lug 3 of EC25. Energize the circuit and measure the dc voltage at lug 4 of EC24. This is the supply voltage for the limiter stage. Jot down the value in the margin. Measure the ac voltage at lug 4 of EC24. You should read zero, as this point is at signal ground.

2.5V

Now apply each of the input voltage levels given in the chart in Fig. 57-5 and measure and record the corresponding output voltages. You should find that limiting takes place at a low input signal level.

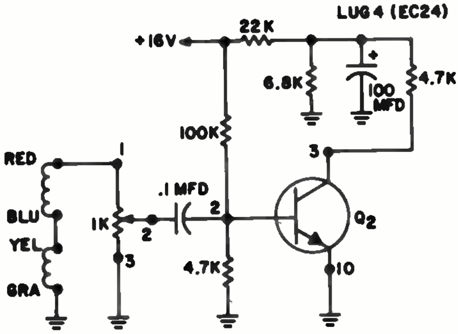

Fig. 57-4. The circuit for Step 2.

INPUT VOLTAGE	OUTPUT VOLTAGE
.05	.038
.1	.041
.2	.041
.4	.041
.6	.041
.8	.042
1.0	.043

Fig. 57-5. The chart for Step 2.

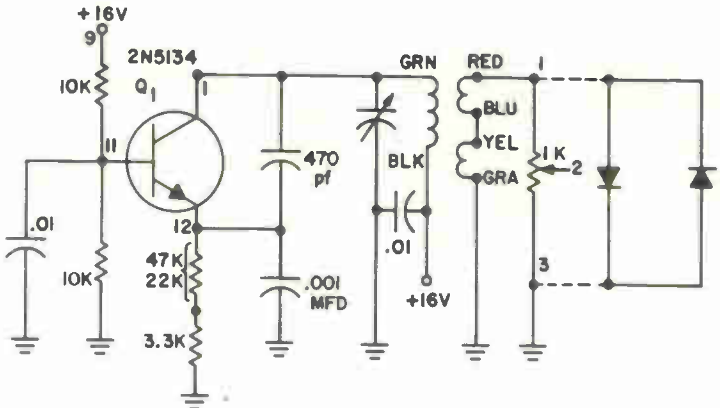

Fig. 57-6. The circuit used in Step 3.

Step 3: To show diode limiting.

For this step, you will connect diodes across the secondary winding of the oscillator transformer. You will then vary the oscillator output level and observe the effect of the diodes on the output signal level. You will use the circuit shown in Fig. 57-6.

Unsolder and disconnect the .1-mfd capacitor from terminal 2 of the 1k-ohm potentiometer and push the lead aside. Also disconnect the lead of the 3.3k-ohm emitter resistor from lug 12. Connect a 47k-ohm resistor between lug 12 and the free lead of the 3.3k-ohm resistor. Energize the circuit and measure the ac voltage across the 1k-ohm potentiometer, which is the output load resistance. You can connect the tvom between the red terminal of the oscillator coil and ground. Record your voltage reading on the first line of the second column of Fig. 57-7.

Connect two signal diodes across terminals 1 and 3 of the 1k-ohm potentiometer as shown in Fig. 57-6 by the broken lines. Measure the ac signal voltage across the potentiometer again. Record this value in the second column of Fig. 57-7.

Replace the 47k-ohm resistor in the emitter circuit of the oscillator with a 22k-ohm resistor. Repeat the measurements, first with the diodes disconnected, and then with the diodes connected across the transformer winding. Record both values on the second line of Fig. 57-7.

Unsolder and remove the 22k-ohm

SERIES RESISTOR	LOAD VOLTAGE	
	WITHOUT DIODES	WITH DIODES
47K	.3V	.23
22K	28	0
None	0	0

Fig. 57-7. The chart for use with Step 3.

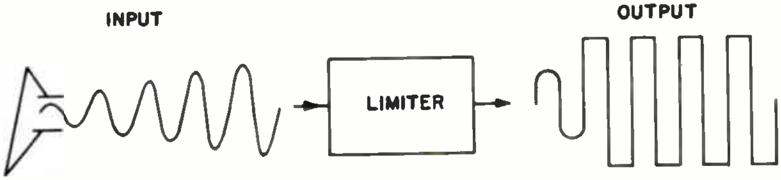

Fig. 57-8. Typical input and output waveforms for a limiter stage.

resistor and reconnect the 3.3k-ohm resistor to lug 12. Again measure the output voltage with and without the diodes and record your voltage readings in the chart.

Turn your equipment off.

Discussion: In this experiment, you demonstrated the action of a limiter-amplifier stage and diode limiting. You should have found that with both methods the output variation was significantly reduced by the limiter action.

The limiter stage which you used in Step 1 can be classified as an overdriven amplifier. The stage has high voltage gain and requires only a very low level of input signal for maximum output. When this level is exceeded, limiting occurs. If the limiter is properly biased, the transistor should be driven into cutoff on one-half of each cycle of the i-f signal and into saturation on the other half-cycle. Fig. 57-8 shows typical input and output signal voltage waveforms for this type of limiter.

Your chart in Fig. 57-3 shows that the amplifier has high gain for low level signals and that the gain drops off as the input signal level is increased. When the input is greater than about .4V, limiting takes place. The output at this point is about 6V. Thus, as long as the signal is .4V or more, the output will be maximum.

In Step 2, you found that the limiter was more effective than it was in Step 1. The transistor became saturated on the positive peaks of the input signal. On the negative peaks, the transistor was cut off and collector voltage rose to the level of the supply voltage, about +3.5V.

In Step 3, you found that the diodes across the transformer secondary winding caused a very noticeable decrease in the amount by which the transformer output voltage varied. At NRI we found that without the diodes, the voltage across the secondary varied from .3 to about 1.5V. This is a change of about 1 to 5. On the other hand, with the diodes in place, the variation was from .3V to .4V. This change was about one-third. Note that the minimum output level was about the same whether or not the diode limiting was used.

The diodes you used are silicon signal diodes which conduct when the voltage at the anode becomes about .6V more positive than the cathode. The diodes are connected with opposite polarities so that one will conduct whenever the voltage across them becomes either positive or negative by about .6V. Each diode conducts on one-half cycle. Therefore, the peak-to-peak voltage across the load will be about 1.2V. Due to the waveform, the tvom will indicate about .4V ac.

In many portable FM receivers, you will see diodes labeled "overload" connected across windings of one or more of the i-f transformers. In reality they are limiters and their function is to limit the amplitude of the signal to minimize distortion in the following stages.

Instructions for Statement 57: For this Report Statement, you will increase the value of the collector load resistor in the limiter circuit used in Step 2 and note the effect on the limiting action.

Remove the two diodes connected across the 1k-ohm potentiometer and reconnect the .1-mfd capacitor to the center terminal of the potentiometer.

INPUT VOLTAGE	OUTPUT VOLTAGE
.05	.12
.1	.12
.2	.12
.4	.12
.6	.12
.8	.12
1.0	.12

Fig. 57-9. The chart for Statement 57.

Replace the 4.7k-ohm resistor connected between the Q_2 collector terminal, lug 3, and lug 4 of EC24 with a 22k-ohm resistor.

Energize the equipment and make the ac voltage measurements necessary to complete the chart in Fig. 57-9. When you finish this, compare the charts in Fig. 57-3 and 57-9 and answer the statement.

Statement No. 57: When I increased the value of the collector load resistor, I found that the limiter circuit:

(1) had higher gain.

(2) limited more sharply.

(3) did not limit.

EXPERIMENT 58

Purpose: To demonstrate amplitude modulation and demodulation.

Introductory Discussion: An AM signal is one in which the amplitude of the fixed frequency carrier is varied by the intelligence or the audio modulating signal. This is illustrated in Fig. 58-1A. An rf carrier and an audio signal are applied to a modulator stage. In this stage the modulating signal causes the amplitude of the carrier to vary. The amount by which the rf amplitude varies is determined by the strength of the audio signal. The rate of amplitude variation is determined by the frequency of the audio signal.

Detection, which is the process of recovering the audio from the rf carrier, is illustrated in Fig. 58-1B. Notice that the modulated rf is fed into the demodulator circuit and the audio signal appears at the output. In the process, the rf carrier is filtered out.

In this experiment, you will use your rf

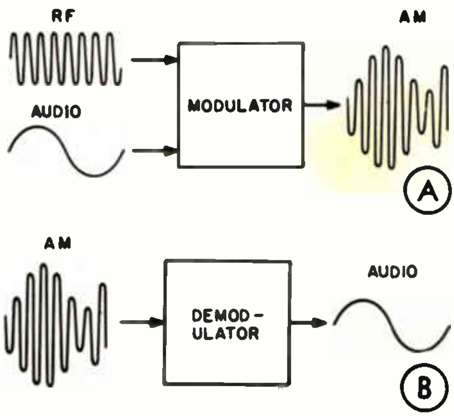

Fig. 58-1. (A) Amplitude modulation; (B) basic amplitude demodulation.

oscillator as an rf carrier signal source. This rf voltage will be modulated by a 60 Hz sine wave to produce an amplitude modulated signal similar to that shown in Fig. 58-1. The modulated rf will be transformer-coupled to a diode detector circuit. As you will demonstrate, the detector recovers the 60 Hz modulating signal.

Experimental Procedure: For this experiment, you will need the experimental chassis with the power supply and rf oscillator circuit, your tvom and the following:

- 1 PNP transistor (TS22, 2N5138)
- 1 RF transformer (TR31)
- 1 150k-ohm resistor
- 1 100k-ohm resistor
- 1 15k-ohm resistor
- 1 4.7k-ohm resistor
- 1 1k-ohm resistor
- 1 .25 mfd tubular capacitor
- 2 .05 mfd disc capacitors
- 1 .001 mfd disc capacitor
- 1 470 pf disc capacitor
- 1 Trimmer capacitor (CN58)
- 1 50k-ohm potentiometer (PO100)
- 1 Signal diode (CR10)
- 1 4-lug terminal strip
- 1 3/8" X 6-32 screw
- 1 6-32 hex nut

Before you begin the experiment, you must prepare the chassis and circuit board. Unsolder and remove transistor Q_2 and all parts and leads connected to lugs 2, 3 and 10 of the experimental circuit board and lug 4 of circuit board EC24. Be careful to avoid overheating the transistor.

The PNP transistor should have been removed from the other experimental circuit board (EC26). Solder the PNP transistor to circuit board EC25 as shown in Fig. 58-2.

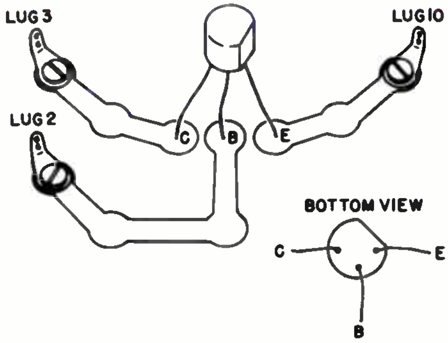

Fig. 58-2. Mounting the 2N5138 transistor.

Refer to Fig. 58-3 as you perform the next four steps.

Mount the rf transformer at holes AL and W. Position the transformer so the terminals color-coded red, yellow and blue are toward the front of the chassis. Remove the screw at hole W. Also remove one nut from each mounting screw on the rf transformer. Slip the mounting screws through the holes in the chassis, attach the nuts and tighten.

Remove the 1k-ohm potentiometer from hole AW, and install a 50k-ohm potentiometer in its place.

Mount the trimmer capacitor on top of the chassis at hole AK. Use the screw, lockwasher and nut just removed from the chassis.

Install a 4-lug terminal strip at hole U. Position the strip as shown. Attach with a 6-32 screw, lockwasher and nut. This is terminal strip C and its terminals are labeled on the photo.

Now wire the circuit shown in the schematic diagram in Fig. 58-4. The oscillator circuit is unchanged. However, note that only the blue/red winding of the oscillator transformer is used to couple the rf signal to the experimental circuit.

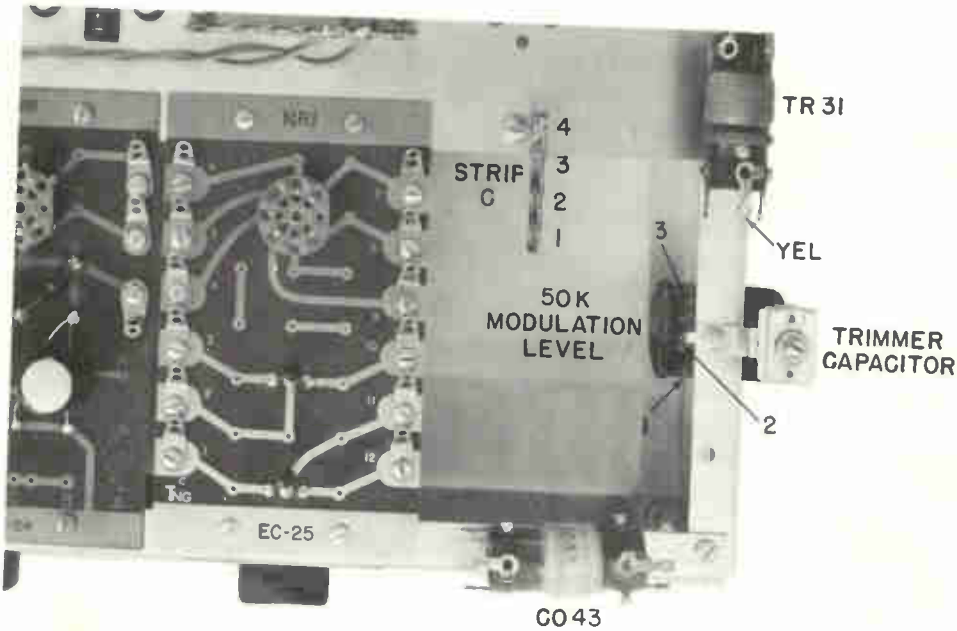

Fig. 58-3. Mounting the parts on the chassis.

The circuit is fairly complex. To avoid undesirable coupling, etc., perform the wiring carefully. Use short lengths of hookup wire when possible and route the leads where they will not cause interference.

Unsolder and disconnect all leads and parts from the gray, yellow, red and blue terminals of the oscillator coil.

Unsolder the lead of the 10k-ohm resistor from lug 5 of EC24 and solder it to the black terminal of the oscillator coil.

Connect a length of wire from lug 5 of EC24 to lug 9 of EC25.

Connect a 1k-ohm resistor between lug 9 and lug 10 of EC25.

Connect a .001-mfd capacitor between

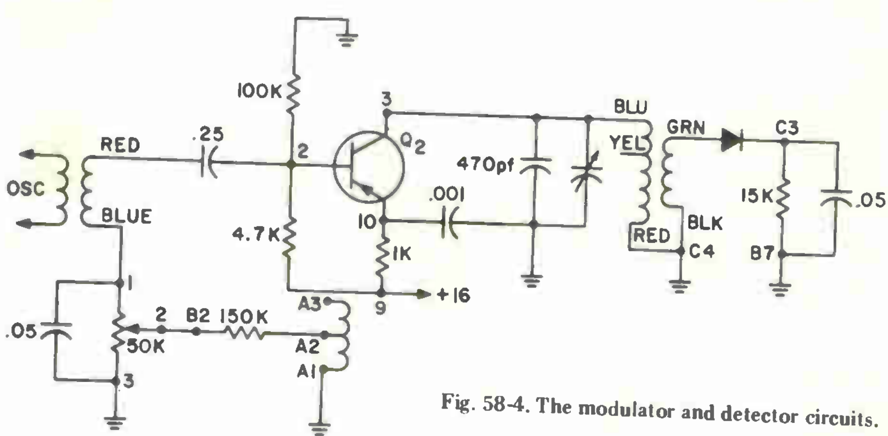

Fig. 58-4. The modulator and detector circuits.

lug 10 of EC25 and terminal C4. Solder lug 10.

Connect a 4.7k-ohm resistor between lug 5 of EC24 and lug 2 of EC25.

Solder a 100k-ohm resistor between lug 2 of EC25 and ground.

Connect a .25-mfd capacitor from the red terminal of the oscillator coil to the foil near lug 2 of EC25. Position the capacitor under the circuit board and push the lead up through the hole in the foil. Solder both connections.

Connect a length of wire from the blue terminal of the oscillator coil to the terminal of the 50k-ohm potentiometer nearest the front panel. Solder the potentiometer terminal.

Solder a .05-mfd capacitor between the blue terminal of the coil and ground.

Connect a length of hookup wire from terminal 3 (the terminal toward the rear) of the 50k-ohm potentiometer and terminal C4. Solder the lead to the potentiometer terminal.

Connect a 150k-ohm resistor between terminals A2 and B2. Solder A2.

Solder a length of hookup wire from terminal B2 to the center terminal of the 50k-ohm potentiometer.

Before you connect any leads to the rf transformer, be sure to remove all wax from the terminals. If any wax remains on the terminals it will be impossible to make a solder connection.

Connect a short length of hookup wire from the blue terminal of the rf transformer (TR31) to the nearer terminal of the trimmer capacitor. Connect a length of wire between the red transformer terminal and the free terminal of the capacitor. Solder both capacitor terminals carefully. Make sure all of the blades are soldered at each terminal.

Solder a 470-pf disc capacitor across the terminals of the trimmer capacitor.

Solder a length of hookup wire from lug 3 of EC25 to the blue terminal of the rf transformer.

Connect a length of wire between the red and black terminals of the rf transformer. Solder the red terminal.

Solder a length of hookup wire from the black terminal of the rf transformer to terminal C4.

Solder the anode lead of a signal diode to the green terminal of the rf transformer. Solder about a 2-inch length of wire to the cathode lead and connect the end of the wire to terminal C3.

Solder a .05-mfd capacitor and a 15k-ohm resistor in parallel between terminals C3 and B7.

Check your wiring with the schematic and be sure all connections are soldered.

Step 1: To adjust the modulator circuit.

Slip the test clip on the probe of the tvom and clip it to the green terminal of the rf transformer. Clip the ground lead to the chassis. Set the tvom to measure ac voltage on the 12V range. The polarity switch should be in the normal position.

Set the oscillator frequency selector to 70 on the dial scale, turn the 50k-ohm potentiometer fully counterclockwise, and energize the circuit. Adjust the trimmer capacitor fully clockwise. While observing the meter, turn the adjusting screw in the trimmer capacitor slowly counterclockwise. The reading should rise to a peak and then begin to fall. Set the trimmer for the voltage peak near the fully clockwise position. Readjust the frequency control to 50 on the dial. Use this frequency throughout the experiment.

Move the tvom probe to terminal C3 and measure the ac voltage at the output of the diode detector. Vary the 50k-ohm potentiometer, which is the modulation level control, and note the variation in the ac voltage. If necessary, switch the tvom to a lower range.

Step 2: To show amplitude modulation.

Turn the modulation control fully counterclockwise. Connect your tvom to measure the ac voltage between the green terminal of the rf transformer and ground. The tvom will indicate the unmodulated rf carrier voltage across the transformer winding. Record your reading in the first column in Fig. 58-5.

Turn the modulation control fully clockwise, then disable the rf oscillator by shorting lugs 11 and 12 of EC25 together. This will stop the oscillator. Again measure the ac voltage across the winding with modulation applied and with the oscillator stopped. Record your reading in the second column of Fig. 58-5. When you have recorded your results remove the short from the oscillator circuit.

With the modulation control still set fully clockwise and the oscillator operating, measure the amplitude modulated voltage across the transformer secondary winding. Record this value in the last column of Fig. 58-5.

Step 3: To show diode detection.

Move the tvom probe to terminal C3. Your meter now reads the voltage across the diode detector load consisting of the 15k-ohm resistor and the .05 mfd capacitor.

(A) Turn the modulation control to minimum (fully counterclockwise) and measure and record the ac voltage in the first column for Step 3A Fig. 58-5. Adjust the modulation control to maximum and short lugs 11 and 12 together. Read the ac voltage and record it in the second column of Fig. 58-5. Finally, measure and record the ac voltage with the rf carrier amplitude modulated. Turn the circuit off.

(B) With the tvom probe still connected to terminal C3, switch the tvom to read positive dc voltage on the 3V range.

Turn the circuit on, turn the modulation control fully counterclockwise, and measure the dc voltage with the rf carrier only. Record the reading in the first column of Fig. 58-5 for Step 3B. Similarly, measure and record the dc voltage with the rf oscillator shorted out and modulation applied, and with the rf

STEP	VOLTAGE MEASUREMENT	RF ONLY	60 Hz ONLY	MODULATION
2	AC across secondary			
3A	AC at detector			
3B	DC at detector			

Fig. 58-5. Use this chart for Steps 2 and 3.

oscillator fully modulated. Turn the circuit off.

Step 4: To see the effects of removing the .05 mfd rf filter from the detector load.

Unsolder the lead of the .05 mfd capacitor from terminal C3. Energize the circuit and measure the dc voltage as you vary the modulation control. You should see some small variation.

Switch the tvom to read ac voltage. Observe the ac voltage across the 15k-ohm resistor as you vary the modulation. Note that when you turn the modulation control to minimum, the voltage does not go to zero. Turn the circuit off.

Discussion: An amplitude modulated signal consists of a carrier frequency signal which has intelligence in the amplitude variations. The carrier alone contains no useful information. It must be modulated or changed in some way.

In Step 2, you found that the rf carrier by itself produced an ac voltage across the secondary of the rf transformer. This voltage is proportional to the strength (level) of the carrier. The voltage is present only when the rf oscillator is operating. This is because the 60 Hz modulating frequency is too low in frequency to pass through the resonant circuit in the collector circuit of Q_2.

You should have found in Step 3 that there is an ac voltage at the detector output which varies with the modulation. This is the detected or demodulated 60 Hz ac voltage which was used to modulate the rf carrier. You also found that the detector produced a dc voltage which varied with the strength of the carrier signal.

A diode detector is a half wave rectifier and filter circuit very similar to the circuit you used in your power supply experiments. The diode passes only the positive portion of each cycle of rf, thus causing current flow up through the 15k-ohm load resistor. The .05 mfd capacitor filtered out the pulses of rf voltage, leaving only the low modulating frequency at the output. With the capacitor removed you should have observed that even with no modulation present there was still an ac voltage developed across the 15k-ohm load resistor.

Instructions for Statement 58: For this Report Statement you will simulate a defective detector diode and determine how it affects the detector output signal.

Solder a short length of wire across the leads of the diode between terminal C3 and the green terminal of the rf transformer. Reconnect the lead of the .05 mfd capacitor to terminal C3.

Energize the circuit and measure the ac and dc voltages across the 15k-ohm resistor and .05 mfd capacitor with the modulation control fully counter-clockwise and fully clockwise. This should give you enough information to answer the statement.

Turn the equipment off and answer the Statement here and on your answer sheet.

Statement No. 58: When the diode was shorted, the detector circuit:

(1) worked normally.
(2) produced no output.
(3) produced a high negative dc voltage.

The FM Detector

In your regular lessons you have learned that there are several types of FM detectors in wide use. Two of the more common types in FM receivers are the phase detector, commonly known as the discriminator, and the ratio detector.

When the discriminator is used, it is always preceded by a limiter stage. The purpose of the limiter stage is to eliminate variations in the carrier amplitude caused by static or other electrical noise. The FM signal fed to the discriminator therefore has a constant amplitude.

The ratio detector does not need a limiter stage because, under ordinary conditions, it is unaffected by variations in carrier strength. In this case, the detector can be preceded by an i-f amplifier. You may find in some receivers that a limiter stage is used with a ratio detector. The limiter is added to make certain that no noise pulses get through to the output.

In the next experiment you will study the phase detector or discriminator. Later you will study the ratio detector.

Although the principles of FM operation have been covered thoroughly in your regular lessons, we will review the detector action here. Let us see how a discriminator demodulates an FM signal by studying the basic Foster-Seeley Discriminator shown in Fig. 13.

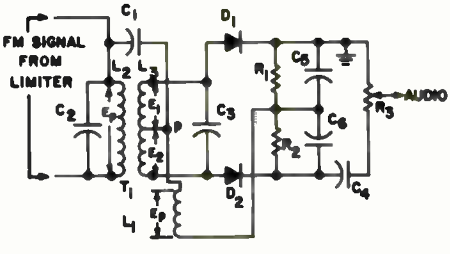

Fig. 13. Basic Foster-Seeley discriminator circuit.

The discriminator transformer, T_1, is of special design. Its primary winding, L_2, is tuned to the resting frequency by C_2, and its center-tapped secondary winding, L_3, is tuned to the same frequency by C_3. The current flowing through L_2 induces a corresponding FM voltage in L_3, and produces across the two sections of L_3 voltages E_1 and E_2, which are always equal in magnitude and 180° out-of-phase with each other.

At the same time, the primary voltage E_p is applied through C_1 to choke coil L_1. Since the reactance of C_1 is small, the voltage across L_1 is very nearly equal to E_p.

The limiter output voltage E_p (across L_1) in series with E_1 is applied to diode 1. Likewise, the limiter output voltage E_p in series with E_2 is applied to diode 2. These voltages are not in-phase: E_1 and E_2 are 180° out-of-phase with each other, and each is out-of-phase with E_p. The net voltage applied to each diode section is, therefore, the vector sum of the two individual voltages acting on that section.

Each diode rectifies its net applied rf voltage, and produces a proportional dc output voltage across its load resistor. The load resistor for diode 1 is R_1, and that for diode 2 is R_2. Electrons flow in opposite directions through R_1 and R_2, as you can easily see by tracing the diode circuits. This means that the combined voltage across R_1 and R_2, which is the output voltage of the discriminator, at any instant is equal to the difference between the individual voltages across these resistors. If the individual voltages are equal, the discriminator output voltage will be zero. If the voltages across R_1 and R_2 are different, the combined voltage will have the polarity of the larger of the two individual voltages, and will be equal in magnitude to their numerical difference.

Now let us consider the factors that make the output voltage of one diode higher than that of the other. First of all, we must choose some reference voltage or current. Since E_p is common to all circuits under study, we can use it as our reference voltage.

Phase relationships in this discriminator circuit must be considered for three different conditions: 1) when the signal frequency is equal to the frequency to which the discriminator resonant circuits are tuned; 2) when the signal frequency is lower than the resonant frequency; 3) when the signal frequency is higher than the resonant frequency. The vector diagrams for these three conditions are shown in sketches A, B, and C, respectively, of Fig. 14, with primary voltage E_p serving as the reference vector in each case. The rf voltage E_s that is induced in secondary winding L_3 is 180° out-of-phase with the primary rf voltage E_p, so it is shown 180° out-of-phase with reference vector E_p in each of the vector diagrams.

When the signal is exactly at the i-f resting value to which the discriminator circuits are tuned (in other words, when no sound is being transmitted), the secondary tuned circuit L_3-C_3 is at resonance, and the secondary current, I_s, flowing through L_3 is in phase with E_s, as indicated in sketch A of Fig. 14. When this current flows through the inductance L_3, the voltage produced across this inductance must lead the current by 90°. The coil ends must always be 180° out-of-phase (when one end is positive, the other is negative). Therefore, if we assume that voltage E_1 leads I_s by 90°,

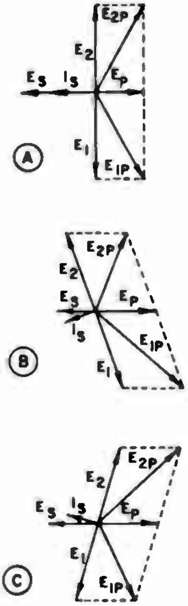

Fig. 14. Phase relationships in the discriminator circuit. (A), when signal is at resonant frequency; (B), when signal frequency is below resonant frequency; (C), when signal frequency is above resonant frequency.

then E_2 must lag 90° behind I_s. This makes E_1 and E_2 each 90° out-of-phase with E_p, because E_p is 180° out-of-phase with I_s.

Adding E_p and E_2 vectorially gives E_{2p} as the resultant voltage acting upon diode 2. Likewise, adding E_p and E_1 vectorially gives E_{1p} as the resultant voltage acting upon diode 1. The vector diagram in sketch A shows these two voltages E_{1p} and E_{2p} for the no-modulation condition; therefore, the dc voltages developed across R_1 and R_2 by the two diodes are equal in magnitude and their sum is zero. This is just as it should be, since no audio signal should be obtained when there is no modulation at the transmitter.

When the frequency of the signal is lower than the i-f resting frequency to which resonant circuit L_3-C_3 is tuned, the circuit becomes capacitive, and I_s leads E_s as shown in Fig. 14B. Since voltages E_1 and E_2 must be 90° out-of-phase with I_s, the resultant voltages (E_{2p} and E_{1p}) are unequal, with E_{1p} (the voltage applied to diode 1) the larger. Referring to Fig. 13, you can see that with diode 1 getting the higher rf voltage, there is a higher dc voltage across R_1 than across R_2. The combined voltage across R_1 and R_2 is, therefore, negative with respect to ground. The more the signal frequency swings below the i-f resting frequency, the greater the negative voltage applied to the audio amplifier input.

By a similar analysis we can get the vector diagram shown in Fig. 14C, in which the signal frequency is higher than the resonant frequency. When this occurs, the net voltage applied to the input of the af amplifier (the sum of the drops across R_1 and R_2) is positive with respect to ground.

Thus the frequency discriminator circuit shown in Fig. 13 produces a dc voltage that is proportional to the deviation between the incoming signal frequency and its resting value. Its polarity is determined by the direction of this frequency deviation. In this way the discriminator converts an FM signal directly into a replica of the original audio signal voltage that was used to modulate the FM transmitter.

RF bypass capacitors C_5 and C_6 in Fig. 13 must have a low reactance at the i-f resting frequency, and yet must have a high reactance at audio frequencies so that there will be no serious shunting effect upon the af voltage developed across R_1 and R_2.

The relationship between the incoming rf signal frequency of an FM receiver and the dc output voltage of a discriminator is

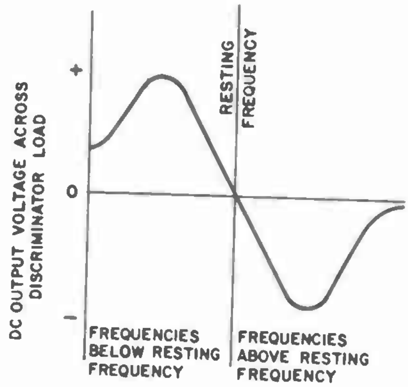

Fig. 15. Typical S response curve for a discriminator circuit.

shown in Fig. 15. At the resting frequency, the dc voltage across the discriminator load resistors is zero when the circuit is properly adjusted. When the frequency is above or below the resting frequency, a dc voltage that is equal to the difference between the voltages across the individual load resistors appears across the combined load. This voltage may be either + or – with respect to the zero level at the resting frequency. A discriminator set up like the one we just described has the response shown in Fig. 15, in which frequencies below resonance produce positive output voltages. This curve is commonly known as an "S" curve.

EXPERIMENT 59

Purpose: To show that in an FM discriminator the amplitude and polarity of the dc output voltage depend upon the frequency deviations of the incoming signal; and

To show that unless this circuit is preceded by a limiter stage, variations in the amplitude of the rf carrier will affect the dc output.

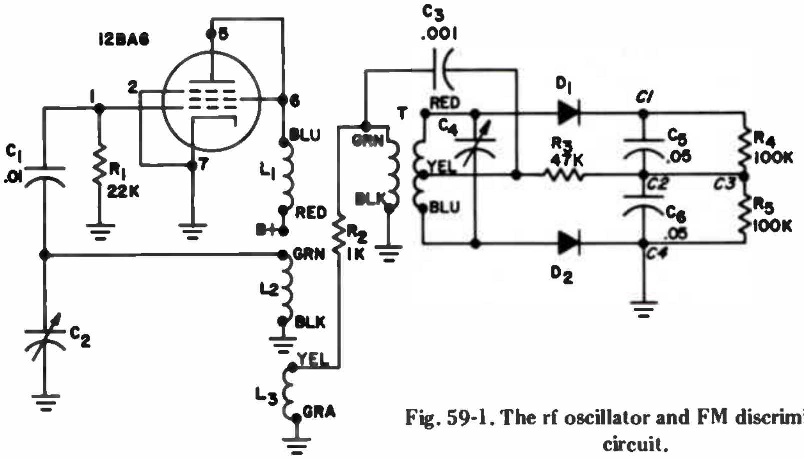

Fig. 59-1. The rf oscillator and FM discriminator circuit.

In proving that a phase discriminator will demodulate an FM signal, you will use the circuit shown in Fig. 59-1. As you can see, it is essentially the same as the basic circuit in Fig. 13. Although we have substituted a resistor for the series inductance L_1 in Fig. 13, the circuit action is the same as that described for the basic circuit.

In normal operation, the audio modulating voltage changes the frequency of the rf carrier so rapidly that the S-curve characteristic can be observed only with an oscilloscope.

However, if we manually adjust the frequency of the rf oscillator to different values above and below an assumed resting frequency, we can measure the dc output voltage for each frequency and plot the S curve.

As shown in Fig. 15, the polarity of the dc voltage across the discriminator load depends on whether the incoming rf signal is above or below the resting frequency. If an ordinary voltmeter is used to indicate the dc output, the polarity of the test leads must be changed when the voltage changes polarity. To avoid this troublesome procedure, servicemen use a voltmeter that has its zero at the center of the scale. Negative voltages swing the meter pointer to the left of zero and positive voltages swing it to the right of zero. There is no need to change the polarity of the test leads to make a reading.

The tvom which you are using in your practical training course can be adjusted so that the zero voltage pointer position is at the center of the scale. When this is done, of course, each range is effectively cut in half. For example, on the 12-volt range you can measure positive or negative 6 volts. When you are instructed to do so, set the tvom to center zero by rotating the zero control and take your readings on the lower two scales. As you perform the steps in the experiment, you may take readings on any range that seems convenient. The important thing is that you take all your readings on the same range.

Experimental Procedure: In order to perform this experiment you will need your tvom, the experimental chassis with the parts on it and the following:

1 1k-ohm resistor
1 22k-ohm resistor

1 47k-ohm resistor
2 100k-ohm resistors
1 .001 mfd disc capacitor
1 .01 mfd disc capacitor
2 .05 mfd disc capacitors
1 12BA6 tube
2 Signal diodes

Some of these parts will be removed from circuits which you used earlier.

First dismantle the circuit wired on the chassis. Unsolder and remove all parts and leads connected to the rf transformer except the leads connecting the blue and red terminals to the trimmer capacitor. Disconnect the leads and parts from the 50k-ohm potentiometer, the oscillator coil, and the 4-lug terminal strip, strip C. Also, remove the leads and the parts connected to all lugs except lugs 4 and 5 on circuit board EC25. Unsolder the tuning capacitor lead from lug 1 of EC25 and connect it to the green terminal of the oscillator coil.

Loosen the screw at hole U and turn the 4-lug terminal strip around so that terminal C1 is toward the rear of the chassis.

Construct the circuit shown in the schematic in Fig. 59-1. Coils L_1, L_2, and L_3 are windings of the oscillator coil mounted at the front of the chassis. The transformer connected to the diodes is the rf transformer. To wire the circuit, proceed as follows:

Connect a length of wire from lug 6 to lug 8 on EC25. Solder lug 8. Solder a length of hookup wire from lug 6 to terminal B1.

Connect a length of wire from the foil connected to pin 6 of the tube socket to lug 9. Solder a length of wire from lug 9 to the blue terminal of the oscillator coil at the front of the chassis.

Connect a 22k-ohm resistor from lug 7 to terminal B7. Solder a .01 mfd capacitor to lug 7. Solder a short length of wire between the free lead of the capacitor and the green terminal of the oscillator coil.

Solder a length of wire from the black terminal of the oscillator coil to ground. Connect a short length of wire from the gray terminal of the oscillator coil to ground. Solder a length of wire from the red terminal of the oscillator coil to terminal A6.

Solder a 1k-ohm resistor to the yellow terminal of the oscillator coil. Solder a piece of hookup wire to the free lead of the resistor and connect the other end of the wire to the green terminal of the rf transformer.

Connect a .001 mfd capacitor between the green and yellow terminals of the rf transformer. Connect the black terminal of the rf transformer to ground, using a short length of wire.

Connect a 47k-ohm resistor between the yellow rf transformer terminal and terminal C2.

Connect a 100k-ohm resistor between terminals C1 and C3. Connect another 100k-ohm resistor between terminals C3 and C4.

Connect a .05 mfd capacitor between terminals C1 and C2. Connect a .05 mfd capacitor between terminals C2 and C4. Solder a piece of wire between terminals C2 and C3.

Connect a signal diode between the red rf transformer terminal and terminal C1, with the cathode lead to terminal C1. Connect a second signal diode between the blue transformer terminal and terminal C4, with the cathode lead to C4. (Use lengths of wire to extend the diode leads.)

Insert the 12BA6 tube in the socket on EC25.

When you complete the wiring, check your work against the schematic diagram. Look for short circuits between the B+ circuit and ground and around the lugs on the circuit board. Also look for poor connections.

To test the oscillator circuit, turn the circuit on and measure the negative grid leak bias voltage across the 22k-ohm resistor in the grid circuit. You should read a negative voltage of 25 volts or more. The presence of grid leak bias is a good indication that the circuit is oscillating.

Step 1: To make the preliminary adjustment of the discriminator circuit.

Set your tvom to measure dc voltage on the 12V range. The polarity switch should be set to reverse, as you will be measuring a negative voltage.

Turn the adjusting screw on the trimmer capacitor fully clockwise for maximum capacity. Clip the tvom ground lead to the chassis. Slip the test clip on the tvom probe and clip the probe to terminal C2.

Set the tuning capacitor to 50 on the dial scale and energize the circuit. Adjust the trimmer capacitor for maximum negative voltage on the meter. If necessary, switch to a higher range to keep the meter from going off scale. Set the trimmer capacitor for the highest negative voltage.

Step 2: To complete the adjustment of the discriminator circuit.

Disconnect the probe from the circuit and return the polarity switch to "normal." Adjust the zero adjust control for center scale zero. The tvom should be set to the 12V range. Clip the probe to terminal C1 and turn the circuit on. Observe the meter carefully. If it does not indicate exactly zero (center scale), readjust the trimmer capacitor slightly until you read zero on the meter. This adjustment is critical so make it very carefully.

Step 3: To show that frequency variations in the incoming signal will cause a variation in the dc output voltage.

Leave your meter connected from terminal C1 to the chassis, and vary the frequency of the incoming signal by varying the setting of the tuning capacitor. Note that when you move the pointer to the right of 50, the meter pointer will go in one direction; when you move the pointer to the left, it will go in the other direction. This shows that the discriminator responds to frequency variations.

Step 4: To show that the polarity of the dc output voltage depends upon whether the frequency deviation of the

RF OSCILLATOR DIAL SETTING	OUTPUT VOLTAGE
0	+
10	+
20	+
30	+
40	+
50	0
60	–
70	–
80	–
90	–
100	–

Fig. 59-2. Record your readings for Experiment 59 here.

carrier is above or below the resting frequency of the carrier.

Reset the rf oscillator frequency control to 50 on the scale, and check to make sure that the meter pointer has not moved to the right or to the left of the center zero position. If it has, bring it back by carefully adjusting the trimmer capacitor.

Set the tuning capacitor to 0 (maximum capacity), and read the meter on the ±6V (12V) scale. Record your reading in Fig. 59-2.

Set the tuning capacitor to each of the dial settings listed in Fig. 59-2, read the meter on the 12V scale for each setting, and record your readings in Fig. 59-2. At 50 the meter pointer should be at center scale, indicating 0 volts. Meter deflections to the right indicate positive polarity; meter deflections to the left indicate negative polarity.

Step 5: **To plot your results on the graph in Fig. 59-3.**

Oscillator dial settings below 50 on the scale should have produced positive voltages and caused meter pointer deflections to the right of the center zero position. Oscillator dial settings above 50 should give negative voltage readings, causing deflection to the left of the center zero position. Plot the point for the voltage reading for each setting of the dial. Then connect them by drawing a smooth line through the points.

When you have your curve completed, compare it to the curve shown in Fig. 15. Your curve should have a similar shape. It probably won't be as symmetrical as this, but it should be approximately S-shaped.

Step 6: **To show that variations in the amplitude of the rf carrier affect the output of the discriminator.**

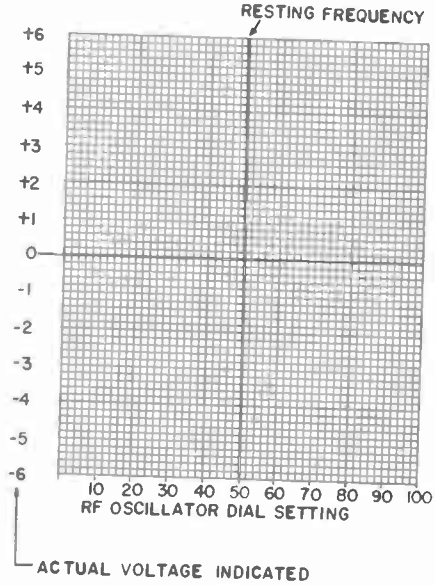

Fig. 59-3. Plot readings for Exp. 59 here.

Adjust the tuning capacitor to some point above or below the resting frequency at which an appreciable meter deflection is obtained, and change the rf input by momentarily shorting the green terminal at the rf transformer, TR31, to the chassis with a screwdriver blade. When this is done, the output of the discriminator should vary. Turn your equipment off.

Discussion: You have shown that changing the frequency of the rf carrier signal applied to a discriminator changes the amplitude of the dc output voltage. Thus, in an FM receiver the dc voltage at the output of the discriminator corresponds to the original signal used to frequency-modulate the carrier. This shows that the discriminator detects, or demodulates, the signal. As you vary the oscillator frequency through resonance with the tuning capacitor, output also varies. The output curve you plot should have nearly an **S** shape.

Under ideal conditions the **S** curve will be symmetrical above and below the zero voltage axis of the graph. However, in a practical circuit it is unlikely that the curve will be symmetrical. The circuit may not be balanced due to unequal capacities to ground, variations in the tubes, etc.

In the last step you showed that amplitude variations also affect the dc output. This effect is undesirable in an FM receiver. In an actual receiver a limiter stage is used to remove the amplitude variations, so that the signal applied to the discriminator is of a constant amplitude. In a ratio detector, amplitude variations in the carrier caused by noise or static have very little effect on the output. Thus, a limiter stage is ordinarily not necessary. You will work with a ratio detector in the next experiment.

Instructions for Statement 59: For your report on this experiment you are to find out what will happen when one of the diodes become defective.

Connect the tvom to measure the dc voltage between terminal C1 and the chassis, with the probe connected to C1. Adjust the tuning capacitor so that the voltage is at zero center between the two peaks.

Now disconnect the diode lead from the blue terminal of the rf transformer. Again measure the voltage between C1 and the chassis, and see if the voltage between these points is still zero. Answer the Statement here and on the Report Sheet. Reconnect the diode lead to the blue terminal of the rf transformer.

Statement No. 59: When I disconnected the diode lead to simulate a defective diode, I found that the voltage between the chassis and C1 was:

(1) still at zero.
(2) no longer at zero.

EXPERIMENT 60

Purpose: To show that a ratio detector will demodulate an FM signal, and that its characteristic has an S shape similar to that of a phase discriminator.

Introductory Discussion: As you learned in the last experiment, the phase discriminator can respond to variations in the amplitude of the input signal, and it will respond to noise signals as well as to the desired FM signal. This response can be overcome by adding a limiter stage between the last i-f amplifier and the FM detector. Many FM receivers, however, use a detector circuit that is in itself relatively insensitive to variations in the amplitude of the rf carrier.

One of these amplitude-insensitive detectors is the "ratio" detector shown in Fig. 60-1. As you can see, it is similar to the discriminator you built in the last experiment, except that one diode is reversed, capacitor C_4 is added, and a change is made in the output connections. As in the phase discriminator,

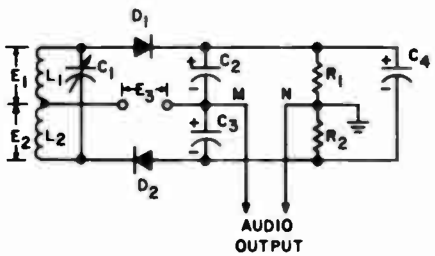

Fig. 60-1. Ratio detector circuit for Exp. 60.

voltages E_1 and E_2 are 180° out-of-phase, and voltage E_3 is 90° out-of-phase with the voltages across L_1 and L_2 when the rf voltage at the input is unmodulated.

As long as the input i-f signal remains at the frequency that corresponds to the center resting frequency of the FM signal, the voltage $E_1 + E_3$ is equal to the voltage $E_2 + E_3$, so the rectified dc voltage across capacitor C_2 is equal to that across capacitor C_3. Since one of the diodes (D_2) is reversed from the connection used in a phase discriminator, the dc voltage across capacitor C_2 and C_3 is the sum of the two voltages rather than the difference. This voltage is across the load resistors R_1 and R_2 and is also applied to capacitor C_4.

The audio output of the stage is developed between points M and N. When the voltages across capacitors C_2 and C_3 are equal, the dc voltage is the same at M as at N. Thus, the audio output, as seen in Fig. 60-2A, is zero when the received signal is at the resting frequency.

Let us suppose we have a voltage of 5 volts each across capacitors C_2 and C_3 in Fig. 60-2A. This makes the total voltage across capacitor C_4 10 volts. Since the value of this capacitor is rather large, it holds its charge for an appreciable time even when the input changes.

Suppose that the frequency of the input i-f signal changes so that the voltage across C_2 increases to 8 volts; the voltage across C_3 decreases to 2 volts. This is shown in Fig. 60-2B. The sum is still 10 volts; and the sum voltage divides equally across the equal value resistors R_1 and R_2. This means that the voltage at M will be 3 volts negative with respect to N. Similarly, if the input frequency should deviate the same amount in the other direction, the voltage across C_2 will decrease to 2 volts, and that across C_3 will increase to 8 volts. As shown in Fig. 60-2C, M will then be 3 volts positive with respect to N.

The action so far is the same as that of the usual phase discriminator circuit. However, the presence of capacitor C_4 makes a difference because it minimizes the effect of amplitude variations in the input. Let us see how.

Capacitor C_4 is charged so that the average voltage across it is proportional to the FM signal strength. Since the capacitor is large, generally 5-mfd to 20-mfd, the time-constant of the circuit consisting of C_4, R_1, and R_2 is about 0.1 to 0.4 second. This means that C_4 is slow in responding to variations in the amplitude of the input signal. If the input signal increases or decreases suddenly, the capacitor voltage is not able to follow the variations. The dc voltage across C_4 can, however, follow slow variations in the amplitude of the input signal.

Let us assume, for example, that a certain value of frequency deviation pro-

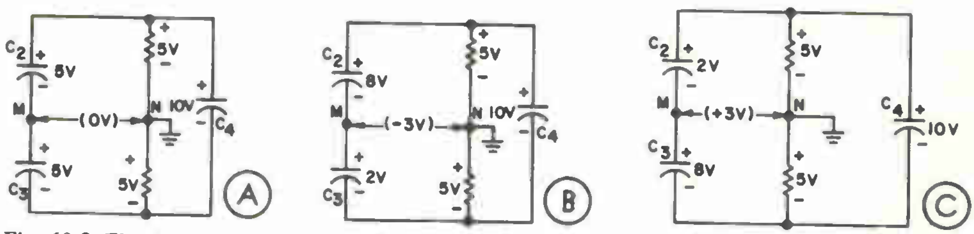

Fig. 60-2. The dc output voltage of a ratio detector is the difference between the voltages of points M and N.

duces an 8-volt drop across C_2, and 2 volts across C_3, as shown in Fig. 60-2B. The output voltage will be −3 volts. Now assume that for some reason, say a burst of static or an interfering station, the amplitudes of voltages E_1, E_2, and E_3 all increase equally. The voltages across capacitors C_2 and C_3 will both try to increase. However, since they must always be equal to that across C_4, which cannot change quickly, the voltages across C_2 and C_3 will remain constant despite the sudden increase in input voltage. The extra voltage will be dropped across D_1 and D_2 because more current will flow through them as they attempt to increase the charge on C_4.

Experimental Procedure: For this experiment you need the setup from the last experiment, plus:

- 1 .01-mfd capacitor
- 1 6-mfd electrolytic capacitor

Wire the circuit as shown in Fig. 60-3. Only a few changes are necessary to convert your phase discriminator into a ratio detector. First, reverse the connections to diode D_1 so that the cathode is connected to the red terminal at the rf transformer and the anode is connected to terminal C1. Second, separate the junction of R_4 and R_5 from the junction of capacitors C_5 and C_6. To do this, remove the piece of bare wire you connected between terminals C2 and C3. You will measure a dc voltage between these points to get the necessary data for drawing an S curve. Finally, connect a 6-mfd electrolytic capacitor between terminals C1 and C4. Make sure you observe the polarity of the capacitor; connect the positive lead to terminal C4, as shown in the diagram. Check your work carefully.

Step 1: Adjust the ratio detector circuit.

The adjustment of this circuit is essentially the same as for the phase discriminator, except that the connections for dc output voltages are different. Adjust your tvom for center scale zero as in the last experiment. Connect the ground clip at the junction of resistors R_4 and R_5, terminal C3, and the probe at the junction of capacitors C_5 and C_6, at terminal C2. The tvom should be set to

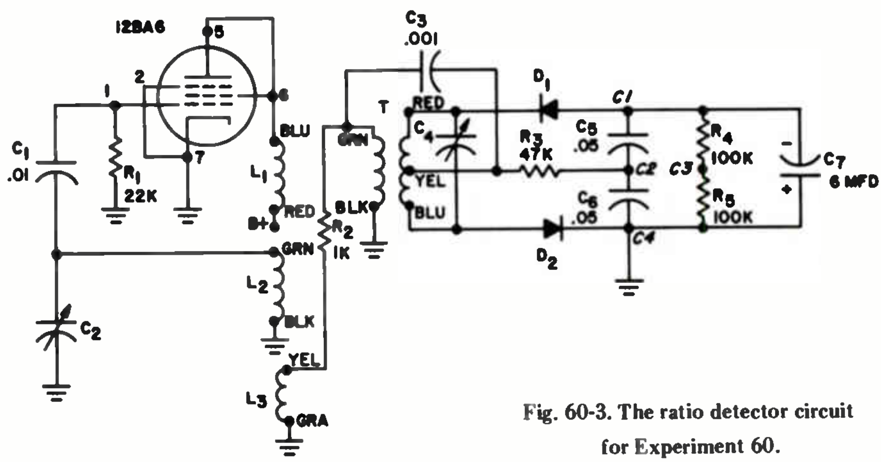

Fig. 60-3. The ratio detector circuit for Experiment 60.

"normal." Apply power to the circuit. Now, set the tuning capacitor to 50 and adjust the trimmer capacitor for the zero-center reading between the two peaks.

Step 2: To show that a ratio detector will demodulate an FM signal.

Apply power and tune the tuning capacitor to either side of the resting frequency as you did in the previous experiment, noting that the dc output voltage changes as the input signal varies in frequency.

Step 3: To show that a ratio detector has an S-shaped dc output characteristic.

With the tvom connected as described in Step 1, turn the range selector switch to 12V, and measure the dc output of the ratio detector. You will not make measurements over the entire frequency range, only enough to show the S-shaped characteristic.

RF OSCILLATOR DIAL SETTING	OUTPUT VOLTAGE
30	+
35	+
40	+
45	+
50	0
55	–
60	–
65	–
70	–

Fig. 60-4. Record readings for Exp. 60 here.

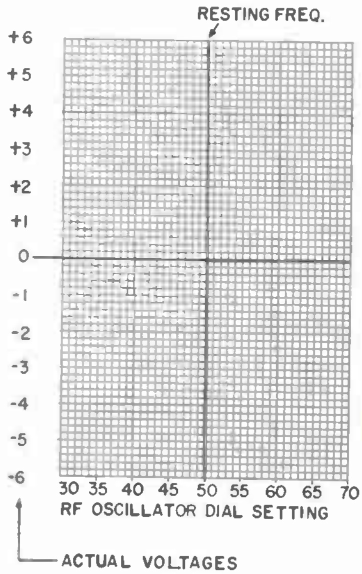

Fig. 60-5. Plot results for Exp. 60 here.

Starting with the tuning capacitor, set at 30, take the readings of the dc output at each of the settings listed in Fig. 60-4. Record your readings in Fig. 60-4. Notice that the readings for dial settings below 50 should make the meter pointer move to the right. Frequencies higher than the resting frequency should make the meter pointer move to the left.

Plot your results in Fig. 60-5. The curve should be S-shaped.

Discussion: Again as in the previous experiment, the S curve is small because of the limited rf input voltage. We can increase the rf input by reducing the value of R_2, but doing so will decrease the degree of isolation between L_3 and the rf transformer. If the rf transformer is not sufficiently decoupled from L_3, any adjustment of capacitor C_4 will tend to change the frequency of the rf oscillator.

A ratio detector is properly tuned when the secondary of the rf transformer is set for zero dc output at the i-f resting frequency. In some ratio-detector circuits a single resistor is used in place of R_4 and R_5. In order to check a circuit of this type for proper tuning, you will have to add a series combination of two resistors of equal value in parallel with this single resistor. This will give you a point to which you can connect a dc voltmeter.

Instructions for Statement 60: For your report on this experiment you are to determine how the capacity of the stabilizing capacitor C_7 affects the dc voltage across resistors R_4 and R_5 when the amplitude of the input is varied rapidly.

Solder a short length of hookup wire to the yellow terminal of the rf oscillator coil. Arrange the free end of this lead so that you can tap it against the chassis two or three times a second, thereby varying the rf input rapidly between its normal value and zero. Readjust the Zero control so that the meter pointer is at 0 on the left side of the meter scale. Connect the ground lead of the tvom to the chassis and connect the probe to terminal C1. Set the polarity switch to reverse.

After making sure that the ratio detector is properly adjusted, measure the dc voltage across capacitor C_7. Now vary the amplitude of the rf carrier by tapping the lead you soldered to the yellow terminal at the oscillator coil against the chassis. Watch the meter when you do this. There should be very little if any change in the meter reading.

Now, disconnect the 6-mfd capacitor C_7, and connect a .01-mfd capacitor in its place. Check the dc voltage across this capacitor, repeat the grounding procedure to simulate a varying rf amplitude, and watch the meter. Turn your equipment off and indicate the results of this test in the Statement for this experiment.

Statement No. 60: When I decreased the capacity of capacitor C_7 to .01-mfd, and then rapidly changed the amplitude of the rf signal, the dc voltage across the .01-mfd capacitor:

(1) remained unchanged.
(2) varied appreciably.

A REVIEW

This completes your demonstrations of basic circuit actions; you will go on to service techniques in your next kit. Let us review what you have learned.

First of all, you have learned how to solder, a technique all radio and television technicians must master. You should now be able to use just the right amount of solder to make good electrical connections. Also, you should have formed the habit of checking your soldering iron tip frequently, and filing and retinning it when necessary.

By assembling and dismantling circuit after circuit, you have learned how to handle many kinds of electronic parts. Perhaps you learned the hard way that resistor and capacitor leads may break after being bent back and forth several times, and that you must be careful when you work with them.

Your work of assembling and tracing circuits undoubtedly speeded up after you learned to identify resistor values by the color code and after you became adept at handling your pliers, cutters, hookup wire, and the NRI tvom. You no longer should find it necessary to puzzle over the connections for any kind of measurement the instrument will make. The correct procedures should now come to you naturally.

Another important accomplishment you have gained is the ability to assemble a circuit without the aid of a pictorial diagram. You now know that there are many different ways in which a circuit can be assembled and still correspond electrically to a schematic.

Your work with rf circuits taught you the important technique of tuning circuits to resonance at a given frequency so as to produce a maximum output voltage. You will use this every time you align a radio or TV set.

If there is any question in your mind concerning your ability in any one of the techniques we have listed here, concentrate on that particular technique. For example; if you still find it difficult to use a schematic diagram to locate parts, get an old receiver and the circuit diagram for it and practice tracing out the circuit. It is still not too late to master the technique of tuning resonant circuits, of tracing circuits, or of soldering.

These are only a few of the many practical things you have learned as you demonstrated fundamental circuit actions ranging from Ohm's Law to the theory and practice of frequency modulation.

LOOKING AHEAD

In your next kit you will build an ac-dc receiver, complete with a PM speaker and an efficient ferrite loop antenna. You will get a special chassis on which to assemble the set, and a 2-gang tuning capacitor. When you have the receiver assembled, you will carry out complete voltage measurements and make point-to-point resistance tests on it. Then you will align it for normal operation within the standard broadcast band.

The ten experiments in the next kit have been designed to give you practical experience in recognizing the symptoms of common defects in general radio service work. This experience, plus the training you have already had, will give you the background you need to qualify as a real expert.

You will probably want to do some experimenting on your own using the parts left over from the experiments. If so, you will want to put your audio oscillator back into operation and you will want to build an rf oscillator.

Audio Frequency Oscillator. The oscillator which you used in the early part of this kit is complete except for the 1k-ohm stability control. Reinstall the potentiometer on the board and wire it in as shown in the schematic diagram in Fig. 6. To use the oscillator, connect 12V to 20V dc between the ground foil and square 5F and take the output signal between square 1E and ground.

When you need a 1k-ohm potentiometer in the experiments in the future kits, you will have to remove the potentiometer from your oscillator.

RF Oscillator. The schematic diagram of an oscillator which you can build from your available parts is shown in Fig. 16. This is a Clapp oscillator and, as you can see, it is very similar to the Colpitts oscillator which you used in experiments 56 through 58. You should still have circuit board EC25, the oscillator coil and the tuning capacitor mounted on the

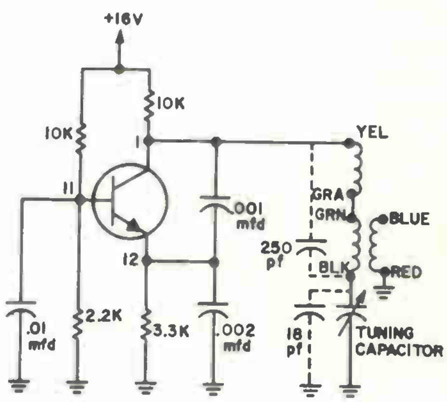

Fig. 16. Schematic of rf oscillator circuit.

chassis. Therefore you will find the circuit easy to wire. Wire the oscillator from the schematic. For the present, do not connect the 250 pf and 18 pf capacitors. The connections to the transistor are made to lugs 1, 11, and 12, and the operating voltage is supplied by the low voltage power supply on circuit board EC24.

Remove all other parts from the chassis and clean their leads and terminals. Put the parts in a safe place as you may need them for carrying out future experiments.

To test the oscillator, you can measure the ac voltage across the secondary (red/blue) winding of the oscillator coil. You should read up to 1V ac as you vary the oscillator frequency. A more reliable way to test the oscillator is to tune an AM receiver to a station at about the center of the dial and see if your oscillator can produce interference. Solder about a 3 ft length of hookup wire to the yellow terminal of the oscillator coil and bring the end near the receiver. Tune your oscillator throughout its range while listening to the radio. You should be able to hear the interference.

Refer to the schematic in Fig. 16 to see how the oscillator works. The transistor is operated in the common base configuration, with the input applied to the emitter and the output taken off at the collector. The feedback necessary to sustain oscillations is coupled through the capacitive voltage divider from the collector to the emitter. Collector voltage is provided through the 10k-ohm load resistor.

The frequency of oscillation is determined by the network made up of the series-connected coils, the tuning capacitor and the capacitive voltage divider. The tuning capacitor, being in series with the two coils, varies the effective or net inductance of the coils. This net inductance, in turn, resonates with the total capacitance of the capacitors in the voltage divider. The oscillator frequency is approximately equal to the resonant frequency of this circuit.

The frequency range of the basic oscillator circuit is from about 570 kHz to about 1650 kHz, which nearly covers the AM broadcast band. The frequency range can be lowered to include the AM receiver intermediate frequency by connecting the 250 pf and 18 pf capacitors as shown in Fig. 16. The lower range is approximately 410 to 540 kHz.

You can determine the oscillator frequency by "zero beating" its output with known radio frequencies such as the carrier frequencies of AM radio stations. Tune in a station on the radio and adjust the oscillator until you hear a squeal in the audio. What you hear is the difference frequency between the radio station carrier frequency and the output of your oscillator. As the oscillator frequency is brought closer to the carrier frequency, the pitch of the audio becomes lower. The oscillator frequency is then nearly equal to the carrier frequency.

To set the oscillator to the receiver intermediate frequency, (usually about 455 kHz) connect the 250 pf and 18 pf capacitors into the circuit as shown by the dotted lines in Fig. 16 and tune the oscillator until you hear a squeal in the receiver. This should occur at a dial setting of about 50. Try other stations. They all have the same i-f, therefore they should all have interference.

Disconnect the oscillator circuits from the low voltage power supply whenever they are not being used to minimize undesirable interference.

Will Power and Won't Power

People point out a successful man and say he has a lot of will power. It's true that will power is a necessary requisite of success. But seldom mentioned and just as important is "won't power" – the power to say "No" at the proper time.

"Won't power" alone does not guarantee success in any venture, but when used at the right time, is as important as will power.

When you are tempted to neglect your studies, use *won't* power. If you have not already done so, lay out a schedule for regular study every week and use *will* power to stick to it.

That combination of "I will" and "I won't" can lift you to heights even beyond your fondest dreams today.

John G. Thompson

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ACHIEVEMENT THROUGH ELECTRONICS

nri

TRAINING KIT MANUAL

7TT

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PRACTICAL DEMONSTRATIONS OF RADIO-TV FUNDAMENTALS

INSTRUCTIONS FOR PERFORMING
EXPERIMENTS 61 THROUGH 70

7TT

In this kit you build this complete five-transistor, line-operated AM radio receiver and conduct experiments on it.

Index of Sections

NATIONAL RADIO INSTITUTE, WASHINGTON, D.C. 20016

CEC1M1275 1975 EDITION Litho in U.S.A.

INSTRUCTIONS FOR PERFORMING RADIO-TV EXPERIMENTS 61 THROUGH 70

This transistor radio kit is designed to give you practical experience working with transistor circuits. You are already familiar with the principles of operation of a radio receiver. In previous kits you have worked with typical circuits found in receivers. From your transistor experiments you know how transistor stages operate. In this kit you perform experiments on every stage of an all-transistor radio receiver.

You may or may not have already performed the 7YY experiments on the NRI ac-dc five-tube radio receiver. If you have experimented with the tube receiver, you are familiar with many troubleshooting techniques that are common to both tube and transistor receivers. That experience will help you with your transistor radio troubleshooting. For example, a block diagram of an AM receiver will apply to either type; the same signals are present in the various sections of either type of receiver.

However, from the standpoint of practical servicing, the receiver types are quite different. Big differences are found in the voltage level of signals in various sections of the receiver. The impedance levels tend to be very low in transistor circuits compared to similar points in tube circuits. Many test procedures that work on tube receivers are useless on transistor sets.

On the other hand, if you have not experimented with the tube set, it will not cause difficulties. This transistor radio set of experiments is complete in itself, just as the tube experiments are complete. After you complete these experiments on the transistor receiver, you may want to obtain the 7YY Kit on the tube receiver. Both kits give you practical experience in troubleshooting radio receivers. The 7YY Kit helps you learn to service tube receivers and the 7TT Kit pertains to transistor receivers.

Before you perform the experiments in this kit, you assemble the receiver. The set goes together quickly because most of the parts are mounted on a printed circuit board. Since this may be your first experience with printed circuit boards, you are given instructions pertaining to soldering, replacing components, and repairing printed circuit boards.

Even if you have worked with printed circuit equipment, you can learn from these instructions. We have included some extra printed circuit wiring on the board especially for these instructions. Since this part of the board is not used for the radio, you don't have to worry about damaging the foil. You experiment with this wiring before any parts are mounted on the board.

You complete the receiver and test it before you run the experiments. In some experiments, you remove and replace components from the circuit board. This duplicates parts replacement, which is often performed when repairing receivers. In one of your final experiments, you practice alignment procedures and finally peak up your receiver for best operation. After completing the experiments you install the receiver in its cabinet. You then have an attractive table model receiver for your own use.

CONTENTS OF THIS KIT

In this kit you receive all the parts necessary for building your complete transistor radio. Additional parts are supplied for experiments. Some of the parts for the experiments are parts that are left over from previous kits.

IMPORTANT: The oscillator and i-f transformers supplied in this kit have been preset. Do not move the adjustments on these transformers until you are told to do so. The use of preset transformers assures that your receiver alignment will be accurate enough to receive some stations when you complete construction. After you have the set in operation, you will be instructed how to improve the alignment.

The parts for building the radio are illustrated in Fig. 1 and listed below the photograph. The parts used in the experiments are listed separately. The list indicates those parts left over from previous experiments that will be used again here.

Check the parts you receive against the Parts List to be sure you have all of them. If any part in the kit is obviously defective or has been damaged in shipment, return it to NRI immediately, as directed on the packing slip included in this kit.

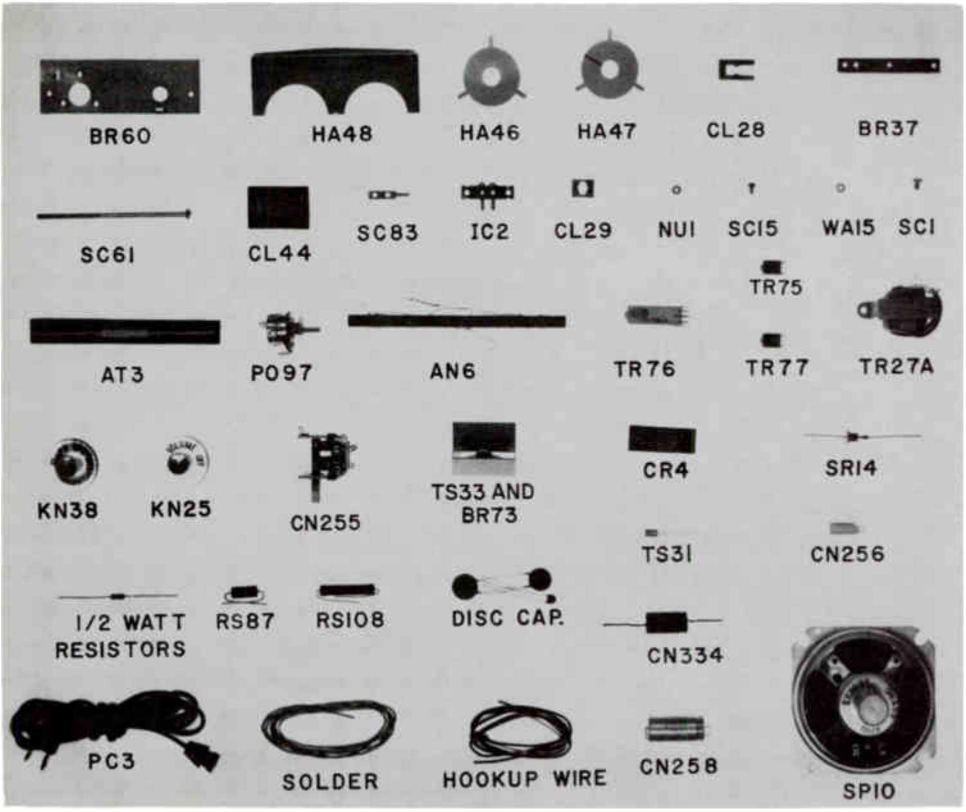


Fig. 1. Parts used to construct Kit 7TT.

Quan.	Part No.	Schematic Symbol	Description	Price Each
1	AN6	L_1	Loopstick antenna	.78
1	AT3		Alignment tool	.32
2	BR37		Chassis support brackets	.16
1	BR60		Volume control bracket	.16
1	BR73		Heat sink	.40
*1	CB15		Radio cabinet	3.15
1	CL28		Power cord clamp	.15
4	CL29		Speaker mounting clips	.02
2	CL44		3/8″ cable clamps	.05
1	CR4	D_1	Detector diode	.35
1	EC21		Etched circuit board	4.72
1	HA46		Plain round dial plate	.20
1	HA47		Round dial plate w/red line	.35
1	HA48		Gray edge molding	.40
1	HA16		10′ length solder	.20
1	IC2		Interlock	.25

*not shown

Quan.	Part No.	Schematic Symbol	Description	Price Each
1	KN25		Volume control knob	.38
1	KN38		Tuning knob	.38
12	NU1		6-32 hex nuts	12/.15
*1	PA17		Front panel	1.50
1	PC3		Interlock power cord	.46
1	PO97	P_1	2.5K-ohm volume control pot w/switch and control nut	.76
9	SC1		1/4" X 6-32 screws	12/.15
2	SC13		3/8" X 6-32 screws	12/.15
8	SC15		No. 6 X 1/4" self-tapping screws	12/.15
2	SC61		4-1/4" X 8-32 screws	.12
2	SC83		1" X 6-32 spade bolts	.06
1	SP10		4" .05 oz. magnet speaker	1.59
1	SR14	D_2	Rectifier diode	.64
1	TR27A	T_4	Audio output transformer	1.00
1	TR75	T_1	Oscillator transformer	.31
1	TR76	T_2	Input i-f transformer	1.31
1	TR77	T_3	Output i-f transformer	.40
4	TS31	Q_1, Q_2, Q_3, Q_4	EN1132 transistors	.46
1	TS33	Q_5	High voltage NPN power transistor	1.90
2	WA5		No. 8 flat metal washers	12/.15
15	WA15		No. 6 split ring lockwashers	12/.15
1	WR257		7" red hookup wire	**
1	WR258		7" white hookup wire	**
1	WR259		48" black hookup wire	**

CAPACITORS

Quan.	Part No.	Schematic Symbol	Description	Price Each
1	CN180	C_{14}	6.8 pf disc	.15
1	CN229	C_6	220 pf disc	.15
1	CN34	C_7	.001 mfd disc	.15
1	CN245	C_9	.005 mfd, Z5F disc	.15
2	CN86	C_{20}, C_{24}	.01 mfd, 1kV disc	.15
1	CN142	C_{15}	.02 mfd, 500V disc	.15
6	CN204	C_5, C_{10}, C_{12} C_{13}, C_{17}, C_{21}	.05 mfd, +80 −20 100V, Z5U disc	.36
1	CN104	C_8	.1 mfd, 50V disc	.34
*1	CN257	C_{18}	100 mfd, 10V elect.	.40
1	CN258	C_{23}	100 mfd, 150V elect.	1.05
1	CN334	C_{22}	220 mfd, 35V elect.	.45
3	CN256	C_{11}, C_{16}, C_{19}	10 mfd, 10V elect.	.40
1	CN255	C_1, C_2, C_3, C_4	2-gang tuning	1.13

RESISTORS

Quan.	Part No.	Schematic Symbol	Description	Price Each
1	RE26	R_7	100-ohm	.15
1	RE143	R_{16}	180-ohm	.15

*not shown
**additional wire available in 12' lengths (only) each color.25

Quan.	Part No.	Schematic Symbol	Description	Price Each
1	RE113	R_{17}	270-ohm	.15
1	RE114	R_{14}	560-ohm	.15
1	RE56	R_{10}	680-ohm	.15
1	RE59	R_3	820-ohm	.15
1	RE30	R_8	1k-ohm	.15
1	RE112	R_{15}	1.5k-ohm	.15
1	RE58	R_4	2.2k-ohm	.15
1	RE29	R_{13}	4.7k-ohm	.15
2	RE50	R_1, R_{19}	6.8k-ohm	.15
1	RE31	R_{18}	10k-ohm	.15
1	RE32	R_{11}	18k-ohm	.15
2	RE33	R_2, R_{12}	22k-ohm	.15
1	RE52	R_9	82k-ohm	.15
1	RE61	R_6	270k-ohm	.15
1	RE38	R_5	470k-ohm	.15
1	RS87	R_{20}	10k-ohm, 2 watt	.24
1	RS108	R_{21}	250-ohm, 4 watt	.60

The following parts are used in the experiments:

Quan.	Part No.	Description	Price Each
*1	BA1	1.5V D-cell battery	.16
*1	PO7	1k-ohm potentiometer	.61

CAPACITORS

1	CN114	27 pf disc	.15
1	CN131	2200 pf	.15
1	CN34	.001 mfd disc	.15
1	CN35	.005 mfd disc	.15
1	CN86	.01 mfd, 1kV disc	.15
1	CN9	.27 mfd, 400V tubular	.25

RESISTORS

1	RE27	220-ohm	.15
1	RE28	470-ohm	.15
1	RE56	680-ohm	.15
3	RE30	1k-ohm	.15
1	RE111	1.2k-ohm	.15
1	RE58	2.2k-ohm	.15
1	RE50	6.8k-ohm	.15
1	RE31	10k-ohm	.15
1	RE33	22k-ohm	.15

*left over from previous kits

LEARNING TO WORK ON CIRCUIT BOARDS

Etched circuit boards are widely used in all types of electronic equipment. The circuit board, EC21, supplied with this kit is typical of those used in radio and TV receivers. Examine the circuit board carefully. The board is made of a phenolic insulating material with a pattern of copper foil bonded onto one side. The terms "etched circuit" or "printed circuit" board come from the manufacturing process. The stock board consists of the phenolic material with a thin sheet of copper foil bonded to one side.

The circuit pattern is transferred to the foil by a photographic process or a silk-screen process similar to that used in the printing industry. The board is then placed in a chemical bath that etches away the copper foil in those places not covered by the circuit pattern. The board is cleaned. Then the writing and symbols are screened on to the "phenolic" or "component" side of the board. The component leads are soldered to the circuit wiring on the "foil" or "circuit" side of the board.

Certain precautions must be followed when working on circuit boards to prevent damage. The phenolic material is somewhat brittle. It can break easily if it is dropped or if too much pressure is applied to it. An assembled board with heavy components on it is subject to cracking.

Rough handling will sometimes produce a board crack that breaks one or more of the foil circuit paths. These cracks often produce intermittent defects and may be difficult to locate. In cases where you cannot see the crack, it is sometimes easiest to simply flow molten solder along the circuit path where a crack is suspected. The solder will bridge the break and repair the circuit.

On some finished circuit boards, the entire foil surface is covered with solder. The solder is put on as part of the board assembly operation. The component leads are inserted through the holes in the board, the foil side of the board is dipped into a container of molten solder. Solder adheres to all exposed foil and solders all the component leads in place at one time.

Excessive heat can weaken the bond between the foil and the phenolic; heat and pressure will cause the foil to peel off the phenolic. Once the foil breaks clear of the phenolic, it is quite fragile and will break off easily. A 35-watt soldering iron is adequate for assembling or repairing the circuit board. If you use a higher wattage iron, you must not hold it against the foil for too long a time. Excessive heat can also char the phenolic material and produce leakage paths between different circuits on the board.

The foil associated with holes Q, R, S, and T on your circuit board is not part of the radio circuit. This foil is for you to practice on. You can apply enough heat to damage the foil. In steps that follow we even show you the wrong way to solder the circuit board. In this way you will get a feel for how much heat it is safe to apply when constructing or repairing etched circuits.

Practice Wiring to Circuit Board. You will need your hand tools, etched circuit board EC21, and two 1k-ohm resistors (brown-black-red) that are among the parts furnished for experiments.

Bend the leads 90° on each end of a 1k-ohm resistor. Insert the leads through holes Q and S from the phenolic side of the board. Push the resistor firmly onto the board. Spread the leads slightly so the resistor stays in place when you turn the

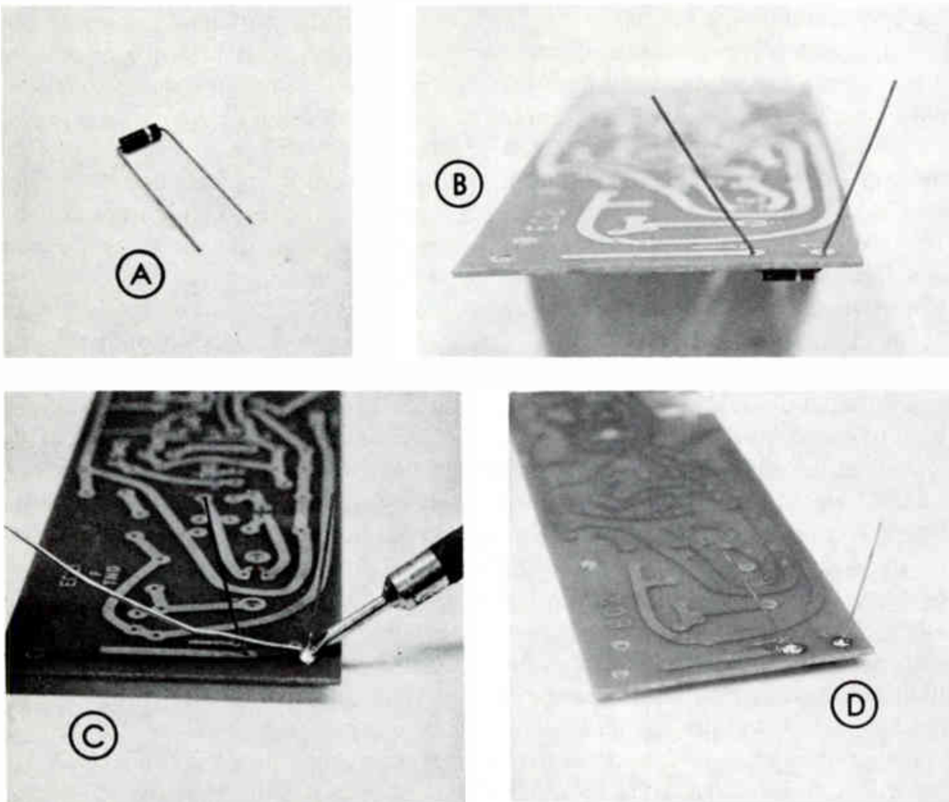


Fig. 2. (A) Bend the resistor leads 90° before inserting into mounting holes of circuit board; (B) bend leads slightly to hold resistor in place during soldering; (C) hold the soldering iron tip in contact with both foil and lead while solder is being applied; (D) use just enough solder to fill in the joint between foil and lead.

board over. Fig. 2A and Fig. 2B show how to install the resistor.

Next hold the hot soldering iron in contact with both the foil and the lead, as shown in Fig. 2C. Touch the solder to the junction of the iron tip and the circuit. Watch the solder spread over the foil and the lead, making sure that it adheres to both of them. Limit the amount of solder that you apply to the junction. Use just enough to produce smooth rounded fillets between the lead and the foil, as shown in Fig. 2D.

Excess solder can be removed by heating the joint and holding the board in a position that lets the solder run down onto the iron tip. Too much solder or too little heat produces round globs of solder that do not "wet" down into the junction. Too little solder leaves the junction weak or fails to fill in all around the lead. Too much heat causes the junction to smoke and the area to change color. When the solder hardens, clip off the lead that extends beyond the soldered connection.

When troubleshooting on a circuit board, it is sometimes desirable to disconnect one end of a component from the circuit. This can be done if you work carefully. Try it on the resistor you just installed at holes Q and S. Simply heat the connection on the foil side at hole Q. Use a scratch awl or thin-bladed screwdriver to pry the resistor away from the phenolic side of the board while you hold the iron tip against the connection. Lift the end of the resistor at hole Q high enough to remove the lead from the hole. The resistor is now positioned so that you can take resistance measurements or other tests for which the resistor must be isolated from the circuit.

Clean the solder out of the hole before you attempt to reconnect the resistor lead to the circuit. A round toothpick makes an excellent tool to clean the solder from the hole. Simply heat the solder, force the end of the toothpick into the hole from the foil side of the board, and remove the soldering iron. The solder will cool and will leave a hole when you remove the toothpick. In place of the toothpick, you can use a wire paper clip or other wire that solder will not stick to.

If you attempt to reconnect the resistor lead without cleaning the hole, you risk pulling the foil loose from the board. When you force the lead through the hole, the lead tends to catch on the edge of the foil in the hole. Heat and pressure will then cause the foil to separate from the board. The narrow sections of foil like that at hole Q are especially liable to damage. Try reconnecting the lead at hole Q. When you are satisfied with the connection, unsolder and remove the resistor from holes Q and S. If the foil is not damaged, reheat the foil at hole Q. Apply enough heat, and if necessary some pressure, so you see what is required to remove the foil.

Examine the unbonded edge of the foil. Notice that it is quite thin and brittle. From this you can see that once the foil separates from the board, that part of the foil can no longer be counted on to form a reliable portion of the circuit. You have to perform additional repairs to the foil circuit for a reliable repair job.

The foil at hole S may have separated from the board when you removed the resistor. When applying heat to the foil on a circuit board, always consider the area of the foil. Hole S has only a small area of foil so it is easy to overheat it. When the foil is wider or covers a larger area, the heat is conducted away from the point where the soldering iron touches and the foil is less likely to be damaged.

Clean the solder off the leads of the resistor that you removed from holes Q and S. Adjust the lead spacing to fit and install the resistor at holes R and T. Seat the resistor body against the phenolic side of the board and carefully solder the lead connection, using the right amount of heat and solder.

How to Repair Broken Wiring. As mentioned before, etched circuits may develop cracks from rough handling. Or during troubleshooting you may want to isolate a component by cutting the foil on a circuit board. In either case you need to repair the break to put the circuit back in operation. Simulate this condition by cutting the foil that extends from hole R. Use a pocket knife or razor blade to make a narrow cut at right angles to the strip of foil, as shown in Fig. 3A. Only a little pressure is necessary to cut through the foil. You can check with an ohmmeter to be sure that the foil is separated. Next, touch your soldering iron to the foil on one side of the cut. Flow some solder onto the heated foil. Notice that the solder does not readily flow across the cut. A hairline crack can often be exposed by this means. The solder melts right up to the crack, but the crack prevents the heat from conducting to the parts of the foil beyond the break.

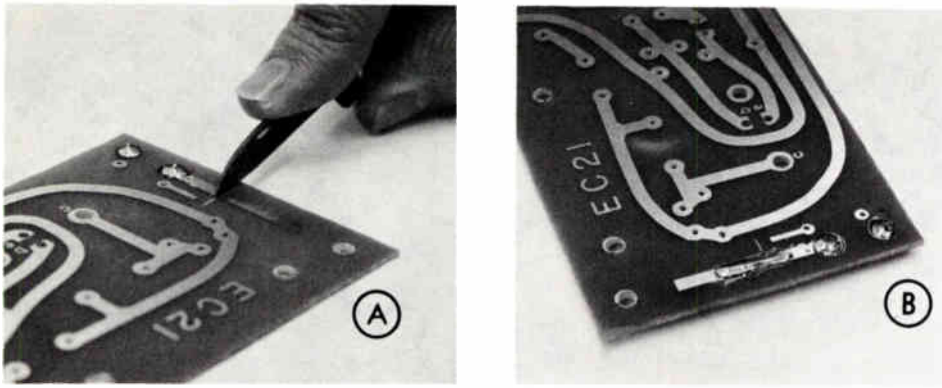


Fig. 3. (A) Cut through the foil to break the etched circuit board wiring, (B) the broken circuit can be bridged by soldering a piece of wire to foil.

Flow some solder onto the foil on the other side of the break and bridge the molten solder across the break. For a narrow break where the phenolic has not been damaged, this repair is adequate. However, if you made a wide cut you may have trouble getting the solder to bridge across it. In that case, reinforce the break with a short piece of bare hookup wire. Simply lay the wire along the foil so it extends across the break and solder it in place, as shown in Fig. 3B. The repair is stronger than the original circuit.

This repair technique can be varied to repair almost any damaged circuit foil. On occasion, you may wish to repair a board where the phenolic is cracked or where a piece has actually broken off the board. A stronger repair can be made by drilling a small hole on each side of the break. Use bare hookup wire to join the two sections together. Then solder the wire to the foil while holding the pieces of the board together in place.

How to Replace Components from the Top of the Circuit Board. The circuit board for your 7TT receiver is not very crowded with components. The parts have been spread out, so it is easy to assemble and perform experiments on the board. This will not always be true for sets that you may have occasion to repair. In some radios and on many TV receivers, the parts are densely packed on the circuit board. In other cases it is difficult to remove the board or reach the foil side of the board. Replacing a component from the top of the board may save you hours of work. You can practice this type of repair by replacing the resistor that you have installed at holes R and T of your circuit board.

Fig. 4 shows the steps involved in replacing a resistor from the top of the board. Use your diagonal pliers to crush the body of the resistor, as shown in Fig. 4A. Use your longnose pliers to straighten the short resistor leads that extend above the board, as shown in Fig. 4B. Next, bend the leads of the replacement resistor to attach them to the short leads extending through the board holes. The 1k-ohm replacement resistor may or may not be placed against the circuit board, depending upon how much room you have to work in. Twist the wires about half a turn so that connections are mechanically secure, as shown in Fig. 4C. Now solder

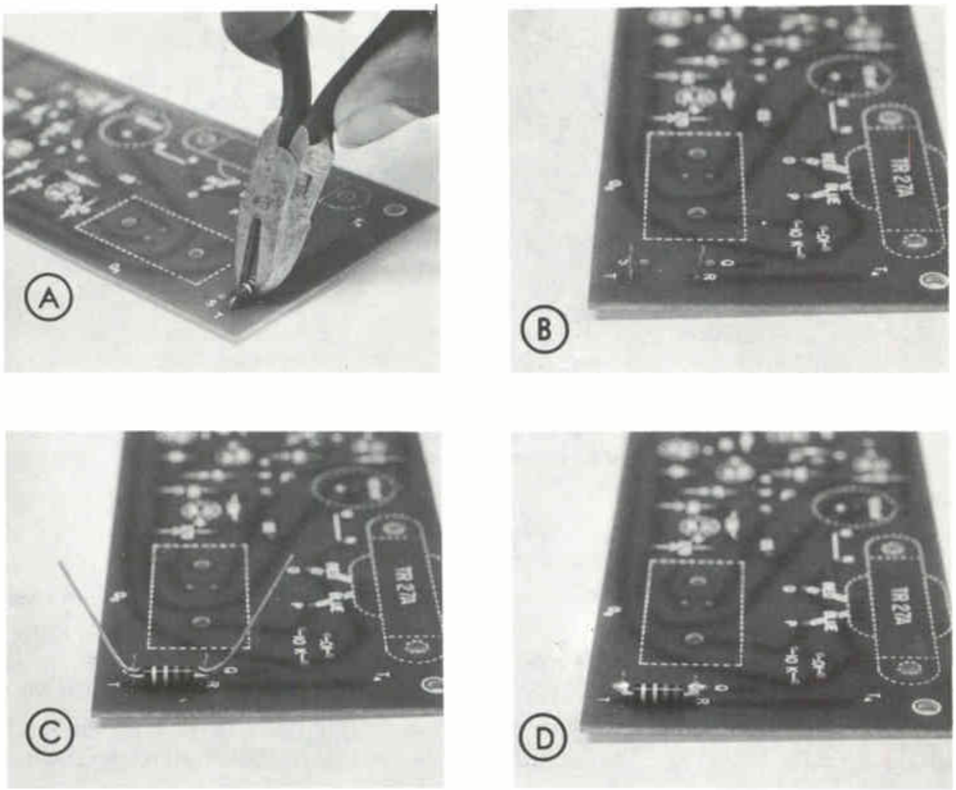


Fig. 4. Steps in replacing a resistor from the component side of the board. Crush the resistor with pliers as shown at (A); straighten the remaining leads as shown at (B). Connect the new resistor leads to the existing leads as shown at (C); solder the connections and clip off the excess lead length as shown at (D).

both joints. Make the solder connections quickly so you do not melt the solder that connects the original resistor leads to the foil on the board. Use your diagonal pliers to trim off the excess wire for a neat connection, as shown in Fig. 4D.

The techniques you practice here can be adapted to almost any repair problem that you will encounter when working on circuit boards.

Unsolder and remove the resistor that you connected at holes R and T.

Assembling Your Experimental Receiver

Your assembly work on your receiver is divided into three sections. First you assemble the etched circuit board. Then you assemble the parts that attach to the front panel. Finally you attach the assembled circuit board to the front panel and perform the interconnecting wiring.

When you perform the assembly work on this kit, remember that you are manufacturing a complete receiver. This is quite different from assembling an experimental kit where you expect to tear down the assembly after you complete the experiments. In this kit you are expected to make permanent wiring connections and be careful with parts placements and lead dress. Take the necessary time and effort to do a professional job. You will be repaid in pride of workmanship, and you will have the satisfaction of the set working the first time you turn it on.

Read and understand the entire sentence or paragraph of each step before you perform the work. Position each part and lead according to the description and illustrations. After you have completed each step, place a check mark in the space provided. This will ensure that you complete the steps in the correct sequence and do not omit any.

ASSEMBLING THE CIRCUIT BOARD

In this section you mount and solder the parts that attach to the circuit board. The instructions for mounting the parts are contained in Figs. 5, 6, 7, and 8. (Figs. 6, 7, and 8 are in the center of this book.) Fig. 5 is a detailed drawing. Fig. 6 shows the steps for mounting the resistors; Fig. 7 shows the steps for mounting the capacitors; Fig. 8 gives the steps for mounting the transformers, transistors, and diodes. Be sure to read all the instructions for work that you must perform before you carry out steps shown in the figures.

Mounting the Resistors. You will need your hand tools and soldering iron at your work surface. Gather the following parts:

1 Etched circuit board (EC21)
1 AC interlock (IC2)
2 1/4" X 6-32 screws
2 No. 6 lockwashers
2 6-32 hex nuts
1 82k-ohm resistor
1 470k-ohm resistor
1 270k-ohm resistor
2 22k-ohm resistors
1 18k-ohm resistor
1 10k-ohm, 2W resistor
1 10k-ohm, 1/2W resistor
2 6.8k-ohm resistors
1 4.7k-ohm resistor
1 2.2k-ohm resistor
1 1.5k-ohm resistor
1 1k-ohm resistor
1 820-ohm resistor
1 680-ohm resistor
1 560-ohm resistor
1 270-ohm resistor
1 250-ohm, 4W resistor
1 180-ohm resistor
1 100-ohm resistor
Black hookup wire

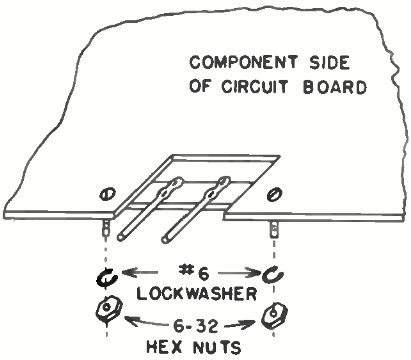


Fig. 5. Details for mounting the ac interlock at the cutout on the board.

Mount the ac interlock in the cutout at the rear edge of the circuit board. Place the interlock on the foil side of the board with the metal pins up toward the phenolic side of the circuit board, as shown in the detailed drawing, Fig. 5. Insert 1/4" X 6-32 screws through the mounting holes from the phenolic side of the board. The screws extend through the mounting holes of the interlock. Attach a No. 6 lockwasher and a 6-32 hex nut to each screw. Tighten the screws . . . . ( )

Next, perform the steps for mounting the resistors and jumpers as outlined in Fig. 6. When you install a resistor, measure the part against the two mounting holes that the leads are to go in. Then bend the leads so they are at right angles to the body of the resistor, and so that the leads fit into the mounting holes. Put the leads through the holes from the phenolic side of the board. Bend the leads slightly on the foil side of the board so that the part will not fall out before it is soldered in place.

After you have mounted a few parts, stop and solder the leads to the copper on the foil side of the board, and then clip off the excess lead lengths.

NOTE: Use only RADIO ROSIN-CORE SOLDER. This is the type we supply with this kit. Do not use acid-core solder or paste flux. Either will ruin a circuit board so that it cannot be repaired. We cannot repair any kit on which acid-core solder has been used.

INSTALLING THE RESISTORS

In steps 5, 11, and 21 of Fig. 6, form each jumper from a piece of bare wire. Resistor lead scraps will do nicely. Install the jumpers from the component side of the board.

In step 20 of Fig. 6, the 250-ohm, 4-watt resistor connects between one mounting hole and one terminal of the ac interlock. Since this resistor gets warm in operation, mount it so the body of the resistor is from about 1/8" to about 1/4" above the board. The 2-watt resistor used in step 18 should be mounted about 1/8" above the board. All other resistors are mounted tight against the board.

In step 21 of Fig. 6, connect the jumper from hole G of the circuit board to the adjacent terminal of the ac interlock.

When you have completed the steps outlined in Fig. 6, place a check mark here . . . . ( )

INSTALLING THE CAPACITORS

You will need the following parts:

- 1 220 pf disc capacitor
- 1 6.8 pf disc capacitor
- 1 220 mfd at 35 VDC electrolytic capacitor
- 1 100 mfd at 150 VDC electrolytic capacitor
- 1 100 mfd at 10 VDC electrolytic capacitor

3 10 mfd at 10 VDC electrolytic capacitors
1 .1 mfd disc capacitor
6 .05 mfd disc capacitors
1 .02 mfd disc capacitor
2 .01 mfd disc capacitors
1 .005 mfd disc capacitor
1 .001 mfd disc capacitor

The instruction steps for mounting the capacitors are contained in Fig. 7. When you mount the electrolytic capacitors, be sure to observe the polarity markings. A plus mark is screened on the circuit board near the hole for the positive lead of the capacitor. The 100 mfd capacitor installed in Step 8 may not have the positive lead identified. It is the lead in the center of the capacitor body, while the negative lead is bent down along the outside of the body. In Step 14, bend the positive lead down along the body of the capacitor before you install it. The circuit board may be screened "200 mf" at this location.

When you have completed all the steps outlined in Fig. 7, place a check mark here . . . . ( )

INSTALLING THE TRANSFORMERS, TRANSISTORS, AND DIODES

You will need the following parts:

1 Oscillator transformer (TR75)
1 Input i-f transformer (TR76)
1 Output i-f transformer (TR77)
1 Audio output transformer (TR27A)
4 EN1132 transistors
1 Power transistor
1 Heat sink (BR73)
1 Detector diode
1 Power rectifier diode
4 3/8" X 6-32 screws
6 No. 6 lockwashers
4 6-32 hex nuts
2 No. 8 flat metal washers

The instruction steps for mounting the listed parts are contained in Fig. 8. Be sure to identify these parts carefully when installing them. It is very difficult to unsolder and remove the 5 or 6 terminals if you happen to mount a transformer in the wrong place.

In step 4 of Fig. 8, a green dot on the base of the transformer is used to identify terminal 1 of the transformer. Position the transformer so the dot on the transformer matches the dot indication on the screening of the circuit board.

In step 9 of Fig. 8, position the audio output transformer on the phenolic side of the board so the bare wires extend toward the edge of the board. Insert 3/8" X 6-32 screws through the mounting feet of the transformer and place a No. 8 flat washer over each screw. Pass the screws through the mounting holes in the circuit board so the two washers are between the mounting feet and the board.

Attach a No. 6 lockwasher and a 6-32 hex nut to each screw. Tighten the screws. Shorten the red and blue transformer wires to a length of about 2". Strip off about 1/4" of insulation from the end of each lead. Solder the red lead of the transformer into hole O and the blue lead into hole P, as shown in Fig. 8.

Consult the detailed drawing, Fig. 9, for identification of the transistor leads for steps 2, 3, 5, and 8. Mount these transistors about 1/4" above the board so the leads are not pulled tight against the mounting holes. You can use an alligator

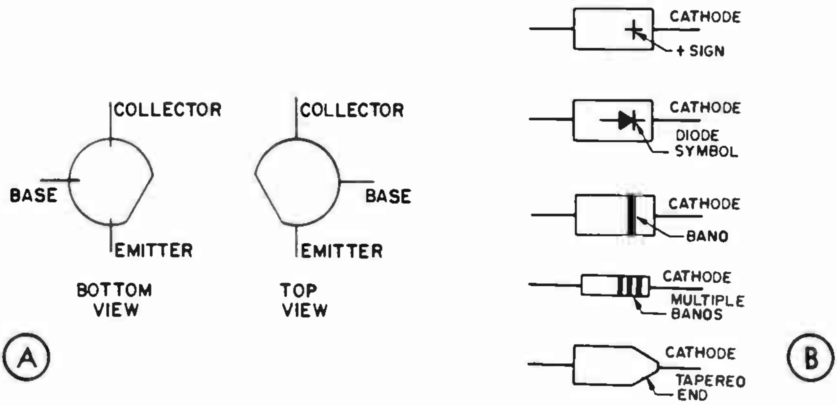


Fig. 9. How to identify transistor leads (A) and diode polarity (B).

clip as a heat sink while soldering the leads of the transistors. Simply attach the alligator clip to the lead on the component side of the board. Turn the board over and solder the connection.

In step 10 of Fig. 8, mount the power transistor (TS33) and its heat sink (BR73) with two 3/8" X 6-32 screws, four No. 6 lockwashers, and two 6-32 nuts (see detail A). First place the transistor inside the heat sink so that its pins pass through the small holes in the center of the heat sink, and so that the transistor mounting holes line up with the large holes at the ends of the heat sink. Pass a 3/8" X 6-32 screw through the transistor and heat sink holes at each end. Then put a No. 6 lockwasher on each screw. Now attach the assembly to the circuit board with two more No. 6 lockwashers and two 6-32 nuts. Be sure to position the transistor so that its pins plug easily into the circuit board. Finally, tighten the mounting hardware and solder the two transistor pins to the circuit board foil. Observe the polarity of the diodes for steps 7 and 11 of Fig. 8.

When you have completed the steps outlined in Fig. 8, place a check mark here . . . . ( )

This completes the assembly of your circuit board. Examine your work carefully. Look for poor solder connections where you used too little heat or too much solder. If necessary, reheat the connection and remove excess solder. Make sure you have not bridged solder from one part of the foil to the foil in another circuit. When you are satisfied with your work, set the board to one side while you assemble the other parts of the receiver.

ASSEMBLING THE FRONT PANEL

In this section you fasten parts to the front panel. Some hardware and parts are put together as an assembly before you attach the assembly to the panel. Treat the panel with care, because rough handling can mar the plastic finish or even crack the mounting posts.

You will need your hand tools and the following parts:

1 Front panel
1 Dial plate with red line
1 Plain dial plate
1 Gray edge mounting
2 Circuit board support brackets
2 Spade bolts

1 Tuning capacitor
1 Volume control bracket
1 Volume control with switch
1 Loopstick antenna
1 Speaker
2 3/8" cable clamps
8 1/4" No. 6 self-tapping screws
4 Speaker mounting clips
3 1/4" X 6-32 screws
4 6-32 hex nuts
5 No. 6 lockwashers

Attach Trim to the Front Panel. Refer to Fig. 10A and Fig. 10B as you mount the decorative trim on the front panel.

Position the dial plate with the red line so that the red line is pointing straight up. Put the dial plate in the upper recess of the panel after bending the three tabs so they pass through slots 1, 2, and 3 of the panel as shown in Fig. 10A. The red line should be between slots 1 and 2 . . . . ( )

Put the plain round dial plate in the lower recess after bending the three tabs so they pass through slots 4, 5, and 6. ( )

Mount the gray edge molding so the four mounting tabs pass through slots 7, 8, 9, and 10. Slot 9 is on the rear edge of the panel . . . . ( )

With the three trim pieces pressed firmly against the front panel, bend the 10 mounting tabs as shown in Fig. 10B ( )

Circuit Board Support Brackets. The next step will be to prepare the support brackets and fasten them to the front panel (as shown in Fig. 11 and Fig. 12).

Attach a 6-32 hex nut to each of the two spade bolts. Tighten the nuts against the "spade" part of the bolt . . . . ( )

Fasten one of the 6-32 spade bolts in hole B of one of the support brackets as shown in Fig. 11. Position the "spade" part parallel to the short dimension of the bracket and secure with a No. 6 lock-washer and a 6-32 hex nut . . . . ( )

In a similar manner, fasten the other

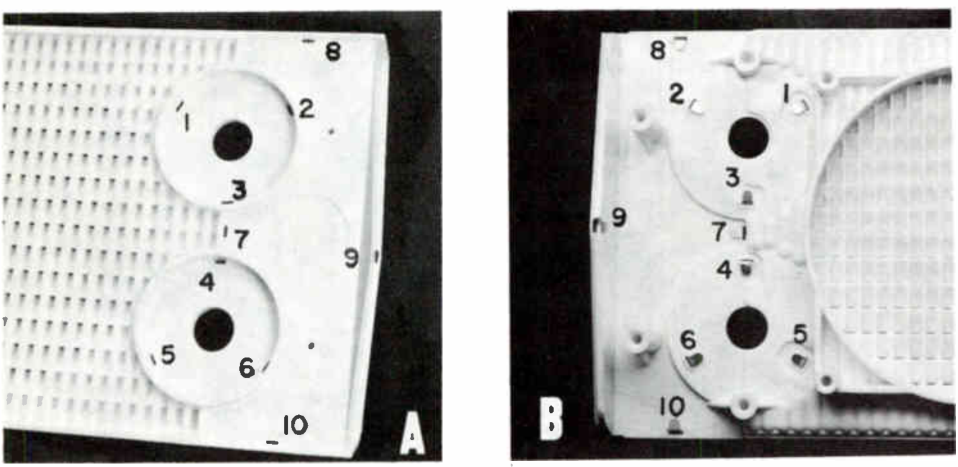


Fig. 10. Mounting the slots for panel trim (A); bending mounting tabs of panel trim (B).

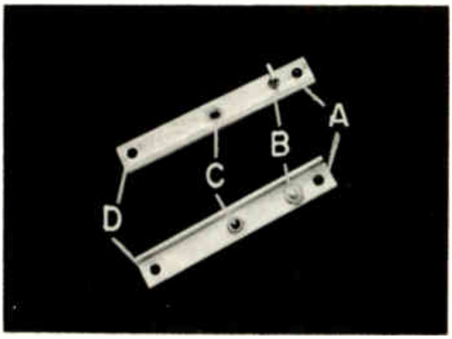


Fig. 11. Circuit board mounting brackets.

6-32 spade bolt in hole B of the other support bracket .... ( )

Place the front panel face down on a cloth in front of you. Position the two large holes in the panel to your left, as shown in Fig. 12.

Place one of the support brackets over the two posts on the left of the panel. Position the bracket so that holes A and D are over the holes in the ends of the posts. The "spade" part of the spade lug should be nearest you and pointing straight up. Fasten the bracket to the front panel with two 1/4" No. 6 self-tapping screws. It is important that you tighten these screws very slowly and that you do not overtighten them. As you turn the screw, it cuts threads in the plastic. If the screw starts to turn hard, back off about a quarter turn and again tighten the screw. This will tend to clear the threads and enable you to get the screw all the way in without cracking the plastic. The plastic posts, although strong, may crack if too much force is used in tightening these screws .... ( )

In a similar manner, fasten the other support bracket to the two posts on the right end of the front panel. Fig. 12 shows the support brackets mounted in place .... ( )

Mount the Speaker. Position the loudspeaker on the front panel with speaker lugs S1 and S2 to your right, as shown in Fig. 12 .... ( )

Push a loudspeaker mounting clip over each of the four loudspeaker mounting posts on the front panel. Make sure that the speaker presses evenly at all points against the front panel .... ( )

Mount Parts on the Volume Control Bracket. Set the front panel out of your

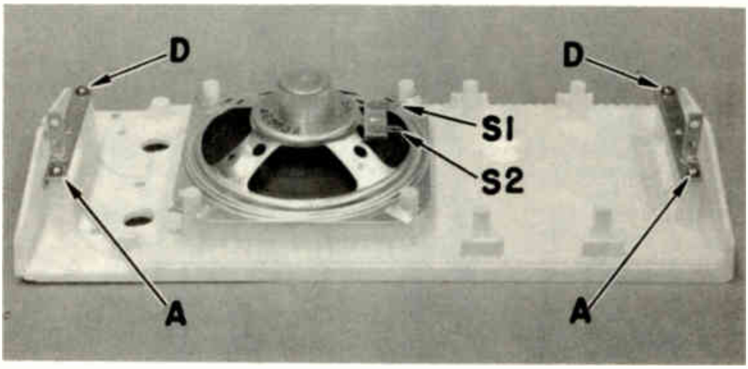


Fig. 12. Rear view of front panel with support brackets and speaker mounted.

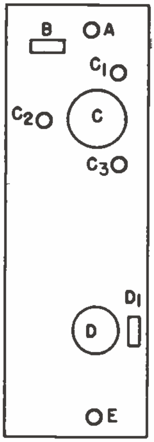


Fig. 13. Rear view of volume control bracket with holes identified.

way temporarily while you assemble the parts on the volume control bracket. Fig. 13 shows a rear view of the bracket with the holes identified. Fig. 14 shows the bracket with the parts mounted.

Slip the shaft of the volume control potentiometer through hole D from the rear of the bracket. Position the control so the locating lug extends through hole D_1. Attach a control nut and tighten it firmly . . . . ( )

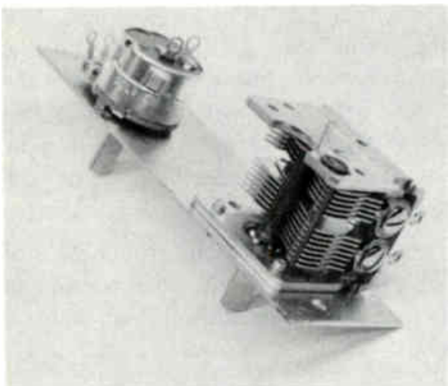


Fig. 14. Volume control bracket with parts mounted.

Slip the shaft of the tuning capacitor through hole C from the rear of the bracket. Position the capacitor so holes C_1, C_2, and C_3 line up with the three threaded holes in the tuning capacitor frame. Slip a No. 6 lockwasher over each of three 1/4" X 6-32 screws. Insert a 1/4" X 6-32 screw with lockwasher attached into holes C_1, C_2, and C_3 from the front of the bracket. Tighten the screws into the threaded holes in the frame of the capacitor . . . . ( )

Attach Volume Control Bracket, Antenna. Fig. 15 shows the front panel with all parts, except the circuit board, mounted in place. Position the volume control bracket, with parts attached, to the rear of the front panel so the shafts extend through the control shaft holes. In this position, holes A and E in the volume control bracket line up with mounting posts on the front panel.

Insert 1/4" No. 6 self-tapping screws through holes A and E and into the mounting post holes. Carefully tighten the screws into the plastic. Do not overtighten . . . . ( )

Examine your loopstick antenna. The black ferrite core is quite brittle and will break rather easily if it is dropped. Also be careful not to apply any flexing pressure to the rod. The rod is partially covered with two wire windings. The long winding forms the coil for the rf tank circuit. The short winding is the secondary winding that carries the received signal to the input circuitry of the receiver. As shown in Fig. 15, the short winding end of the loopstick goes toward the tuning capacitor.

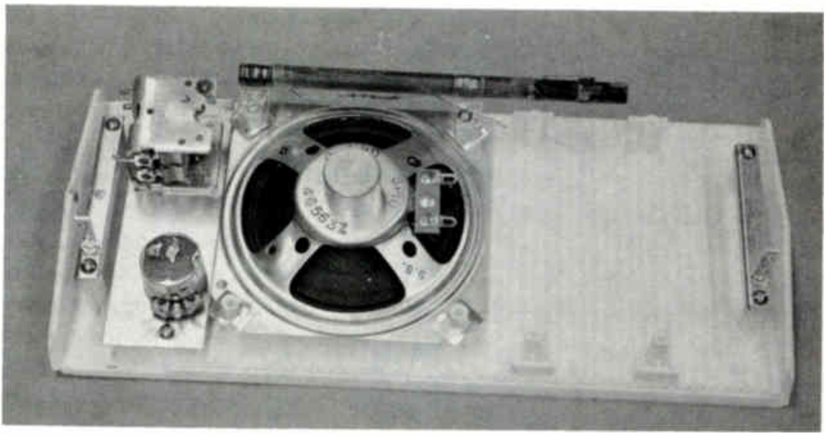


Fig. 15. Rear view of front panel with all parts, except the circuit board, mounted in place.

Slip a 3/8" plastic cable clamp over the long winding section of the loopstick. Slip another 3/8" plastic cable clamp over the bare end of the ferrite core at the short winding end. Hold the antenna next to the two top speaker mounting posts and slide the cable clamps to fit the posts. Insert 1/4" No. 6 self-tapping screws through the cable clamp mounting holes and into the holes of the speaker mounting posts. Tighten the screws carefully. Do not overtighten . . . . ( )

FINAL ASSEMBLY AND WIRING

In this section you attach the assembled circuit board to the assembled front panel and complete the final wiring of the receiver. Fig. 16 shows a top view of the completed wiring. Fig. 17 shows a bottom view of the completed wiring.

You will need the assembled front panel, the preassembled circuit board, and:

- 1 **Tuning knob**
- 1 **Volume control knob**
- 2 **1/4" X 6-32 screws**
- 2 **No. 6 lockwashers**
- 2 **6-32 hex nuts**
- **Assorted hookup wire**

Position the circuit board to the rear of the panel so the board rests on the spade portion of the spade lugs. Position the board so the two board mounting holes line up with the holes in the spade lugs. Use the holes farthest from the panel so the board clears the switch terminals and speaker. Insert a 1/4" X 6-32 screw from the top of the board into each mounting hole. Attach a No. 6 lockwasher and 6-32 hex nut to each screw. Tighten the nuts firmly . . . . ( )

Connect a 1-1/4" wire from hole A of the circuit board to one terminal of the on-off switch. Insert the wire into the hole from the top of the board. Route the wire over the edge of the board to the switch terminal. Solder both of the connections . . . . ( )

Connect a 1-1/4" wire from hole B of the circuit board to the other terminal of the on-off switch. Solder both connections . . . . ( )

Connect a 2-3/4" wire from hole C of the circuit board to the solder lug on the frame of the tuning capacitor. Solder hole C of the circuit board . . . . ( )

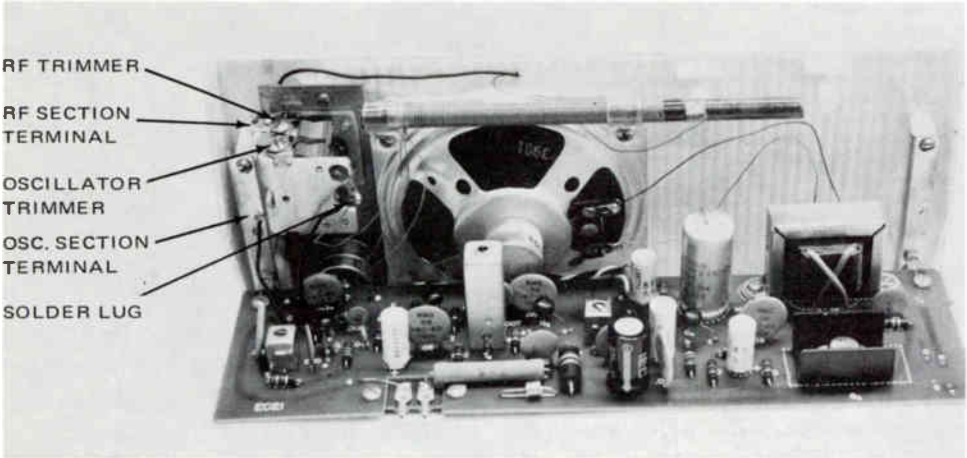


Fig. 16. Top view of receiver with wiring completed.

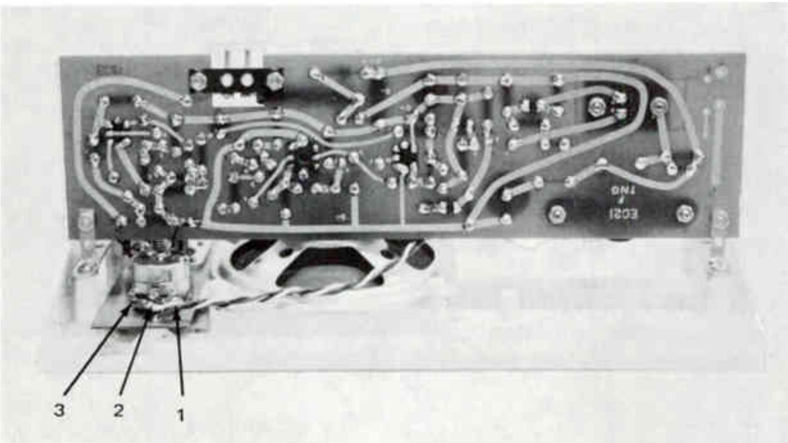


Fig. 17. Bottom view of receiver with wiring completed.

Connect a 2-1/4″ wire from hole D of the circuit board to the terminal on the oscillator section of the tuning capacitor. Solder both connections . . . . ( )

Locate the two varnished wires from the secondary of the audio output transformer. Connect a transformer wire to each speaker terminal. Solder both terminals . . . . ( )

Prepare a 7″ cable from three pieces of hookup wire. Cut a 7″ piece each of red, white, and black hookup wire. Twist the three wires together so that they form a loose cable. Strip 1/4″ of insulation off of the end of each piece of wire in the cable . . . .( )

Refer to Fig. 18 when you perform the following steps.

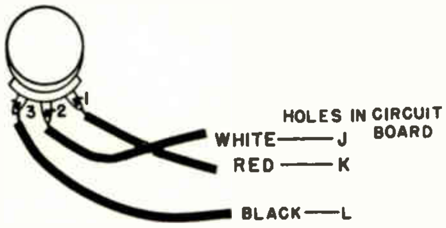


Fig. 18. Details for wiring the volume control to the circuit board.

Connect the wires at one end of the 7″ cable to holes J, K, and L from the top of the circuit board. The white wire goes into hole J, the red wire into hole K and the black wire into hole L. Solder all three wires to the foil on the circuit board . . . . ( )

Route the end of the cable over the front edge of the circuit board and over to the volume control potentiometer terminals . . . . ( )

Connect the red wire of the cable to terminal 1 of the volume control potentiometer. Solder the connection . . . . ( )

Connect the white wire of the cable to terminal 2 of the volume control potentiometer. Solder the connection . . . . ( )

Connect the black wire of the cable to terminal 3 of the volume control potentiometer. Solder the connection . . . . ( )

Identify the wires from the coils of the loopstick antenna. Two wires come from the short secondary coil and two wires come from the long rf coil. These wires are rather fragile and can be broken by rough handling. If you break a wire, or if a wire is too short to reach the indicated terminal, splice on a piece of hookup wire to reach the terminals.

Connect one wire from the short secondary coil of the loopstick antenna to hole E of the circuit board. Solder the wire to the foil . . . . ( )

Connect the other wire from the short secondary coil of the loopstick to hole F of the circuit board. Solder the wire to the foil . . . . ( )

Connect one wire from the long rf coil of the loopstick to the solder lug on the frame of the tuning capacitor. Solder the connection . . . . ( )

Connect the other wire from the long rf coil of the loopstick antenna to the terminal on the rf section of the tuning capacitor. The rf section contains the largest number of plates and is the section nearest the front panel. Route the wire close to the front panel. Solder the connection . . . . ( )

Push the tuning knob onto the shaft of the tuning capacitor . . . . ( )

Push the volume control knob onto the shaft of the volume control potentiometer . . . . ( )

This completes the assembly and wiring of your receiver. You will not install the receiver in the cabinet until after you perform the experiments. Examine your work carefully. Look for bits of wire that may have fallen on top of the circuit board. Look for unsoldered connections, poorly soldered connections, or globs of solder that could cause short circuits. When you are satisfied with your work, proceed to the next section where you are given instructions for testing the receiver.

Testing and Analyzing the Receiver

In this section, you become familiar with your receiver circuitry in preparation for performing the experiments. You record a set of voltage and resistance measurements on your receiver. This assures you that your receiver is wired correctly. Also, you use the recorded voltage measurements as a reference when you are performing the experiments.

As you know, the voltage measurements will vary from set to set. These variations are caused by normal parts tolerances. When you record a set of readings using your own meter on your own receiver, you have a valid set of readings that you can refer to. This is important for analyzing results of experiments. The accurate readings are also helpful in case you have to troubleshoot your receiver.

For this section you will use two important illustrations that are located in the center of the book. Fig. 19 is the schematic diagram of the receiver. You will want to keep this diagram handy to follow circuit discussions. Fig. 20 is a "see-through" diagram of the circuit board. This diagram shows the circuit board as it appears from the foil side of the board. The components are shown in schematic form as they would appear if you could see through the circuit board. Use this drawing to locate test points in the circuit and parts on the circuit board.

CAUTION

Dangerous voltages are present in your receiver. As you know, any ac-operated device carries sufficient voltage to kill you. Even if you use an isolation transformer, the lethal voltages are present within the receiver circuitry. The isolation transformer only protects you from a difference in potential between the receiver and an external earth ground.

Since you have not installed the set in the cabinet, you have in effect defeated the purpose of the ac interlock. Observe all safety precautions. If you are not using an isolation transformer, be sure you are standing on an insulated surface. A damp concrete surface is especially dangerous. Do not work close to an earth ground such as a water pipe.

Unplug the line cord when you make changes in the circuitry. It is almost as easy to unplug the cord from the interlock as it is to turn off the switch. Unplugging the cord gives you complete protection to work on the circuitry. If you work on the energized receiver, steady the set by holding on to the plastic front. Use only one hand to touch live points in the circuit.

Remember that dangerous voltages are present at some points on the component side of the board. For example, the body and vaned heat sink of transistor Q_5 is at the B++ potential of approximately 120 volts dc.

PRELIMINARY TESTS

Before you plug your receiver into the ac power line, you should perform one simple ohmmeter test. Connect the ground clip of your meter to the foil marked B– on the circuit board. Touch the probe to the foil marked B++. You should measure about 4k-ohms of resistance. If you read 0 ohms or a sizable amount less than 4k-ohms, look for a short circuit on the circuit board. Look for solder that is bridged between the B++ and the B– foil on the board. Look for pieces of bare wire that may be shorting between component leads on the component side of the circuit board. If you energize the receiver before clearing the short, you will probably damage components in the power supply circuit.

When you are satisfied that the B++ line is not shorted, energize the receiver. Connect the power line cord to the ac interlock of the receiver. Plug the other end of the cord into a 115-volt ac outlet or into the outlet of an isolation transformer.

Turn the receiver on by rotating the volume control clockwise to actuate the on-off switch. Advance the volume control about halfway. Rotate the tuning knob to tune in a station. Adjust the volume control for normal listening level.

Determine what AM radio stations are available in your area and the transmission frequency of these stations. Your local newspaper probably lists all the local stations, their call letters, and their frequencies.

Tune your receiver across the band and determine if you can receive all available stations. Note the position of the tuning dial for each station to see if your dial indicates the frequencies of the received stations.

The transformers in your receiver are preset so the receiver should be fairly well aligned, but you can improve the alignment. Locate the plastic alignment tool, AT3, that is furnished with the receiver. You will need this tool and a small screwdriver.

Tune the receiver to a weak station. Make sure you are tuned exactly on the station, which is the tuning point where the signal comes in loudest. Using the "see-through" diagram in Fig. 20, locate the input i-f transformer, T_2, on the circuit board. Use your alignment tool to adjust the slugs in the transformer. The hexagon-shaped part of the tool at one end fits the hexagon hole in the transformer slug.

Rotate the top slug either clockwise or counterclockwise, as necessary, to increase the volume of the received station. A fraction of a turn should be all that is necessary to peak the signal. Reach the alignment tool through the hole in the circuit board to adjust the bottom slug in transformer T_2.

Locate the i-f output transformer, T_3. Use a screwdriver to fit the slot in the core at the top of the transformer. Adjust the core as necessary to again peak the received signal. The i-f amplifier is now properly adjusted.

Tune your receiver to the lowest frequency station that you can receive in your area. See if the tuning dial indicates the correct frequency. If not, set the dial to the correct frequency for the station and use a screwdriver to rotate the slug in transformer T_1 in either direction, as necessary, to receive the station.

Next, tune to the highest frequency station that you can receive. Identify the frequency of the station. Observe the position of the tuning dial to see if it indicates the frequency of the received station. If it does not, set the tuning dial to the frequency of the received station and adjust the oscillator trimmer capacitor to receive the station. The oscillator trimmer capacitor is attached to the oscillator section of the tuning capacitor. The oscillator section of the tuning capacitor is the section farthest from the front panel and having the fewest plates. Use a screwdriver to adjust the screw in the trimmer capacitor.

If you moved the core of T_1 very far or adjusted the oscillator trimmer very far, repeat these two adjustments until you get no further improvement.

Finally, adjust the trimmer capacitor on the rf section of the tuning capacitor. This is the trimmer closest to the front panel. Tune the receiver to a weak station near the high end of the broadcast band. Adjust the rf trimmer for maximum received signal.

The touch-up alignment adjustments that you just performed should be adequate for now. In your last experiment, you will perform alignment experiments and finally perform a complete alignment procedure on your receiver.

CIRCUIT DESCRIPTION

The line-operated, superheterodyne AM broadcast-band radio receiver shown in schematic form in Fig. 19 uses five transistors and two diodes. Diode D_2 rectifies the 115-volt ac from the power line. The 250-ohm, 4-watt resistor, R_{21}, is a surge-limiting resistor used to limit the current through the diode. The .01 mfd capacitor, C_{24}, protects the diode from line transients. The output of the half-wave rectifier is filtered by C_{23} and supplies about 120 volts dc B++ to the power output stage, Q_5. The B++ voltage is dropped by the 10k-ohm resistor, R_{20}, to about 19 volts B+ to supply all other stages of the receiver. The B+ line is filtered by the 200 mfd capacitor, C_{22}. Capacitor C_{21} is a ceramic disc capacitor used to provide an rf bypass on the B+ line.

The rf signals from broadcast-band radio stations are picked up by the loopstick antenna, L_1. The rf section of the tuning capacitor, C_1, and the trimmer capacitor, C_2, form the capacitor portion of the tuned rf tank circuit of the antenna. The received rf signals are transformer-coupled to the low-impedance secondary winding of the loopstick antenna, L_1.

The rf signal from the secondary is coupled through R_7 to the base of the mixer stage, Q_2. A local oscillator signal is coupled through C_7, developed across R_6 and C_9, and applied through the secondary of L_1 and through R_7 to the base of Q_2.

The local oscillator signal is generated by the transistor Hartley oscillator stage, Q_1. A positive supply voltage is applied through the voltage-dropping resistor, R_{19}, and through the 3-5 winding of the primary of T_1 to the emitter of the PNP transistor, Q_1. The entire primary winding of T_1 forms the inductive portion of the oscillator tank circuit. The oscillator section of the tuning capacitor, C_3, provides the capacitive portion of the oscillator tank circuit. Capacitor C_4 is the oscillator trimmer capacitor in parallel with C_3. The .05 mfd capacitor, C_5, completes the signal path circuit of the tank.

The secondary winding of T_1 provides a feedback path for the oscillator circuit and provides the oscillator output signal that is coupled through C_7 to the mixer stage. The phase of the signal at terminal 4 of the secondary of T_1 is of the correct polarity to sustain oscillation. The signal is coupled through C_6 to the base of Q_1. Transistor Q_1 is biased to its operating point by the potential at the junction of R_2 and R_1.

The 470k-ohm resistor, R_5, and the .1 mfd capacitor, C_8, isolate the capacitor frame and the volume control bracket from B−. As you know, B− connects to one side of the ac power line. If B− is connected directly to the capacitor frame and the volume control bracket, a dangerous situation could develop. It would then be possible to touch one side of the ac line by removing a knob and touching the metal shaft of either the tuning capacitor or the volume control. The R-C network, consisting of R_5 and C_8, provides a signal path to the tuning capacitor frame and keeps ac leakage to a safe value.

The PNP mixer stage, Q_2, is supplied a positive voltage from the B+ line through the 820-ohm dropping resistor, R_3, to the emitter. The collector circuit of Q_2 is completed to B− through the 5-3 tap-down section of the primary of T_2. The tapped winding on the primary of T_2 provides a low impedance match for the collector of Q_2, and the full primary winding and the capacitor across the winding form a high Q tank circuit tuned to the 455 kHz intermediate frequency of the receiver.

The fixed bias network for Q_2 is combined with the avc circuit. The voltage at the junction of R_6 and R_8 is applied through the secondary winding of L_1, and through R_7 to the base of Q_2. B+ voltage is supplied through the detector circuit (and through volume control P_1), through the 18k-ohm resistor, R_{11}, through R_8 and R_6 and returned to B−.

The detected audio signal at the output of the second detector, D_1, is a positive voltage that adds to the positive fixed bias. The larger the signal at the second detector, the larger the positive voltage that is added to the fixed bias. Since a positive voltage on the base of Q_2 acts as reverse bias, a larger detector signal reduces the gain of the mixer stage, Q_2. In this way, avc is applied to the mixer stage. The avc voltage is filtered by the 10 mfd filter capacitor, C_{11}.

An avc voltage is also applied to the i-f amplifier stage, Q_3. To see how this is done, examine the base circuit of Q_3 and the emitter circuit of Q_2. A static or fixed bias is applied to the base of Q_3 by the action of the voltage divider network consisting of R_3, R_4, and R_9. The dc potential at the emitter of Q_2 follows the dc potential at the base of Q_2.

Therefore, when an avc voltage raises the potential at the base of Q_2, the transistor conducts less and the emitter voltage also increases. The voltage at the emitter of Q_2 is filtered by C_{10}. The dc voltage at the emitter of Q_2 is supplied through R_4 and through the 2-6 winding of T_2 to the base of Q_3. In this way, avc voltage changes are applied to the base of Q_3 and affect the gain of the stage.

Since a positive avc voltage is applied to both Q_2 and Q_3, the avc voltage is reverse-acting. That is, a strong signal produces a positive avc voltage that reduces the conduction of Q_2 and Q_3, and reduces the gain of both stages.

The selected rf station signal and the local oscillator signal are heterodyned in the base-emitter junction of transistor Q_2. Amplified sum and difference signals, plus the two original signals, appear in the collector circuit of Q_2. The tuned i-f amplifier transformer, T_2, selects only the difference, 455 kHz, and rejects all other frequencies. The 455 kHz i-f signal is transformer-coupled to the secondary of T_2 and applied to the base of Q_3.

Transistor stage Q_3 is a transformer-coupled, neutralized, i-f amplifier. The amplified i-f signal is developed in the primary winding of the tuned i-f transformer, T_3, and coupled to the low impedance, untuned secondary winding of T_3. A sizable interelement capacitance exists between the base and collector of the transistor. The interelement capacitance can cause degeneration and loss of gain. Or when the collector load is inductive, it is possible for the capacitance to cause oscillation. To prevent this capacitance from causing degeneration, the capacitance is neutralized by the neutralizing capacitor, C_{14}. The signal at terminal 4 of T_3 is of the correct polarity to neutralize the effect of interelement capacitance in the transistor when the i-f is tuned to 455 kHz.

Now the signal from the secondary of transformer T_3 is applied to the second detector circuit. Diode D_1 rectifies the i-f signal and capacitor C_{15} filters the rectified signal. The detected audio signal is developed across the volume control potentiometer, P_1.

The desired amount of audio signal is picked off by the slider of P_1 and coupled through the 10 mfd electrolytic coupling capacitor, C_{16}, to the base of the audio driver stage, Q_4. The operating point for Q_4 is set by the voltage divider network consisting of R_{13} and R_{12}. The PNP transistor, Q_4, is supplied from the B+ line through the 560-ohm bypassed emitter resistor, R_{14}. The collector circuit is completed to B− through resistors R_{15} and R_{16}.

The amplified audio signal at the collector, Q_4, is direct-coupled to the base of Q_5. Since the circuit is direct-coupled, the collector potential for Q_4 is also the base voltage for Q_5. Therefore the operating point for Q_5 is fixed by the average conduction of Q_4.

Transistor Q_5 is an NPN transistor and is supplied from B++ through the primary of the audio output transformer, T_4, to the collector of Q_5. Resistor R_{18} and capacitor C_{20} damp out voltage transients that could exceed the breakdown voltage rating of the transistor. Capacitor C_{17} in the base circuit of Q_5 helps filter signal transients that could develop damaging voltages in the collector circuit of Q_5. The unbypassed emitter resistor, R_{17}, provides negative feedback that reduces distortion originating in the output stage, Q_5.

Capacitor C_{19}, in the emitter-base circuit of Q_5, improves the impedance match and shapes the audio response curve. The audio signal at the emitter of Q_5 is the same phase as the driving signal at the base of Q_5, because the emitter signal follows the base signal. Capacitor C_{19} couples the emitter signal back to the junction of R_{15} and R_{16} in the base circuit of the transistor.

The values of the resistors in the R_{15}-R_{16} network determine the amount of feedback. Since the signals are in phase, the feedback is essentially positive feedback that increases the gain of the stage. Also the positive feedback reduces the driving power required by the signal driving Q_5. This increases the effective input impedance of the Q_5 base circuit, so it more nearly matches the impedance of the collector circuit of Q_4.

The audio response is limited to a band of frequencies from about 100 Hz to about 6000 Hz. Capacitor C_{17} attenuates the high frequencies, including noise. Low frequency roll-off is caused by coupling capacitor C_{16} and by the small inductance of the audio output transformer. The audio section has more than adequate gain for normal strength stations. On strong local stations, the repro-

		VOLTAGE CHART					
		COLLECTOR		BASE		EMITTER	
		TYPICAL READING	YOUR READING	TYPICAL READING	YOUR READING	TYPICAL READING	YOUR READING
LOCAL OSCILLATOR	Q1	0 VDC	00V	4.6 VDC	4.2	4.9 VDC	4.4
MIXER	Q2	0 VDC	0	18.2 VDC	[illegible]	18.9 VDC	[illegible]
I-F AMPLIFIER	Q3	0 VDC	0	18.2 VDC	18.0	18.9 VDC	18.5
AUDIO DRIVER	Q4	7.2 VDC	7.0	16.2 VDC	16.0	16.9 VDC	16.5
AUDIO OUTPUT	Q5	110 VDC	103	7.2 VDC	6.8	6.7 VDC	6.4

	TYPICAL READING	YOUR READING
B++	120 VDC	112
B+	19 VDC	19
AC SUPPLY	117 VAC	114

NOTE: All measurements taken with high-impedance meter. All measurements taken from B− to the indicated test point. Receiver tuned to a point where no station is received.

Fig. 21. Typical voltage readings with spaces for recording your readings.

		RESISTANCE CHART					
		COLLECTOR		BASE		EMITTER	
		TYPICAL READING	YOUR READING	TYPICAL READING	YOUR READING	TYPICAL READING	YOUR READING
LOCAL OSCILLATOR	Q1	0-ohm	0	5k-ohm	5K	*900-ohm	6K
MIXER	Q2	4-ohm	4	22k-ohm	30K	10k-ohm	10K
I-F AMPLIFIER	Q3	2-ohm	2.5	12k-ohm	10K	10k-ohm	10K
AUDIO DRIVER	Q4	*900-ohm	600	10k-ohm	10K	10k-ohm	10K
AUDIO OUTPUT	Q5	20k-ohm	20K	*900-ohm	600	270-ohm	250

		TYPICAL READING	YOUR READING
B++ LINE		15k-ohm	20K
B+ LINE		10k-ohm	9K
AC SUPPLY	HIGH SIDE	30k-ohm	50K
	LOW SIDE	0-ohm	0

*NOTE: Varies with ohmmeter scale because the reading indicates transistor resistance. Readings taken with ohmmeter section of tvom using the scale that gives the nearest mid-scale reading. Readings taken between B− and the indicated test points. Readings taken with on/off switch in the ON position and the line cord unplugged. Low side of AC supply connects through on/off switch to B−. "Normal-Reverse" switch of tvom to "Normal."

Fig. 22. Typical resistance readings with spaces for recording your readings.

duced sound will distort badly before the volume control is turned wide open. Distortion remains well below 2% for audio output levels below 500 milliwatts. This is more than adequate sound for normal listening levels.

VOLTAGE AND RESISTANCE CHARTS

The voltage chart in Fig. 21 and the resistance chart in Fig. 22 give typical readings obtained on the CONAR Model 7TT receiver. Spaces are provided in the charts to record your own readings on your receiver. Use the schematic diagram of the receiver, Fig. 19, and the "see-through" drawing of the circuit board, Fig. 20, to locate the test points on your receiver. Be sure to observe the notes on the charts that give you the setup conditions for taking the readings. You will find these charts very useful in understanding the effects of defects that you insert in the receiver circuitry when performing experiments.

Performing Experiments 61 Through 70

Your receiver should now be in good operating condition for performing the experiments. In performing these experiments, you often remove parts and make circuit changes. We usually remind you to test the receiver after you complete each change. If you fail to correct a wiring change and go on with the experiment, you can end up with confusing symptoms.

As you complete each experiment, perform the step for answering the statement question. Be sure to read carefully all choices for each statement. In some cases a choice may be partially correct. In other cases you have to choose the most nearly correct of several choices. If you have made careful observations while doing the experiment and the step for the statement, you will have no trouble answering the statement. Take special care to correctly transfer your answers to the Report Statement sheet that you mail in for grading.

EXPERIMENT 61

Purpose: To show that a meter can be used to indicate the presence or absence of signals in certain stages of a transistor radio receiver.

Introductory Discussion: Your meter (vtvm or tvom) can often be used to quickly isolate a defect in a radio receiver. In this experiment you examine the capabilities and limitations of the meter for determining if signals are present in certain stages of the receiver.

It is convenient to be able to test for signals with the meter. When you first open the defective receiver, one of your first tests may be to check for the presence of the required power supply voltage. For this test, you would normally use your meter.

Since you have the meter hooked up to the receiver, it is convenient to use it to test for signals. In most cases, a reading or two with your meter will isolate the trouble to one section of the receiver or even to a particular stage. At least you will be able to eliminate several of the possible causes of the defect. Also, the results of your test will indicate to you what other methods of investigation should be used to locate the defect in the particular receiver you are working on.

In this experiment, you will examine what signals can be observed using only the meter. You may know of better ways to test a particular function of a receiver. For example, a circuit disturbance or signal injection method is probably the quickest and easiest way to test the audio section. But you can also trace the audio signal with your meter.

An experienced serviceman will always have several different methods of testing to choose from. He may use an alternate method of testing to prove a suspected defect, or special conditions may make the preferred test method impractical.

Knowing many test methods improves your understanding of circuit operation. It also reduces the chance of your being stumped by an unusual defect that does not respond to your usual preferred test methods.

Experimental Procedure: To perform the steps of this experiment, you need only your operating receiver and your meter.

Set the receiver on your work surface with the foil side of the printed circuit board facing you. A convenient position is with the chassis resting on its left end. The left edge of the front panel and the left edge of the circuit board support the receiver in a stable, upright position. In this position, the weight of the receiver is not resting on any parts that could otherwise be damaged. Also you can reach both sides of the circuit board. Tack-solder a short piece of hookup wire to the B– foil. This provides a convenient place to clip the common lead of your meter.

Use the schematic diagram of the receiver (Fig. 19) to follow the discussions relating to circuit operation. Use the "see-through" diagram (Fig. 20) of the circuit board to locate test points and components on the circuit board.

Test your receiver operation both before and after each step of an experiment; otherwise, you may introduce another defect before the previous one is corrected. This can cause waste of time, confusing results from an experiment, or damage to some components of your receiver.

Step 1: To show how the meter can be used to localize a defect causing a dead set to one section of the receiver.

The audio detector is the dividing line between the rf section and the af section of a receiver. A test at this point will isolate the defect to either one of these two signal-handling sections of the receiver. This test is a logical first step in isolating the defect in a dead receiver.

Tack-solder a short piece of hookup wire across the voice coil terminals of the speaker. This will simulate a dead receiver and allow you to turn the volume control maximum without the annoyance of the loud audio. Connect the ground clip of your meter to B– on the receiver. Set your meter to measure +dc on the 30-volt range. Touch the meter probe to terminal 3 of the volume control, P_1. You should read 15 volts or more.

From the schematic diagram, notice that the volume control is connected to the B+ line, so you will read approximately B+ anywhere in the detector circuit. Notice also that terminal 3 of P_1 connects to the output of the detector diode. Therefore, the detected audio signal will simply add to the B+ voltage value.

Tune the receiver slowly across the band while observing the meter pointer. The reading increases when you tune to a station, indicating that the detector is rectifying the received signal.

Move the ground clip of your meter to terminal 1 of the volume control, P_1. Turn the Range switch to the 3-volt range. Again touch the probe to terminal 3 of the volume control and tune across the band. With the meter hooked up this way, the meter indicates only the voltage produced by the action of the diode detector. On strong stations, you may get a reading of .5 volt or more. A very weak station may produce a reading of only .1 volt. Between stations, the pointer returns to zero.

This test tells you definitely that the rf section is working, and that the defect lies in the af signal path between the detector and the speaker.

Step 2: To trace a signal through the audio section of the receiver with a meter.

Leave the receiver and test equipment set up as you had it for Step 1. Switch the meter Function switch to ac and again touch the probe to terminal 3 of P_1. On a strong station, you should observe that the meter needle fluctuates a small amount, but does not give a very definite reading. Connect the ground clip of the meter to B– and touch the probe to the base of Q_4. When the volume control is turned fully clockwise, the ac reading will be about the same as that obtained at the output of the detector.

If you are used to working with tube radios, you may find these results unusual. As you know, the transistor is a current-operated device. The output of the detector must work into the relatively low impedance of the base circuit of the driver transistor. Therefore, the volume control potentiometer is 2.5k-ohms instead of about one-half a megohm, as usually found in tube receivers. Also, the coupling capacitor is 10 mfd instead of the .01 to .05 mfd commonly found in tube sets. This circuit is designed to vary the base current of the driver transistor. Therefore, the ac voltage variations are too small to give a usable indication on the meter.

Next, switch the Range switch of your meter to the 12-volt scale and touch the probe to the collector of the driver transistor, Q_4. You should read between 1 and 6 volts, depending on the strength of the station you are tuned to. The meter reading will fluctuate with the contents of the program. Vary the volume control setting, and notice that the amplitude of the reading also varies. Touch the meter probe to the emitter of Q_4. You do not get a reading because the emitter resistor, R_{14}, is well bypassed by the capacitor, C_{18}.

From the schematic diagram, notice that the signal at the collector of Q_4 is also the signal at the base of Q_5 because the transistors are direct-coupled. Next, touch the probe to the emitter of Q_5, and again observe a reading similar to that obtained at the base. This is what you would expect, because the emitter resistor, R_{17}, is not bypassed, and the emitter signal tends to follow the base signal.

Turn the Range switch to the 120-volt position and touch the probe to the collector of Q_5. With the volume control fully clockwise and tuned to a strong station, you should read 50 or 60 volts ac. The reading will fluctuate with changes in the audio signal.

From these tests you can see that the meter is not very good for tracing the audio signals in the circuit immediately following the detector of a transistor receiver. However, you do get a usable indication in the stages after the signal has been amplified. Therefore, the test can isolate the defect to a very small section of circuitry. For example, suppose your test indicates that the detector is working but you do not get a signal at the collector of the driver transistor, Q_4. The suspected circuitry would include the coupling capacitor, C_{16}, the transistor Q_4, and its associated circuitry.

Step 3: To show that the meter can be used to indicate the presence of signals in some stages of the rf section of the receiver.

Unsolder and remove the short piece of hookup wire that you connected across the terminals of the speaker. In this step you can turn the volume down to the desired level and it will not affect the readings in the rf section of the receiver. Tune the receiver to a strong local station. Set the meter to read ac on the lowest range. Connect the ground clip to B- and touch the probe to terminal 4 of T_3, which is the junction of the i-f output transformer and the detector diode.

You should get a readable indication of about .25 to .5 volt if you are tuned to a strong station. Tune across the station, and notice that the reading is greatest when properly tuned, and drops to zero between stations. Also notice that touching the probe to this point in the circuit does not noticeably affect the volume of the recovered sound. The secondary of the i-f output transformer is a low-impedance circuit, so the capacitance of the probe does not detune or load the circuit appreciably.

Next, touch the probe to terminal 2 of T_3, and again read an indication of the presence of the 455 kHz i-f signal. Notice that touching terminal 2 detunes the primary circuit and lowers the volume of the recovered sound. Touch the probe to terminal 6 of T_3, which is also the collector of Q_3, and read an indication of the i-f signal. This point is a lower impedance than terminal 2, so touching it produces little or no detuning. Touch the probe to the base of Q_3 and look for an indication on the meter. The signal is too small to give you a usable indication.

Touch the meter probe to the collector of Q_2 and tune to a strong local station. You should read some small value of ac voltage as an indication of the presence of a signal. The meter gives a fair-sized indication, because four signals are present at this point.

As you know, the collector of the mixer, Q_2, carries the oscillator signal, the incoming rf signal, the sum of these, and their difference, or i-f signal. The combined effect of these four signals is sufficient to produce a reading on the meter. Attempt to measure the signal at the base of Q_2. The local oscillator signal is coupled to the base circuit through C_7 and the rf signal is direct-coupled from the loop antenna. However, these signals are too small at this point to give an indication on your meter.

Next, use your meter to determine if the local oscillator is operating. Touch the probe to terminal 4 of the oscillator transformer and measure a small value of ac voltage. Tune the receiver across the band, and notice that the amplitude varies somewhat at different points. This is normal, since the efficiency of the oscillator varies for different frequencies. The amplitude variations are unimportant as long as the oscillator signal is above the minimum amplitude required to properly operate the mixer stage.

Touch the probe to the base and then the emitter of Q_1. The oscillator signal is too small at these points to produce a usable meter indication. Touch the probe to terminal 2 of T_1 and measure an ac voltage of 2 to 5 volts. Since this measurement is taken across the high-impedance tank circuit, you get a sizable reading. Tune the receiver across the band, and notice the large change in oscillator voltage amplitude at various settings of the tuning capacitor.

The results of this step show that the meter has limited value for tracing signals in the rf section of the receiver. However, the ability to use the meter to determine that the local oscillator is operating is very useful in troubleshooting. Also, being able to determine that an i-f signal is present in the i-f output transformer is useful. For example, suppose you get no indication of an audio signal at the output of the detector. If you then read an i-f signal at the i-f output transformer, you can be pretty sure that the detector diode is open. If the diode is shorted, it will, of course, short the i-f signal to the detector filter circuit and no appreciable signal can be measured on the i-f output transformer.

Instructions for Statement 61: For this statement you will use your meter to determine if the local oscillator is operating, and investigate the effect of meter loading, if any, on the operation of the receiver.

When servicing the receiver, it is convenient to measure the local oscillator signal at the tuning capacitor because this point is easy to locate in the circuit. You know that the local oscillator tunes to a frequency higher than the incoming rf signal. Therefore, the small section (fewer plates) of the tuning capacitor is the variable capacitance for the local oscillator. To take the reading you simply clip the ground lead of the meter to B-, touch the probe to the capacitor terminal, and measure the ac oscillator voltage.

Perform the preceding test on your receiver. Attempt to tune in a station while the probe is in contact with the capacitor terminal. Remove the probe, tune in a station, and again touch the probe to the capacitor terminal. Observe the effect, if any, on the received signal, then answer the statement.

Statement No. 61: When I touched the meter probe to the terminal of the oscillator tuning capacitor to measure the local oscillator voltage,

(1) the meter probe loaded the circuit only slightly and I was able to receive most stations at their usual places on the tuning dial.

(2) the meter probe capacitance changed the frequency of the local oscillator and the few stations I could tune to appeared at the wrong place on the tuning dial.

(3) the meter probe loading shunted out the radio station i-f signals, so I was not able to receive any stations.

EXPERIMENT 62

Purpose: To show how to use a circuit disturbance test to isolate a defective stage.

Introductory Discussion: A circuit disturbance test is the equivalent of a signal-injection test. As you know, signal injection consists of injecting the type of signal normally carried by the circuit to some point in the signal path and determining if the circuit processes the signal. For example, if an audio signal is injected into any point in the audio signal path circuits, the amplified audio signal should be heard from the loudspeaker.

If a modulated i-f signal is injected anywhere in the i-f amplifier circuit signal path, the circuit should amplify the signal, the detector should detect the audio modulation, the audio amplifier should amplify the detected signal, and you should again hear the processed signal from the loudspeaker. Likewise, a modulated rf signal can be applied to the antenna to test the operation of all circuits in the receiver.

In practical servicing, a circuit disturbance test is usually substituted for signal injection because it is quicker and produces satisfactory results. For a circuit disturbance test, you need only change the level of the dc voltages somewhere in the signal path to produce an audible click at the speaker.

In the audio section of the receiver, you can inject a 60 Hertz signal by merely touching your finger to the signal path. Your body picks up enough 60 Hertz signal from the house wiring to provide a usable signal for the high-gain audio amplifier stages. You will then hear a 60 Hertz hum from the speaker.

In a transistor receiver, touching the signal path in the rf or i-f section of the receiver may or may not produce enough disturbance to get a click at the loudspeaker. As you know, the slight change in dc operating voltage levels must shock-excite the tuned circuit in the stage. This will produce a few cycles at the resonant frequency of the tuned circuit. The oscillations quickly die out. The change in amplitude of the rf signal constitutes the modulation, so the detector produces a small signal that is reproduced in the speaker as a click. At some points in a low impedance transistor circuit, touching the low impedance point may not produce enough change to be heard in the speaker.

Experimental Procedure: For this experiment you will need your operating receiver, your meter, your hand tools, and the following part:

1 .27 mfd capacitor

Step 1: To show that a sudden change in current through the output transformer primary will produce a click in the loudspeaker.

Unplug the receiver from the power line. Set the Function switch of your meter to ohms and the Range switch to the lowest range. Clip the meter ground lead to the collector of the output transistor, Q_5. Touch the ohmmeter probe to the B++ line. Observe the schematic to see that with this connection you are placing the ohmmeter across the primary of the audio-output transformer. You should hear a click in the speaker each time you make or break the connections. The battery in your ohmmeter is forcing a small amount of current through the primary of the transformer. The change in current through the primary induces a current in the secondary that drives the voice coil of the speaker to produce the click. Remove the meter ground clip from the collector of the output transistor.

This procedure tests the audio output transformer and the speaker. This is an easy test to make on these parts when testing a dead receiver. If this test does not produce a click, then you would use the ohmmeter to measure continuity through the transformer primary and secondary and through the voice coil of the speaker.

It is necessary to disconnect one wire from the speaker to measure its continuity. Both the secondary of the transformer and the voice coil are in parallel and both have a very low resistance.

Many receivers do not have an audio-output transformer. Instead, the voice coil of the speaker is driven directly from the output transistors. In these receivers it is sometimes necessary to disconnect one lead of the speaker to make a valid resistance check of the speaker voice coil.

Step 2: To show how a circuit disturbance test can be used to prove whether or not the audio section of the receiver is operating.

Connect the receiver to the power line and tune to a point between stations. Turn the volume control fully clockwise. If you are in a noisy location, you will hear a lot of noise from the loudspeaker. To get rid of the noise, tack-solder a short piece of hookup wire from terminal 3 to terminal 4 of the i-f transformer, T_3. This simulates a defect in the i-f section of the receiver.

Touch the blade of a screwdriver to terminal 2 of the volume control (center terminal) and touch your finger to the screwdriver blade. You should hear a 60 Hertz hum from the loudspeaker. Rotate the volume control from maximum to minimum, and notice that the volume drops to zero. From the schematic diagram, you can see that when the volume control is at minimum, terminal 2 is in effect connected to terminal 1, which is also the B+ line. Therefore, the filtering on the B+ line filters the 60 Hz pickup signal from your body and no hum is produced in the speaker.

Touch the screwdriver to the base of Q_4 and again hear the 60 Hertz hum. Notice that varying the volume control still changes the volume. The signal is lost through the large coupling capacitor, C_{16}, to the B+ line when the volume control is turned down. You should still hear a click when you touch the circuit. Next, touch the screwdriver to the base of Q_5, which is also the collector of Q_4. Again you will hear a click, but the 60 Hertz hum is not audible. The single stage does not have enough gain to give a usable indication of the hum signal. The collector of Q_5 is at a high positive voltage of about 110 volts dc. Touch the collector of Q_5 and notice that it does not produce an audible click.

Remove the short circuit that you tack-soldered across terminals 3 and 4 of the i-f output transformer, T_3. Tune to a place on the dial between stations and turn up the volume control. Again perform the circuit disturbance tests in the audio section. Notice that you get a distinct click in the speaker when you touch any point in the audio signal path. Even when you touch B++ or B- you hear a click. This occurs because the disturbance produces an rf signal that is picked up by the antenna. Even though the signal is quite weak, the high gain of the receiver is such that it processes the signal and produces a click in the speaker. From this experiment, you can see why a receiver picks up electrical noise from appliances, machinery, etc.

Step 3: To show how a circuit disturbance test can be used to indicate the operation of an i-f or mixer stage.

Use a clip lead or a short piece of hookup wire to short out the oscillator tank circuit. Connect the short between the capacitor terminal on the oscillator section of the tuning capacitor and the ground lug on the frame of the capacitor. This connection will stop the local oscillator. The signal path through the radio is unaffected, but no stations will be received. Turn the volume control fully clockwise.

Energize the receiver and touch the screwdriver blade to the collector of Q_3. You should get a loud click from the receiver. Touch the base of Q_3, the collector of Q_2, and the base of Q_2. In each case, the circuit disturbance will produce a loud click in the speaker, indicating that the stages are able to pass a signal. Touch the antenna terminal where it connects to the rf section of the tuning capacitor. A disturbance in the rf tank circuit of the antenna induces a signal in the secondary of the loopstick, which in turn acts as a signal to the base of Q_2. Try holding your hand against the wires of the loopstick. You should hear noise and hum from the speaker, depending on the amount of pickup signal available in your area. These tests indicate that the rf and i-f sections of your receiver are capable of amplifying a signal.

Touch your screwdriver blade to the base and then to the emitter of the oscillator transistor, Q_1. Even though the circuit is not oscillating, it amplifies the circuit disturbance and injects a signal to the base circuit of Q_2, producing a click in the speaker.

Disconnect the receiver from the power line and carefully unsolder the collector lead from Q_2. Energize the receiver and again perform the circuit disturbance test in the rf and i-f sections of your receiver. Touching the collector and base of Q_3 produces the usual loud click. Also when you touch terminal 5 of T_2, which is the point where the collector of Q_3 usually is connected, you get a loud click. The circuit disturbance in the primary of T_2 is readily coupled to the secondary to furnish a signal to the base of Q_3.

Touch the base of Q_2 and other points in the signal path ahead of Q_2. You may hear a faint click in the speaker, but not nearly as loud as when Q_2 was operating.

The preceding tests show how you can use the circuit disturbance to isolate the defect to one stage of the receiver.

Step 4: To show limitations of the circuit disturbance tests.

Carefully resolder the connection of the collector of Q_2 to the circuit board. Temporarily disconnect the short on the oscillator section of the tuning capacitor, and test the radio for proper operation. Then disable the oscillator by reconnecting the tuning capacitor short circuit. Next, tack-solder a short piece of hookup wire from terminal 4 of T_2 to B– (the foil at terminal 3 of T_2 is a convenient B– point for the connection). This connection places a short circuit across the primary of the transformer, T_2.

Energize the receiver and perform the circuit disturbance test in the rf and i-f sections of your receiver. When you touch the base and collector of Q_2, you should get an audible click from the speaker. You may note that the sound is not quite as loud as before you shorted the transformer, but the stage is still passing the signal.

Now remove the short from the oscillator section of the tuning capacitor to activate the local oscillator. Attempt to tune in a station. If you have a very strong local station in your area, you will be able to hear it faintly. Unplug the receiver from the power line. Unsolder and remove the short circuit that you had connected from terminal 4 of T_2 to B–. Test the receiver for proper operation.

The results of this step indicate that the circuit disturbance tests have serious limitations. Thus a short in the relatively low-impedance transistor circuit did not prevent the circuit from passing a circuit disturbance signal. In an earlier step, you found that touching the oscillator transistor produced a click even though the oscillator was not oscillating. Therefore, you can see that the circuit disturbance tests give you only rough indications of whether the circuits are working or not. The fact that these tests can be made quickly makes them useful even though they have serious limitations.

Instructions for Statement 62: For this statement you will investigate the effectiveness of stage blocking in the signal path of a transistor receiver. As you know, stage blocking consists of intentionally killing the signal in one stage at a time. This troubleshooting technique is often used for tracking down the point at which noise is getting into the signal path. For example, suppose you block the i-f output stage. If the noise is still present, you know that the noise is getting into the signal path somewhere between the stage and the speaker. On the other hand, if the noise disappears, it must be getting into the signal path in an earlier stage.

For this statement, you will use a .27 mfd capacitor to attenuate the i-f signal in the i-f section of your receiver. Tune your receiver to a local station and adjust the volume for a normal listening level. Next, use a clip to attach one end of your .27 mfd capacitor to B− on the receiver. Then touch the free end of the capacitor to the foil at the collector of Q_2, and note the effect on the received program. Next, touch the free end of the capacitor to the foil at the base of Q_3, and again note the effect on the program. Finally, touch the free end of the capacitor to the foil at the collector of Q_3. Remove the capacitor, test the receiver for proper operation, and answer the statement.

Statement No. 62: When I attempted to kill the i-f signal by shunting a .27 mfd capacitor from the i-f signal path to B−,

(1) the capacitor completely eliminated the signal at each point that I touched.

(2) the capacitor affected the volume only slightly at each point that I touched.

(3) the capacitor killed the signal when I touched the collectors, but I could still hear the program when I touched the base of Q_3 because this is a low-impedance point in the circuit.

EXPERIMENT 63

Purpose: To show how to use the meter to locate a defective transistor.

Introductory Discussion: Your meter can be an effective tool to determine quickly if a transistor is defective. In most cases, you can determine positively whether or not the transistor is defective without removing it from the circuit. You are able to make these tests by knowing what voltage readings are reasonable at each element of the transistor. The voltage readings you take on the transistors should tell you if the transistor is conducting, and if proper voltages are applied to the transistor. From these voltage tests, you should be able to determine if an inoperative stage is the result of a defective transistor or the result of defective circuitry associated with the transistor.

Let's examine each of the few facts that you must remember while you are making voltage tests on the transistor. These facts about transistor voltages apply to any circuit, and do not require you to know the correct voltages for the particular receiver you are working on.

Fig. 63-1 shows a PNP and an NPN transistor symbol, with the polarity of voltages at each element of the transistor. The polarity markings of the collector and emitter are relative to each other. In each case, the base polarity is the same as the collector to provide forward bias for the transistor.

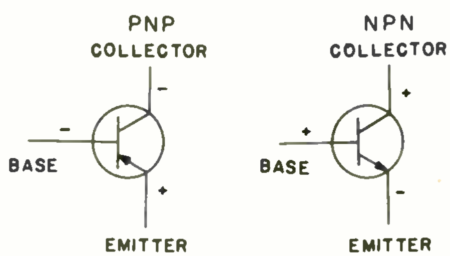


Fig. 63-1. Polarity of the operating voltages at the elements of transistors.

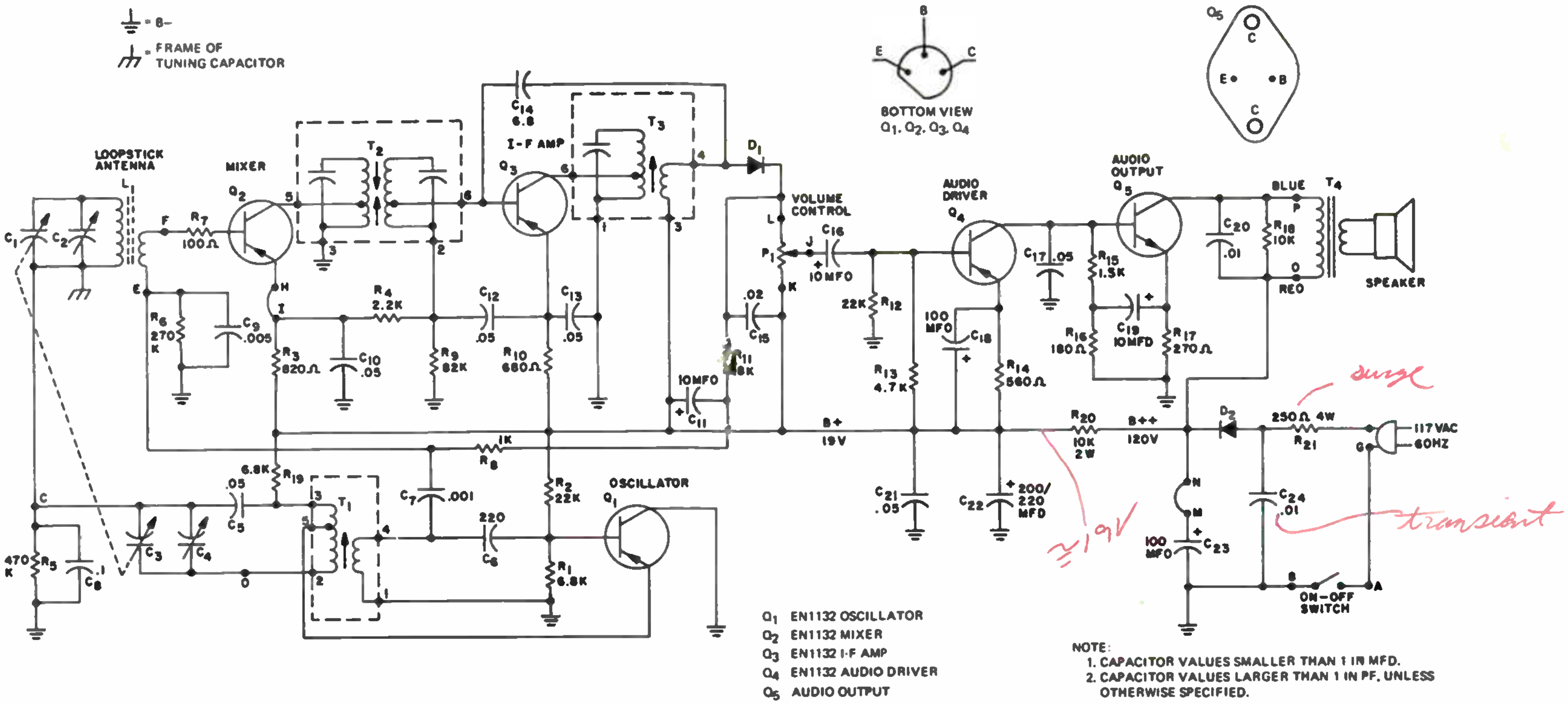


Fig. 19. Complete schematic of 7TT receiver.

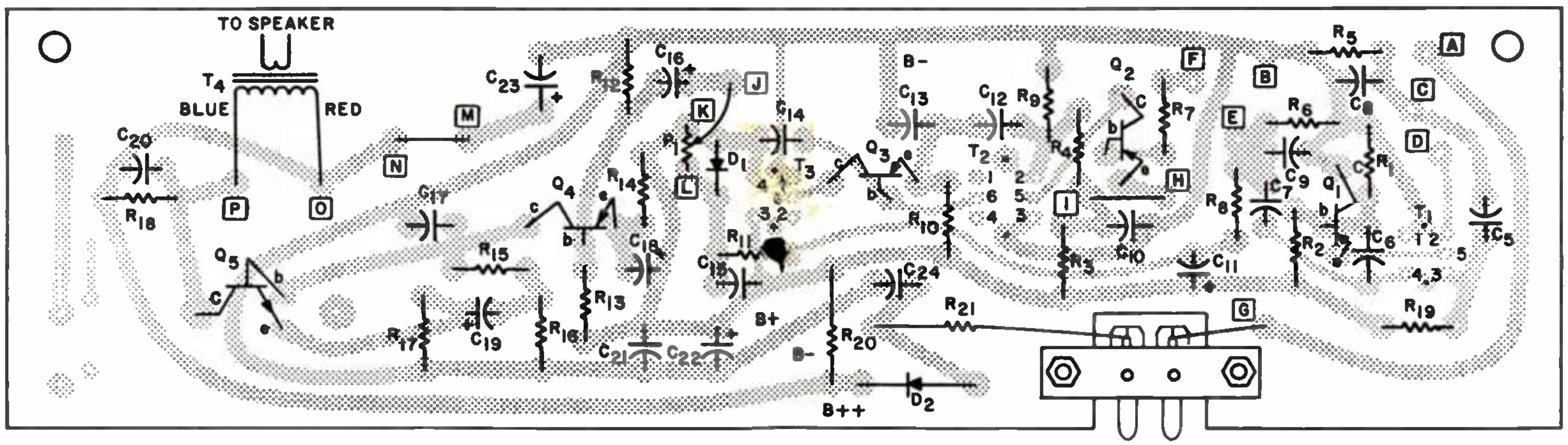
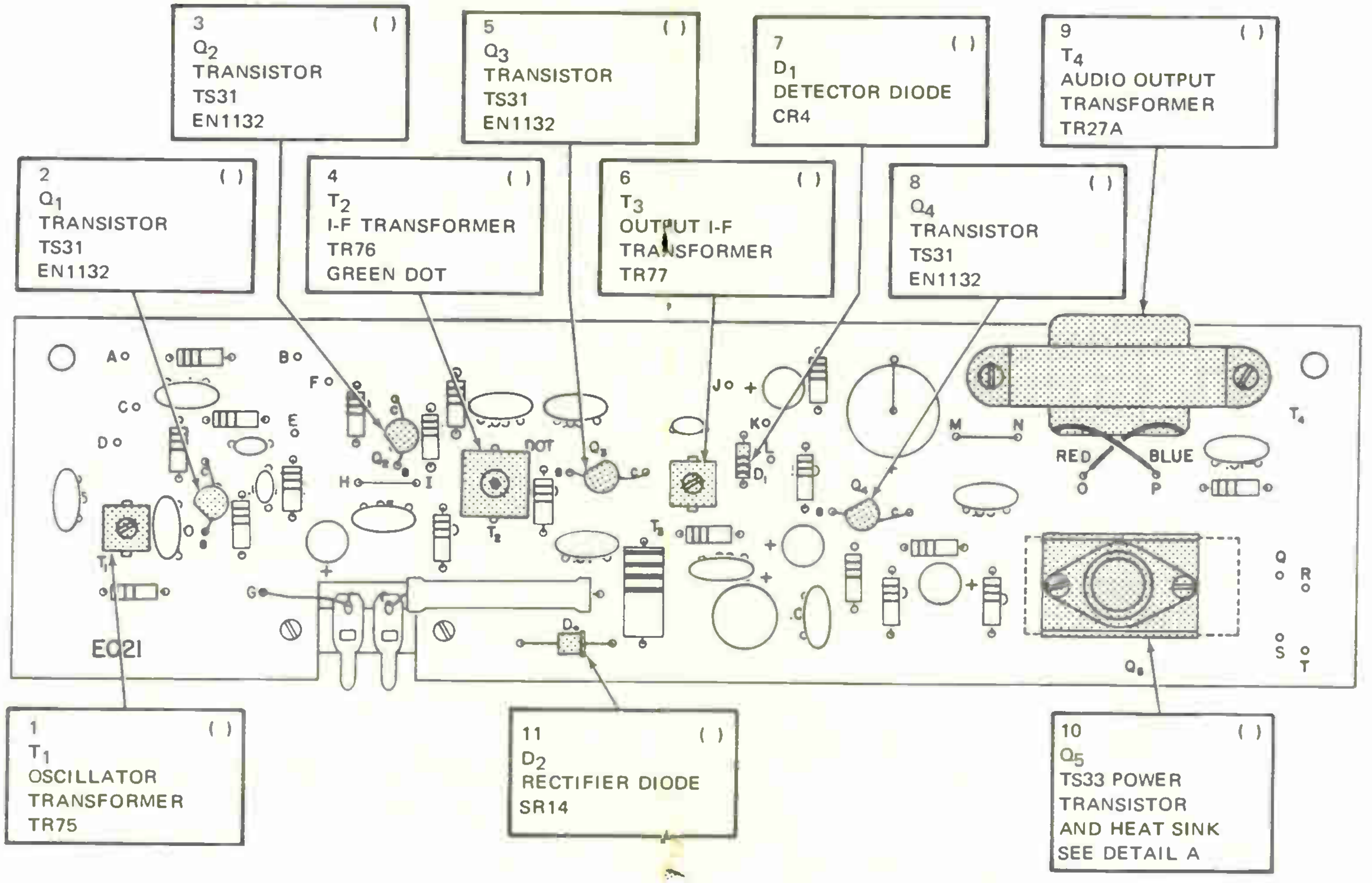


Fig. 20. "See-through" drawing showing location of parts from the foil side of the circuit board.

These diagrams should be removed from the book so you can refer to them quickly and easily. Carefully open the staples, remove the diagrams, and then close the staples again so the book will not fall apart.



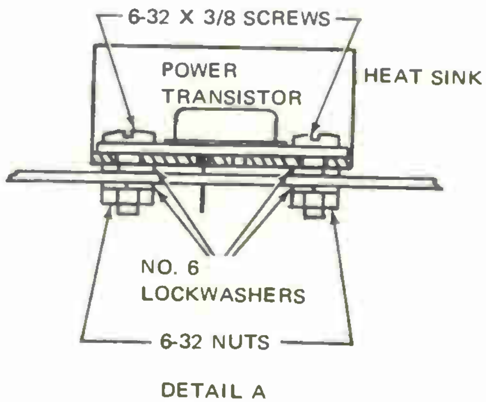


Fig. 8. Installing the transformers, transistors, and diodes on the circuit board.

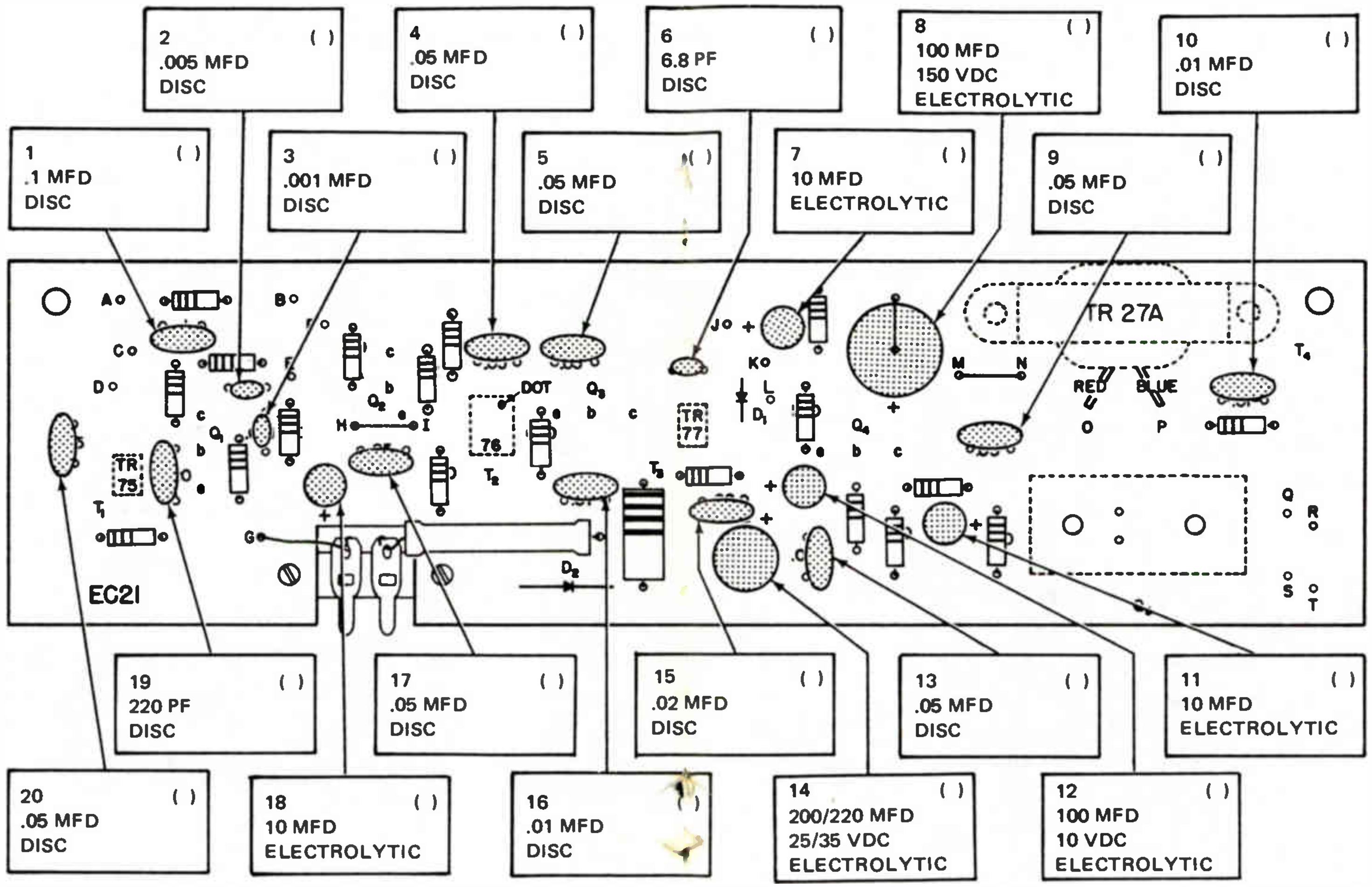


Fig. 7. Installing the capacitors on the circuit board.

These diagrams should be removed from the book so you can refer to them quickly and easily. Carefully open the staples, remove the diagrams, and then close the staples again so the book will not fall apart.

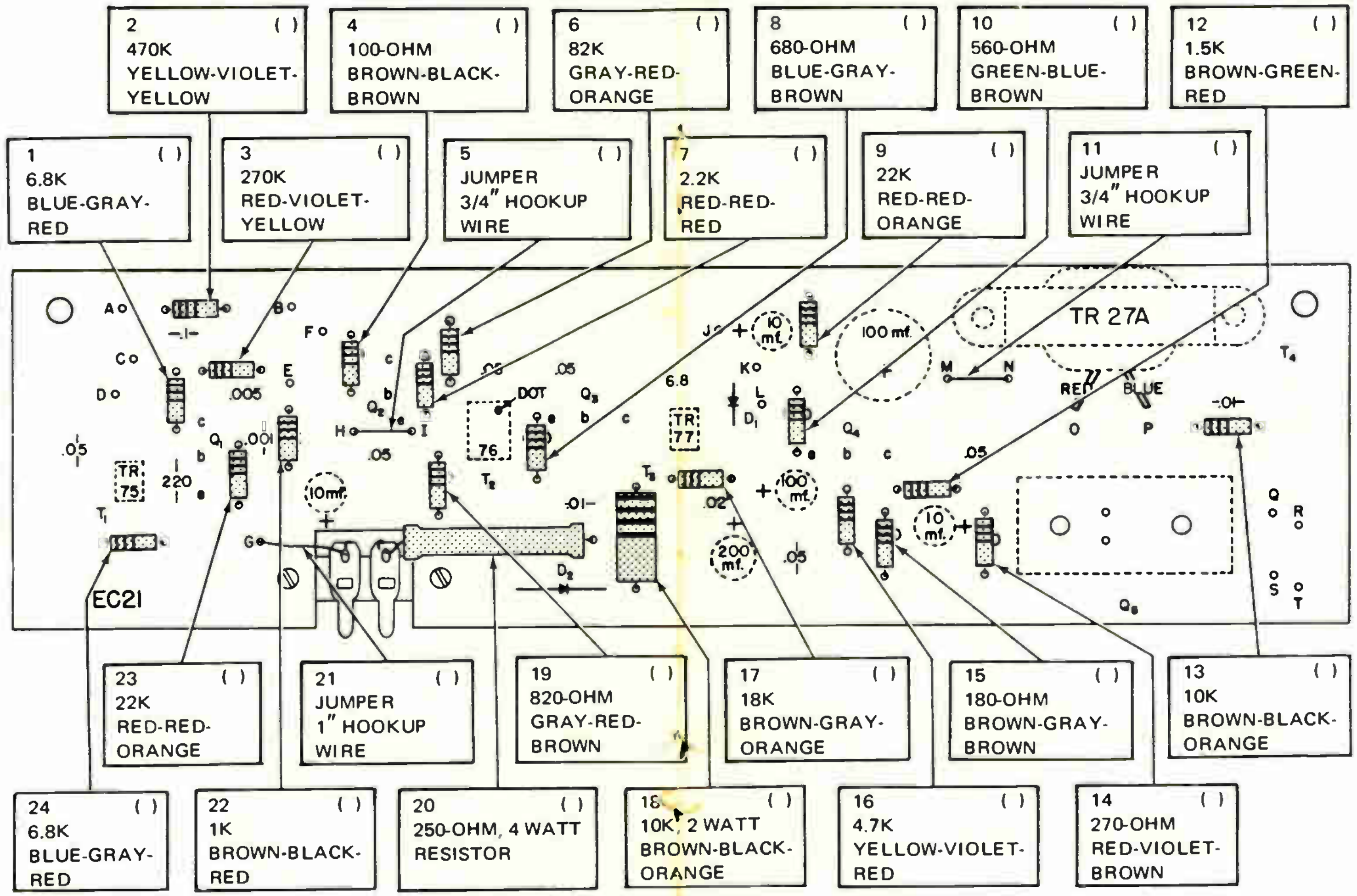


Fig. 6. Installing the resistors on the printed circuit board.

Again examine the schematic diagram of the receiver (Fig. 19) to see how element polarity is applied to a transistor in a circuit. For example, from the schematic you can see that Q_3 is a PNP transistor. Or you can determine the polarity from the transistor symbol. You know that the electrons must flow against the arrow on the emitter symbol. This means that the collector must be negative to force electrons through the transistor against the arrow. Since the collector is negative, the base must also be negative to provide forward bias.

Now look at the schematic of the receiver in terms of taking actual voltage measurements on the elements of transistor Q_3. You clip the ground lead of the meter to a B- point in the circuit. What dc voltage can you expect at the collector of Q_3? From the schematic you see that the collector connects to B- through only a few turns of the transformer, T_3. The dc voltage at the collector will probably read zero volts. But the collector must be negative in relation to the emitter for the transistor to operate.

Therefore we can expect to read a positive voltage at the emitter. If the emitter measures positive, then the collector is negative with respect to the emitter even though the actual collector voltage measured is zero. Next we measure the base voltage. To be forward biased, the base voltage must have the same polarity as the collector.

However, the collector measures zero and the emitter is positive. Therefore, we can expect to measure a positive voltage on the base. As long as the measured voltage is less positive than the emitter, the transistor will be forward biased. The voltage difference between the base and the emitter is usually quite small. In some cases you have to observe the meter needle very carefully to detect the very small difference.

Which voltage measurement will tell us if the transistor is conducting? From the schematic diagram of the receiver, you can see that any current through transistor Q_3 must also flow through the 680-ohm emitter, resistor R_{10}. If this resistor has a drop across it, the transistor must be conducting. Therefore the difference between the B+ voltage and the emitter voltage reading is an indication of how heavily the transistor is conducting.

Some circuits will have a resistor in both the collector circuit and the emitter circuit. Both of these resistors will carry the conducting current of the transistor. The drop across the larger resistor will usually give the best indication of the conduction of the transistor. In some cases, the emitter resistor or the collector resistor may be part of a voltage-divider network. In that case, the drop across the resistor may not be a reliable indication of transistor conduction.

This discussion may seem incomplete to you. Read it again after performing this experiment. In the experiment you will take measurements on transistors with simulated defects. In each case, you should find that the readings on the defective transistor do not meet the requirements presented in the discussion.

Experimental Procedure: For this experiment you will need your operating receiver, meter, and hand tools.

Step 1: To measure the voltages in the circuit of a properly operating transistor stage.

Take the voltage measurements indicated in the table of Fig. 63-2, and record your readings in the spaces provided. Be

	TUNED TO POINT BETWEEN STATIONS		TUNED TO STRONG LOCAL STATION	
	TYPICAL READING	YOUR READING	TYPICAL READING	YOUR READING
B− to Collector	0 VDC	0 V	0 VDC	0
B− to Base	+17.1 VDC	17.5 V	+18.3 VDC	18.0
B− to Emitter	+17.8 VDC	18.0 V	+19 VDC	18.8
Emitter to Base	− .7 VDC	.6 V	− .7 VDC	.55
Drop Across R10	+ .5 VDC	.8 V	+ .3 VDC	.80
B− to B+	+18.3 VDC	18.5 V	+19.3 VDC	19.0

Fig. 63-2. Chart showing typical readings obtained on transistor stage Q_3, with spaces for recording your readings.

sure to check your meter for exact zero before taking each measurement. Estimate the meter reading carefully when the needle indicates between graduations on the scale. On the 30-volt range it is difficult to read the meter accurately to tenths of volts. However, you must read the meter accurately or your readings will be misleading.

The first set of readings in Fig. 63-2 is taken with the receiver tuned between stations. Examine the typical readings. The difference between the B− to base reading and the B− to emitter reading is 17.8 − 17.1 or .7 volt.

In the emitter-to-base column we show a typical reading of −.7 volt. This reading was taken by clipping the common lead of the meter to the emitter and touching the probe to the base (meter set to read −dc on its lowest range). Since the base is more negative than the emitter, the transistor is forward biased. The two values should be the same, but due to the difficulty of reading the scales and meter inaccuracy, the values may not be identical. You can expect similar discrepancies in your readings.

Now compare the first set of readings with those obtained when the receiver is tuned to a strong local station. Observe that B+ is increased by 1 volt with a station tuned in. The reason for this is simple. The received signal produces avc bias that reduced the gain of Q_2 and Q_3. The reduced conduction of these two transistors reduces the B+ current drain. This, in turn, reduces the drop across the 10k-ohm dropping resistor, R_{20}, so the B+ voltage rises.

Notice that the drop across the emitter resistor, R_{10}, decreased by nearly one-half when the station was tuned in. This also indicates that the transistor is passing less current. From the typical readings, there was no readable difference in the emitter-to-base voltage under the two operating conditions. This indicates that it takes only a small change in base-to-emitter voltage to produce a sizable change in transistor current.

Compare your set of readings with the typical readings given. Several factors may cause your readings to be quite different from the typical readings. Line voltage and normal parts tolerances could cause your readings to be considerably higher or lower. Be sure to use your readings for comparison when performing other steps in this experiment.

Step 2: To show typical voltage readings in a transistor circuit when certain elements of the transistor are shorted.

For this step you simulate shorts between the various elements of transistor Q_3 and measure the resultant voltages. In a servicing situation, these defects could be within the transistor or in the external circuitry.

Tack-solder a short piece of hookup wire from the foil at the base of Q_3 to the foil at the emitter of Q_3 to simulate a base-to-emitter short in the transistor. Energize the receiver and measure the voltages on the transistor. Compare your measurements with the readings you recorded for normal operation. The emitter-to-base voltage will, of course, be zero. This means the transistor has no forward bias. The B- to base and emitter will read very nearly the B+ value because the transistor is not drawing current. Likewise, the B+ readings will be very nearly normal.

Measure the drop across R_{10}. A typical reading will be .2 volt. To see why you have current through R_{10}, again examine the schematic diagram. The base-emitter short completes the circuit from B+ through R_{10}, through the short to the base, through part of the secondary winding of T_2 and through R_9 to B-. Current through this circuit produces the voltage drop across R_{10}.

Unsolder and remove the short from the base to the emitter of Q_3. Connect the short from the emitter to the collector. Energize the receiver, and again take voltage measurements. The voltage will, of course, be the same at the emitter and the collector. These two readings (both zero) by themselves would indicate that the transistor does not have the proper operating voltages applied to it.

Next, measure the base voltage. A typical value is about 7 volts, indicating that the transistor is reverse biased. Then measure B+. A typical reading is about 7 volts. Measure a drop of about 7 volts across the emitter resistor, R_{10}.

Now examine the schematic diagram to see why the emitter-collector short produces the voltage readings you observed. The short circuit allows excess current through R_{10}. Since R_{10} is a low-value resistor, it allows enough current to drop B+ to less than half its normal value. If you were servicing this set, you would have to isolate the components to pin down the exact location of the short. For example, the defect could be a shorted capacitor, C_{13}, or an internal emitter-to-collector short in the transistor.

Unsolder and remove the emitter-collector short. Connect the short between the foil at the collector and the base. CAUTION! Do not short the collector-to-base of a transistor circuit unless you are sure that it will not exceed the ratings of the transistor. In your receiver, the emitter resistor of Q_3 limits the current to a safe value. Energize the receiver and again take voltage measurements. The collector and base are at the same potential, so the transistor is forward biased. Measure the emitter-to-base voltage.

A reading of .7 volt is typical, indicating a forward-biased transistor. You may read some small positive voltage from B- to the emitter. B+ again measures very low, about 7 volts, and the drop across R_{10} is about 7 volts.

The preceding readings, if obtained on a defective receiver, would not definitely pinpoint the defect. The excessive drop across R_{10} accounts for the low B+ reading. You would have to isolate components to locate the short. In this case, the base-collector short places a large forward bias on the transistor so that the emitter-collector circuit is almost a short circuit. The transistor conducts heavily, producing a large drop across R_{10} and the resultant low B+ voltage. Unsolder and remove the short that you connected between the collector and the base. Test the receiver for proper operation.

In this step you have investigated the voltage indications of the three possible shorted conditions that might exist within a transistor stage. Voltage measurements at the elements indicate the bias condition and the operating voltages of the transistor. The voltage drop across the emitter resistor indicates the relative amount of current in the transistor circuit. From these tests you can see that, although the voltage tests indicate the presence of a short, you have to remove components and make additional tests to find the exact location of the short.

Step 3: To show typical voltage readings in a transistor stage when certain elements of the transistor are open.

Turn off the receiver and unsolder the collector lead of Q_3 from the foil on the circuit board. Handle the collector lead carefully, as too much flexing of the lead can break it off where it enters the transistor body. Grasp the collector lead with your longnose pliers, heat the foil at the collector connection, and gently pull the collector lead out of the hole. This will simulate an open collector within the transistor.

Energize the receiver and take voltage readings around the Q_3 transistor stage. Compare your readings with those obtained for normal operation. B+ should read normal or slightly above normal. The B- to emitter and B- to base readings should measure approximately the B+ voltage value. A typical emitter-to-base reading is .7 volt, indicating that the transistor is forward biased. However, you will read only a fraction of a volt drop (about .2 volt) across R_{10}, indicating that the transistor is drawing little or no current.

Since your readings indicate a large forward bias and adequate emitter voltage, it is reasonable to assume that either the collector is open internally or there is an open in the collector circuit through the primary winding of T_3. With the receiver turned off, you could use your ohmmeter to confirm the location of the open.

Next, unsolder and remove the base lead connection from Q_3 at the circuit board. Then reconnect and solder the collector lead connection. This simulates an open base in the transistor. Again take voltage readings in the stage. B+ should be slightly higher than normal. The emitter should measure nearly the B+ value, and the base connection (point on the foil where the base is usually connected) should measure something less than the B+ value. The emitter-to-base measures excessively higher than normal, a typical reading being - 1.3 volts. The drop across the emitter resistor, R_{10}, should be zero, since Q_3 is cut off.

The preceding readings definitely indicate a defective transistor. The proper polarity operating voltages are present. The higher-than-normal forward bias should produce transistor conduction. However, the emitter resistor indicates very little transistor current, so the transistor must be defective.

Unplug the receiver, unsolder and remove the emitter lead of Q_3. Then reconnect and solder the base lead to the circuit board. This simulates an open emitter in the transistor. Energize the receiver and again take voltage readings on the stage. B+ should read normal or slightly high.

The point on the foil where the emitter usually connects reads the B+ value and the base reads less than B+. The emitter-to-base reads about −1.5 volts, indicating very large forward bias. However, the drop across the emitter resistor, R_{10}, reads zero, indicating no current through the transistor. It follows then that the transistor or the emitter-collector circuit of the transistor must be open.

Turn off the receiver. Reconnect and resolder the emitter leads of Q_3. Test the receiver for proper operation.

Instructions for Statement 63: For this statement you short-circuit two elements of the audio driver transistor, Q_4, and observe the results. Simply tack-solder a short piece of hookup wire from the foil at the base of Q_4 to the foil at the emitter of Q_4. Energize the receiver, observe its operation, take voltage readings or other tests, as necessary, to answer the statement.

Turn the receiver off. Unsolder and remove the short that you connected from the base to emitter of Q_4. Test the receiver to be sure that it is operating properly.

Statement No. 63: When I shorted between the emitter and the base of the audio driver transistor, Q_4,

(1) the receiver operated almost normally but with reduced volume and some evidence of distortion.

(2) the receiver operated only on strong stations and the sound was garbled.

(3) the receiver produced no sound because the short circuit back-biased the audio driver stage.

EXPERIMENT 64

Purpose: To show the effects of leaky bypass capacitors; and

To show how to locate them with an ohmmeter and with a voltmeter.

Introductory Discussion: The dc power supply line is maintained at signal ground potential by the use of bypass capacitors. Signals are bypassed around the power supply by providing a low impedance path (low impedance to the ac signals) from the dc power line to ground. These bypass capacitors are often electrolytic capacitors that tend to develop leakage. When the dielectric of the capacitor allows direct current to flow through the capacitor, we have leakage.

This condition can vary from a few microamps of leakage to a direct short through the dielectric of the capacitor. We can simulate a leaky capacitor by paralleling it with a resistor. The size of the resistor can be varied to simulate any degree of leakage through the capacitor.

A leaky bypass capacitor usually upsets the dc operating voltages in the receiver. A small amount of leakage will go unnoticed and have negligible effect on the operation of the receiver. In fact, most electrolytic capacitors will normally have some small leakage current. However, when the leakage becomes high, the condition is usually progressive. That is, the receiver may operate quite normally when first turned on, but when the set comes up to operating temperature the leakage increases. The excessive leakage current causes further deterioration of the dielectric and eventually the capacitor will short-circuit.

In this experiment, we limit the simulated leakage to values that will not damage other parts in the receiver. For example, excessive leakage through C_{23} could damage the power supply rectifier diode, D_2. This is a common servicing situation. A shorted filter capacitor overloads the rectifier, causing it to fail. Therefore, whenever you have to replace a rectifier diode, check to see if the filter capacitor is shorted. Otherwise, you may ruin the replacement diode.

Experimental Procedure: For this experiment you will need the operating receiver, the voltmeter, and the following:

1 10k-ohm resistor
1 6.8k-ohm resistor
1 2.2k-ohm resistor

Step 1: To show the effects of leakage in the B++ filter capacitor.

For this step you parallel the 100 mfd filter capacitor, C_{23}, with a 6.8k-ohm resistor. This arrangement exceeds the wattage rating of the resistor, so it will overheat if the receiver is left energized for even a few minutes. Therefore, leave the receiver energized only long enough to take the indicated measurements or observations; otherwise the 6.8k-ohm resistor will burn up.

	NORMAL READINGS	READINGS WITH 6.8K IN PARALLEL WITH C23	
B− to B++ VOLTAGE			
B− to B++ RESISTANCE			

Fig. 64-1. Chart for recording readings for Step 1.

Turn the receiver on and test it for proper operation. Tune in a station and adjust the volume for normal listening. Measure the B++ voltage, and record your reading in the Normal column in Fig. 64-1. Unplug the receiver from the line and measure the resistance between B++ and B−. Record your reading in the Normal column in Fig. 64-1.

Tack-solder the 6.8k-ohm resistor from the B++ foil to the B- foil. Again, measure the resistance from B++ to B- and record your reading in Fig. 64-1.

Set up your meter to measure +dc voltage on the 120-volt scale. Connect the line cord to the receiver, listen to the station, and quickly measure the B++ voltage. Turn off the receiver. Feel the body of the 6.8k-ohm resistor with your fingers. You will probably find it warm, even though the receiver was on for only a short time. Record your voltage reading in the space provided in Fig. 64-1.

Compare the readings you recorded in Fig. 64-1. Paralleling C_{23} with the 6.8k-ohm resistor increased current drain from the power supply. The parallel path caused the resistance to drop to approximately one-fourth of what it was originally. Likewise, the power supply voltage decreased, but only a small amount. You probably noticed little or no change in the operation of the receiver.

Consider what would have happened if the simulated leakage had occurred inside the capacitor. The same heat would be generated by the current through the resistance. The capacitor would probably overheat and fail completely. With less leakage, the receiver would continue to operate.

When servicing a receiver in which you measure lower than normal B+ voltage, always consider the possibility of leakage current. Check to see if the capacitor or other components in the circuit overheat. Then use resistance measurements to locate the leakage path in the circuit.

In a battery-operated transistor receiver, leakage seldom causes overheating. The complaint is more likely to be short battery life. Some reduction in volume or sensitivity may go unnoticed, but the increased drain on the battery can greatly reduce the life of the battery.

Step 2: To show the effects of leakage in the B+ filter capacitor, C_{22}.

For this step you parallel capacitor C_{22} with a 2.2k-ohm resistor to simulate leakage in the capacitor. Examine the schematic diagram of the receiver to see if you can predict the results.

Turn the receiver to a local station, adjust the volume for normal listening, and unplug the line cord. Tack-solder a 2.2k-ohm resistor from the foil at B– to the foil at B+, which is also the positive terminal of capacitor C_{22}. This connection simulates internal leakage in the capacitor. Connect the line cord of the receiver to the ac line and note any change in the reception of the station. Measure the B+ voltage and compare your readings with normal B+ voltage. Also measure B++ voltage to see if it has changed from normal.

Unplug the receiver and measure the resistance between B– and the B+ line. A typical reading is about 1.5k-ohms, with the 2.2k-ohm resistor in parallel with C_{22}. Unsolder the 2.2k-ohm resistor and again measure the resistance. A typical reading is about 10k-ohms.

From these tests, you can see that a sizable leakage is necessary to produce a noticeable change in the operation of the receiver. Even though the B+ voltage decreased by almost one-third, the receiver still operates. In a servicing situation the complaint might be reduced volume or reduced sensitivity.

Your voltage measurements would indicate that excessive current was being drawn from the B+ line; also your resistance measurements would indicate lower than normal resistance on the B+ line. Further voltage measurements on the circuit branches from the B+ line would help isolate the defect. However, you would have to isolate components and take more resistance measurements before you could definitely determine where the leakage exists in the circuit.

Step 3: To show the effects of leakage in the rf bypass capacitor, C_5.

Ceramic disc capacitors seldom develop leakage. This is particularly true in transistor radios where the supply voltages are low. However, leakage or complete short circuits can and do occur. In this step we investigate the effects of a leaky or shorted capacitor, C_5. From the schematic diagram, C_5 appears to be simply an rf bypass capacitor that completes the path for the ac signal in the tank circuit of the local oscillator.

Tune the receiver to a local station and adjust volume for normal listening.

Unplug the receiver and tack-solder a 6.8k-ohm resistor on the foil side of the board in parallel with C_5. Energize the receiver and note the effect, if any, on the receiver operation.

Turn off the receiver and remove the 6.8k-ohm resistor that you paralleled with C_5. In its place, tack-solder a piece of short hookup wire to simulate a shorted capacitor, C_5. Again, test the operation of the receiver. Next, measure the dc voltage from B- to the frame of the tuning capacitor. Six volts or so is a typical reading.

From this step of the experiment, you can see that a leaky or shorted C_5 does not affect the operation of the receiver. To see why C_5 is in the circuit, again examine the schematic diagram of the receiver.

As we stated before, C_5 completes the circuit for the local oscillator tank circuit consisting of the primary of T_1 and the oscillator section of the tuning capacitor. The other function of C_5 is to isolate the capacitor frame from the circuit for safety reasons. As you know, B- connects to one side of the ac power line.

If the capacitor frame were connected to B-, the capacitor mounting plate, the tuning capacitor shaft and the volume control shaft would be "hot". If a knob were removed from the operating receiver, a person could receive a dangerous electrical shock. To prevent this, the network consisting of R_5 and C_8 is used to isolate the metal part from B-.

Consider what could happen if a direct connection were used instead of C_5. A shorted transistor, Q_1, would connect B- through terminals 5 and 3 of the primary of T_1 directly to the metal frame of the tuning capacitor. The metal shafts would again be "hot," presenting a dangerous situation.

Unsolder and remove the short that you connected across C_5. Test the operation of the receiver.

Step 4: To show the effects of leakage in the emitter bypass capacitor, C_{13}.

Tack-solder a 6.8k-ohm resistor from the foil at the emitter of Q_3 to B-. This connection places a resistor in parallel with C_{13} and simulates a leaky capacitor. Energize the receiver and test its operation. Take voltage readings on the base and emitter of Q_3. You should find that both elements are almost exactly the same potential.

Examine the schematic of the receiver to see the effect of leakage in C_{13}. Resistor R_{10} and the leakage through C_{13} form a voltage divider that lowers the positive voltage at the emitter of Q_3. The base voltage must be negative (less positive) in respect to the emitter to provide forward bias for the transistor. The base voltage for Q_3 is set by the conduction of Q_2. With the Q_3 emitter voltage lowered, the transistor remains cut off and the receiver does not operate.

Unsolder and remove the 6.8k-ohm resistor that you had in parallel with C_{13}. Tune in a station and adjust the volume for normal listening. Temporarily shunt a 10k-ohm resistor across capacitor C_{13}. This simulates a smaller amount of leakage through C_{13}. Listen for a change in volume. It should decrease a noticeable amount. Remove the 10k-ohm resistor and test the receiver for normal operation.

From the preceding tests you can see that leakage in C_{13} upsets the dc operating voltages for the transistor. A small amount of leakage will produce reduced sensitivity, and a large amount of leakage will make the set completely inoperative. Careful voltage readings will help point to the cause of the trouble, but you would have to isolate components and take resistance measurements to pinpoint the defective components.

Instructions for Statement 64: For this statement you investigate the effect of simulated leakage in the emitter bypass capacitor of the audio driver stage, Q_4.

On the foil side of the board, tack-solder a 2.2k-ohm resistor to the foil at the terminals of the 100 mfd electrolytic capacitor, C_{18}. This connection simulates leakage through the capacitor. Energize the receiver and test its operation. Examine the schematic diagram of the receiver, take voltage measurements and other tests, as necessary, to answer the statement.

Unsolder and remove the 2.2k-ohm resistor that you tack-soldered in parallel with C_{18}. Test the receiver for normal operation.

Statement No. 64: When I simulated leakage in the emitter bypass capacitor, C_{18}, of the audio driver stage,

(1) the receiver operated normally, because C_{18} is already paralleled by a low value resistor.

(2) the receiver operated, but the volume was reduced and the sound was garbled.

(3) the receiver produced no sound, because the changed operating voltages back-biased the audio driver transistor, Q_4.

EXPERIMENT 65

Purpose: To demonstrate common causes of low sensitivity in a transistor radio receiver; and

To demonstrate forward-acting avc.

Introductory Discussion: A familiar complaint on transistor receivers is loss of sensitivity. The complaint may be that the receiver will no longer pick up a certain station or a station is not as loud as it used to be. In battery-operated receivers, the first thing to try is a new battery. Low battery voltage will usually show up first as loss of volume or reduced sensitivity. In other cases, the set may perform fairly well until the battery voltage becomes so low that the local oscillator drops out. In this case, the complaint will be a dead receiver.

Loss of sensitivity can be caused by faulty operation of any of the signal-handling circuits in the receiver. Good receiver sensitivity is the ability of the receiver to pick up weak stations. Therefore, the condition of the audio section of the receiver does not affect the sensitivity. In practice, however, a weak audio stage makes the receiver appear to have low sensitivity.

The avc circuits in transistor receivers have many variations. In general, a voltage from the second detector is fed back to control the gain of the i-f stages. The avc voltage may affect one or more stages in the receiver. The usual avc circuit uses what is called reverse-acting or reverse-biasing avc.

That is, the avc voltage fed back from the detector is of the correct polarity to reverse-bias the i-f stages. The stronger the received signal, the larger the reverse bias, which results in reduced current and reduced gain of the controlled stages.

Another type of avc circuit uses what is called forward-acting avc. The polarity of the avc voltage increases the conduction of the controlled stages. When you first trace out a forward-acting avc circuit, you may suspect that the detector diode is reversed. The forward-acting polarity is intentional, however.

The increased forward bias causes the transistor to draw increased current and lowers the emitter-to-collector voltage, causing reduced gain. You can think of the transistor as being operated near the saturation point on the transfer curve, which causes reduced gain. In this experiment you vary the bias on an operating i-f stage to simulate circuit conditions for forward-acting avc.

Experimental Procedure: For this experiment you will need your operating receiver, voltmeter, hand tools, and the following parts:

- **1 2200 pf disc capacitor**
- **1 1.5 volt D cell battery**
- **1 1k-ohm potentiometer (PO7)**
- **1 470-ohm resistor**

Step 1: To show the effects of an open circuit in the loop antenna of your receiver.

Unsolder and remove the loop antenna connection to the rf section of the tuning capacitor. Energize the receiver and test its operation. If you have strong local stations, you should be able to receive some of them fairly well. Touch your hand to the bare end of the antenna wire that you disconnected from the tuning capacitor. This should improve reception. Solder the antenna connection back in place to the rf tuning capacitor terminal, and test the receiver for normal operation.

A broken antenna wire is a common defect, especially in portable transistor receivers. The customer may break a connection by careless handling while changing the battery. Careful visual inspection will usually reveal the location of the break. Suspect a break in the antenna wires whenever touching the leads greatly improves reception.

Normally, the antenna circuit is tuned to resonance at the frequency of the incoming rf signal. Therefore, when you touch the terminals, your hand capacitance will tend to detune the circuit and decrease the sensitivity. If touching the circuit improves the reception, as it does when the circuit is broken, your body is providing additional signal pick-up.

This test is not always valid. The antenna tank circuit may not track perfectly at all frequencies across the band. Therefore, you may get some improvement in reception when you touch the circuit, even though the circuit is operating correctly.

Step 2: To show the effects of an open circuit in the secondary winding of the loopstick antenna.

Unsolder and remove the antenna connection from hole E on the circuit board. Energize the receiver and attempt to tune in a station. You should not be able to pick up any stations.

Examine the schematic diagram of the receiver to see why the set is completely dead. Notice that the local oscillator signal is coupled through C_7 and through the secondary winding of the loop antenna to the base circuit of the mixer stage, Q_2. When you open the secondary winding of the loop antenna, you effectively disconnect the local oscillator signal from the mixer stage so that the set is inoperative. Also, the base bias voltage is supplied to the base of the transistor through the secondary winding. When the secondary winding is open, so is the base circuit.

Tack-solder a short piece of hookup wire from the foil at hole E to the foil at the base connection of Q_2. This connection provides a path for the local oscillator signal to reach the base of Q_2.

Energize the receiver and again test its operation. You should be able to receive at least one strong local station. If necessary, touch your hand to the free end of the wire that you disconnected from hole E to improve reception.

Turn off the receiver. Unsolder and remove the short that you connected from the foil at hole E to the base of Q_2. Reconnect and solder the antenna wire at hole E. Test the receiver to make sure that it is operating properly.

In many receivers, the oscillator and the mixer functions are combined in the same stage so that opening the loop secondary will not remove the oscillator signal from the mixer. In these receivers, an open secondary in the loop antenna will simply cause reduced sensitivity.

Step 3: To show the effects of a shorted detector diode on the operation of the receiver.

Tack solder a short piece of hookup wire to the foil at each end connection of the diode detector, D_1. This connection simulates a direct short in the detector diode. Turn the receiver on and test its operation. You may be surprised to find that you are able to receive one or more strong local stations.

Since the detector diode is effectively out of the circuit, detection must be taking place elsewhere. With the diode shorted, the i-f signal is coupled through C_{16} to the base circuit of the audio driver Q_4. Detection takes place in the base-emitter junction of the transistor and the detected audio signal is reproduced in the collector circuit. Some of the i-f signal is attenuated in the detector filter circuit.

Unsolder and disconnect one lead of the .02 mfd filter capacitor, C_{15}. Again test the receiver operation. It should exhibit volume and sensitivity almost equal to that obtained by the diode detector circuit.

Reconnect and resolder the disconnected lead of capacitor C_{15}. Unsolder and remove the short you tack-soldered in parallel with diode detector D_1. Test the receiver for normal operation.

Ordinarily you expect a diode to fail completely when it goes bad. This step shows that you may get detection even if the diode shorts. Thus if you have low sensitivity or low volume, do not overlook the possibility that the diode has failed and some detection is taking place in the base-emitter junction of the first audio stage.

Step 4: To show the effects of a detuned i-f stage on the operation of the receiver.

For this step you detune the i-f transformer by bridging a capacitor across the windings. The added capacitance changes the resonant frequency of the circuit and reduces the gain of the stage. You can either tack-solder the capacitor in place, or simply hold the body of the capacitor between your fingers and touch the leads to the indicated terminals of the transformer.

Energize the receiver, tune to a local station and adjust the volume for normal listening level. Bridge a 2200 picofarad capacitor between terminals 3 and 4 of i-f transformer T_2. Note the change in level of the reproduced signal. Repeat the above procedure for terminals 1 and 2 of transformer T_2, terminals 1 and 2 of transformer T_3, and finally for terminals 3 and 4 of transformer T_3. Remove the capacitor and test the receiver for normal operation.

Paralleling the 2200 pf capacitor with a winding of an i-f transformer detunes the circuit and greatly reduces the gain of that stage. However, the receiver is still able to process strong local signals. You probably notice that shunting the 3-4 winding of T_3 produced only a small loss of signal.

The secondary winding of transformer T_3 is at a low impedance, and it is not tuned. The loss of signal is simply caused by the added capacitance shunting some of the signal that would otherwise go to the detector diode.

Most service situations related to detuning of the i-f occur when someone moves the tuning adjustments on the i-f transformers. This calls for either touch-up alignment or complete realignment of the receiver. In a later experiment you will work with alignment problems.

Step 5: To demonstrate how forward bias, simulating forward-acting avc, causes reduced gain of an i-f stage.

For this step you prepare a variable bias supply to control the gain of the i-f transistor, Q_3. Construct the circuit shown in Fig. 65-1B. (Fig. 65-1A shows terminal identification.) Connect a 470-ohm resistor from the positive terminal of the 1.5-volt cell at terminal 3 of your 1k-ohm potentiometer, PO7.

Connect a piece of hookup wire from the negative terminal of the cell to terminal 1 of the pot. Connect a 12" piece of hookup wire from terminal 3 of the pot to the foil at the emitter of Q_3. Connect a 12" piece of hookup wire from terminal 2 of the pot to the foil at the junction of R_4 and R_9 on the circuit board. This point is also the junction of terminal 2 of T_2 and one lead of C_{12}.

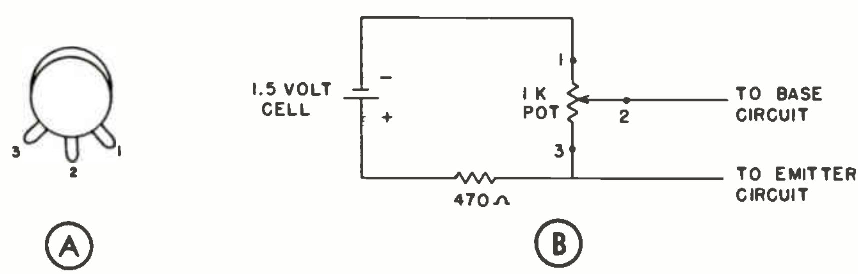


Fig. 65-1. (A) terminal identification; (B) variable bias supply circuit.

These connections will enable you to apply a variable dc bias between the base and emitter of Q_3. With the pot turned all the way clockwise, the difference in potential between the emitter and the base will be approximately zero volts. Rotating the pot counterclockwise applies a negative voltage to the base (in respect to the emitter). The negative voltage forward-biases the transistor.

Energize the receiver and tune to a station. Connect your meter between the emitter and the base of Q_3 so you can read the actual bias on the transistor. Set the meter to read -dc on the lowest scale. Adjust the bias for about -.6 volt and carefully tune in a station. Rotate the bias pot over its full range and note the range of bias voltages that gives reception. The transistor, Q_3, will be completely cut off at a bias voltage somewhere between -.4 and -.5 volt. Maximum gain will be obtained with a bias near -.6 volt.

As you make the bias more negative, the gain decreases. Further rotation of the pot will not produce a corresponding change in bias, because the increased base current produces a voltage drop in the pot circuit, limiting the bias voltage.

The i-f stage may go into oscillation as you increase the forward bias. The neutralizing values are selected for normal operating conditions. With increased forward bias, capacitor C_{14} provides a feedback path that may produce oscillations. Unsolder and disconnect one lead of C_{14} to minimize the tendency to oscillate. Also you can turn the slug adjustment on T_3 one-quarter turn to help prevent oscillation.

Measure the emitter-to-collector voltage change as you vary bias over the full range. With normal operating bias, the emitter-to-collector voltage will measure nearly B+ voltage. This indicates that the transistor is drawing only a small current and only a small amount of voltage is dropped across the emitter resistor, R_{10}. As you increase the forward bias, the transistor current increases and the emitter-to-collector voltage decreases. This decrease in emitter-to-collector voltage helps to explain why the gain decreases as the forward bias is increased.

A forward-acting avc circuit controls the stage gain in the same way as we have shown. The controlled stages have a fixed bias that produces maximum gain. When a station is tuned in, the detector produces avc voltage that is applied to the controlled stages. Polarity of the avc voltage is such that it increases the forward bias on the controlled stages. As you saw in this step, the increased forward bias caused decreased emitter-to-collector voltage and reduced gain for the stage.

Unsolder and remove the leads that you connected from the bias pot to the base circuit and emitter circuit of the board. Unsolder and remove the flashlight cell and other parts that you had connected to the bias pot. Reconnect and solder the disconnected lead of capacitor C_{14}. Energize the receiver and test for proper operation. If necessary, readjust the core of transformer T_3 for maximum output.

Instructions for Statement 65: For this statement you place a capacitor across a part of the secondary winding of i-f transformer T_2 and observe the effect on the operation of the receiver.

Tune the receiver to a station and adjust the volume for normal listening.

Tack-solder a 2200 pf capacitor between terminals 2 and 6 of transformer T_2. Energize the receiver and test its operation. Then answer the statement.

Unsolder and remove the 2200 pf capacitor you connected from terminal 2 to terminal 6 of T_2. Test the receiver for normal operation.

Statement No. 65: When I connected a 2200 pf capacitor from terminal 2 to terminal 6 of i-f transformer T_2,

(1) the receiver operated normally, with no noticeable change in sensitivity.

(2) the receiver operated, but with greatly reduced sensitivity.

(3) the receiver did not operate at all, because the capacitor shunted the small signal normally applied to the base of Q_3.

EXPERIMENT 66

Purpose: To demonstrate typical causes of hum in a line-operated transistor radio receiver.

Introductory Discussion: The hum produced by the 60 Hz line voltage is normally associated only with line-operated receivers. One of the advantages of battery-operated receivers is the freedom from the hum and noise that originate from the power line.

Hum can get into the signal path in two different ways. Insufficient filtering in the B+ line allows an audible sound signal to be produced in the audio circuits of the receiver. If the hum signal gets into the signal path at one of the low signal level stages, the hum signal will be amplified along with the desired signal. Or the 60 Hz signal can modulate any rf stage of the receiver and be detected by the second detector.

This condition can occur even in a battery-operated receiver. If the receiver is in close proximity to a power line, the sensitive rf section of the receiver may pick up enough 60 Hz signal to modulate an rf stage and produce an audible hum.

Noise on the power line may be picked up by either a battery-operated or line-operated receiver. The noise may be described as hum, because it usually varies at the 60 Hz line rate. To hear this noise, simply tune a receiver between stations, turn up the volume control and hold a line cord near the loopstick antenna. The noise will come through loud and clear.

Neon or fluorescent lights are another source of similar noise. Line-operated receivers sometimes have noise filters in the line circuit to minimize this source of noise. The amount of noise on the power line varies with locations. Very little noise is usually present in residential areas, whereas in industrial areas the power lines are usually very noisy.

Experimental Procedure: You will need your operating receiver, voltmeter, hand tools and the following parts:

1 10k-ohm resistor
1 2.2k-ohm resistor
1 .001 mfd capacitor
1 .005 mfd capacitor

Step 1: To show the effects of high resistance in the B++ filter capacitor.

For this step you will simulate the conditions of a filter capacitor that has developed series resistance. A capacitor with this defect is also described as one having a poor power factor. Unsolder and remove the jumper that is connected between holes M and N on the circuit board.

In its place, tack-solder a 10k-ohm resistor. Energize the receiver and test its operation. The hum is clearly audible even with the volume control turned to minimum. The program material will sound garbled and the set will exhibit reduced sensitivity. Measure B++ and B+ voltages. Typical values are 65 volts and 10 volts. This large reduction in power supply voltage accounts for the reduced sensitivity and garbled sound.

The above symptoms always point toward a defective filter capacitor. The symptoms are the same if the capacitor develops reduced capacitance. The fact that the hum is present even with the volume control at a minimum is the clue to power supply trouble, and the capacitor is the most likely component to be defective.

Step 2: To show the effect of a small resistance in the filter capacitor.

In this step you change the size of the resistor in series with the capacitor to simulate a small reduction in capacitance or a small series resistance in the capacitor.

Unsolder and remove the 10k-ohm resistor you tack-soldered from hole M to N of the circuit board. In its place tack-solder a 2.2k-ohm resistor. Energize the receiver and test its operation. Turn the volume control to minimum and listen for hum. You may have to tune between stations and place your ear close to the speaker to hear the hum. On a local station at normal listening levels, the operation may seem quite normal. Turn up the volume and listen for distortion. Measure the B++ and B+ voltage. They should measure low.

This step illustrates the effect of only a small loss of capacitance in the filter capacitor. The operation of the set is marginal. The customer's complaint may be "garbled sound," "reduced sensitivity," "noise," or "hum." A careful listening test should make you suspect the power supply.

When you measure B++ and turn up the volume, you should notice that the meter needle varies with sound. This also is an indication that the power supply is unable to furnish the required current to the output transistor. Again the filter capacitor is the most likely component to be defective.

Unsolder and remove the 2.2k-ohm resistor you tack-soldered from hole M to hole N on the circuit board. In its place, install the original jumper. Test the receiver for proper operation.

Step 3: To show the effect of an open filter capacitor, C_{22}, in the B+ power supply line.

To simulate an open B+ filter capacitor, C_{22}, unsolder and remove the capacitor from the circuit board. To do this, grasp the body of the capacitor and pull gently while you heat the connection on the foil side of the board. This takes a little patience. Each time you melt the solder on a connection, the lead will "give" about 1/16". Then heat the other connection until that lead moves. Alternately heat the connections and pull on the capacitor until you work out the leads and the capacitor comes free. Use a toothpick or a paper clip wire to clear the solder from the holes so that they will be ready to receive the capacitor wires when you reinstall the capacitor.

Energize the receiver and test its operation. A distinct hum is audible even at minimum volume. You may be surprised that the hum level is so low with the filter capacitor removed. When you tune in a station and keep the volume low, the set may appear to function almost normally. Measure the B+ voltage. It should be about normal. The condition of C_{22} does not affect the value of B+ as did the input filter capacitor, C_{23}.

Switch the meter to measure ac on a low range and turn up the volume. As you can see, the lack of filtering allows signals to develop on the B+ line across the 10k-ohm dropping resistor, R_{20}. Tune across the band with the volume control wide open. The set will squeal and sputter. Feedback paths through the unfiltered common power supply line is causing oscillation. In some places the oscillations are so strong that the audio is completely drowned out.

When troubleshooting a receiver with this condition, try paralleling the suspected capacitors with a good capacitor. You usually have more than one capacitor in the power supply that could be causing the trouble. The capacitors may be hard to remove or be of odd sizes. If you parallel a suspected capacitor with a good one, a change in operation of the receiver will indicate that the capacitor is defective.

The test capacitor need not be exactly the same size. For example, a 50 or 100 mfd capacitor in parallel with an open 200 mfd capacitor, C_{22}, would improve the operation enough to prove that C_{22} was open. To effect the repair you would, of course, obtain the correct value capacitor for replacement.

Install the 200 mfd capacitor, C_{22}, in its place on the circuit board. Be careful to remove any globs of solder from the leads of the capacitor. If solder makes the leads oversized, it will be difficult to get them through the mounting holes. Be sure to observe the capacitor polarity. Solder the leads in place to the foil. Test the receiver for proper operation.

Step 4: To demonstrate how a 60 Hz line voltage can modulate an rf stage and produce hum.

Unplug the receiver and tack-solder one lead of a .001 mfd capacitor to the interlock terminal where it connects to the 250-ohm, 4-watt resistor, R_{21}. Tack-solder the other lead of the .001 mfd capacitor to the foil at the junction of R_6 and R_8. From the schematic diagram of the receiver, you can see that this is also the point where the oscillator signal is injected into the base circuit of Q_2.

Energize the receiver and test its operation. Tune to the weakest available station and listen to the quality of the program material. It will probably sound garbled and you should hear a noticeable hum signal. If you are in a noisy (electrical noise on the power line) location, the hum may be masked by power line noise. Or the line noise may appear to vary at the line frequency. With the volume turned up, the hum should be quite noticeable.

In this step you coupled the line voltage through a .001 mfd capacitor to the base circuit of the mixer transistor, Q_2. This connection caused a 60 Hz signal to be mixed with the rf and the local oscillator signal. Also the noise on the power line is coupled into the signal path. This step does not illustrate a practical defect that would occur during servicing, but it does enable you to recognize the symptoms when a condition develops where the line voltage modulates an rf stage in a receiver.

Unplug the receiver, unsolder and remove the .001 mfd capacitor that you tack-soldered from the foil at the junction of R_6 and R_8 to the power line terminal. Test the receiver for proper operation.

Instructions for Statement 66: For this statement you will observe the effect of coupling 60 Hz line voltage into the base circuit of the i-f transistor, Q_3. Unplug the receiver and tack-solder one lead of the .005 mfd capacitor to the interlock terminal where it connects to the 250-ohm, 4-watt resistor, R_{21}. Tack-solder the other lead of the .005 mfd capacitor to the foil at the junction of R_9 and C_{12}. Energize the receiver and test its operation, as necessary, to answer the statement.

Unplug the receiver. Unsolder and remove the .005 mfd capacitor that you had connected from the foil at the junction of R_9 and C_{12} to the power line. Energize the receiver and test it for proper operation.

Statement No. 66: When I coupled the 60 Hz power line voltage through a .005 mfd capacitor to the base circuit of the i-f transistor, Q_3,

(1) the receiver operated normally except for a little more noise.

(2) a loud hum was present as long as the receiver was on, and the hum volume did not change with the setting of the volume control.

(3) the receiver produced garbled sound with hum and noise.

EXPERIMENT 67

Purpose: To show common causes of oscillation and how to locate them.

Introductory Discussion: The high gain stages and compact construction of transistor receivers makes oscillation a common complaint. As you know, a high gain circuit will tend to oscillate whenever energy from the output is fed back into the input. The requirements for oscillation are simple. The energy fed back must be of the proper phase to aid the signal producing the output and the circuit must have sufficient gain to overcome the losses in the circuit.

Since a receiver has many high gain stages, many opportunities for oscillation exist. The common power supply offers one possible feedback path between the output and the input of stages. For example, in a previous experiment, you saw how lack of filtering in the power supply produced oscillation.

The tuned stages in the receiver are particularly susceptible to oscillation. Since the i-f amplifier is tuned to a single frequency, it produces very high gain at that frequency. Even a rather poor feedback path is capable of coupling enough energy from output to input to produce oscillation.

In compact receivers where the parts are closely spaced, the close proximity of a part in an output circuit to a part in an input circuit can couple enough energy to produce oscillation. For this reason, when making repairs you are cautioned to position replacement parts in the same place as the original part. This condition does not exist on your receiver, because the parts are spread out and their position is relatively fixed by the circuit board mounting holes.

Oscillation can occur in high-gain audio stages of a receiver. The frequency of oscillation may vary from only a few Hertz to well above the audio range. The exact frequency at which the circuit oscillates is often determined by the R-C time constant of the feedback path.

The avc circuit of a receiver can provide a feedback path that produces oscillation. The avc circuit varies from receiver to receiver; but in general, a voltage from the output of the second detector is fed back to one or more i-f stages. The avc voltage is filtered, so it is dc that varies in amplitude with signal strength. The circuit has a long time constant compared to changes in signal strength.

A defect in the avc circuit can cause very low frequency oscillation (motorboating) or very high frequency oscillation. Insufficient filtering on the avc line can allow an i-f signal from the output to be fed back to an earlier stage and cause high frequency oscillation. Motorboating can result from a defect in the avc line that produces an extremely long time constant.

In this experiment you simulate defects that can produce oscillation. In some steps you provide feedback paths to produce oscillation so you can recognize the symptoms.

Experimental Procedure: For this experiment you will need your receiver, voltmeter, hand tools, and the following:

- 1 27 pf disc capacitor
- 1 1.2k-ohm resistor
- 1 .001 mfd disc capacitor
- 1 .005 mfd disc capacitor

Step 1: To demonstrate oscillation in the audio stages of the receiver.

Turn off the receiver and tack-solder a .001 mfd capacitor from the collector of Q_5 to the foil at the base of Q_4. Energize the receiver and test the operation. Vary the setting of the volume control to see the effect on the tone of the audio oscillation.

Unsolder and remove the .001 mfd disc capacitor that you tack-soldered from the base of Q_4 to the collector of Q_5. In its place, tack-solder a .005 mfd capacitor. Energize the receiver and note the lower frequency of the audio oscillation. From this you can see that the R-C time constant of the feedback circuit affects the frequency of oscillation.

If you phase a signal through the two-stage audio amplifier you will find that the output of the collector of Q_5 is in phase with the signal at the base of Q_4. Therefore, when you connect these two points with a capacitor, the circuit oscillates.

Unsolder and remove the .005 mfd capacitor that you connected from the collector of Q_5 to the base of Q_4. Test the receiver for proper operation.

Step 2: To demonstrate the symptoms of oscillation in an i-f stage of a receiver.

On the foil side of the board, tack-solder a 27 pf capacitor in parallel with the 6.8 pf capacitor, C_{14}. This capacitor connects between terminal 4 of the secondary winding of T_3 and the base of Q_3. As you know, the function of C_{14} is to neutralize the effect of base-to-collector capacitance in the transistor. When a large capacitance is placed in parallel, it provides an output-to-input feedback path that allows the stage to oscillate.

Energize the receiver and test its operation. You should be able to tune in some stations satisfactorily. Tuning will be accompanied by squeals and howls. The pitch of the squeals should reduce as you approach the station. The audible oscillations are the difference between the intermediate frequency of the signal and the oscillation frequency. The frequency of the oscillating i-f stage remains constant.

The i-f signal frequency is the difference between the local oscillator signal and the incoming rf signals. This frequency varies as you tune toward and away from the station. Therefore, the pitch of the audible difference frequency changes as you tune the receiver. Knowing these facts gives you a clue to the location of the circuit that is oscillating.

Tune the receiver close to a station so you can definitely hear the oscillation. Next, use a screwdriver to rotate the slot adjustment of the core of the output i-f transformer, T_3.

Listen to the oscillation as you rotate the adjustment. You should be able to detune the transformer enough so that the circuit ceases to oscillate. Detuning the stage reduces the stage gain enough so that the available gain does not exceed the circuit losses. Tune the receiver to other stations to prove to yourself that the circuit is not oscillating. Detuning the transformer reduces the receiver sensitivity, but it operates satisfactorily.

This step illustrates a condition that you will run into in practical servicing. When you attempt to peak up the alignment of the receiver, a stage will break into oscillation. You may not be able to locate the exact cause of the feedback and oscillation, or you may have replaced a transistor or tube with one having higher gain.

In some inexpensive receivers it may be easier to leave a stage slightly mistuned than to try to redesign the stage to eliminate the oscillation. This is particularly true if the receiver has adequate sensitivity with one stage slightly mistuned.

Unsolder and remove the 27 pf capacitor that you connected in parallel with C_{14}. Tune the receiver to the weakest available station. Be sure you are tuned exactly to the station. Readjust the transformer core in T_3 for maximum output. Test the receiver to make sure it is operating properly.

Step 3: To demonstrate the effects of an excessive local oscillator signal.

Tack-solder a 1.2k-ohm resistor on the foil side of the board in parallel with R_{19}, the oscillator supply voltage-dropping resistor. This connection will greatly increase the amplitude of the oscillator signal. Next, tack-solder a short jumper wire in parallel with resistor R_7 in the base circuit of Q_2. Energize the receiver and test the operation, especially on high frequency stations.

The symptoms of this condition are almost the same as when you had the i-f stage oscillating. The large oscillator signal drives the i-f stage so hard that the stage tends to oscillate at its natural frequency. The 100-ohm resistor, R_7, normally increases circuit losses and attenuates the signal that is driving the base.

Unsolder and remove the 1.2k-ohm resistor that you connected in parallel with R_{19}. Unsolder and remove the short bare wire that you connected in parallel with R_7. Test the receiver for proper operation.

Instructions for Statement 67: For this statement you simulate an open filter capacitor in the avc line by removing electrolytic capacitor C_{11} from the circuit board. Turn off the receiver. Carefully unsolder and remove the 10 mfd avc line filter capacitor, C_{11}, from the circuit board. Clean the solder from the mounting holes so the board will be ready when you reinstall the capacitor. Turn the receiver on and test its operation as necessary to answer the statement. Be sure to tune across the entire broadcast band.

Install the 10 mfd capacitor, C_{11}, that you removed from the circuit board. If necessary, remove any excess solder from the capacitor leads so they will fit easily into the mounting holes. Be sure to observe the polarity markings on the capacitor and circuit board. Solder the capacitor leads to the foil on the circuit board. Energize the receiver and test it for proper operation.

Statement No. 67: When I removed the avc line filter capacitor, C_{11}, the receiver,

(1) produced motorboating on some stations because of the increased time constant in the avc circuit.

(2) produced squeals and whistles because the i-f circuit was oscillating.

(3) worked normally except for reduced sensitivity, because there was no avc voltage.

EXPERIMENT 68

Purpose: To show common causes of audio distortion and how to locate them.

Introductory Discussion: Any defect that affects the quality of the reproduced sound from the speaker might be considered audio distortion. The defect may cause a loss of only the low frequencies or only the high frequencies in the received program material.

Loss of lows produces the complaint that the radio sounds "tinny." A loss of highs may be described as causing the set to sound "boomy." The normal audio response curve of an inexpensive radio receiver is quite narrow. The low frequency cut-off point is usually around 100 Hz and the high frequencies fall off rapidly above 6000 or 7000 Hz.

Although this is a very narrow band of audio frequencies by high-fidelity standards, it is most satisfactory for AM radio reception. The attenuation of the high frequencies also attenuates the annoying noise associated with AM reception. The low frequency cut-off helps to prevent hum in a line-operated receiver.

Most receivers have only two audio stages so it is easy to isolate the defective stage. In an earlier experiment, you saw how hum could cause garbled sound when the hum signal entered the signal path in one of the i-f stages. Also, audio distortion can result from a power supply defect. Low supply voltage to the audio stage can upset the stage bias and produce distortion. Such defects are quickly isolated by taking voltage measurements in the audio stages.

When a defective speaker produces audio distortion, the trouble can be isolated by substituting a known good speaker. Mechanical defects are the usual cause of audio distortion from a speaker. The voice coil may become misaligned with the magnet.

Rough handling or a warped speaker frame may cause the voice coil to rub on the magnet. You can usually feel the mechanical contact between the coil and the frame by carefully depressing the speaker cone with your finger. Sometimes the condition can be corrected by evening up the pressure on the speaker mounting screws. Usually the speaker has to be replaced.

Most receivers will distort at full volume on a strong station. A strong local station produces a larger signal than the amplifier can handle. In your receiver, the audio driver stage will clip the peaks of a large audio signal and produce noticeable distortion. Therefore you cannot turn the volume up full on strong stations. The reserve gain of the audio amplifier is useful because it enables you to listen to weak stations. At normal listening levels the receiver has low distortion.

Experimental Procedure: For this experiment you need your operating receiver, hand tools, and the following parts:

1 22k-ohm resistor
1 680-ohm resistor
1 220-ohm resistor
1 .01 mfd capacitor

Step 1: To show how insufficient capacitive coupling causes a loss of low frequencies in the audio signal.

Tune the receiver to a local station and adjust the volume control for normal listening level. Unplug the receiver and do not change the volume control setting. Unsolder and remove the 10 mfd coupling capacitor, C_{16}, from the circuit board. In its place, tack-solder a .01 mfd disc capacitor. Plug in the receiver and listen to the received program.

The most obvious change in operation is reduced volume. When you turn up the volume, speech may sound quite normal. However, if you listen to music, the program material will obviously lack the rich deep tones.

Voltage measurements in the audio stages will not isolate this defect. The condition of reduced capacitance can vary all the way from a completely open capacitor to one having only a small loss of capacitance. When you suspect this condition, the easiest check is to bridge the suspected capacitor with a known good capacitor. Any noticeable improvement in operation indicates a defective capacitor.

Unsolder and remove the .01 mfd capacitor you installed in place of the 10 mfd capacitor for C_{16}. Replace the original capacitor, being sure to observe the correct polarity markings. Solder the capacitor in place and test the receiver for normal operation.

Step 2: To show the effects of a leaky or shorted audio coupling capacitor.

Tack-solder a 680-ohm resistor on the foil side of the board in parallel with the 10 mfd coupling capacitor, C_{16}. This simulates a leaky coupling capacitor. Energize the receiver and test its operation. Measure voltages in the audio stages, Q_4 and Q_5. Compare your readings with those you recorded for normal operation in the voltage chart.

As you would expect, the leaky capacitor allows the positive dc potential present in the detector circuit to be applied to the base of the audio driver, Q_4. This increased positive bias reduces the conduction of Q_4 and lowers the collector voltage. Since the collector of Q_4 is directly coupled to the base of Q_5, the forward bias for Q_5 is reduced.

This in turn reduces the conduction of Q_5 and causes increased collector voltage for Q_5. The circuit distorts the audio signal because the transistors are not operating at the correct point on their transfer curves. You can increase the distortion by replacing the 680-ohm resistor with a direct short.

The voltage readings in the audio stages do not tell you for sure that the capacitor is leaky. Perform this additional test. Tune the receiver to a point between stations. Hold your meter probe on the base of Q_4 and observe the meter reading. Take a dc voltage reading with the volume control at minimum and another reading with the control set to maximum. You should observe a change of at least a volt or more.

Examine the schematic diagram to see why the base voltage changes when the coupling capacitor is leaky or shorted. Normally, no direct current flows through the volume control pot. A leaky or shorted C_{16} completes a dc path from the pot slider to the resistor network in the base of Q_4. DC from the B+ line can now flow through the pot, through C_{16} leakage, and through R_{12} to B-. Changing the setting of the volume control pot changes the drop across its resistance, and therefore changes the voltage reading at the base of Q_4. The results of this test are a pretty good indication that C_{16} is defective.

Unsolder and remove the 680-ohm resistor and/or the short circuit that you bridged across capacitor C_{16}. Operate the receiver and test it for proper operation.

Step 3: To show the effects of increased forward bias on the audio driver stage.

In this step you simulate a condition where a resistor in the base bias network for Q_4 changes resistance. Tack-solder a 22k-ohm resistor from the foil at the base of Q_4 to B-. Energize the receiver and test its operation. Tune to a point between stations and take voltage readings. Record your readings in the chart of Fig. 68-1.

Q4	NORMAL READINGS	R12 WITH 22K IN PARALLEL
BASE TO B-		
EMITTER TO B-		
COLLECTOR TO B-		

Fig. 68-1. Chart for recording voltage readings in Step 3.

Examine the schematic diagram of the receiver and relate the voltage readings to the circuit conditions. Reducing the resistance of R_{12} lowers the normally positive voltage on the base of Q_4. Since this is a PNP transistor, the less positive base voltage means an increase in forward bias.

Your voltage readings reveal that the emitter and the collector are at almost the same potential. This indicates that the transistor is conducting very heavily. These facts should tell you why you have audio distortion. Since the bias very nearly saturates the transistor, it is operating close to one end of its transfer curve and cannot provide linear amplification of the applied audio signal. In fact, the negative portion of the audio signals drives the transistor even further into saturation. Only the positive portions of the audio signals are capable of producing reasonable amplification. The result is a clipped and distorted audio signal.

This defect also increased the forward bias on Q_5 and thereby increased its conduction. The base bias for Q_5 is determined by the voltage drop across R_{15} and R_{16}. The current through these two resistors is determined by the amount of conduction of Q_4. Increased conduction of Q_4, caused by the defect, increased the drop across R_{15} and R_{16} and thereby increased the forward bias for the NPN transistor Q_5.

Step 4: To show the effects of an open capacitor in the emitter circuit of the power output transistor.

Energize the receiver, tune to a local station and adjust volume for normal listening level. Unplug the receiver, being careful not to change the setting of the volume control. Unsolder and remove the 10 mfd electrolytic capacitor, C_{19}, from the emitter circuit of the transistor, Q_5. Energize the receiver and listen to the station with the same setting of the volume control.

The sound will have reduced volume. Now listen to the quality of the program material. It sounds flat even with the volume turned up. The sound seems to lack the low frequencies.

Examine the schematic diagram to see the effect of capacitor C_{19}. This capacitor provides a feedback path from the emitter through R_{15} to the base of Q_5. Since the signals at the base and emitter are in phase (the emitter signal follows the base signal) the feedback is a form of positive feedback. This type of positive feedback increases the gain of the stage and, more important, the feedback increases the input impedance of the stage. The .05 mfd capacitor, C_{17}, is shunted from the base of Q_5 to ground. The effect of this capacitor is to reduce the frequency response of the circuit to high frequencies (especially noise). When C_{19} is removed from the circuit, the middle low frequencies, 200 to 600 Hz, receive much less amplification, causing the "flat" sound of the reproduced program material.

Install the 10 mfd electrolytic capacitor, C_{19}, on the circuit board. Be sure to match the polarity markings on the capacitor with the corresponding markings on the circuit board. Solder the capacitor in place. Test the receiver.

Instructions for Statement 68: For this statement you will change the resistance in the base bias network for the audio output transistor, Q_5, and observe the results. Tack-solder a 220-ohm resistor from the foil at the base of Q_5 to B–. Turn on the receiver and test its operation. Take voltage readings and other tests as necessary to answer the statement.

Unsolder and remove the 220-ohm resistor that you tack-soldered from the base of Q_5 to B–. Test the receiver.

Statement No. 68: When I paralleled R_{15} and R_{16} with a 220-ohm resistor and tested the receiver,

(1) the increased forward bias on Q_5 caused increased gain and badly distorted audio.

(2) the reduced forward bias on Q_5 nearly cut off Q_5, causing clipping of the audio signal and badly distorted audio output.

(3) the reduced forward bias on Q_5 caused loss of audio gain and some distortion.

EXPERIMENT 69

Purpose: To show how the mixer and oscillator functions of the receiver can be combined into a single stage.

Introductory Discussion: Most small inexpensive transistor receivers use a single stage as an oscillator-mixer. The advantages of a separate oscillator stage are improved oscillator stability, a better noise figure, and usually more gain in the converter (mixer) stage. These advantages do not necessarily outweigh the economy of one less transistor. As you know, your receiver has a separate local oscillator stage. In this experiment you rearrange the receiver so transistor Q_2 acts as both the oscillator and the mixer stage.

The simplified schematic diagram in Fig. 69-1 shows the circuit for the combined mixer-oscillator stage. Transistor Q_1 is completely out of the circuit. The emitter circuit for Q_2 is completed through the 5-3 winding of the oscillator transformer, T_1. The B+ dropping resistor, R_{19}, has been paralleled by a resistor to provide enough supply voltage for Q_2. A feedback signal from terminal 4 of the oscillator transformer is coupled through C_7 to the base circuit of Q_2. The signal fed back to the base circuit is of the correct polarity to cause the circuit to oscillate.

The rf signal is fed to the base circuit of Q_2 in the usual manner, and the two signals are mixed in the transistor. Transformer T_2 is tuned to the intermediate frequency to select the difference frequency between the incoming rf and the local oscillator frequency. In this way transistor Q_2 powers the local oscillator and performs the mixing function.

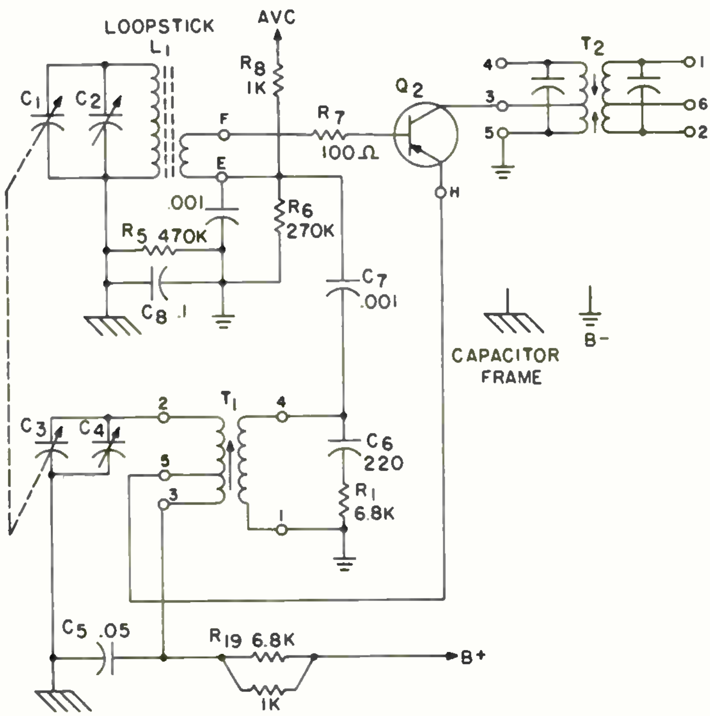


Fig. 69-1. Schematic diagram showing the circuit wired so Q_2 acts as a combined mixer-oscillator stage.

Experimental Procedure: For this experiment you need your operating receiver, voltmeter, hand tools, and the following parts:

1 .001 mfd capacitor
1 1k-ohm resistor

Step 1: To wire your receiver so transistor Q_2 functions as both oscillator and mixer.

Unsolder and remove transistor Q_1 from the circuit board. Unsolder and remove the short jumper wire connected between holes H and I on the circuit board. Unsolder and remove the .005 mfd disc capacitor, C_9, from the circuit board. In its place, tack-solder a .001 mfd disc capacitor. Tack-solder a 1k-ohm resistor in parallel with the 6.8k-ohm resistor, R_{19}, on the foil side of the board. Tack-solder a 1/2" jumper wire from hole H on the circuit board to terminal 5 of T_1 (use the hole where the emitter of Q_1 was connected). Your circuit should now be wired as shown in the schematic in Fig. 69-1.

Energize the receiver and test its operation. You may notice a reduction in sensitivity of the receiver. Also the stations do not come in at the correct place on the dial. The circuit changes have changed the operating characteristics of the oscillator so it does not track the tuned rf circuit of the antenna.

Step 2: To adjust the frequency of the local oscillator so the stations will come in at correct points on the dial.

Tune the receiver to a known frequency station at the low frequency end of the dial. Use a small screwdriver to adjust the core of the oscillator transformer, T_1, to bring the station in at the correct setting of the tuning dial. Next, tune the receiver to a known frequency station near the high frequency end of the dial. Adjust the trimmer capacitor, C_4, on the oscillator section of the tuning capacitor to tune in the station at the correct setting of the tuning dial. Check the reception of the station at the low frequency end of the dial. If necessary, repeat the adjustments until no further improvement is obtained.

Tune the receiver to a station at the high end of the band and adjust the trimmer capacitor, C_2, on the rf section of the tuning capacitor for maximum volume of the received station. Test the receiver and compare its operation now with the operation you experienced when the separate oscillator circuit was in use. You may notice slightly reduced sensitivity but otherwise very little difference. Any difference in the noise figure is probably too small to be noticed.

Step 3: To measure the operating voltage on the combined mixer-oscillator stage.

For this step you measure the voltages in the circuit of transistor Q_2 with it connected as a mixer-oscillator stage. Energize the receiver and tune in a strong local station. Measure the dc voltage between B− and the junction of R_6, C_7, and C_9. Look for a voltage change as you tune across the station.

The positive dc voltage increases when you are tuned exactly on the station, indicating that avc voltage is reducing the forward bias on Q_2 and limiting the gain of the stage. For this hookup, avc is not applied to the base circuit of Q_3.

Next measure the emitter voltage and the B+ voltage. As you can see from the readings, there is very little drop across R_{19} (with the 1k-ohm resistor in parallel). This indicates that the transistor is drawing very little current. Measure the dc voltage between the base and emitter. A typical reading is -.15 volt, indicating that the transistor has only a small forward bias.

Measure the ac voltage at the capacitor terminal of the oscillator section of the tuning capacitor. The probe will detune the oscillator but you should get a reading. Observe the reading as you tune across the band. The output may drop to zero at some points because of the loading of the voltmeter probe.

Leave your circuit wired as it is because you will use it again for the statement of this experiment.

Instructions for Statement 69: For this statement you will change the supply voltage to the mixer-oscillator stage and determine the effect on the operation of the receiver.

Unsolder and remove the 1k-ohm resistor that you tack-soldered in parallel with the 6.8k-ohm resistor, R_{19}. Energize the receiver and test its operation. Take voltage measurements and other tests as necessary to answer the statement.

Turn off the receiver. Unsolder and remove the .001 mfd disc capacitor that you tack-soldered in place of C_9 on the circuit board. Install the .005 mfd capacitor for C_9 on the circuit board. Solder the capacitor in place. Unsolder and remove the 1-1/2" jumper wire that you connected from hole H on the circuit board to terminal 5 of transformer T_1 (terminal 5 connects to the foil at the hole for the emitter lead of Q_1).

Reinstall transistor Q_1. Carefully solder the transistor leads to the foil on the foil side of the circuit board. Install the 3/4" jumper wire from hole H to hole I on the circuit board. Solder the jumper in place. Your receiver is now correctly wired. Energize the receiver and test it for proper operation. Readjust the oscillator frequency and the rf tank circuit as necessary for best operation.

Statement No. 69: When I removed the 1k-ohm resistor that was in parallel with R_{19}, the receiver,

(1) operated normally, with no noticeable change.

(2) operated only on stations at the low end of the broadcast band.

(3) failed to operate because the local oscillator dropped out of oscillation.

EXPERIMENT 70

Purpose: To show receiver alignment problems; and

To show how a receiver can be satisfactorily aligned using only received radio stations.

Introductory Discussion: In the test section of this manual you were shown how to touch up the alignment of your receiver. In an earlier experiment you changed some of the alignment adjustments. Therefore your receiver may not be perfectly aligned at this time. In this experiment you perform various alignment procedures. As a final step you will perform complete alignment to put the set in top operating condition.

Alignment is a regular procedure in repairing radios. After repairing a radio, the least you should do is check to see if the receiver picks up the entire broadcast band and if the stations are received at the indicated points on the dial.

If the receiver seems to lack sufficient sensitivity, you should check the i-f alignment. Making these simple checks will assure customer satisfaction. A touch-up alignment will usually make the receiver operate better then before it developed the defect that you repaired.

Don't expect perfect results when you check the alignment of inexpensive transistor receivers. The tuning dial markings are usually very coarse so you cannot read them accurately. Many receivers will not cover the complete broadcast band from 540 kHz to 1600 kHz. Naturally you should not try to redesign a receiver that does not cover the entire band. Likewise, circuit design or the reception area may produce low sensitivity at some frequencies.

When you touch up the i-f alignment you may find the i-f amplifier oscillates when a certain adjustment is peaked. This condition may have existed since the set was manufactured. The value of your time required to correct this condition could easily exceed the purchase price of the receiver. Again, as a service technician, your repair job should put the receiver back in its original operating condition. If you can improve operation with a touch-up alignment job, you should do it; but you cannot profitably make the alignment perfect on every inexpensive receiver that you repair.

In this experiment you perform alignment using received radio stations. An alignment generator is a real convenience and enables you to do the job quicker. Also, the generator can be used as a troubleshooting tool, but a generator is not absolutely necessary for performing satisfactory alignment on the average radio.

Receiver alignment consists of adjusting the response of three sections of the receiver. These include the i-f amplifier, the local oscillator, and the rf section of the receiver. As you know, the i-f amplifier is a fixed frequency amplifier that provides most of the gain and selectivity of the receiver. In your receiver, the i-f frequency is centered at 455 kHz. The tuned circuits in the i-f amplifier are adjusted to passing a narrow band of frequencies centered around 455 kHz.

The local oscillator is designed to operate above the incoming rf by an amount equal to the i-f amplifier frequency. With this arrangement, the difference between the rf and the local oscillator frequency equals the intermediate frequency.

In your receiver, two adjustments are provided for changing the local oscillator frequency. The core of the oscillator transformer is adjusted to set the frequency of the local oscillator at the low end of the band. A trimmer capacitor in parallel with the local oscillator tuning capacitor is provided to adjust the local oscillator frequency at the high end of the band.

These two adjustments interact to some extent. Adjusting the core of the transformer has a large effect at either the high end or the low end of the band. Adjusting the trimmer capacitor has a small effect at the low end and a large effect at the high end.

At the low end of the band, the tuning capacitor is fully meshed and inserts maximum capacitance in the tuned circuit. In this position a change in the trimmer capacitor represents only a small change in the total capacitance in the circuit.

However, at the high end of the band the tuning capacitor is open, providing minimum capacitance in the tuned circuit. In this position a small change in the trimmer capacitor represents a large percentage change in the total capacitance in the circuit.

Edge capacitance increases the tuning capacitance at the extreme unmeshed position of the tuning capacitor. As the tuning capacitor rotor is rotated counterclockwise, the rotor plates unmesh from the stator plates, causing the circuit capacitance to decrease. However, when the stator plates approach the full unmeshed position, the edges of the rotor plates approach the opposite edges of the stator plates.

This proximity of the plate edges causes the circuit capacitance to increase for the last few degrees of rotation as you reach the high frequency end of the dial. As a result, you may receive the high-frequency station at two points near the high frequency end of the dial. For example, a station at 1600 kHz may be received with the plates fully unmeshed. Then as you rotate the tuning capacitor a couple of degrees clockwise, you will again receive the same station.

Edge capacitance causes the oscillator to produce the correct local oscillator frequency at both positions of the tuning dial. This condition is normal. Simply disregard the last few degrees of rotation near the fully unmeshed position of the tuning capacitor.

The rf section of the receiver consists of only the tuned tank circuit of the antenna. This is the usual arrangement for receivers. Very few broadcast receivers have an rf stage. A trimmer capacitor on the rf section of the tuning capacitor is provided for adjusting the frequency of the rf tank circuit. The trimmer has the greatest effect at the high end of the band and is usually adjusted for maximum response to a frequency near the high end of the band.

Experimental Procedure: For this experiment you need the operating receiver and your hand tools.

Step 1: To demonstrate improper tracking due to a misadjusted trimmer capacitor on the local oscillator circuit.

For this step you misadjust the trimmer capacitor on the local oscillator section of the tuning capacitor and observe the effect.

Tune the receiver to a local station near the upper end of the band. Try to select a station between 1400 and 1200 kHz for best results.

Suppose you select a station at 1240 kHz. Since your tuning dial is only roughly marked, it reads only the approximate frequency of the station you are tuned to. Now tighten the oscillator trimmer capacitor a small fraction of a turn. Readjust the tuning capacitor toward the high end of the dial to again receive the station at a frequency of 1240 kHz. Repeat the above process until you have the trimmer capacitor adjustment nearly tight, and you are receiving the 1240 kHz station at or near the full open position of the tuning capacitor.

What you have done is increase the capacitance by tightening the trimmer capacitor and decrease the capacitance by opening (unmeshing the plates of) the tuning capacitor. You are receiving a station of 1240 kHz, and the tuning dial is indicating nearly 1600 kHz. The loudness of the station probably decreased considerably as you changed the adjustment. The reason for the reduced sensitivity is the loss of rf tracking. That is, the rf section of the tuning capacitor is adjusted for receiving stations close to 1600 kHz when the plates of the tuning capacitor are nearly open.

The fact that you can still receive the 1240 kHz station indicates that the rf section of your receiver is rather broadly tuned. Receiver selectivity is accomplished by the i-f amplifier rejecting those signals that do not fall in the i-f bandpass. Tune your receiver to other stations toward the low end of the band. You will find that all the stations you receive come in at points higher on the dial than they should.

Readjust the local oscillator trimmer capacitor so that the stations track the dial markings. Since you are adjusting only the trimmer, it is easiest to do it on the highest frequency station that you can receive. Simply set the dial to the correct point where you should receive the highest frequency station. Then adjust the oscillator trimmer until you hear that station.

Step 2: To demonstrate improper tracking due to a misadjusted oscillator transformer core.

For this step you again change the frequency of the local oscillator, but you do it by changing the inductance of the tuned circuit. As you know, the oscillator transformer has an adjustable core. Changing the setting of the core changes the inductance of the transformer, and thereby changes the frequency of the local oscillator. This, in turn, will change the point on the dial where you receive a given station.

Tune the receiver to a station near the low end of the broadcast band. Locate the oscillator transformer, T_1, on your circuit board. Use a screwdriver to adjust the slotted core in the top of the transformer. Tune the core a fraction of a turn counterclockwise.

Adjust the tuning dial so that you again receive the same station. Notice that you have to tune to a lower frequency to receive the station. Turning the adjustment counterclockwise in T_1 decreased the inductance and increased the frequency of the local oscillator. To correct for this you had to insert more capacitance into the circuit by moving the tuning dial toward the lower end. Readjust the core of T_1 so the station comes in at the proper place on the dial.

Next, tune to a station near the high end of the broadcast band. Adjust the core of the oscillator transformer slightly clockwise. Adjust the tuning capacitor to again receive the same station. Notice that you have to tune toward the high frequency end of the dial to receive the station. Readjust the core, T_1, so that the station comes in at the correct place on the dial.

In Step 1 of this experiment, you found that adjusting the oscillator-trimmer capacitor had the greatest effect at the high end of the band. This is because a change in the trimmer capacitance represents a larger percentage change in the total capacitance at the high frequency end of the band.

In this step you found that a change in the inductance of the oscillator transformer had about the same effect at either the high or the low end of the band. This is what you would expect because the inductance is not varied when you tune across the band. You will take advantage of these facts when you perform receiver alignment.

Step 3: To show the effects of aligning the i-f amplifier to the wrong frequency.

In this step, you align the i-f amplifier to a frequency lower than 455 kHz, and observe the effect on the operation of your receiver.

Tune your receiver to a local station that you can readily identify. Note the exact position of your tuning dial. Since the dial is only coarsely graduated with the approximate station frequency, you'll have to mark the dial. Use a crayon or a piece of tape to temporarily mark the exact position of the dial. For example, tune the receiver exactly to the selected station and place a small piece of tape on the tuning dial so that the edge of the tape lines up with one edge of the red line behind the dial. Leave the tape in place for now.

Use your alignment tool to change the adjustments in the i-f amplifier transformer, T_2. Turn the top slug of T_2 two full turns clockwise. Next reach through the hole in the circuit board at the center of T_2 and adjust the bottom slug of T_2 two full turns clockwise. Now use a screwdriver to adjust the slug of the transformer T_3 about one-half turn clockwise. These adjustment changes have tuned the i-f amplifier to a lower frequency of approximately 400 kHz. Without a signal generator, you have no way of knowing the exact frequency. Also, the adjustments are not peaked to the new intermediate frequency.

To peak the i-f adjustments, tune the receiver to a weak station and readjust the i-f transformers. Move each slug as necessary to increase the volume of the station that you are tuned to. Go over the adjustments two or three times in order to get the greatest possible response.

Tune your receiver to the station that you marked with the tape on the dial. Definitely identify the station and set the tuning dial until you are tuned exactly on the station.

Now observe the mark that you put on the dial in relation to the red line. You will find that you had to move the dial about 1/16" clockwise to receive the station with the i-f amplifier tuned to a lower frequency.

To understand why the dial position shifted for receiving the selected station, think through the operation of your receiver. Suppose the selected station transmitted at a frequency of 1000 kHz. When your i-f was tuned to 455 kHz, you had to tune your receiver until the local oscillator produced a frequency of 1455 kHz. The difference between the incoming rf signal of 1000 kHz and the local oscillator frequency of 1455 kHz was 455 kHz, which is also the frequency that your i-f amplifier was tuned to. This setting enabled you to receive the station.

Let's see just what happened when you realigned your i-f amplifier to 400 kHz. To receive the 1000 kHz station you had to produce a local oscillator signal that was 400 kHz above the incoming rf signal. Or you need a local oscillator signal of 1400 kHz.

To get the local oscillator frequency down to 1400 kHz, it was necessary to adjust the tuning dial to a point where it would increase the capacitance in the oscillator circuit. The increased capacitance tuned the oscillator to a lower frequency of 1400 kHz. Now the difference is 400 kHz, and you receive the selected station but at a different point on the dial.

Steps 1, 2, and 3 of this experiment should help you to understand alignment procedures. As you know, the i-f amplifier processes only those signals having the frequency to which the amplifier is tuned. Therefore, to receive a certain station, you must generate a local oscillator frequency that is above the incoming rf signal by an amount equal to the i-f. Also, the tuning dial should be calibrated to indicate the received station frequency when the dial is in the correct position to produce the required local oscillator frequency. Likewise, the rf section should be tuned to the indicated frequency.

Step 4: To show how to perform touch-up alignment on your receiver using only received radio stations.

A signal generator is a real convenience for quick, accurate alignment of a radio receiver. If you are used to using a signal generator for alignment, you will probably find this step slow and clumsy. You should perform the step anyway. What you learn will be useful for touch-up alignment of receivers when you do not want to go to the trouble of setting up a signal generator.

At the present time, your receiver has the i-f amplifier aligned to approximately 400 kHz. First we will retune it to approximately 455 kHz. Use your alignment tool to adjust slugs in the transformer, T_2. Tune the top slug two turns counterclockwise. Reach through the hole in the circuit board and turn the bottom slug of T_2 two turns counterclockwise.

Use a screwdriver to turn the adjustment on transformer T_3 one-half turn counterclockwise. Set your tuning dial to the position you marked with the tape so you receive the selected station. The station may come in very weak or you may have to tune slightly off the correct point to hear it at all.

Readjust the top and bottom slug in T_2, and the screwdriver adjustment on T_3 to get maximum volume. Recheck the setting of the tuning dial. If you had to offset is slightly before, you should now be able to set it exactly on and still be able to hear the station. Readjust the preceding three adjustments for maximum volume.

These adjustments should have returned your i-f to 455 kHz, but you may be able to improve the alignment. Tune your receiver to the weakest available station. If all available stations are strong, connect a clip lead from the trimmer capacitor terminal on the rf section of the tuning capacitor to the ground lug on the capacitor frame.

The clip lead shorts out the rf section of the antenna and greatly attenuates the received signals. Again, tune the receiver to a weak station. Make sure you are tuned to the exact center of the received signal. Now readjust the slugs of T_2 and T_3. Tune each slug for the maximum received signal. Your i-f amplifier is now peaked at approximately 455 kHz. Remove the clip lead you used to short out the antenna.

Tune your receiver to the lowest frequency station available in your area. Identify the frequency of the station and check the tuning dial to see if the station comes in at the correct point on the dial.

Since the dial is only roughly graduated, you have to estimate the correct position. If necessary, set the tuning dial to the correct position and adjust the slug in the local oscillator transformer, T_1, to bring in the station. Clockwise rotation of the slug increases the inductance and lowers oscillator frequency.

Next, tune the receiver to the highest frequency station available in your area. Again check the tuning dial reading to see if the station is received at the correct position on the dial. If not, set the dial to the correct point and adjust the trimmer capacitor on the oscillator section of the tuning capacitor to bring in the station.

Recheck reception at the low end of the band. If you made large changes in either adjustment, it may be necessary to repeat both adjustments until no further improvement is possible.

Peak up the adjustment on the rf section. Tune the receiver to a weak station at the high frequency end of the dial. Adjust the trimmer capacitor on the rf section of the tuning capacitor for maximum volume.

This procedure may not produce perfect alignment, but it is satisfactory for all practical purposes. For example, your i-f amplifier is probably not aligned to exactly 455 kHz. Your receiver may not tune to the extremes at both ends of the band. The stations may not come in at exactly the correct point on the tuning dial, and the rf section may not track across the entire band. But you receive all available stations with adequate volume.

Step 5: To perform complete alignment procedures using only the received radio stations.

In this step we assume that your receiver is completely misaligned so that you are unable to receive stations at all. This could happen if you failed to identify adjustments before you moved them, or you may have had a defect in the receiver and thought the problem was alignment. The procedure we give here will enable you to realign the receiver using only received radio station signals. Some steps in this procedure will involve trial and error before you get all sections of the receiver tracking properly. The following adjustments steps, (a) through (e), are followed by a discussion of what to do if you are unable to get satisfactory results from some steps.

(a) Preset all adjustments. Do not force any adjustment beyond its limit, or point where the adjustment moves easily. The preset positions we give here are a starting point from which you will perform the alignment. Tighten the trimmer capacitors on the tuning capacitor. Then turn each trimmer screw one-half turn counterclockwise. Adjust the slug of the oscillator transformer, T_1, to its mid-position. The full adjustment range of the slug is about two turns, so tighten the slug and then turn it counterclockwise one full turn. Do the same for the i-f output transformer T_3.

Preset the slugs in the i-f transformer, T_2. Start by moving the slugs to the ends of the coils so that there is maximum separation between the slugs. Next, adjust the top slug about four full turns clockwise so the top of the top slug is about 3/8″ from the top of the can. In the same way, adjust the bottom slug four full turns into the coil, so the bottom slug is 3/8″ up from the circuit board.

All alignment adjustments are now preset to an approximate position, so you should be able to receive at least one station, although it may come in weak. Move the tuning knob slowly across the band until you pick up a station. Disregard the frequency of the station or where it comes in on the dial.

(b) Align the i-f amplifier for maximum signal on a received station. Adjust the top and bottom slugs in T_2 and the single slug in T_3 for maximum signal. If the station becomes too strong, tune to a weaker station. Most accurate adjustments are made on the weakest signal that you can hear. Readjust all three i-f adjustments until no further improvement is possible. The i-f amplifier is now aligned, although it may not be aligned to exactly 455 kHz.

(c) Adjust the oscillator frequency at the low end of the broadcast band. Identify the lowest frequency station that you can receive. Set the tuning dial to the correct point where the station should be received. Adjust the slug in the oscillator transformer, T_1, to bring in the station.

(d) Adjust the oscillator frequency at the high end of the broadcast band. Identify the highest frequency station you can receive. Set the tuning dial to the correct point where that station should be received. Adjust the trimmer capacitor on the oscillator section of the tuning capacitor to bring in the station. Repeat steps (c) and (d) until no further improvement is obtained.

(e) Adjust the trimmer capacitor on the rf section of the tuning capacitor. Tune the receiver to the highest frequency station you receive. Be sure you are tuned exactly to the station. (Tune for maximum volume.) If you have a choice of several stations near the high end of the band, select the weakest station. Adjust the trimmer capacitor on the rf section of the tuning capacitor for maximum received signal.

If you were able to complete each of the five steps listed above, your receiver is probably satisfactorily aligned. Check the receiver operation to see if all available stations are received at the correct points on the dial.

Since the dial is only roughly calibrated, you have to estimate the exact frequency readings. Unsatisfactory alignment may show up as inability to receive stations at the high end or the low end of the band, low sensitivity, stations received at the wrong points on the dial, or i-f oscillation.

Try repeating steps (b) through (e). Examine the position of each adjustment to see if it is very far from the preset position. You should be able to hear the response fall off each side of the correct adjustment point when making each adjustment.

In step (d), if you turn the trimmer capacitor much more than one full turn counterclockwise, the adjustment screw becomes quite loose and has little effect. To correct this, readjust the slug in T_1 a fraction of a turn counterclockwise. This reduces the inductance and increases the oscillator frequency.

The trimmer adjustment point will be reached with the screw closer to the tightened position. Changing the oscillator slug will move the lowest frequency station down on the tuning dial. You may have to compromise to get a satisfactory adjustment in both steps (c) and (d).

Low sensitivity can be caused by the i-f amplifier being improperly aligned. Peak each adjustment in step (b) on the weakest available station signal. Be sure that the response falls off either side of the final adjustment point of each slug. Be sure that the slugs are somewhere close to the preset positions given in step (a).

If you are unable to receive the highest frequency stations or the lowest frequency stations, your i-f may be aligned to a frequency far from 455 kHz. As a result, you may be unable to adjust the oscillator adjustments far enough to receive some stations. Try changing the alignment frequency of the i-f amplifier. To lower the frequency, turn each slug in transformer T_2 one-quarter turn clockwise (move both slugs toward the center of the coil). Turn the slug on T_3 one-eighth turn clockwise. Tune to a weak station and perform step (b). This will align the i-f at a lower frequency. Now repeat steps (c),(d), and (e).

You can raise the i-f amplifier alignment to a higher frequency by moving the i-f transformer slugs counterclockwise. Adjust each slug in T_2 one-fourth turn counterclockwise. Move the slug in T_3 about one-eighth turn counterclockwise. Tune to a weak station and peak up the i-f adjustment as outlined in step (b). This will align the i-f amplifier to a higher frequency. Again perform steps (c), (d), and (e). By repeating these steps you should be able to find an i-f amplifier frequency that will enable your receiver to track satisfactorily.

Instructions for Statement 70: For this statement you will change the frequency of the local oscillator by paralleling the oscillator section of the tuning capacitor with a 27 pf capacitor and observing the results.

Tack-solder a 27 pf disc capacitor from the terminal on the oscillator section of the tuning capacitor to the solder lug on the frame of the tuning capacitor. Energize the receiver and test its operation as necessary to answer the statement.

Unsolder and remove the 27 pf capacitor that you tack-soldered from the terminal of the oscillator section of the tuning capacitor to the ground lug on the frame of the tuning capacitor. Test the receiver for proper operation.

Statement No. 70: When I placed a 27 pf capacitor in parallel with the oscillator section of the tuning capacitor,

(1) all stations that I could receive were received at a lower frequency setting of the tuning capacitor.

(2) all stations that I could receive were received at a higher frequency setting of the tuning capacitor.

(3) the receiver failed to operate because the local oscillator failed to oscillate.

Installing the Receiver In the Cabinet

Now that you have completed the experiments, you will want to install the receiver in its cabinet for normal use. In the final experiment you performed alignment. Your receiver should now be in tip-top operating condition. Examine the circuit board and other parts carefully.

Look for poorly soldered connections or bits of wire that could short out the circuits. See that the wiring, especially around the loopstick antenna and on the volume control potentiometer, is dressed close to the panel so that the wires will clear the cabinet. When you are satisfied with the condition of the receiver, perform the following steps to install it in the cabinet.

Remove the power cord from both the receiver and from the ac outlet.

Insert the interlock end of the power cord through the rectangular cutout marked "Interlock" .... ( )

Slip the power cord clamp on the interlock connection, as shown in Fig. 23. . ( )

Pull the cord through the rectangular cutout until the interlocking portion of the cord extends through the rectangular cutout, as at "1" in Fig. 24. The power cord clamp is now positioned against the inside of the cabinet at the cutout . . . .( )

With the cabinet right-side up, position the receiver so the circuit board rests in the guide strips on either side of the inside of the cabinet .... ( )

Slowly slide the receiver into the cabinet. Position the interlock connector so the interlock prongs on the circuit board fit into the female connector on the power cord .... ( )

To make sure that the interlock is correctly seated, plug in the receiver and turn it on. If it operates, the interlock is

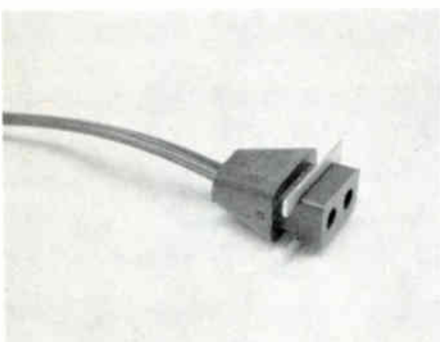


Fig. 23. Placement of the cord clamp on the interlock.

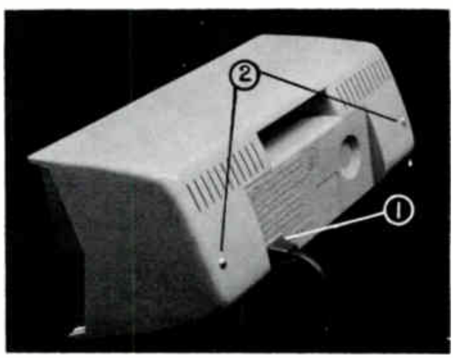


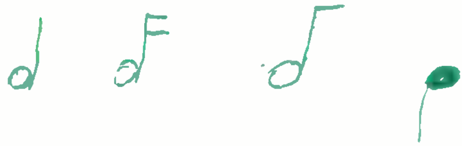
Fig. 24. Mounting the receiver in its cabinet for normal use.

properly connected. If it does not operate, pull the receiver forward and reseat the interlock connector . . . . ( )

Place the two 4-1/4" screws through the two holes in the rear of the cabinet as shown at "2" in Fig. 24. Tighten the screws evenly . . . . ( )

Your receiver is now completely assembled and installed in its cabinet ready for normal use.

NOTES



WHY DO YOU WANT TO SUCCEED?

There are several answers to this question. You may want to succeed for the very human reason that you want more money with which to enjoy life, or you may have a family for whom you want to provide those comforts they deserve – a home, a new car, good clothes, life insurance, and financial security.

Your ambition to succeed may be promoted by the desire to bring happiness to an aged father, mother, or relative whose chief hope in life is to see that you enjoy prosperity and prestige, to see you on the pinnacle of success.

Pause for just a minute and think – what is your reason for wanting success? With this reason in mind, resolve firmly that you will never allow your ambition to weaken. Resolve that you will never swerve from the direct path of your goal. Make this resolution now and keep it, so the years to come will be happier and more prosperous for you.

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ACHIEVEMENT THROUGH ELECTRONICS

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TRAINING KIT MANUAL

7YY

NATIONAL RADIO INSTITUTE • WASHINGTON, D. C.

PRACTICAL DEMONSTRATIONS OF RADIO-TV FUNDAMENTALS 7YY

INSTRUCTIONS FOR EXPERIMENTS 61 TO 70

In this kit you build a complete 5-tube ac-dc receiver and conduct experiments on it. This is an excellent receiver that you can use in your home or in your shop.

INDEX OF SECTIONS

NATIONAL RADIO INSTITUTE, WASHINGTON, D.C. 20016

CEC5C176 1976 EDITION Litho in U.S.A.

Instructions for Performing Experiments 61 to 70

The experiments that you have carried out so far have shown how certain stages in a receiver operate, but you have not yet worked on a complete receiver.

Before you carry out any of the experiments in this manual, you will assemble a complete 5-tube ac-dc radio receiver. This is the type of table model radio most commonly used today, and ac-dc TV sets are also quite common.

You will then learn the correct trouble-shooting procedures for locating the cause of a dead receiver, a receiver with hum, and af and i-f oscillations. You will show how important i-f alignment is for tracking and sensitivity of superheterodyne receivers. You learn three different methods of troubleshooting radio receivers; the voltage measurement, resistance measurement, and circuit disturbance methods. You see where each of these methods should be used and learn the limitations of each.

Building a complete receiver and then making standard servicing checks on it will give you valuable practical training. When you finish the experiments, you will have an excellent receiver complete with modern cabinet that you can use in your home, as a shop set, or as a set to lend out to customers while their sets are in your shop.

You will wire the set in steps. When you finish each step, you should check your work carefully. After you have completed the receiver, carry out each test procedure carefully and completely. If you fail to get the correct results, recheck your work and correct the trouble before you go on to the next step. If you cannot locate the trouble, write to NRI on a regular Experiment Consultation Blank. When you write for help, be sure to give complete details, because the only information we will have is what you send in your letter.

Even if the set is completely dead, take the voltage and resistance measurements indicated on pages 22 and 23, and let us know the results. This information will help us locate your trouble.

CONTENTS OF THIS KIT

In this kit you will receive two new tubes, a 50C5 power output tube, and a 35W4 rectifier tube. You will also receive a loudspeaker, a two gang tuning capacitor, a dual section electrolytic capacitor, and various resistors and capacitors.

IMPORTANT: The i-f transformers sent in this kit have been pretuned at the factory. Do not turn the adjustments on these i-f transformers until you are told to do so. If you do, you may get them so badly out of adjustment that you will not be able to align the set without a signal generator.

The parts included in 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.

If any part of this kit is obviously defective or has been damaged in shipment, return it to NRI immediately as directed on the packing slip included in this kit.

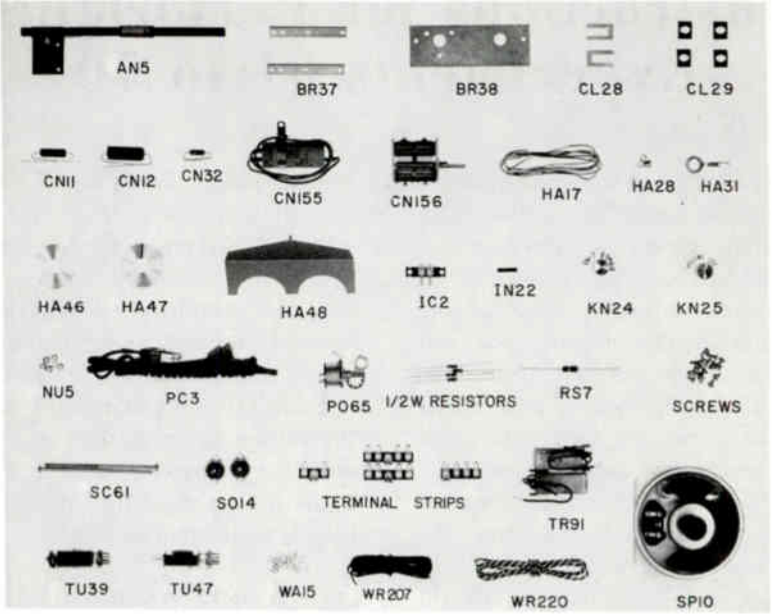


Fig. 1. The parts you receive in this kit are shown above and listed below.

Quan.	Part No.	Description	Price Each
1	AN5	Loopstick antenna	1.06
1	AT3	Alignment tool*	.40
1	CB15	Plastic radio cabinet*	3.65
1	CH50	Chassis*	2.60
1	HA8	3′ length solder	.10
1	IC2	Chassis interlock connector	.25
1	IN22	5/8″ length spaghetti	.10
1	KN24	Tuning knob	.48
1	KN25	Volume control knob	.48
6	NU5	4-40 hex nuts	12/.15
1	PA17	Front panel*	1.70
1	PC3	Interlock power cord	.58
1	PO65	500k-ohm pot. w/switch	.95
2	SO14	7-pin miniature sockets	.15
1	SP10	4″ loudspeaker w/mtg. slot	1.59
2	TR91	455 kHz i-f transformers	1.30
1	TU39	50C5 tube	1.10
1	TU47	35W4 tube	.83
24	WA15	No. 6 split-ring washers	12/.15
1	WR207	6′ length hookup wire	**
1	WR220	36″ length black and white twisted wire	.35

*Not shown in photo.

** Additional wire available in 12′ lengths only, each color .25.

CAPACITORS

1	CN50	25 pf	.15
1	CN32	47 pf	.15
1	CN11	0.01 μf	.18
1	CN12	0.1 μf	.18
1	CN155	50-30 μf, 150-volt, elect.	1.24
1	CN156	Two-gang tuning	1.57

HARDWARE

2	BR37	Chassis support brackets	.55
1	BR38	Volume control bracket	.70
2	CL28	Power cord clamps	.15
4	CL29	Speaker mounting clips	12/.15
3	HA28	1/4" spacers to pass No. 6 screws	.05
1	HA31	Pot. ground lug	12/.25
1	HA46	Plain round dial plate	.21
1	HA47	Round dial plate w/red line	.35
1	HA48	Gray edge molding	.40
1	ST5	2-lug terminal strip	.04
2	ST21	4-lug terminal strips	.10
1	ST28	4-lug terminal strip	.09

RESISTORS

(All resistors are 10%, 1/2-watt unless otherwise specified)

2	RE47	150-ohm	.15
1	RE44	2.2-megohm	.15
1	RE42	10-megohm	.15
1	RS7	1 k-ohm, 1-watt	.18

SCREWS

4	SC6	4-40 X 1/4"	12/.15
2	SC11	6-32 X 1/4" spade bolts	12/.15
4	SC13	6-32 X 3/8"	12/.15
6	SC15	No. 6 X 1/4"	12/.15
2	SC61	8-32 X 4-1/4"	.12

Assembling Your Experimental Receiver

In all the assembly instructions, read the entire sentence or paragraph of each step before you proceed with the actual construction. Position each part and lead according to the description and illustrations. Be sure and cut the leads of all parts to the proper length for neat assembly. You will not be using any of these parts in later kits. Solder carefully. Above all, take your time. The few extra minutes it takes for careful construction may save you hours of checking to find a mistake. As you complete a step, put a check in the space provided.

MOUNTING THE PARTS

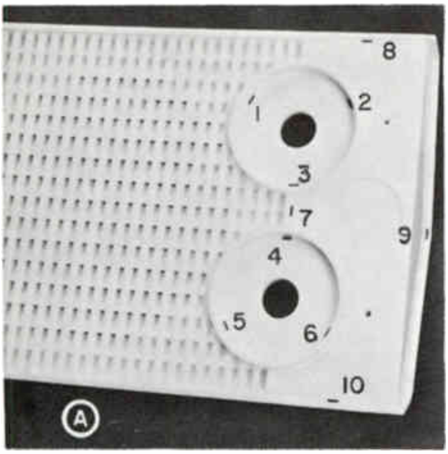
Before you do any wiring, you will mount most of the parts on the chassis and front panel. Gather the following parts from those you had left over from your other kits and from those you received in this kit.

- 1 Front panel
- 1 Round dial plate with red line
- 1 Plain round dial plate
- 1 Gray edge molding
- 2 Chassis support brackets
- 2 6-32 X 1/4" spade bolts
- 4 No. 6 X 1/4" self tapping screws
- 1 Chassis
- 2 I-F transformers
- 5 7-pin miniature tube sockets
- 1 Oscillator coil
- 2 4-lug terminal strips
- 1 3-lug terminal strip with ground lug
- 1 2-lug terminal strip
- 1 Audio output transformer
- 1 Dual 50/30 electrolytic capacitor
- 12 4-40 X 1/4" screws
- 12 4-40 hex nuts
- 5 6-32 X 1/4" screws
- 4 6-32 X 3/8" screws
- 12 6-32 hex nuts
- 22 No. 6 lockwashers
- 1 Male chassis interlock connector
- 1 Volume control bracket
- 1 Tuning capacitor
- 1 500k-ohm potentiometer with switch, lockwasher and mounting nut
- 1 Potentiometer ground lug
- 1 Ferrite antenna rod
- 1 Antenna coil
- 1 Fiber antenna mounting bracket
- 3 1/4" spacers

Decorative Trim. Refer to Figs. 2(A) and 2(B) as you mount the decorative trim on the front panel.

Position the dial plate with the red line so that the red line is pointing straight up. Put the dial plate in the upper recess of the panel after bending the three tabs so they pass through slots 1, 2, and 3 of the panel as shown in Fig. 2(A). The red line should be between slots 1 and 2. . . ( )

Put the plain round dial plate in the lower recess after bending the three tabs so they pass through slots 4, 5, and 6. ( )



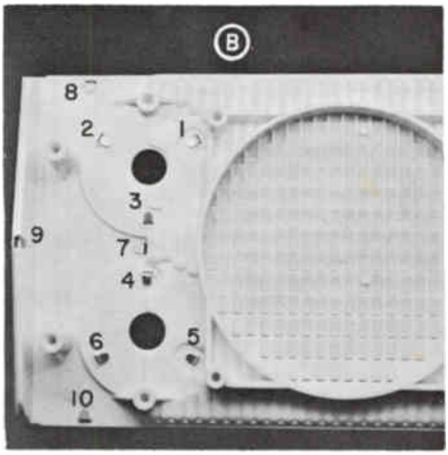


Fig. 2. (A) Mounting slots for panel trim, (B) bending mounting tabs of panel trim.

Mount the gray edge molding so the four mounting tabs pass through slots 7, 8, 9, and 10. Slot 9 is on the rear edge of the panel. . . . . ( )

With the three trim pieces pressed firmly against the front panel, bend the ten mounting tabs as shown in Fig. 2(B). ( )

Chassis Support Brackets. The next step will be to prepare the chassis support brackets and fasten them to the front panel. This step is shown in Figs. 3 and 4.

Fasten one of the 6-32 spade bolts in hole B of one of the chassis support brackets as shown in Fig. 3. Position the "spade" part parallel to the short dimension of the bracket, and secure with a No. 6 lockwasher and a 6-32 hex nut. . . . ( )

In a similar manner, fasten the other 6-32 spade bolt in hole B of the other chassis support bracket. . . . . ( )

Place the front panel face down on a cloth in front of you. Position the two large holes in the panel to your left, as shown in Fig. 4. . . . . ( )

Place one of the two chassis support brackets over the two posts on the left of the panel: Position the bracket so that holes A and D are over the holes in the ends of the posts. The "spade" part of the spade lug should be nearest you and pointing straight up. . . . . ( )

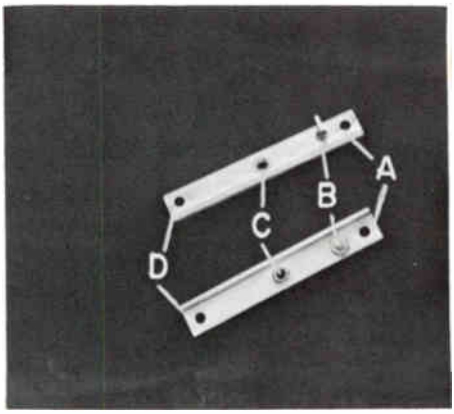


Fig. 3. Chassis support brackets.

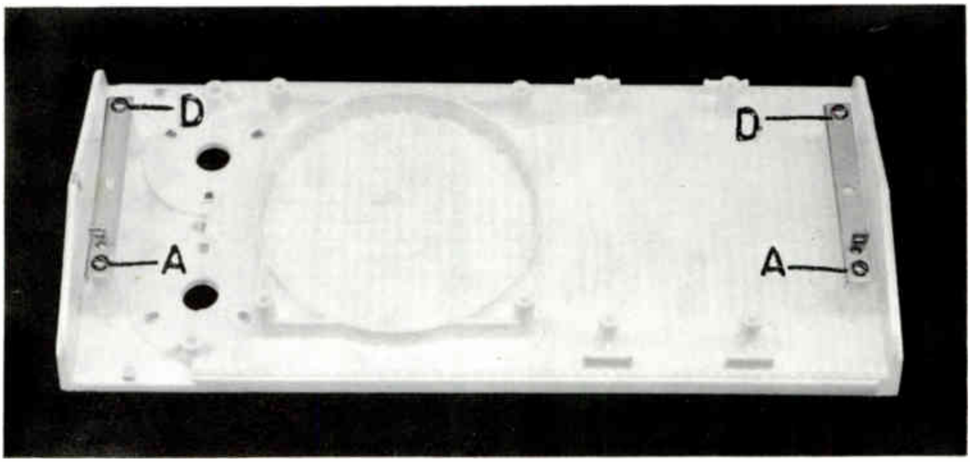


Fig. 4. Rear of front panel.

Fasten the bracket to the front panel with two No. 6 X 1/4" self-tapping screws. It is important that you tighten these screws very slowly and that you do not overtighten them. The plastic posts, while strong, may crack if too much force is used in tightening these screws. . . . ( )

In a similar manner, fasten the other chassis support bracket to the two posts on the right end of the front panel. Figure 4 shows the chassis mounting brackets in place. . . . . ( )

Mounting Parts On The Chassis. Figure 5 identifies the various holes in the chassis as viewed from the bottom. You can mark the chassis with a marking crayon if you wish. Refer to Figs. 5, 6, and 7 as you mount the parts.

Position the chassis in front of you as shown in Fig. 5. . . . . ( )

Place a 7-pin socket in hole B. Pass a 4-40 X 1/4" screw through hole B1 from the top of the chassis and fasten with a

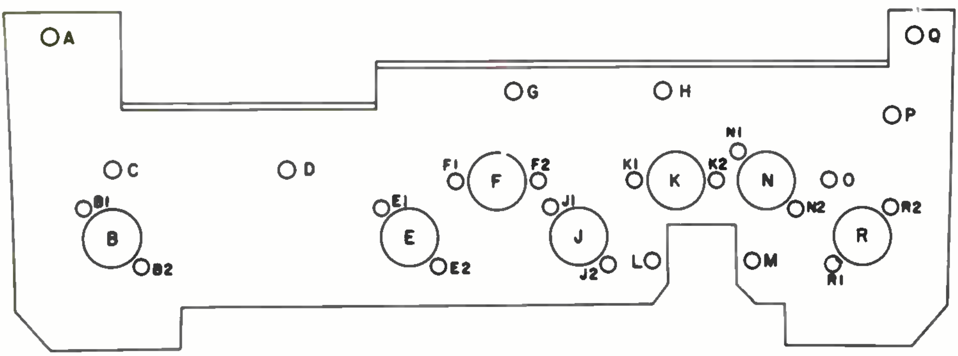


Fig. 5. Bottom view of receiver chassis with holes identified.

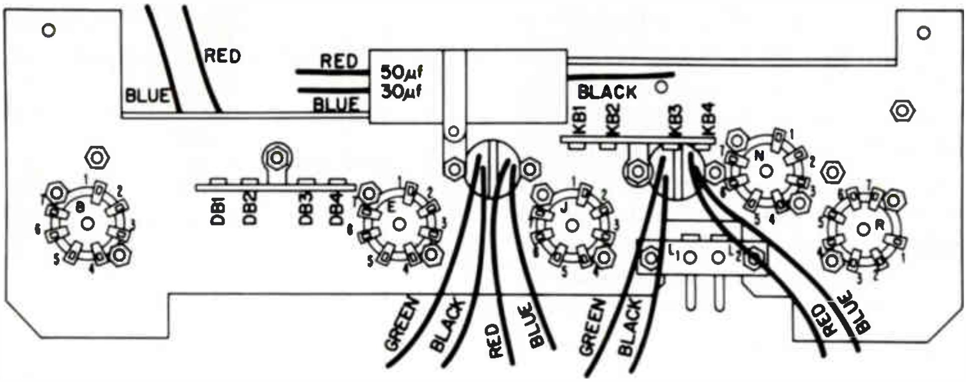


Fig. 6. Parts mounting on bottom of chassis.

No. 6 lockwasher and a 4-40 hex nut. Secure the socket with another 4-40 X 1/4" screw, lockwasher, and nut in hole B2. Be sure the socket is positioned with the space between pins 1 and 7 as shown in Fig. 6. This socket will be referred to as "socket B." . . . . ( )

In a similar manner, mount sockets in holes E, J, N, and R. Position these sockets as shown in Fig. 6. . . . . ( )

Using two 6-32 X 1/4" screws, two No. 6 lockwashers, and two 6-32 hex nuts, mount the male interlock connector in the space between holes L and M. . ( )

Mount the oscillator coil on top of the chassis with two 6-32 X 1/4" screws, two No. 6 lockwashers, and two 6-32 hex nuts in holes O and P. Position the lugs with the red, black, green, and orange dots as shown in Fig. 7. . . . . ( )

Mount the output transformer on top of the chassis with a 6-32 X 1/4" screw, No. 6 lockwasher, and 6-32 hex nut in hole C. Position the transformer so the red and blue leads are shown in Figs. 6 and 7. . . . . ( )

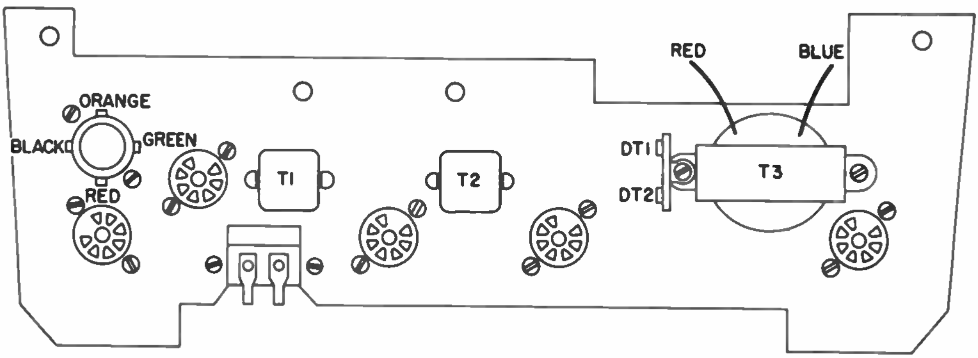


Fig. 7. Parts mounting on top of chassis.

Pass a 6-32 X 3/8" screw through the mounting foot of the 2-lug terminal strip, then through the remaining mounting hole of the output transformer from the top of the chassis over hole D. Place a 4-lug terminal strip on the projecting end of this screw and fasten with a No. 6 lockwasher and a 6-32 hex nut. Position the lugs of the two terminal strips as shown in Figs. 6 and 7 and tighten the nut securely. . . . . ( )

Next, you are to mount the two i-f transformers on top of the chassis. Pass the leads of one of the i-f transformers through hole K from the top of the chassis. Turn the transformer so the red and blue leads will be in the position shown in Fig. 6. Run the spade bolts on the shield can through holes K1 and K2. . . . . ( )

Place a No. 6 lockwasher and a 6-32 hex nut on the spade bolt projecting from hole K2 and tighten just enough to securely hold the transformer. Too much force may pull the spade bolts from the can. . . . . ( )

Position the other 4-lug terminal strip over the spade lug projecting from hole K1 as shown in Fig. 6 and secure with a No. 6 lockwasher and 6-32 hex nut. . ( )

Mount the other i-f transformer in hole F. Position the leads as shown in Fig. 6 and secure with one No. 6 lockwasher and one 6-32 hex nut at F2. . . . . ( )

Mount the dual electrolytic capacitor on the remaining spade lug at F1 with a No. 6 lockwasher and a 6-32 hex nut. Position the red, blue, and black leads as shown in Fig. 6. . . . . ( )

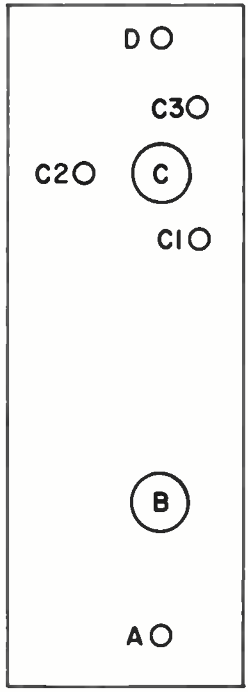


Fig. 8. Rear view of volume control bracket.

Mounting Parts On The Volume Control Bracket. Figure 8 shows the rear of the volume control bracket and identifies the holes.

Place a lockwasher and then the potentiometer ground lug over the shaft of the 500k-ohm potentiometer with the bent lug pointed to the rear of the control. ( )

Push the shaft of the potentiometer through hole B of the volume control bracket. Position the lugs as shown in Fig. 9 and fasten with the potentiometer mounting nut. . . . . ( )

Place three 6-32 X 3/8" screws through holes C1, C2, and C3 from the front of the bracket. . . . . ( )

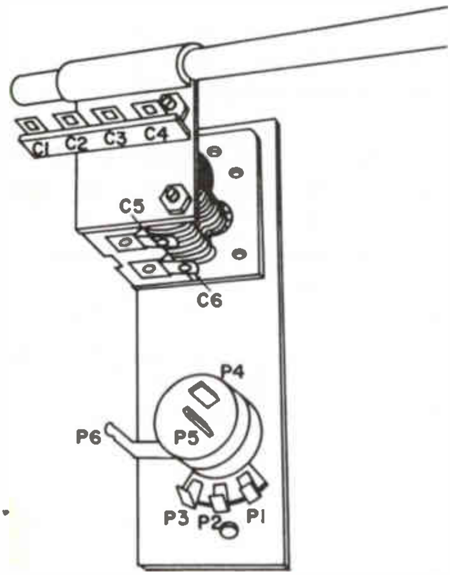


Fig. 9. Parts placement on volume control bracket.

While holding the heads of the three 6-32 screws, slip a 1/4" spacer over the end of each screw. . . . . ( )

Carefully position the tuning capacitor, as shown in Fig. 9, with the two trimmer capacitors nearest hole D. The shaft of the capacitor goes through hole C. . . ( )

Line up the ends of the three screws with the corresponding tapped holes on the front mounting plate of the tuning capacitor. Move the capacitor and bracket together and tighten the three 6-32 screws. . . . . ( )

Make sure the plates of the tuning capacitor are fully meshed. . . . . ( )

To insure safe arrival, the ferrite rod antenna has been shipped to you in three separate parts: the fiber mounting bracket, the ferrite rod, and the antenna coil itself. You will now assemble the three parts of the antenna.

Slip one end of the ferrite rod into the sleeve of the mounting bracket. Position the rod as shown in Fig. 10. . . . . ( )

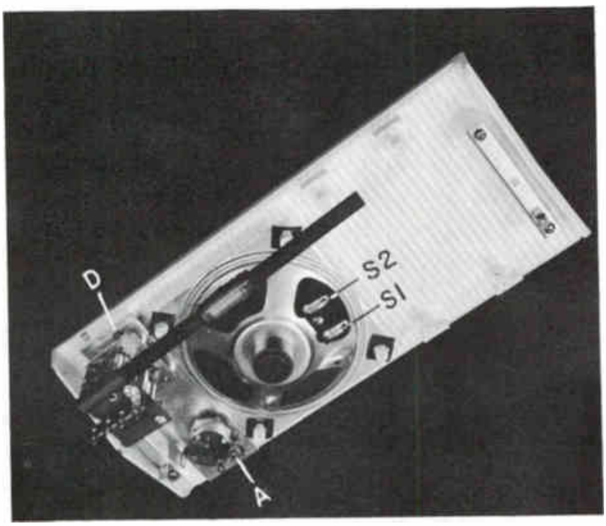


Fig. 10. Parts mounted on front panel.

Examine the antenna coil and notice that there are two separate windings: a small winding and a large winding. Slide the antenna coil onto the ferrite rod with the larger winding nearest the fiber mounting bracket. Figure 10 shows the relative positions of the three parts of the assembled antenna. . . . . ( )

Mount the assembled antenna and four-lug terminal strip to the rear plate of the tuning capacitor as shown in Fig. 9. These parts are fastened with two 4-40 X 1/4" screws and two 4-40 hex nuts in the two small holes near the edge of the rear frame of the tuning capacitor. . . ( )

Final Mounting of Parts on the Front Panel. You will need the following parts in this step of the assembly:

- 1 Loudspeaker
- 1 Volume control bracket with parts mounted.
- 2 No. 6 X 1/4" self tapping screws
- 4 Loudspeaker mounting clips.
- 1 Front panel assembly

Place the front panel in front of you on a soft cloth and position the loudspeaker with the speaker lugs S1 and S2 as shown in Fig. 10. . . . . ( )

Push one of the loudspeaker mounting clips over each of the four loudspeaker mounting posts on the front panel. . . ( )

Position the volume control mounting bracket as shown in Fig. 10. . . . . ( )

Fasten the bracket to the front panel with a No. 6 X 1/4" screw in hole A of the bracket. Again, do not overtighten this screw or you may break the plastic mounting post. . . . . ( )

Slip the other No. 6 X 1/4" screw between the tuning capacitor frame and the mounting bracket at hole D. . . . . ( )

Push the screw through hole D and fasten to the front panel. Use a thin-bladed screwdriver to tighten this screw. This will make it easier to clear the capacitor frame. . . . . ( )

You have now completed mounting the parts. Compare your work with Figs. 6, 7, 9, and 10. You are now ready to go ahead with the wiring.

WIRING THE FILAMENTS AND B–

In doing the wiring, follow the techniques you have learned. Keep your soldering iron clean and well-tinned, and be sure it is hot when you use it. In connecting hookup wire, remove just enough insulation from the ends to make a hook, and hook the bare end through the terminal lug. Use temporary hook joints in all your connections so that, if you have to disconnect them in the experiments, it will not be so difficult. You will be given instructions on when to solder each connection. Cut the leads of the parts to the proper length, make your wiring neat, and keep the wires and leads short.

For this step you will need black and white twisted wire and hookup wire.

First, prepare two lengths of black and white twisted wire as shown in Fig. 11 and the following instructions.

Cut off a 9" length of twisted wire. ( )

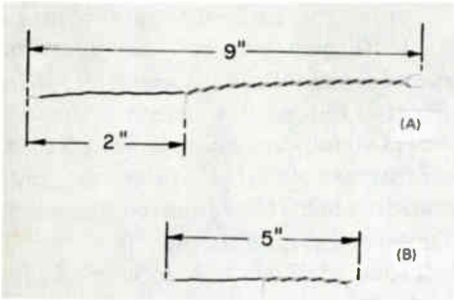


Fig. 11. Twisted filament wires.

Carefully cut only the WHITE wire 2″ from one end. Untwist and remove the short length of white wire and straighten the remaining black wire. . . . . ( )

Cut a 5″ length of twisted wire. . . ( )

Carefully cut only the WHITE wire 2″ from one end. . . . . ( )

Untwist and remove the short length of white wire. . . . . ( )

Now wire the filaments and B– according to the instructions in Table I and the layout of Fig. 12. As you finish each connection, put a check mark in the last column.

PART	FROM	TO	SOLDER	√
LONG BLACK LEAD OF 9" TWISTED WIRE	3 OF SOCKET R	3 OF SOCKET B	BOTH	
WHITE LEAD OF 9" TWISTED WIRE	4 OF SOCKET J	4 OF SOCKET B	BOTH	
LONG BLACK LEAD OF 5" TWISTED WIRE	4 OF SOCKET E	3 OF SOCKET N	BOTH	
WHITE LEAD OF 5" TWISTED WIRE	3 OF SOCKET J	4 OF SOCKET N	BOTH	
HOOKUP WIRE	4 OF SOCKET R	L2	BOTH	
HOOKUP WIRE	2 AND CENTER POST OF SOCKET R	CENTER POST OF SOCKET N	2	
HOOKUP WIRE	CENTER POST OF SOCKET N	CENTER POST OF SOCKET J	NO	
HOOKUP WIRE	CENTER POST OF SOCKET J	3 AND CENTER POST OF SOCKET E	3 OF SOCKET E	
HOOKUP WIRE	CENTER POST OF SOCKET E	DB1	NO	

Table I. Instructions for wiring filaments and B–.

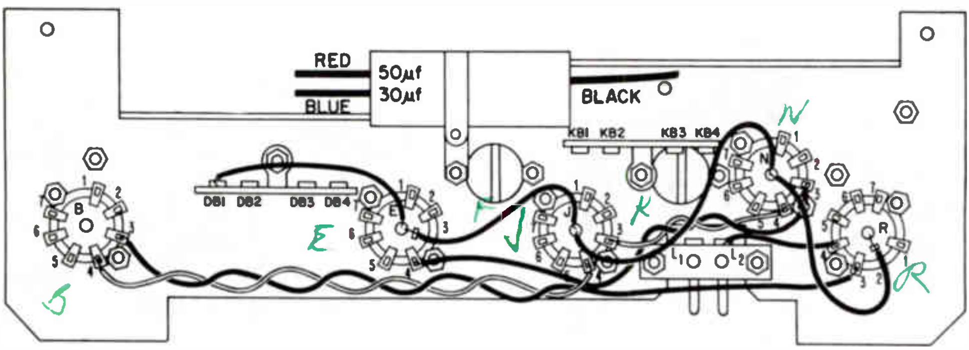


Fig. 12. Pictorial diagram of filament and B– wiring.

PRELIMINARY I-F AND RF WIRING

Next, you will wire the i-f amplifier and parts of the detector and converter stages. Follow the instructions in the layout of Fig. 13 and Table II.

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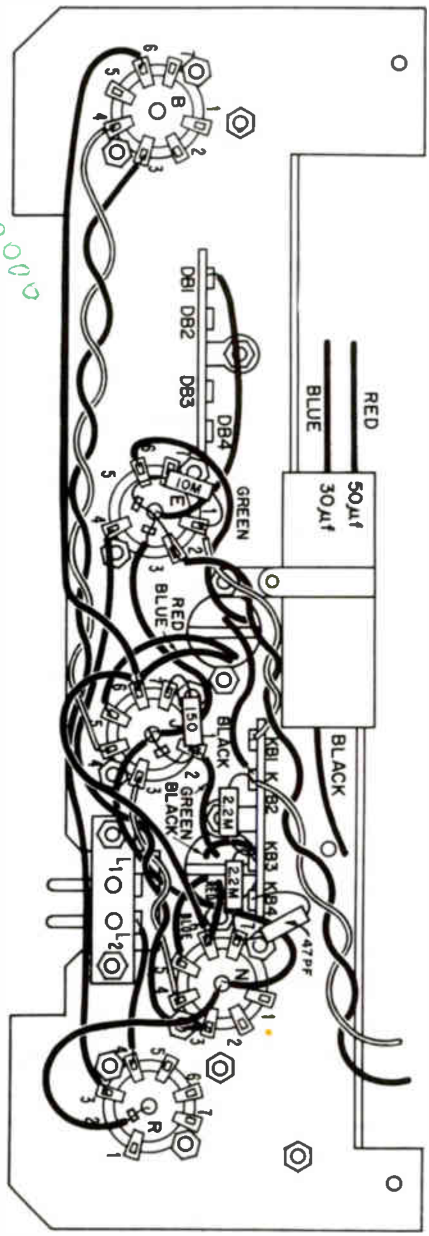

Fig. 13. Pictorial diagram of i-f amplifier and rf wiring.

Before you begin the wiring steps in Table II, you will have to prepare a special length of twisted wire as shown in Fig. 14. Cut a 7-3/4" length of twisted wire. Carefully cut only the white lead at a distance of 2-1/2" from one end. Untwist about 1/2" from both sides of the cut and strip all six ends.

Figure 15 shows how to connect one lead of the 10 meg resistor. Notice that the lead goes through terminal 5, the center post, and terminal 2 of socket E. Also, be sure to leave 1/4" from the body of the resistor to terminal 5.

You will need the following:

- 1 150-ohm, 1/2-watt resistor
- 2 2.2-meg, 1/2-watt resistors
- 1 10-meg, 1/2-watt resistor
- 1 47 pf capacitor
- Twisted wire
- Hookup wire

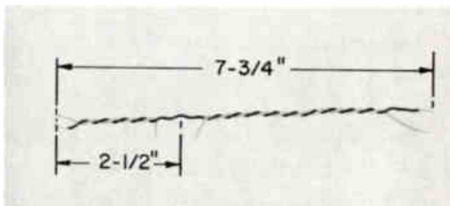

Fig. 14. Prepared twisted wire.

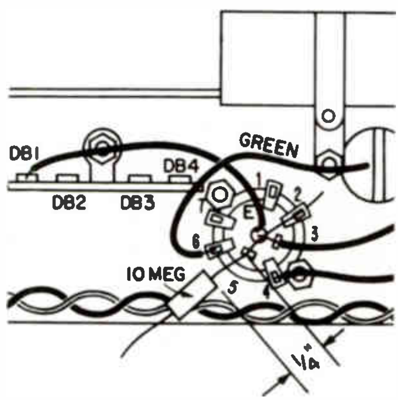

Fig 15. How to mount the 10 meg resistor.

PART	FROM	TO	SOLDER	✓
BLUE LEAD	HOLE K	5 OF SOCKET N	YES	
RED LEAD	HOLE K	6 OF SOCKET N	NO	
GREEN LEAD	HOLE K	1 OF SOCKET J	YES	
BLACK LEAD	HOLE K	KB3	NO	
BLUE LEAD	HOLE F	5 OF SOCKET J	YES	
RED LEAD	HOLE F	6 OF SOCKET J	NO	
BLACK LEAD	HOLE F	KB2	NO	
GREEN LEAD	HOLE F	6 OF SOCKET E	YES	
HOOKUP WIRE	6 OF SOCKET N	6 OF SOCKET J	SOCKET N	
HOOKUP WIRE	6 OF SOCKET J	6 OF SOCKET B	SOCKET J	
2.2 MEG RESISTOR	KB2	KB3	NO	
47 PF CAPACITOR	KB4	7 OF SOCKET N	NO	
2.2 MEG. RESISTOR	KB3	7 OF SOCKET N	SOCKET N	
150 OHM RESISTOR	2 AND CENTER POST OF SOCKET J	7 OF SOCKET J	ALL	
10 MEG. RESISTOR	5, CENTER POST, 2 OF SOCKET E	1 OF SOCKET E	5 AND CENTER POST OF SOCKET E	
SHORT WHITE LEAD OF TWISTED WIRE	1 OF SOCKET E	KB1	SOCKET E	
BLACK LEAD OF TWISTED WIRE	2 OF SOCKET E	-------	YES	
WHITE LEAD OF TWISTED WIRE	KB2	-------	YES	

Table II. Instructions for preliminary wiring of if-rf stages.

WIRING THE POWER SUPPLY AND AUDIO STAGES

Figure 16 shows the wiring layout of the power supply and audio stages.

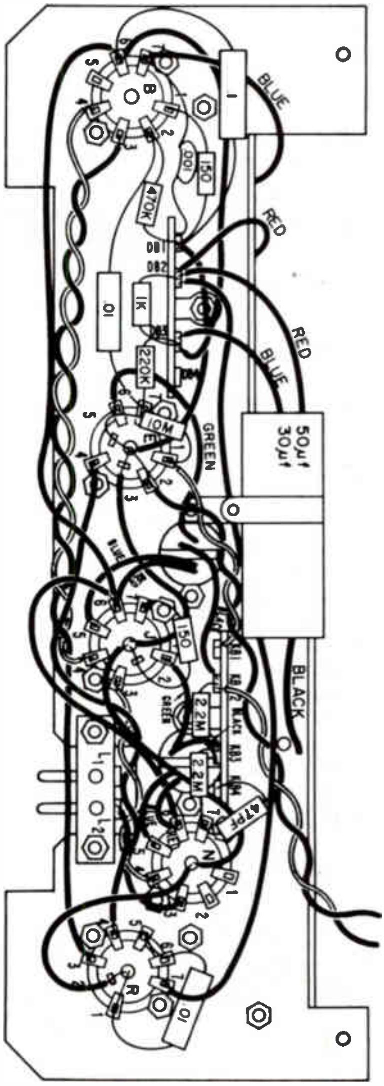

Fig. 16. Wiring layout of the power supply and audio stages.

The parts you will need are:

1 150-ohm, 1/2-watt resistor
1 220k-ohm, 1/2-watt resistor
1 470k-ohm, 1/2-watt resistor
1 1k-ohm, 1-watt resistor
1 0.1 μf capacitor
2 0.01 μf capacitors
1 0.001 μf capacitor
Hookup wire

Follow the instructions in Table III and the layout of Fig. 16 in wiring the power supply and audio stages.

PART	FROM	TO	SOLDER	✓
.01µf CAPACITOR	1 AND CENTER POST OF SOCKET R	5 AND 6 OF SOCKET R	5 AND 6	
HOOKUP WIRE	7 OF SOCKET R	DB2	7	
HOOKUP WIRE	DB3	6 OF SOCKET B	NO	
BLUE LEAD	ELECTROLYTIC CAPACITOR	DB3	NO	
RED LEAD	ELECTROLYTIC CAPACITOR	DB2	NO	
RED LEAD	AUDIO TRANSFORMER	DB2	NO	
1K, 1W RESISTOR	DB2	DB3	DB2	
220K, 1/2W RESISTOR	DB3	7 OF SOCKET E	DB3	
.01µf CAPACITOR	7 OF SOCKET E	2 OF SOCKET B	7	
470K, 1/2W RESISTOR	2 OF SOCKET B	DB1	2	
BLUE LEAD	AUDIO TRANSFORMER	7 OF SOCKET B	NO	
.001µf CAPACITOR	7 OF SOCKET B	DB1	7	
150 OHM,1/2W RESISTOR	1 OF SOCKET B	DB1	1	
.1µf CAPACITOR	6 OF SOCKET B	DB1	BOTH	

Table III. Instructions for wiring the power supply and audio stages.

WIRING THE OSCILLATOR

In this step you will finish wiring the oscillator section. Some of the wiring is on the top of the chassis and some is on the bottom of the chassis.

Figure 17(A) shows the wiring on the bottom of the chassis, and Fig. 17(B) shows wiring on top of the chassis.

You will need:

1 22k-ohm, 1/2-watt resistor
Twisted wire
Hookup wire

Proceed with the wiring instructions given in Table IV and Fig. 17.

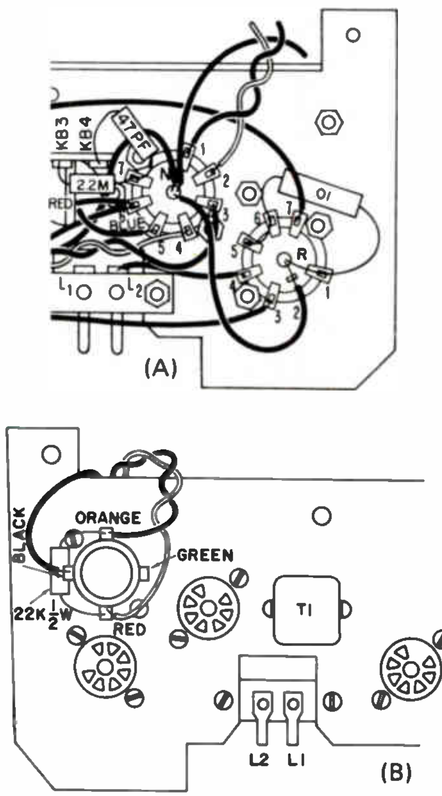

Fig. 17. (A) Wiring on bottom of chassis for the oscillator, and (B) wiring on top of chassis.

PART	FROM	TO	SOLDER	✓
BLACK LEAD OF TWISTED WIRE	1 OF SOCKET N	ORANGE LUG OSC. COIL	1	
WHITE LEAD OF TWISTED WIRE	2 OF SOCKET N	RED LUG OSC. COIL	2	
HOOKUP WIRE	CENTER POST OF SOCKET N	BLACK LUG OSC. COIL	BOTH	
22K, 1/2 W RESISTOR	ORANGE LUG OSC. COIL	RED LUG OSC. COIL	BOTH	

Table IV. Wiring instructions for the oscillator section.

PREPARING THE FRONT PANEL

For this step you will connect some leads to the antenna, switch, and loudspeaker to make final assembly of the receiver easier.

You will need:

The front panel assembly
Hookup wire
Twisted wire
1 25 pf capacitor

Figure 18 identifies the four leads of the antenna. Leads 1 and 2 go to the large winding and leads 3 and 4 go to the smaller winding. Do not cut any of these leads. You will need the full length later when you adjust the position of the antenna coil.

Instructions are given in Table V. Refer to Fig. 9 and Fig. 19 for wire placement and terminal identification.

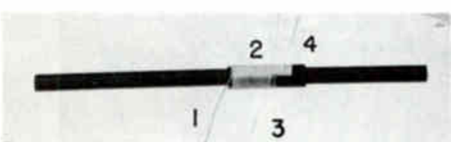

Fig. 18. Lead identification on the ferrite rod antenna.

PART	FROM	TO	SOLDER	✓
NO. 1 WIRE	ANTENNA	C1	NO	
NO. 2 WIRE	ANTENNA	C4	NO	
NO. 3 WIRE	ANTENNA	C2	YES	
NO. 4 WIRE	ANTENNA	C3	YES	
HOOKUP WIRE,	C1	C6	C1	
4-1/2" LENGTH HOOKUP WIRE	C6	------	YES	
25 PF CAP.	C4	C5	C4	
1-3/4" LENGTH HOOKUP WIRE	C5	------	YES	
WHITE LEAD OF 5" LENGTH OF TWISTED WIRE	S1	------	YES	
BLACK LEAD OF TWISTED WIRE	S2	------	YES	
3-1/2" LENGTH HOOKUP WIRE	P4	------	YES	

Table V. Instructions for wiring the front panel.

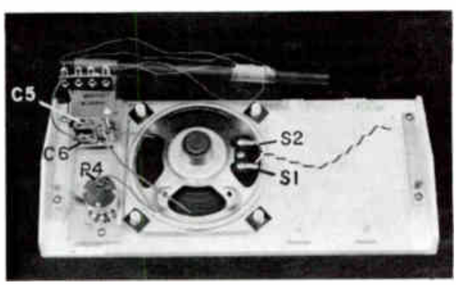

Fig. 19. Front panel wiring.

FINAL ASSEMBLY

In this step you will join the front panel and the chassis and complete the wiring. You will need the following:

Partially wired chassis
Front panel

1 100 pf capacitor
1 0.01 μf capacitor
1 0.05 μf capacitor
1 0.1 μf capacitor
1 No. 6 solder lug
2 6-32 X 1/4" screws

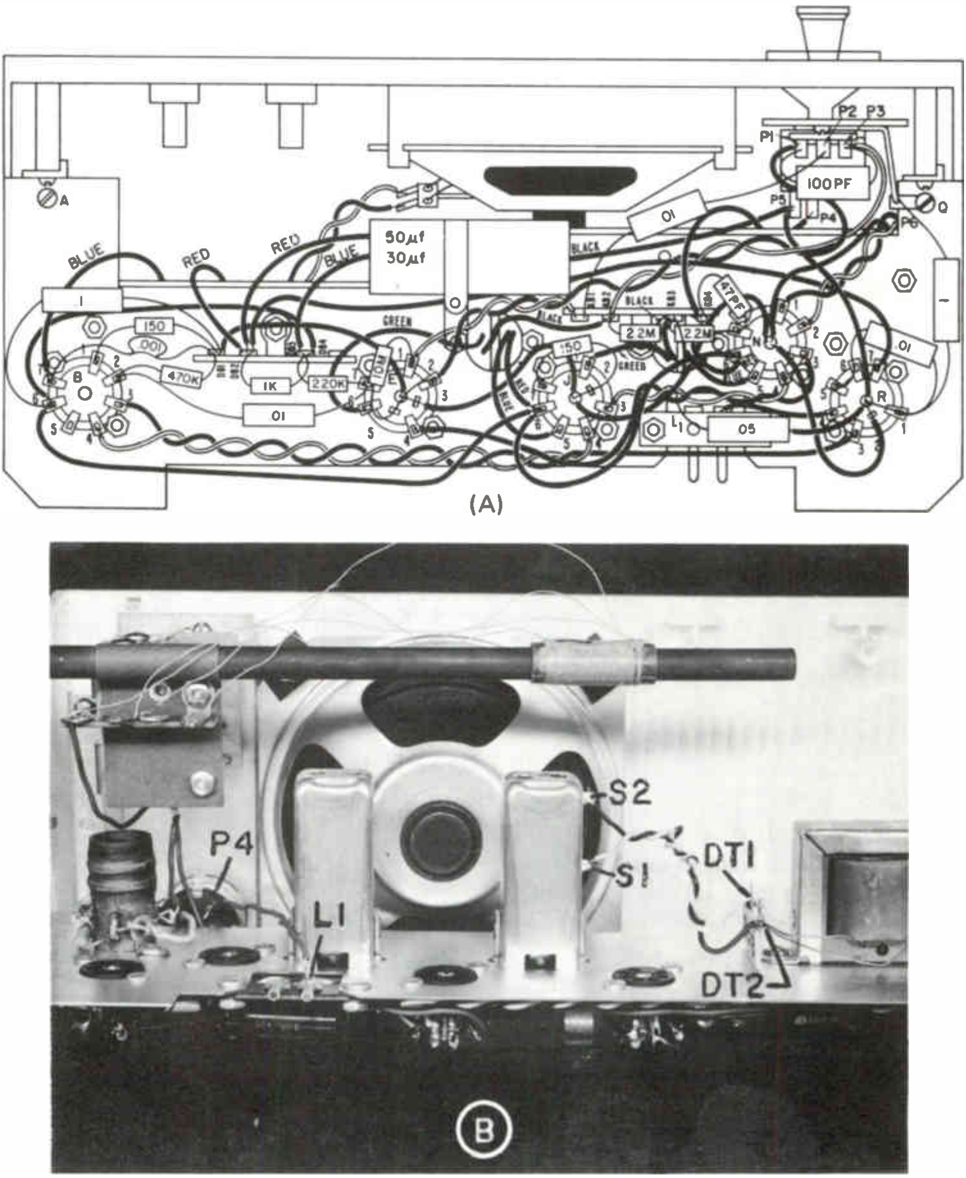

Fig. 20. (A) Chassis and panel assembled and wired, (B) final assembly.

2 6-32 hex nuts
2 No. 6 lockwashers
1 Insulated sleeving

Figure 20(A) shows how the chassis and panel go together, as well as the placement of wires and parts under the chassis. Figure 20(B) shows the wiring on top of the chassis.

Insert one of the 6-32 X 1/4" screws through hole A of the chassis from the bottom. Position the chassis and panel as shown in Fig. 20(A). Push the 6-32 screw on through the hole in the protruding spade bolt on the chassis support bracket and fasten with a No. 6 lockwasher and one of the 6-32 hex nuts. . . . . ( )

Insert the other 6-32 X 1/4" screw through the large hole in the No. 6 solder lug. . . . . ( )

With the solder lug facing toward the volume control, push the 6-32 screw through hole Q of the chassis and the hole in the spade bolt on the chassis support bracket. . . . . ( )

Fasten in place with a No. 6 lockwasher and the remaining 6-32 hex nut. ( )

Bend the solder lug so it is touching the ground lug P6 of the volume control. Both lugs together are now P6. . . . . . ( )

Next, complete the assembly of your receiver following the instructions in Table VI. Figure 20 shows parts placement.

This completes the wiring of your receiver. Before plugging in the tubes and turning the set on, carefully inspect all connections on the chassis. Every connection should be well soldered, with no

PART	FROM	TO	SOLDER	✓
WIRE	P4	L1	YES	
WIRE	C6	KB4	YES	
WIRE	C5	GREEN LUG OSC. COIL	YES	
BLACK LEAD	S2	DT2	NO	
WHITE LEAD	S1	DT1	NO	
ENAMEL WIRE	AUDIO TRANS-FORMER	DT2	YES	
ENAMEL WIRE	AUDIO TRANS-FORMER	DT1	YES	
.05 µf CAPACITOR WITH SLEEVE	KB3	CENTER POST OF SOCKET R	KB3	
BLACK LEAD	ELECTRO-LYTIC CAPACI-TOR	P5	NO	
HOOKUP WIRE	P5	CENTER POST OF SOCKET R	BOTH	
100 RF CAPACITOR	P1	P3	NO	
WHITE LEAD	KB2	P3	YES	
BLACK LEAD	2 OF SOCKET E	P1	YES	
.01 µf CAPACITOR	P2	KB1	BOTH	
.1 µf CAPACITOR	1 OF SOCKET R	P6	BOTH	

Table VI. Instructions for the final wiring of the receiver.

stray wires shorting to other terminals. Lug DB4 should be the only lug which has no connections made to it. Compare your wiring with that in the figures. Parts must be positioned exactly as shown in order for the chassis to fit easily inside the cabinet. One of the best ways of checking your wiring is to have someone else go over it.

When you are certain that you have made no mistakes and that all connections are securely soldered, insert the five tubes in the following sockets:

50C5	in socket B
12AT6	in socket E
12BA6	in socket J
12BE6	in socket N
35W4	in socket R

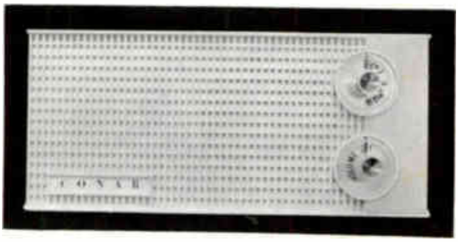

Fig. 21. Front of receiver with knobs in place.

With the tuning capacitor shaft turned fully clockwise (plates meshed) and the volume control fully counterclockwise (switch off), push the knobs on as shown in Fig. 21.

Take the power cord and mate it with the interlock connector prongs, L1 and L2.

Testing and Analyzing the Receiver

Before you start your experiments, you will make tests on your receiver to see that it is operating properly. Refer to the complete schematic diagram shown in Fig. 22 to locate terminals and parts.

PRELIMINARY TESTS

Receivers brought to the shop for repair work, as well as new equipment such as the receiver you have just constructed, should be tested before being placed in operation. Defects in the receiver may ruin parts if the set is plugged in and turned on without these preliminary tests.

If you have faithfully followed all instructions and the quality of your workmanship is good, it would probably be safe to turn on the set. However, you should not take a chance that everything is all right. A simple test and an inspection lasting a few minutes will tell you if it is safe to apply power to the set, so wait until you have carried out the tests suggested in this section.

The greatest danger is from a short in the B supply system, which might damage the rectifier tube.

The easiest way to work on the receiver so that you can perform the following experiments is to stand it up on one end with the tuning capacitor and volume control nearest the work table. You will then have easy access to both the top and bottom of the chassis.

First, set your tvom for high-range ohmmeter measurements, and connect the ground clip to pin 1 of the 35W4 and the probe to the cathode, pin 7 of the 35W4 tube socket. The meter pointer will indicate a low resistance because the filter capacitors are discharged. As the 1.5-volt cell in the ohmmeter section of the tvom gradually charges up the capacitors, the pointer will rise, indicating higher and higher resistance. In about two minutes the reading will reach its maximum. The resistance measured should not be less than 150,000 ohms. If the reading is lower than 100,000 ohms, there is certainly a short in the B+ circuit which you must locate and remove before trying the set out; otherwise the 35W4 may be ruined.

If you do measure abnormally low resistance, look for bare parts leads that are shorting to other terminals or leads, look for solder that has dropped from one terminal to another or to the chassis, and then check the wiring against Fig. 22. If you don't find anything wrong, disconnect the positive leads of the electrolytic capacitors one at a time. If the reading goes up when a capacitor lead is disconnected, that capacitor is leaky and must be replaced.

If your test shows that the resistance is normal, it is safe to try out the set.

Notice that there is a trimmer capacitor on top of each tuning capacitor section. The one toward the front (nearest the front panel) is the rf trimmer; the other is the oscillator trimmer. Before turning on the receiver, use a screwdriver to tighten the screw on each trimmer as far as it will go in the clockwise direction.

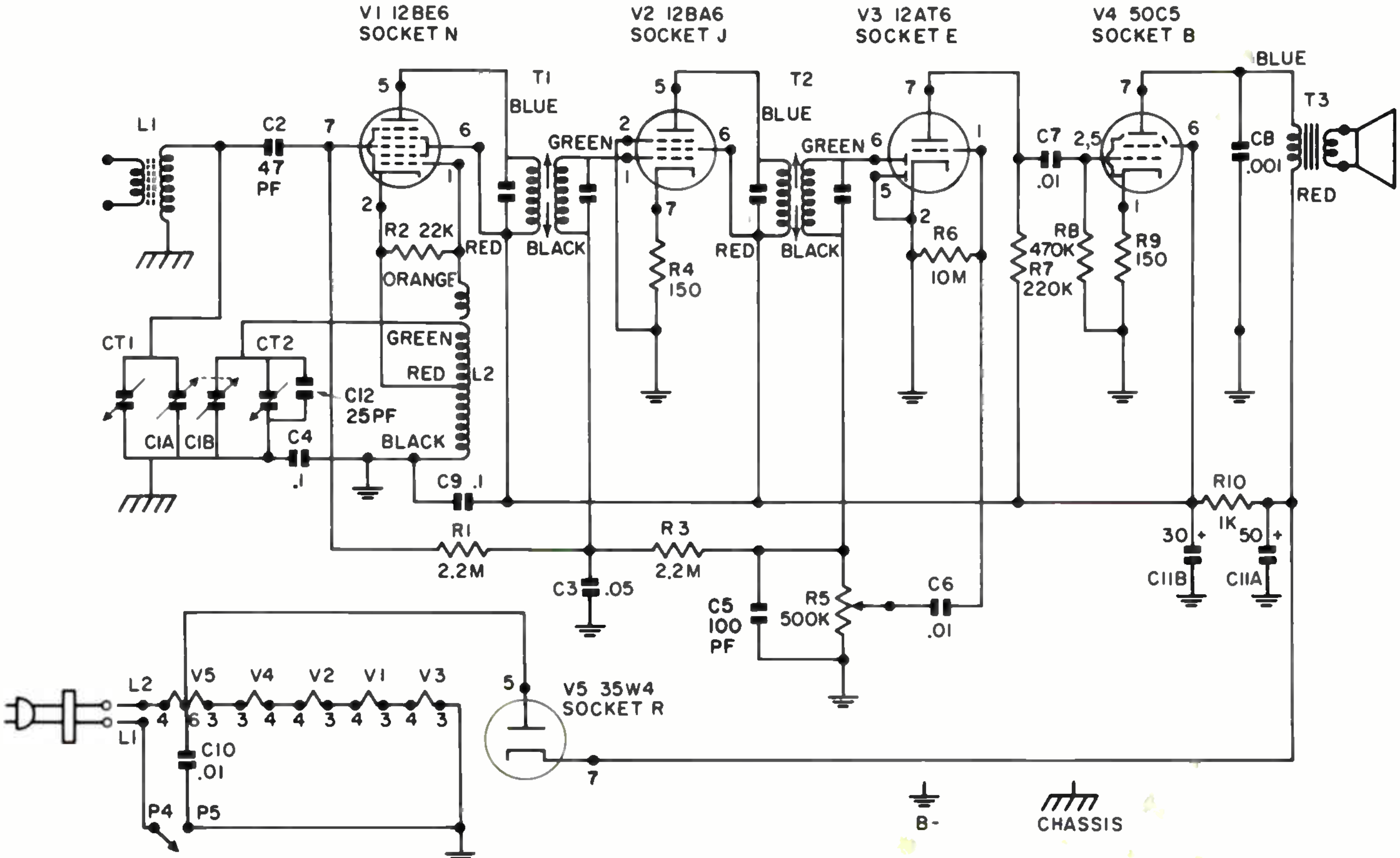

Fig. 22. Schematic diagram of the 7YY receiver.

Insert the power plug into the wall outlet and turn the set on. Turn the volume control all the way clockwise, and tune the receiver across the dial. If you are near stations, you should be able to pick one up somewhere near the high-frequency end of the dial around 1400 kHz or 1500 kHz. (Notice that the final two zeros have been omitted from each of the dial numbers; for example, 1400 kHz is at 14 on the dial.) The station will probably not come in at the proper dial setting. Identify the station by picking it up on another receiver, or by waiting for a station announcement. Then, tune your receiver to the correct dial setting for that station.

Adjust the oscillator trimmer CT2 very carefully until you receive the station again, this time at the proper dial setting. CT2 is the trimmer on top of the tuning capacitor farthest from the front panel. CT1 is the trimmer closest to the font panel. Next, adjust the rf trimmer CT1 for maximum volume. You should then be able to pick up a number of stations at their correct dial settings.

To get a better adjustment of the rf trimmer, connect your dc voltmeter across the volume control, with the ground clip to terminal P1 and the probe to terminal P3 of the volume control. Set the Function switch for -DC voltages, and choose a range setting that gives an appreciable reading when the set is tuned to a station near the high-frequency end of the dial. Now adjust the tuning dial for maximum voltage, even though you have to shift the dial setting slightly. Now, adjust the rf trimmer for maximum voltage across the volume control. You should be able to pick up stations at various points on the dial.

Tune in a station near the middle of the dial. Slowly slide the antenna coil up and down on the ferrite rod until the signal is maximum. This adjustment will increase the sensitivity of your receiver by correctly matching the antenna to the input circuits of the receiver.

The i-f transformers have been preset at the factory, and should need little adjustment. However, because of variations in parts values and tube characteristics in the diode detector circuit, the second i-f transformer may need some adjustment. Follow the procedure very carefully, making only the adjustments you are told to make.

Leave the tvom connected between terminals P1 and P3 to measure the avc voltage, and tune the receiver to a station near the high-frequency end of the dial. Now, refer to the top view of the chassis, Fig. 7, and find the second i-f transformer, T_2. You are to peak each slug for maximum avc voltage as indicated on the meter. Use the alignment tool (AT3) provided. Note that there are two slugs in each of the i-f transformers; one adjusts the resonant frequency of the primary winding, and the other affects that of the secondary. Turn the top slug from the top of the chassis, and the bottom slug from the wiring side. Insert the alignment tool only far enough to reach the closer slug.

DO NOT ADJUST THE SLUGS IN THE FIRST I-F TRANSFORMER. You will make these adjustments later when you do the experiment on alignment. If you adjust them now, you may get the receiver so far out of alignment that you will need a signal generator to realign it.

Carefully turn each slug a very small amount to the right and to the left of its original setting, until the avc voltage is at maximum. This adjustment is critical; usually a fraction of a turn is enough.

When you have peaked the top slug for maximum avc voltage, repeat the adjustment on the bottom slug in the same way. Your receiver should now operate satisfactorily. Do not attempt to make any further adjustments until you are told to do so.

If your set does not work and you write for help, let us know if the tubes light, and if there is a loud buzz from the speaker when you touch the control grid of the 12AT6 tube with your finger. Even if your set does not work, take the voltage and resistance measurements as instructed in the next section, and let us know the results. This will help us to diagnose your trouble.

TAKING VOLTAGE AND RESISTANCE MEASUREMENTS

Point-to-point voltage and resistance values are given in most manufacturers' service diagrams. If you cannot diagnose a defect by observing the symptoms, or cannot localize it, you can sometimes find the trouble by checking the resistance and voltage values and comparing them with the published values. Your values and those given by the manufacturer will not necessarily match, but with experience you will be able to decide if the variations are normal.

TUBE	VOLTAGE	PIN 1	PIN 2	PIN 3	PIN 4	PIN 5	PIN 6	PIN 7
V1 12BE6	TYPICAL	-11V DC	0	11.2V AC	21.7V AC	+84V DC	+85V DC	-.27V DC
	YOURS	0	+.84	10.6	23	93	93	-.28
V2 12BA6	TYPICAL	-.35V DC	0	21.5V AC	33V AC	+84V DC	+85V DC	+1.15V DC
	YOURS	-.36	0	22	32	105	97	1.4
V3 12AT6	TYPICAL	-.75V DC	0	0	11.2V AC	0	-.5V DC	+46V DC
	YOURS	-.67	0	0	10.8	0	-.52	52
V4 50C5	TYPICAL	+4.8V DC	0	75V AC	33V AC	0	+84V DC	+90V DC
	YOURS	5.8	0	76	32		77	96
V5 35W4	TYPICAL	0	0	75V AC	118V AC	98V AC	98V AC	+104V DC
	YOURS	0	0	78	108.5	102	103	106

Fig. 23. Voltage values for the 7YY receiver. Record the voltages you measure below the typical values.

PIN	V1-12BE6		V2-12BA6		V3-12AT6		V4-50C5		V5-35W4	
TVOM GROUND TO B−										
1	22K	22K	2.7M	4M	10M	10M	150Ω	120	0Ω	0
2	1.2Ω	1.0	0Ω		0Ω		470K	460K	0Ω	0
3	19Ω	30	28Ω	45	0Ω		82Ω	112	80Ω	130
4	31Ω	50	39Ω	60	16Ω	20	35Ω	50	120Ω	200
5	—		—		0Ω		470K	500K	110Ω	180
6	—		—		500K	430K	—		110Ω	180
7	5M	6M	150Ω	110	—		—		—	
TVOM GROUND TO B+										
5	1K	1K	1K	1K	—		—		—	
6	1K	1K	1K	1K	—		1K		—	
7	—		—		220K	200K	400Ω	300	—	

Fig. 24. Resistance values for the 7YY receiver. Record your values beside the typical ones.

Typical voltage values for the 7YY receiver are given in Fig. 23 and typical resistance values are given in Fig. 24. Make your own measurements and record them regardless of whether your set is working properly or not.

Remember that for voltage measurements, the set must be plugged into the power line. Since this is an ac-dc set, connect the meter ground clip to pin 1 of the 35W4, which is at B−. Do not connect it to the chassis. Tune the receiver to the high-frequency end of the dial at a point where no station is coming in when you take the voltage measurements.

When taking resistance readings, be sure that the receiver is disconnected from the power line. Notice that for some resistance measurements the ground clip is to be connected to B−, and for some it is to be connected to B+. Use pin 7 of the 35W4 as the B+ connection. Measure your resistances, and record them in Fig. 24 so you will have them for future use. If you were servicing a receiver, you would not write down your results, but would compare each measurement with the manufacturer's listed reading as you made it.

The charts in Figs. 23 and 24 show where to place the probe for each measurement, and the typical value indicates which range to use. Note that some of the voltages measured are negative, some positive, and some ac. In the resistance measurements, an infinity reading means that the resistance is too high to be measured. The reading from B− to pin 7 of V5 depends upon the condition of C11A and C11B, and how long the test leads are attached to the circuit.

In your service work, you may notice some unusual effects when taking resistance measurements in a radio or TV set. As you have learned, resistance measurements are always made with the receiver disconnected from the power line. Sometimes, if a resistance measurement is made immediately after the equipment being tested is unplugged from the line, the cathodes of the tubes will still be hot and will still be emitting electrons. This will affect the ohmmeter readings and will cause completely erroneous results. You can easily demonstrate this.

With the receiver operating, connect the ground clip of your tvom to B−, and set up the tvom for ohmmeter measurements. Remove the plug from the wall outlet, and quickly touch the probe to mixer grid pin 7 of the 12BE6 tube. Again notice that the reading is very low. Leave the probe connected and watch the meter pointer. The pointer will gradually rise until you measure approximately 5 megohms. The reason for these peculiar results is that the cathode of the 12BE6 tube was still hot and was continuing to emit electrons. When the tvom is used as an ohmmeter, the probe is positive, and connecting it to the mixer grid made the mixer grid positive, and electrons flowed from the cathode to the mixer grid and through your tester.

If you had reversed the meter connections, placing the ground clip on pin 7, and the probe on B−, you could have measured the true circuit resistance before the tube cooled off. It is not necessary to do this, however, because tubes will cool rather quickly. In servicing radio or TV receivers, be on the lookout for the ohmmeter actions that you have just demonstrated so that you will not be confused by them.

ANALYZING THE RECEIVER

The i-f transformers between the 12BA6, 12BE6, and 12AT6 tubes, and the oscillator circuit used with the 12BE6 tube, identify this set as a superheterodyne.

The Power Supply. The diagram shows that this is an ac-dc receiver. We know this because there is no power transformer. Since there is a half-wave rectifier connected to the power line, a B supply voltage could be obtained from either an ac or a dc power line. On dc, the plug must be inserted so that a positive voltage is applied to the plate of the rectifier. The tube filaments in series across the power line can also be supplied from either an ac or a dc source.

In the filament circuit, the sum of the filament voltages required by the various tubes is 12 volts + 12 volts + 12 volts + 50 volts + 35 volts, or 121 volts. Since the average power line will furnish between 112 and 120 volts, each tube will receive approximately its rated filament voltage. Even a large variation in line voltage will have little effect on cathode heating, since the tube filament voltages are not at all critical.

The 35W4 tube functions as a half-wave rectifier. However, the plate of the tube, instead of being connected directly to one side of the power line, is connected to a tap on its own filament. This means that the plate current of the 35W4 flows through the top part of the filament, connected to pins 4 and 6. The resistance of this filament section will protect the B supply in case of a short by limiting the plate current of the tube. Excess current, however, will burn out the filament between pins 4 and 6.

Signal Circuits. Let us follow a signal through the receiver. Radio signals in the air induce a voltage in the ferrite rod antenna, L1. At the resonant frequency (the frequency to which the receiver is tuned), determined by the values of L1 and tuning capacitor C1A, resonance step-up occurs, and a large signal appears across the tuning capacitor C1A. This signal is applied through C2 to the mixer grid, pin 7 of the 12BE6 tube, and through capacitor C4 and the red and black taps on the oscillator coil to the cathode. This signal, acting between the mixer grid and the cathode, modulates the electron stream flowing from the cathode to the plate. At the same time oscillation occurs in the 12BE6, and the oscillator signal at oscillator grid 1 also modulates the plate current electron stream.

The oscillator circuit that is used is standard. It is the same one you have used before. Coil L3 is not actually an inductance, but serves to give capacity coupling between the oscillator grid (pin 1) and L2 which is the oscillator tank coil. An actual capacitor could have been used just as well. The frame of the tuning capacitor is connected to the chassis, and in order to complete the circuit from the black lead of the oscillator coil to the tuning capacitor, we install capacitor C4. This also completes the path in the resonant circuit of L1 and C1A. The fact that the capacitor is common to both resonant circuits is of little importance. If some of the oscillator signal is injected directly into the mixer grid circuit, no harm will result. The two signals are mixed in the tube and the resulting beat signals and the original signals flow through the primary of the first i-f transformer, T1. The primary winding is tuned to the intermediate frequency, which is the difference between the incoming signal and the local oscillator signal. Since the reactance is low at off-resonance frequencies, such signals pass through the transformer primary without inducing an appreciable voltage in the secondary, and are bypassed to B– through C9 and C11B. Ordinarily C11B would be all the bypass required, but it is an electrolytic capacitor, and because of its construction, not effective for bypassing high-frequency signals, particularly when it has been in use for a long time. C9, on the other hand, is an excellent rf bypass, and is ready to take over if C11B (because of an increasing power factor) does not bypass the rf signals.

The secondary of T1 is tuned to resonance at the desired frequency so that when the desired signal is applied to the primary, a corresponding signal is induced in the secondary. It is applied directly to the control grid of the 12BA6, and through C3 and R4 to the cathode of the tube. Remember that a signal must always be applied between the control grid and the cathode. Just tracing the signal to the grid is not enough.

Resistor R4 has a value of only 150 ohms, so very little voltage is developed across it. However, the resistor is not bypassed, and the voltage developed across it will be of such a polarity as to oppose the signal voltage. The resulting degeneration tends to make the stage stable and to prevent oscillation.

The 12BA6 tube amplifies the signal, and the amplified signal appears across the primary of the second i-f transformer, T2. The action of this resonant circuit is to boost the i-f signal and remove all others that may still be present in the plate circuit of the 12BA6. The signal induced in the secondary undergoes further selection, and is applied to diode plate, pin 6, of the 12AT6, and through C5 to the cathode.

When the i-f signal makes the diode plate negative, no current flows through the tube, but when the i-f signal makes the diode plate positive, electrons flow from the cathode to diode plate 6, through R5 and back to the cathode. A voltage drop appears across R5. Since the current flows only when the plate is positive, rectification or detection results, and we have the audio across resistor R5.

The dc component across R5 is used for avc purposes. To get a pure dc voltage, the audio voltage that is also present across the volume control must be filtered out. This is done by means of R3 and C3, and only the dc voltage appears across C3. The dc voltage is applied to the mixer grid of the 12BE6 and the control grid of the 12BA6. If the signal increases, the voltage across R5 also increases, and the gain of the 12BE6 and 12BA6 tubes decreases. On the other hand, if the signal tends to fade, less voltage will appear across R5, and the gain of the 12BE6 and 12BA6 tubes will increase. Any part of the available audio voltage across R5 can be applied to the control grid and cathode of the 12AT6 tube. The part that is applied depends upon the setting of R5, which is the volume control. The connection to the control grid is through C6, and the cathode connection is direct, since the lower end of the volume control is in electrical contact with the cathode.

The 10-megohm resistor R6 is used to bias the control grid of the 12AT6 tube. The tube amplifies the signal applied to its control grid-cathode, and the amplified signal appears across the plate load resistor R7. This signal is applied to the control grid -- pin 2 or pin 5 of the 50C5, and through output filter capacitor C11B and resistor R9 to the cathode of the 50C5. Again amplification occurs, and this time large amounts of power are developed across the primary of output transformer T3. Voltage is induced in the secondary, and the resulting current flow through the voice coil sets the cone in motion, thus reproducing the sound waves which were picked up by the microphone at the broadcasting station.

The bias voltage for the output tube V4 is obtained from the voltage drop across the 150-ohm resistor, R9, in the cathode circuit. The bypass capacitor, C8, in the plate circuit is used to make the plate circuit capacitive so that the tube will not go into oscillation at high frequencies, which may be beyond the audible range. As long as the plate circuit is capacitive, oscillation will not take place.

Notice that capacitor C10 is connected directly across the power line. The purpose of this capacitor is to prevent rf signals from entering the receiver by way of the power line, and causing hum modulation. If there are poorly soldered connections somewhere in the power line, the 60 Hz power line signal could modulate the rf signal, resulting in an annoying hum, Bypassing the signal before it can get into the receiver circuit prevents hum modulation, because then only the signal induced in the loop will be amplified, detected, and reproduced by the loudspeaker.

Although the foregoing description is brief, it should give you an idea of how your receiver works and how the various parts work together. Study the several sections of the receiver carefully to become more familiar with the operation of the receiver.

Performing the Experiment

The ten experiments in this manual are designed to give you practical experience in servicing all types of sets, not just ac-dc sets.

In the first two experiments, you will learn to isolate trouble to one section of the receiver. In the later experiments you will demonstrate symptoms produced by defects you will frequently find, and you will learn the test procedures to follow in finding each defect. You will conduct experiments covering the following major defects:

1. Dead receiver.
2. Hum.
3. Noise.
4. Oscillation.
5. Distortion.
6. Weak reception.
7. Misalignment.

EXPERIMENT 61

Purpose: To show that a meter can be used to indicate the presence or absence of signals in certain stages of the receiver.

Introductory Discussion: When a set is dead, the expert serviceman will need to make only a few tests to find the defective section or stage. There are two basic methods of finding a stage that does not pass a signal. You can tune to a station so that a signal is applied to the input of the dead stage. If the signal is strong enough, you can use the tvom to see if the signal is present at both the input and the output of the stage. In receiver stages where the signal is too weak to be identified with a tvom, the technician must use a more sensitive instrument, such as a signal tracer (described in your regular lessons), or he must use some other method of testing the suspected stage.

In this experiment, we will deal with the first method: identifying the signal with the tvom where possible. We will also point out where it is not possible to use the tvom. The experienced technician will know the limitations of various instruments and will know when it is necessary to turn to other methods of diagnosis. These experiments will give you valuable experience in using test instruments and in carrying out standard troubleshooting procedures. Refer to the schematic diagram in Fig. 22 as you carry out the various tests so that you will become more familiar with the receiver and get more experience in reading diagrams of this type.

Experimental Procedure: To conduct the steps in this experiment, you need only the receiver in operating condition and the tvom.

Step 1: To show how the tvom can be used to localize a defect causing a dead set to one section of the receiver.

As you know, there are two signal-handling sections in a radio receiver -- the rf and the af sections. The dividing point is the output of the second detector, which is considered a part of the rf section.

Tune in a strong local station, and short the loudspeaker voice coil to kill reception by soldering a short piece of bare hookup wire across the voice coil terminals. Now turn the volume control all the way clockwise. If you hear any of the program, it will be extremely weak.

Now connect the ground clip of the tvom to B- and set the Function switch for -dc voltage. Touch the probe to terminal P3 of the volume control. You should measure a small voltage. Adjust the tuning knob throughout its range. Notice that the voltage drops as you tune away from the station, and that it reappears as you tune past other stations. The presence of this voltage proves that a signal is reaching the second detector, so you know the rf section is working normally. The fact that the rf section works is also proof that the power supply is all right.

Step 2: To trace the signal through the af system with the tvom.

First tune to a point on the dial where a large diode load voltage, measured across the volume control as in Step 1, is produced. Now switch the tvom for ac voltage measurements, and leave the ground clip on B-. Touch the probe to terminal P3 of the diode load resistor (the volume control).

There will be a very small voltage, which can be identified as an audio signal, by noting that it disappears when you tune away from the station. Also, notice that the meter pointer fluctuates. Tune the signal back, and touch the probe to the control grid, pin 1 of the 12AT6 tube. You should measure as much signal here as at the diode load. Lack of signal would indicate an open in coupling capacitor C6.

Move the probe to plate socket pin 7 of the 12AT6 tube; reset the Range switch if the meter pointer goes off scale. You should measure an increased voltage. If the voltage is not larger here than it was on the grid, or if there is no voltage at all on the plate, you know that there is a defect somewhere in the 12AT6 tube circuit. Move the probe to the grid of the 50C5, pin 2. You should measure as much voltage as at the plate of the 12AT6. Lack of signal voltage at the 50C5 grid would indicate an open in coupling capacitor C7.

To see if the signal is present at the output of the 50C5, touch the probe to plate pin 7. You will have to switch to a higher voltage range, because a large signal voltage is present at this point. Since we have a signal at the plate of the 50C5, but no reception, the defect would have to be in the voice coil-output transformer secondary circuit.

In service work, you will probably never find a defective output transformer secondary or a shorted voice coil. Most defects in this part of the receiver are caused by open voice coils. Since the voice coil is in parallel with the transformer secondary, it is necessary to disconnect one lead of the transformer secondary to check the secondary and voice coil individually for continuity. If there is no continuity, there is an open in the part under test.

Let us see why it is necessary to disconnect one of the leads. Turn off the receiver, and remove the piece of wire you soldered across the voice coil terminals. Then, set up your tvom for ohmmeter measurements, using the lowest range. Connect the test leads across the voice coil terminals. You will measure about 0.4 ohm. Now disconnect one of the transformer secondary leads from the voice coil, and check directly across the secondary winding. Move the transformer lead back to the voice coil connection, and you will see that there is no appreciable change in resistance reading with the voice coil in or out of the circuit. These readings are definite proof that to check a voice coil for an open, you must disconnect one of its leads so it can be checked by itself.

Step 3: To show that the tvom is not satisfactory for tracing signals in the rf section.

Resolder the transformer lead to the voice coil terminal, tune in a strong station, and turn the volume control down.

Clip the ground lead of the tvom to B– and set the tvom for ac voltage measurements. Measure the i-f signal at plate pin 6 of the 12AT6 tube. Identify this as an i-f signal by tuning back and forth across the station frequency, noting that the signal voltage is at a maximum when you tune in the station. Now move the probe to the plate, pin 5, of the 12BA6. You should get a little more signal here than at the 12AT6 diode plate. The transformer coupling between the stages, of course, is the reason that the signal is reduced. If the signal is present at the 12BA6 plate, but not at pin 6 of the 12AT6, you would look for trouble in the second i-f transformer.

Now move the probe to the control grid of the 12BA6, pin 1. The signal at this point will be too weak to give a usable indication on the tvom. This means that the tvom is of little value as a signal tracer in the rf section of a receiver. As a matter of interest, however, touch the probe to plate pin 5 of the 12BE6. Since you measured practically no i-f signal voltage at the 12BA6 control grid, you wouldn't expect to measure an i-f signal at the 12BE6 plate. However, you will find a readable rf voltage at the 12BE6 output. This is not an i-f signal, but consists mainly of the oscillator signal, which is present in the mixer plate circuit. Its absence at the 12BA6 control grid shows the effectiveness of the i-f transformer in rejecting undesired signals.

Discussion: The fact that you can trace signals fairly well in the af section of a receiver does not mean that you should use this method to the exclusion of all others. Use it when you start doing service work, along with other test procedures. Then, you will be able to decide whether you like it well enough to use it every time you service a dead set, or whether to use it only on those occasions where other methods leave you in doubt as to the results.

As a matter of fact, an expert technician seldom uses one test procedure exclusively. He knows many test methods, and uses the one that he thinks from experience will best solve the particular problem at hand.

In this experiment, you did not get much output when you measured the i-f signal voltages because the capacity of the tvom probe detuned the circuit. If you were to tune the receiver first for maximum signal strength, then connect the probe, and reset the tuning slug of the i-f section in question, you would measure a larger signal. However, when you removed the probe, you would have to readjust the tuning slug for maximum output. If the set is dead to start with, adjusting the tuning slug might cause trouble. We do not suggest that you attempt it on your receiver, because if you get the i-f badly misaligned, you may have trouble in realigning it.

Instructions for Statement 61: In this experiment you saw that it was necessary to unsolder the output transformer secondary lead from the voice coil terminal to see if the voice coil was open. You did not measure the dc resistance of the voice coil, but from the effect you noted in checking the resistance of the transformer secondary with the voice coil in and out of the circuit, you should be able to complete the statement. If you are not sure, check the voice coil resistance with your ohmmeter. Then, answer the statement here and on the Report Sheet. Resolder the output transformer lead to the voice coil terminal before going on to the next experiment.

Statement No. 61: The resistance of the voice coil is:

(1) more than
(2) less than
(3) the same as

that of the output transformer secondary.

EXPERIMENT 62

Purpose: To show how to use a circuit disturbance test to find the defective stage.

Introductory Discussion: A signal-injection test is based on the fact that if a signal injected into a certain stage produces a noise in the loudspeaker, you know that all stages between the point where the signal is injected and the loudspeaker must be in operating condition. There are several ways to carry out the test. You can start from the input of the receiver and work toward the loudspeaker, or you can start from the power output stage and work toward the input. In either case, the stage preceding the live point nearest the input is defective. A live point is one where an injected signal produces a sound in the loudspeaker.

When we speak of injecting a signal, we usually think of feeding an audio signal into the af section, and a modulated rf signal into the rf section. To inject such signals would require an af-rf signal generator. These are in common use and are found in most service shops. However, the experienced technician seldom uses them for signal injection when checking a dead receiver, because there is a faster, simpler way to do the job. This is the circuit-disturbance test, which requires only a screwdriver or no tool at all. Your body picks up some 60 Hz ac from the house wiring, so if you touch the input of a high gain audio amplifier with your finger, a 60 Hz signal will be heard in the loudspeaker.

Similarly, if you touch the input of an rf or i-f stage, there will be a slight change in the tube plate current. If there are tuned circuits, they will be shock-excited, and a signal voltage at the resonant frequency will be produced for a few cycles. The strength of this signal will fall off rapidly. This change in amplitude is a modulation on the signal, which can be detected and passed through the audio amplifier to the loudspeaker, where it produces a thud or click. By disturbing the circuit in this way, you can quickly localize trouble to a stage in the receiver, and then use your tvom to locate the defective part.

In this experiment, you will practice circuit disturbance testing.

Experimental Procedure: The only parts that you will require are your receiver in operating condition, your tvom, and your hand tools.

Step 1: To show that a sudden change in current through the output transformer primary will produce a click in the loudspeaker.

Unplug the receiver from the power line, and set up your tvom for low-range ohmmeter measurements. Clip the tvom ground lead to the screen, pin 6, of the 50C5 tube. Tap the probe against plate pin 7. This will cause a slight current to flow through the primary of the output transformer, and you will get a click from the loudspeaker each time the circuit is opened and closed. Use the lowest range of your ohmmeter when doing this, because on the higher ranges, the current flow will be limited, and you may not hear the click.

This shows that only a slight change in current through the transformer primary is necessary to produce a click in the loudspeaker. This procedure can be used to check output transformers and voice coils of pm loudspeakers. Now remove the ground clip from pin 6 of the 50C5 tube socket.

Step 2: To show that a change in the plate current of the output tube will produce a click in the loudspeaker.

Plug in the set, turn it on, and let it warm up. Have the volume control turned down all the way so radio programs will not interfere with the test.

Use a screwdriver that has a long thin blade, and hold it so that your hand is in contact with the metal blade. If you hold the screwdriver by its insulated handle, you may not get a click from the loudspeaker when you carry out the tests. Scrape the end of the blade across pin 2 of the 50C5 or on the lead of resistor R8 that is connected to pin 2. You will hear a noise in the loudspeaker. If you cannot definitely hear a noise or click, momentarily short pins 1 and 2 of the 50C5 together with the screwdriver blade. This will remove the bias from the 50C5, and the speaker will produce a loud click.

Move the blade of the screwdriver to plate pin 7 of the 12AT6 tube. You should again hear a click when the blade touches the plate terminal, if coupling capacitor C7 is in good condition. Do not touch the chassis or the other parts of the receiver when the blade touches the 12AT6 plate, or you will be shocked. However, be sure you have your hand in contact with the blade when you touch the tube socket pin.

Make sure that the 12AT6 is working by touching its control grid, pin 1, or any lead from pin 1. If your hand is in contact with the screwdriver blade, you will hear a hum from the loudspeaker. Hold the screwdriver by its insulated handle, and note that instead of the hum, there is only a click when you touch pin 1. For this test most servicemen use one finger instead of a screwdriver. Try this, being sure to touch only pin 1. Incidentally, this is the first check to make on a dead receiver. If you hear a signal from this point, you know that the audio system is operating, and that the trouble is between the second detector and the antenna. If you do not hear a click or hum, you know the trouble is in the audio system or power supply, and you can proceed accordingly.

Now, short the oscillator tuned circuit to kill reception, and turn the volume control completely on. You can short the tuned circuit by putting a screwdriver blade between terminal C5 of the tuning capacitor and the chassis. Arrange the screwdriver so that it will be self-supporting. Touch terminal P3 of the volume control with your finger. A hum indicates that everything from this point to the loudspeaker is working. If you get a hum at the 12AT6 grid, but not at terminal P3, sometimes called the "hot" terminal, of the volume control, coupling capacitor C6 might be open. Technicians usually touch this volume control terminal rather than the grid of the first audio tube because the volume control is easier to find.

Step 3: To show the effectiveness of a circuit disturbance test in localizing a defect.

Unplug the receiver and disconnect the B+ end of the 12AT6 plate load resistor R7 from the circuit. This removes plate voltage from the 12AT6 tube. Plug in the receiver and touch pin 2 of the 50C5, and then pin 7 of the 12AT6. Each of these will produce a click. Next, touch pin 1 of the 12AT6 tube. You will hear nothing, showing that the trouble lies between this point and the plate of the 12AT6 tube. It could be due to lack of plate voltage, as happens to be the case, or to a control-grid-to-cathode short in the tube. It could also be due to loss of emission in the tube. A few checks with your tvom and trying a new tube would enable you to make a quick repair.

Step 4: To show how the input of the rf and i-f stages can be disturbed to produce a click in the loudspeaker.

With the receiver unplugged, resolder the B+ end of R7 to the proper point in the circuit, but leave the screwdriver shorting out the oscillator section of the tuning capacitor in place. Plug in the receiver and turn the volume control on completely. Hold another screwdriver blade or your longnose pliers in your hand, and touch the free end to control grid pin 1 of the 12BA6 tube. You will hear a click in the loudspeaker. Now touch the mixer grid, pin 7 of the 12BE6; you will again hear a click.

Step 5: To show that the circuit-disturbance test is effective in isolating trouble to an rf stage.

Unplug the receiver and unsolder cathode bias resistor R4 in the i-f amplifier stage from pin 7. Remove the screwdriver that is shorting the oscillator tank circuit, turn up the volume control all the way, and try tuning in a station. The set should be dead.

You can tell that the af system is working by touching the hot terminal of the volume control with your finger. Now touch the diode plate, pin 6, of the 12AT6 tube. You should get the same amount of hum, showing that the secondary of the i-f transformer is not open.

Now, touch the plate of the 12BA6, pin 5, with the screwdriver blade. Since your hand is touching the blade, be sure your body is not grounded and does not touch any part of the receiver. You should hear a click in the loudspeaker when you touch the plate, showing that signals are capable of passing from this point, through the second detector-audio amplifier, and to the loudspeaker.

Now touch the control grid, pin 1 of the 12BA6 tube. Compare what you hear (which will probably be a very faint click if anything at all) with the click you heard when R4 was in the circuit. The faint click that you may have heard was due to the disturbance signal feeding back through the avc and power supply line to the audio section. The signal, however, did not go through the 12BA6 tube.

Thus, to locate the defect, you would check the tube, the operating voltages, and the component parts in the i-f amplifier stage.

Resolder resistor R4 back to pin 7 before going on to the next step.

Step 6: To show that touching the oscillator grid will also result in a loudspeaker noise.

Tune to a point on the dial where a station is not received, and touch the oscillator grid, pin 1 of the 12BE6, with your finger or the screwdriver blade. Note the noise produced from the loudspeaker.

Discussion: The circuit disturbance test is very useful in working on a dead receiver, or on a set that is so weak it is practically dead. Sometimes, because of interaction between stages, the circuit disturbance test is not effective. You probably noticed this when you touched the grid of the i-f amplifier stage in Step 5. However, there are other techniques that can be used, which you will learn later.

In making the circuit disturbance test, bear in mind that in some places, especially in the rf and i-f stages, touching the grid of a tube with an insulated screwdriver will produce a click. In the first audio stages, your hand should be in contact with the screwdriver blade. In still others, where the gain is low between the point of disturbance and the loudspeaker, you may have to make a radical change in plate current. You did this when you shorted the control grid of the 50C5 to the cathode. Removing all bias in this manner causes a very large change in plate current with a resulting loud click from the speaker. As long as you do not leave the short in the circuit for any length of time, there is no chance of damaging good parts as a result of the short.

Instructions for Statement 62: Although the circuit disturbance test is very useful, it may not always tell you what you want to know. Here you will compare its effectiveness to the effectiveness of measuring the dc bias voltage of the oscillator in deciding if an oscillator is operating.

First, tune to a point where a station is not received, and turn the volume control up completely. Touch the oscillator grid, pin 1 of the 12BE6, with your finger or a screwdriver blade. Now measure the dc voltage between pin 1 and B−.

Next, short the oscillator tank with your screwdriver as you did previously. Recheck the dc voltage on pin 1, comparing it with that obtained when the oscillator was working. With the tank still shorted, touch pin 1 with your finger, and compare the loudspeaker noise to that heard when the oscillator was working. You now have sufficient data to complete the statement.

Statement No. 62: If the oscillator is suspected of being dead, a circuit disturbance test:

(1) is a satisfactory
(2) is not a satisfactory

method of determining if the oscillator is working.

EXPERIMENT 63

Purpose: To show the effects of some common filament defects.

Introductory Discussion: In servicing an ac-dc receiver, you may find any one of three filament circuit defects. These are:

1. No tubes light.
2. Tubes light intermittently.
3. Some tubes light -- others are dark.

This experiment illustrates still another filament circuit defect. Before going on, however, let us discuss the three defects listed above.

In a normally operating ac-dc receiver, the tube filaments are in series, and the same current flows throughout the entire filament circuit. You would expect an open anywhere in the circuit to prevent all of the tube filaments from lighting. This is why many technicians are puzzled when they find an ac-dc set where some of the tubes light and some do not. At first it would appear that if any of the tubes light, they should all light; and that if one does not light, none should light. However, both types of defects can occur in the filament circuit of an ac-dc set.

Experimental Procedure: For the following steps you will need:

2 120 ohm resistors
tvom
receiver

Step 1: To check filament circuit continuity with the ohmmeter.

When you have an ac-dc set where none of the tubes light, you know that either the wall outlet is not delivering power or that there is an open in the series filament circuit consisting of the power cord, the On-Off switch, and the tube filaments as shown in Fig. 63-1.

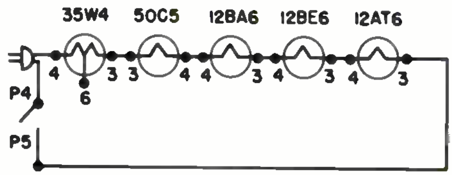

Fig. 63-1. Filament circuit of 7YY receiver.

The power outlet can be quickly checked, either directly or indirectly. A direct check is made either by plugging a piece of apparatus, such as a floor lamp, into the wall outlet and seeing if it lights, or by measuring the supply voltage. To check the voltage, you can push a thin-bladed screwdriver into either of the holes in the wall outlet and connect the ground clip of your tvom to the screwdriver blade. Push the probe into the other wall outlet hole, and measure the available voltage.

An indirect check of the outlet can be made by removing the receiver power plug from the wall outlet and connecting the ohmmeter across the prongs of the plug. Turn on the switch, and if you find continuity, you know that the filament circuit is not open. Therefore, the defect must be in the wall outlet. If you do not find continuity, you know the defect is in the receiver.

To see how to localize an open in the filament circuit, simulate an open by turning off the On-Off switch. Remove the power cord from the wall outlet, clip the ground lead to one prong of the plug, and touch the probe, using the R X 10 range, to pin 4 of the 35W4 tube. If you measure zero resistance, that side of the line cord is not open. If you get an open circuit reading, switch the ground clip to the other prong and repeat the measurement. If you get zero resistance, that side of the line cord is not open.

Now, leave the ground clip attached to the prong of the power cord where you measured zero resistance, and move the probe to pin 3 of the 35W4 tube. You will get a reading on the ohmmeter, indicating that there is continuity, and that the tube filament is not open. Now move the probe right around the circuit to pin 3 of the 50C5, 4 of the 50C5, 4 of the 12BA6, 3 of the 12BA6, 4 of the 12BE6, 3 of the 12BE6, 4 of the 12AT6, 3 of the 12AT6, terminal P5 of the On-Off switch, and finally to terminal P4 on the On-Off switch.

In each case, if you get a reading, you know there is continuity from the line plug to that point. You should get a reading each time, until you touch the probe to terminal P4 of the On-Off switch. This indicates that the tube filaments are not open, and you would suspect that the switch is defective. When checking continuity in this manner, remember that if you get a reading at one point but no reading at the next test point, you have located the circuit defect.

Instead of making point-to-point continuity measurements, you could remove the tubes and check their filaments individually with your ohmmeter. Try this on the 35W4 tube. Connect the clip of your tvom to pin 4, and touch the probe first to pin 6 and then to pin 3. In each case you should get a resistance reading.

This is the method to use if the receiver is in the cabinet so that you cannot get at the bottom of the tube sockets. Each tube should be checked individually. If all the tubes have continuity, then you know there is probably an open in the power cord or a defective On-Off switch. An open in the power cord is usually right at the power plug, and you can cut off the old plug and install another. Do not repair the power cord until you have checked the switch. You will have to remove the receiver from the cabinet to check it. These switches, however, seldom become defective.

Step 2: To check filament circuit continuity using ac voltage measurements.

You can check the filament circuit with your voltmeter instead of with the ohmmeter. The test procedure is almost the same.

To see how to do this, plug your receiver into the wall outlet, and remove the 12BE6 tube to simulate an open in its filament, and turn the set on. None of the tubes will light, since the filament circuit is open. Now connect the ground clip of your tvom to the power line side of the On-Off switch, terminal P4.

Set your tvom so that it will measure the full ac line voltage. Touch the probe to each of the filament pins of the tubes, working from the 12AT6 back toward the 35W4, as shown in Fig. 63-1. You will not get a reading when you touch pins 3 and 4 of the 12AT6 and pin 3 of the 12BE6 tube socket. When you touch pin 4 of the 12BE6 socket, you will measure the full line voltage. Since the circuit is open, normal current is not flowing through the tube filaments, and there is no voltage drop across them.

Reinsert the 12BE6 tube, and pull out the 50C5. Note that you do not get a reading as you work from the 12AT6 tube socket, until you again measure full line voltage when you touch pin 3 of the 50C5.

Turn the set off temporarily, and connect the ground clip of the tvom to pin 4 of the 50C5. Turn the set on, and touch the probe to pin 3. You will measure full line voltage just as you did when the clip was connected to the line. Now reinsert the 50C5 tube, and again touch the probe to pin 3. Note that in this case you measure approximately 50 volts, the normal filament voltage of the tube.

When you are looking for an open in the filament string, always remember to have the Range Selector switch set so that the tvom will measure full line voltage. If you have the Range switch set so that you can measure normal filament voltage, the meter will be overloaded when it is connected across the defective tube filament. Since this is a tvom the meter will not be damaged, but you should always get in the habit of using a range which will not cause the meter pointer to go off-scale.

Step 3: To show the effects of heater-cathode shorts.

To introduce a defect in which some tubes light and others are dark, temporarily connect a lead from pin 4 to the center post of the 12AT6 tube socket. This represents what would happen if a cathode-to-heater short developed in the 12AT6 tube.

Turn the receiver so that you can see the tubes, plug the power cord into the ac wall outlet, and turn the set on. All of the tube filaments will light except the 12AT6. This tube is dark. Remove the short between pin 4 and the center post of the 12AT6 socket.

You do not have to use test instruments when you find a condition of this type. Simply examine the schematic and consider what would happen if the cathode of any of the tubes shorted to its filament. The filament circuit beyond that point would be shorted out. In your 7YY receiver, if the short is in the 12AT6 tube, only that tube would not light, as you have just demonstrated. If you found that both the 12BE6 and the 12AT6 tubes were dark, you would suspect a cathode-to-heater short in the 12BE6 tube.

Step 4: To show the effects of a heater-cathode short in the audio output stage.

Take the two 120-ohm resistors and lay them side by side. Twist the adjacent leads together a turn or two to connect the two resistors in parallel. We will refer to the parallel 120-ohm resistors later as a 60 ohm resistor. Clip off one of the leads from each end of the resistor combination.

With the set unplugged, solder one end of the 60-ohm resistor to pin 1 of the 50C5. Solder the other lead to pin 4 of the same tube. Before you plug in the receiver, examine Fig. 63-1 and try to determine the results of your sabotage. Will all the filaments light? Will the set be dead? Plug the receiver in and observe its behavior. Check to see if all filaments light. Try to tune in a station. Turn off the receiver and remove the 60-ohm resistor from between pins 1 and 4.

Discussion: We have not attempted to show the effect of the third filament defect -- an intermittently open filament. The filament of a tube may become brittle with age and crack. When it is heated, the filament will expand, and the circuit will open. When the circuit opens, all of the tube filaments will go out. As the defective filament cools, it will contract, and the broken ends of the filaments will come back together, thus re-establishing current flow through the circuit. The time intervals between light and no light from the filaments are generally equal.

This defect cannot be located with an ohmmeter because when the tube filament is cold, there is continuity. Usually you cannot locate an intermittent open of this type with a tube tester. Very often the cathode will remain hot after the filament has opened, and will continue to emit electrons until the filaments have cooled sufficiently to come together again.

Trouble of this type, however, can be located with an ac voltmeter. You would use the same procedure given previously, by leaving the voltmeter connected in each test position long enough for the filament to open. If the voltage reading drops to zero, you know that the tube you are measuring across is not defective. However, if the voltage rises to the full line voltage, you have located the defective tube.

You can either make your measurements from one end of the filament string, or you can connect the meter directly across the filament of each tube, one at a time. Regardless of which method you use, the Range Selector switch of the meter should be set so that the full line voltage can be measured. Remember this test procedure. You will have occasion to use it in servicing TV sets as well as radios.

In each of the tests you have just conducted, the defect causing the receiver to be dead was indicated by the fact that some or all of the tubes failed to light. There are many other defects causing a set to be dead, which give no visible symptom. When you cannot see the underlying cause of a defect, you must use some servicing method that will quickly lead you to the defective section, stage, and part.

Instructions for Statement 63: In this experiment you have seen the effects of heater-cathode defects in some of the receiver circuits. For this statement you will observe the effects of a heater-cathode short in the i-f amplifier stage.

Solder one lead of the 60-ohm resistor to pin 4 of the 12BA6. Solder the other lead to pin 7 of the same tube. Turn on the receiver and observe the tube filament. Turn the volume control up and observe the results. Turn off the receiver, remove the 60-ohm resistor and answer the statement below and on your Report Sheet.

Statement No. 63: When I simulated a heater-cathode short in the i-f amplifier stage, I found

(1) all filaments
(2) the 12 volt filaments
(3) no filaments

were dark and the 60 Hz hum

(1) was louder
(2) was weaker
(3) did not change

as I advanced the volume control.

EXPERIMENT 64

Purpose: To show the effect of low emission in an amplifier tube and to show methods of quickly locating the defective tube.

Introductory Discussion: When we say that a tube has low emission, we mean that the cathode does not give off as many electrons as normal. We can demonstrate this by reducing the filament current to the point where the cathode is insufficiently heated to emit a normal quantity of electrons. We will do so in this experiment by partially shorting the filament of the 12AT6 with a resistor. This will lower the filament voltage of the 12AT6 from about 12 volts to approximately 4 volts ac. The extra voltage will be divided among the other tube filaments, but the increase of each will be too small to cause excessive filament current.

Shunting the tube filament also illustrates another defect frequently found in receivers. In some cases an internal short develops in a tube filament; and in an ac-dc filament string, the effect is exactly the same as that of an external resistor across a filament.

For this experiment you need your receiver, in first-class working condition, your tvom, and:

1 120-ohm resistor
1 60-ohm resistor

Step 1: To measure the plate voltage and the filament voltage of the 12AT6 tube.

Turn your set on, and when it warms up and is operating, measure the voltage between B- and the plate, pin 7 of the 12AT6 tube, and the filament voltage (B- to pin 4) of the same tube. Record your readings in Fig. 64-1.

CIRCUIT CONDITION	PLATE VOLTAGE	FILAMENT VOLTAGE
NORMAL	5CVDC	12AC
FILAMENT PARTIALLY SHORTED	80VDC	3AC

Fig. 64-1. Record your readings for Exp. 64 here.

Next, feel the envelope of the 12AT6 tube so you can judge its temperature. Do not grasp the tube too tightly or you may burn your fingers. Now turn the set off and let it stand for five or ten minutes while the tubes cool.

Step 2: To measure the plate and filament voltages with the filament partially shorted.

Connect a 120-ohm resistor in parallel with the two already connected in parallel and connect the resulting 40-ohm resistor between pins 3 and 4 of the 12AT6 tube socket. Do not connect the third 120-ohm resistor permanently to the resistor combination since you will use it in a later experiment.

Turn the set on, and let it warm up for about five minutes. With the reduced filament voltage, it will take quite some time for sufficient heat to reach the cathode to produce any electron emission. Touch your finger to the grid of the 12AT6 from time to time so you can see how long it takes for the cathode of the tube to warm up.

When touching pin 1 of the 12AT6 tube causes a slight buzz in the speaker, try tuning in stations with the volume control all the way up. If you are near any stations and your line voltage is normal (115 volts or more), you will be able to pick up programs, but they will be quite weak.

Now repeat the plate and filament voltage measurements you made in Step 1. Record your readings in Fig. 64-1. Then, feel the tube envelope; notice how the heat produced compares to that when normal filament voltage is applied.

Discussion: You will frequently get sets for repair that take a long time to warm up. In some cases, the volume will be almost normal when the receiver does warm up. In others, the volume will remain quite weak.

In ac-dc receivers, you should suspect that one of the tubes has a partially shorted filament. A defective electrolytic capacitor will also cause the set to take a long time to warm up. Any tube can have a partially shorted filament, but it is more common in higher voltage tubes, such as rectifiers and power output tubes.

It is a good idea to be careful when you touch any of the tubes in a receiver. You may be badly burned if you grasp a tube firmly without first finding out how hot it is. Therefore, just barely touch the tube. If you find that it is not very hot, then you can grasp it more firmly.

Insufficient heat can be caused by a partially shorted filament, as in this case, or a lack of cathode emission. A partially shorted filament reduces the power dissipation in the filament, which is the greatest heat source in the tube.

You will seldom find this trouble in an ac-operated set. If a partial short does occur, the current through the rest of the filament will rise to the point where the filament will burn out, and the tube filament will be completely open. In ac-dc receivers, partial filament shorts are fairly common.

A partially shorted filament cannot be found with a tube tester, because in a tube tester, normal filament voltage is applied to the filament regardless of its condition. Thus, the tube will test good. However, you can test a tube suspected of having a partially shorted filament by measuring the ac filament voltage or by substituting another tube.

If you find that the filament voltage of a tube in a heater string is lower than normal, you can be pretty certain that the tube has a partially shorted filament, and you should install another tube.

The variations in the dc operating voltages that you recorded in Fig. 64-1 were due to the plate current variations of the tube. When the plate current is extremely low, there is little voltage drop across the plate load resistor. Therefore, the plate voltage has almost the same value as the B supply voltage. When the tube is drawing normal plate current, there is a large drop across the plate load resistor, and the plate voltage is lower. Remember that when there is a high value plate-load resistor in the circuit, excessively high plate voltage indicates lower-than-normal plate current.

Instructions for Statement 64: Remove the 40 ohm resistor from across the filament of the 12AT6 tube, and put it across the filament (pins 3 and 4) of the 12BE6 tube. You will not be able to pick up any stations when you try to tune them in. Check all operating voltages on the 12BE6 tube, and compare your results with those you recorded in Fig. 23. Think about the significance of the dc voltages you measure and complete the statement. Then, remove the resistors from pins 3 and 4 of the 12BE6 tube socket.

Statement No. 64: The receiver is dead when the 12BE6 tube has low emission because:

(1) the plate and screen voltages are too high.

(2) the oscillator is dead.

(3) no rf signal voltage is being applied to the input of the stage.

EXPERIMENT 65

Purpose: To show the effect of leaky bypass capacitors in the B supply circuit;

and how to locate them with an ohmmeter and with a voltmeter.

Introductory Discussion: Leakage in a capacitor results when the dielectric resistance decreases to the point where dc can readily flow through the capacitor. To make a circuit act as though a bypass capacitor in it has become leaky, we can connect a resistor across the capacitor. We can simulate any degree of leakage merely by using resistors of various sizes.

To avoid damaging the rectifier tube, we will limit the leakage in each case to 3000 ohms. In an actually defective capacitor, the leakage could be higher or lower but 3000 ohms will show what can be expected and how the capacitor can be located with standard test procedures. We will simulate leakage in the plate bypass capacitor in the output stage, where leakage is frequently found, and in the rf bypass capacitor. The rf bypass capacitor in the plate and screen supply circuit of ac-dc sets does not become leaky as often as the one in the plate circuit of the output stage, but in TV receivers and in ac-operated radio sets where the B+ supply is higher, they often fail.

Experimental Procedure: For this experiment you will need the receiver in good operating condition, your tvom, and:

1 3k-ohm resistor

Step 1: **To show the effect of leakage in the output tube plate bypass capacitor.**

Solder one end of the 3k-ohm resistor to the plate, socket pin 7, of the 50C5 tube, and the other end of the resistor to terminal DB1.

CAUTION: With this resistor in the circuit, do not leave the receiver turned on too long, because abnormally high current will flow through the resistor and overheat it. For short periods of time, long enough to make the necessary measurements, it will be safe to have the set turned on. As soon as you have finished making a measurement or observation, turn the set off.

Turn the receiver on, allow it to heat up, and tune in a station. You may be able to note that the sensitivity is somewhat lower than normal. Turn the set off, and prepare your tvom for positive dc voltage measurements. Set the Range switch in the 120-volt position, and clip the ground lead of the tvom to a B– point. Turn on the receiver, allow it to heat up, and measure the dc voltage on screen pin 6 of the 50C5, and plate pin 7 of the 50C5. Record the values in Fig. 65-1, and turn off the receiver. Now compare these voltages to those you recorded in Fig. 23.

MEASUREMENT FROM B– TO	STEP 1 VOLTAGE	STEP 2 RESISTANCE
CATHODE OF 35W4 (PIN 7)		4K
SCREEN GRID OF 50C5 (PIN 6)	53v	4.5K
PLATE OF 50C5 (PIN 7)	84	3.4K

Fig. 65-1. Record your voltage and resistance measurements here when the plate bypass capacitor is leaky.

Step 2: **To show how leakage in the plate bypass capacitor of the output tube affects the dc resistance measurements.**

Disconnect the set from the power line. Leave the ground lead of the tvom connected to B- Discharge the filter capacitors by shorting the cathode of the rectifier to B- with a screwdriver blade or a piece of hookup wire. Now measure the resistance from B- to the cathode of the 35W4, to the screen of the 50C5, and to the plate of 50C5. Record the values in Fig. 65-1. Compare your readings with the normal readings to B- in Fig. 24.

Disconnect the 3k-ohm resistor from the plate of the 50C5 (pin 7) and from B-.

Step 3: To show the effect on dc operating voltages if the rf bypass capacitor C9 is leaky.

Connect the 3k-ohm resistor from the screen (pin 6) of the 50C5 tube to B-. Turn the set on, let it warm up, and tune in a station. You may be able to notice that the sensitivity is again somewhat lower than normal. Next, perform the voltage measurements indicated in Fig. 65-2. Record the values.

Study these readings, comparing them with the ones for Step 1 and with the normal readings in Fig. 23. See if they will tell you anything about the probable location of the leaky part.

MEASUREMENT FROM B-TO	STEP 3 VOLTAGE	STEP 4 RESISTANCE
CATHODE OF 35W4 (PIN 7)		4,5K
SCREEN GRID OF 50C5 (PIN 6)	73VDC	3,5K
PLATE OF 50C5 PIN 7)	84VDC	4,6K

Fig. 65-2. Readings for Steps 3 and 4.

Step 4: To show the effect of leakage in the rf bypass capacitor on resistance measurements.

Unplug the receiver from the power line, and measure the resistance from the cathode of the 35W4 to B-. If the meter pointer reads off-scale, discharge the electrolytic filter capacitors by shorting the cathode of the 35W4 to B- with a piece of hookup wire.

Now measure the resistance from the screen of the 50C5 to B- and the resistance from the plate of the 50C5 to B-. Record your readings in Fig. 65-2. Study the values carefully, comparing them with those in Step 2, and also with the normal readings in Fig. 24. See if you can deduce from these measurements the probable location of the trouble.

Discussion: When either of the two shorts you introduced was in place, the receiver played with only slightly reduced sensitivity. If either of the capacitors had actually been leaky, the condition would have become progressively worse, and, eventually, the receiver would have gone dead. Perhaps the filament tap on the 35W4 would have opened. However, the method to use in localizing trouble of this kind through measurements is the same, regardless of the degree of leakage.

When looking for a defect of this kind, small variations from the normal voltage values are very important. In Step 1 all the readings should be lower than normal. The important thing to notice is that the reading at the screen of the 50C5 is considerably below normal and that the reading at the plate of the 50C5 changed even more. You will be able to see the variations more clearly if you will subtract the voltage values you recorded in

Fig. 65-1 from those recorded in Fig. 23. Enter them in the margin opposite the values in Fig. 65-1.

Even if it were only 1 or 2 volts, the fact that the plate voltage decreased more than the screen voltage is sufficient to indicate that the short is probably on the plate side of the output transformer primary rather than on the screen side. Then, if you studied the schematic diagram of the set carefully, you would see that leakage in the plate bypass capacitor of the tube would cause these particular readings, and you would disconnect the capacitor to check it. You could check the capacitor with an ohmmeter; or you could simply disconnect it and repeat the voltage measurements. If you measure normal voltages with the capacitor out of the circuit, you know that the capacitor is leaky.

In Step 2 the resistance between the plate of the 50C5 and B- should be the lowest. The resistance from the screen of the 50C5 to B- should be slightly higher, again showing that the leakage is on the plate side of the tube rather than on the screen side.

The fact that the resistance from the cathode of the 35W4 to B- is higher than from the plate of the 50C5 to B- indicates that the short is not on the cathode side of the output transformer but somewhere on the plate side or in a part connected to the plate side. The diagram shows that there is a plate bypass capacitor, so you would check it first.

In Step 3 again all of the voltages decreased, but this time the greatest decrease is in the screen voltage. Again subtract the values in Fig. 65-1 from the normal values in Fig. 23, and enter them in the page margin. The larger screen voltage variation indicates that the excess leakage is somewhere in the B+ line.

By examining the schematic diagram, you can see that the trouble could be due to leakage in C9 or C11B, or that there could be a partial short in one of the tubes or from any terminal in this circuit to B-. The voltage measurements show the approximate location of the trouble, but do not point to any particular part. You will have to check the parts you suspect are causing the trouble until you locate the defect.

When looking for a defect of this type, do not go through the receiver and check and replace parts indiscriminately. After you have located the defective stage or circuit, refer to the schematic diagram and determine what part would cause that type of defect. This is the procedure used by all successful radio-TV technicians.

In Step 4, the resistance measurements show that the lowest resistance is from the screen of the 50C5 to B-. This indicates that the trouble would not be in plate bypass C8 or in the input filter capacitor. It is somewhere in the regular B+ line.

Both the voltage and resistance measurements point to the defective circuit, but do not show which part in the circuit is defective.

Looking at the diagram, you would see that leakage in either C9 or C11B could cause the trouble, so you would disconnect the capacitors one at a time, and check them either by measuring the circuit voltage without the capacitor or by making resistance measurements on the capacitor itself. In most cases you would quickly find the defective part.

Instructions for Statement 65: In some receivers, you will find a small rf plate bypass capacitor between the plate and the cathode of the first audio amplifier stage. The capacitor is not needed in the plate circuit of the 12AT6 tube in this receiver because the circuit consisting of C5 and R5 acts as an i-f filter. These components prevent practically all the i-f signal from reaching the control grid of the 12AT6 tube.

For this statement, let us suppose that the 12AT6 uses such a capacitor, and that it has developed a leakage path with a resistance of 3000 ohms. To simulate this, connect your 3k-ohm resistor between pin 7 of the 12AT6 tube and terminal DB1.

For the statement of this experiment, you are to determine which of the three troubleshooting methods--voltage measurements, resistance measurements, or circuit disturbance tests -- is the quickest and easiest method to use in localizing the defect to a particular section of the receiver.

Turn the set on, allow it to warm up, and try to tune in a station. You will find that the receiver is dead. Measure the B- to cathode voltage of the rectifier, the B- to screen voltage of the output tube and the B- to plate voltage of the output tube. Then, measure the B- to plate voltage of the 12AT6 tube. Compare the values with those you recorded in Fig. 23.

Turn the set off, and measure the resistance from B- to cathode, of the 35W4, B- to screen to the 50C5, B- to plate of the 50C5, and B- to plate of the 12AT6 tube. Compare these measurements with the normal measurements in Fig. 24.

Finally, turn on the receiver, and momentarily short the grid and cathode pins 1 and 2 of the 50C5 tube with a screwdriver. Next, momentarily touch the plate of the 12AT6 tube with the screwdriver, and notice whether there is a buzz or click from the loudspeaker. Then, touch the grid, pin 1, of the 12AT6 and again listen for the buzz or click.

Consider the symptoms you would be called upon to repair, and decide which method is the quickest and easiest to use in localizing the defect. Then answer the statement. Remove the 3k-ohm resistor.

Statement No. 65: With a leaky plate bypass capacitor in the 12AT6 circuit, I found that the quickest way to localize the trouble to this stage was by:

(1) voltage measurements.
(2) resistance measurements.
(3) a circuit-disturbance test.

EXPERIMENT 66

Purpose: To demonstrate typical causes of hum in a receiver; and to show how the hum can be localized to one section and to one stage of the receiver.

Introductory Discussion: When a technician finds hum in a set, he usually looks for its cause in the power supply, because the filter system in the power supply is supposed to remove hum (ripple) and deliver pure dc to the tube electrodes. The filter capacitors are the most frequently defective.

In this experiment you will learn about filter capacitor defects, and about other causes of hum. Some of these are not common, but finding them can be very time-consuming. You will learn how to localize hum to one section and to one stage.

Experimental Procedure: To carry out this experiment, you need your receiver, your tvom, and the following parts:

1 20-μf, 150-volt capacitor
1 3k-ohm resistor
1 220-ohm resistor
1 0.25 μf or 0.27 μf capacitor

Step 1: To demonstrate the effects of high power factor in the input filter capacitor.

Turn the volume control down to the no-sound level. Then, use your ac voltmeter to measure the ac ripple voltage between B- and each of the following points: the 35W4 cathode, the 50C5 screen grid, and the 50C5 plate. Record the readings in Fig. 66-1.

To simulate a high power factor in the input filter capacitor, unplug the receiver and unsolder the lead of the electrolytic capacitor going to terminal DB2. Connect the 3k-ohm resistor in series with this lead and terminal DB2.

Turn on the set, and allow it to warm up. Note that there is a hum coming from the loudspeaker.

Now, measure the ac ripple voltage at the cathode of the rectifier and at the plate and screen grid of the output tube, and record the readings in Fig. 66-1. Compare these with the normal readings.

Try tuning in various stations to judge the performance of the set. You will find the performance is somewhat different from normal. Now check the defective capacitor just as a technician would by shunting the 20 μf, 150-volt electrolytic from the 35W4 cathode to B-. When installing an electrolytic in a circuit, you must observe its polarity markings. If you connect the capacitor with the wrong polarity, it will be ruined. Use the same polarity as for the original capacitor.

Solder the negative lead of the test capacitor to B-. Now, with the set on and a station tuned in, touch the positive lead of the test capacitor to terminal DB2. The hum should drop to almost its normal level at the same time the volume comes up. You may not be able to detect the increase in volume since the hum effectively masks the change in volume, so you will use your tvom to measure it. Set the tvom to measure ac volts on the 120-volt range. Tune to a station that is broadcasting speech and measure the ac voltage from pin 7 of the 50C5 to B-. Adjust the volume so that the average speech level will produce a variation of about two divisions (4 volts) on the meter scale. With the tvom still connected to

AC RIPPLE FROM B- TO	NORMAL	HIGH POWER FACTOR IN C11A	HIGH POWER FACTOR IN C11B	SHORT BETWEEN + LEADS OF FILTER CAPACITORS
CATHODE OF 35W4	5	34	4.7	3.2
SCREEN GRID OF 50C5	.35	2.6	2.8	3.3
PLATE OF 50C5	3	25	7.4	6.7

Fig. 66-1. Record your readings for Exp. 66 here.

the plate of the 50C5, touch the positive lead of the test capacitor to terminal DB2. Now note the average variations indicated on your tvom. Even though they are at a lower average level, the variations should be considerably larger than before, indicating an increase in volume.

Next, check the dc voltage at pin 7 of the 35W4 with and without the test capacitor in place. Note the radical drop in dc voltage caused by an input filter capacitor that is open or has developed a high power factor. (The two troubles are practically the same as far as a serviceman is concerned because they give similar results.) From this we can conclude that a high power factor in the input filter capacitor causes weak reception as well as hum. In a set using a filter choke rather than a filter resistor, less hum will be heard and at the same time there will be a smaller drop in dc supply voltage. Thus, the complaint would probably still be weak reception as well as hum.

Step 2: To show the effect of a high power factor in the output filter capacitor.

Remove the 3k-ohm resistor from the input filter capacitor circuit and resolder the positive lead of the input capacitor to terminal DB2. Next, unsolder the positive lead of the output filter capacitor from terminal DB3 and solder one free lead of the 3k-ohm resistor to the capacitor lead you just disconnected. Solder the other end of the 3k-ohm resistor to terminal DB3. The output filter will now act as if it has developed a high power factor or has become open. An open means that the capacitor lead is broken inside the case and does not make contact with the foil used as the plate.

Now turn on the set, and with the volume control adjusted for no sound, listen to the hum from the loudspeaker. You will find that there is a considerable hum present, indicating that an open or high power factor in the output filter capacitor produces considerable hum. If the loudspeaker were in its cabinet, the hum level would be even higher than it is.

Now, measure the ripple voltage at the rectifier cathode, at the screen, and at the plate of the 50C5. Record your readings in Fig. 66-1. Compare these to those you measured for a defective input filter capacitor.

Measure the dc voltage at the rectifier cathode and at the screen and the plate of the 50C5. Compare them with the values you recorded in Fig. 23. You will find that the high power factor in the output filter capacitor has little or no effect on the dc voltages. For this reason you would not expect any great change in volume.

Now with the receiver turned on and the volume turned all the way down, shunt the output filter capacitor with your 20 μf test capacitor. The negative lead of the test capacitor should still be connected to B-. Connect the positive lead to terminal DB3. This connects the test capacitor across the original output filter capacitor and the 3k-ohm resistor. The capacitor must shunt both of them because the 3k-ohm resistor represents the resistance inside the case of a defective capacitor.

Notice how the hum level drops as soon as you connect the test capacitor across the defective part. This is the method used by technicians to test a capacitor for high power factor or an open. Remember, however, that a capacitor must be disconnected from the circuit to test it for leakage.

Step 3: To show the effect of a short between the positive leads of filter capacitors in a common container.

Restore the receiver to its original condition by removing the 3k-ohm resistor from the circuit, and resoldering the positive lead of the output filter capacitor to terminal DB3. Try the set out to make sure it is working normally and that the hum is back to its normal level.

To show what happens when a direct short occurs between the positive leads of the filter capacitors, solder a piece of hookup wire from terminal DB2 to terminal DB3. Turn on the set, and notice the hum. Measure the ripple voltage at the rectifier cathode and at the plate and screen of the 50C5. Record the values in Fig. 66-1. Notice that the ripple voltage at the screen of the 50C5 is the same as that at the cathode of the 35W4. This indicates that there is no voltage drop across the filter resistor.

Now, try to reduce the hum by alternately shunting the input and output capacitors with your test capacitor. Be sure to observe the polarity of the test capacitor. You will find that shunting the test capacitor across either the input or the output capacitor has little effect on the hum level. This is a pretty good indication that there is a short or leakage between the positive leads of the filter capacitors. When you suspect this defect, there is only one thing to do. Completely unsolder the original capacitors from the circuit and install others. If this clears up the trouble, you know there is a short between the positive leads of the original capacitors.

The capacitor sections may not be completely shorted as they are here. To simulate a partial short, remove the piece of hookup wire, and solder one lead of a 220-ohm resistor to terminal DB3. Position the other lead so that it can be pushed into contact with terminal DB2. Turn on the set and move the free lead of the 220-ohm resistor into contact with terminal DB2 using a screwdriver or pencil. Notice the hum level increases with the partial "short" in place.

Remove the 220-ohm resistor. Then, check the receiver to be sure it is working properly before going on with the next step.

Step 4: To illustrate the effects of inter-element leakage, and to show how the stage at which the hum enters can be localized.

Leakage in a tube is not necessarily between the cathode and heater, although this is the most common type of leakage. There may be leakage between a diode plate and the filament. To see the effect of this, connect a 220-ohm resistor between pins 4 and 6 of the 12AT6 tube. This simulates a diode-plate-to-filament short.

Turn on the set, and allow it to warm up. Then advance the volume control. The hum level should increase as the control is advanced.

Since you can use the potentiometer to control the hum level, you know that the hum is originating on the input side of the volume control. With the control turned all the way down, the grid of the 12AT6 is essentially at B– potential as far as signals are concerned. As the control is gradually advanced, hum is fed to the grid of the tube and is amplified by the entire audio amplifier.

Advance the control to a point where you can hear the hum clearly. Then, take your 0.27 μf capacitor and touch one lead to B–, and touch the other to the control grid of the 12AT6. Note that the hum drops to zero, indicating that it was getting into the grid circuit of the tube. Now, touch the free lead of the 0.27 μf capacitor to plate pin 5 of the 12BA6 tube. There will be no change in hum, indicating that the hum is not originating in the 12BA6.

Now touch the free lead of the capacitor to the plate pin 7 of the 12AT6 tube. Again the hum will drop to a low level. These tests are pretty definite proof that the trouble originates in the 12AT6 tube or in its input circuit. You would try a new tube in such a case. Remove the 220-ohm resistor.

Step 5: To show the effect of hum modulation.

Hum modulation is hum that is heard only when an rf carrier is tuned in. To demonstrate this effect, disconnect the antenna lead at terminal C4 of the strip on the rear of the tuning capacitor. Hold the bare end of the free lead in your hand. Turn the receiver on, and allow it to warm up. Advance the volume control to a point where you can tune in stations. You will notice that as each station is tuned in, you will hear hum, and the sound may be distorted. In some cases, the sound may be clear, but it will still be accompanied by hum. If no hum is heard, reverse the power plug connected to the power outlet. This is sometimes due to cathode-to-heater leakage in an rf tube, and is sometimes due to signals picked up through the house wiring and modulated (because of a poor connection in the house wiring) by the 60 Hz current. If these signals get into the receiver, the 60 Hz modulation will be demodulated along with the radio signal, and will be heard in the loudspeaker. It is for this reason that the 0.01 μf bypass capacitor, C10, is included across the power line at the input to the receiver. Any signals attempting to enter by way of the power line are bypassed by this capacitor.

Now resolder the antenna connection to terminal C4 and make sure that the receiver is operating properly.

Discussion: Open loop antennas can cause trouble, and may block reception entirely, making the receiver dead. They may also cause chopped-up or intermittent reception, or may produce a form of hum. If you suspect an open in the loop antenna, check for continuity between the loop terminals. In receivers where the loop is attached to the cabinet, the defect is usually in the connecting leads.

Hum in either ac or ac-dc receivers is generally due to defective electrolytic capacitors, or to cathode-to-heater leakage in one of the tubes. In servicing, therefore, check these possibilities first -- shunt the capacitors one at a time with good ones, and check the tubes in a tube tester or by substitution.

You also demonstrated the effect of leakage between sections of the electrolytic capacitor. This frequently happens through the capacitor case, and very often occurs under the capacitor mounting strap. If you suspect this, push the capacitor so that the part under the strap is exposed. If there are green corroded spots, there is leakage to the strap and the capacitor should be replaced. Sometimes just moving the position of the strap will clear up the trouble, but there is usually enough leakage through the cardboard casing of the capacitor to prevent normal operation.

Instructions for Statement 66: In shunting the electrolytic capacitors with your test capacitor, you probably noticed a large arc between the capacitor lead and the 35W4 cathode as the uncharged capacitor charged. Ordinarily this does not cause trouble, but in some receivers sufficient current may be drawn from the rectifier to burn out the rectifier filament. This is particularly true in some of the older three-way portable receivers.

To avoid the surge of current into the uncharged capacitor, you can precharge the capacitor before connecting it across the input of the filter. To demonstrate this, turn the set on, and let it warm up. The 20 μf capacitor should still be connected to B–. Therefore, short the leads of your test capacitor, and then connect it to the cathode of the rectifier.

Now discharge the test capacitor, and connect it from B– to the screen of the output tube. You will see an arc as the capacitor charges, but the 1k filter resistor limits the charging current to a safe value. Now, without discharging the capacitor, shift its positive lead from the screen of the 50C5 to the cathode of the rectifier and note the arc. You now have sufficient information to answer the statement. Remove the capacitor from the circuit.

Statement No. 66: I found that if the capacitor connected across the input filter has previously been charged, the current flowing into the capacitor when contact is made to the rectifier cathode is:

(1) more than
(2) less than
(3) about the same as

when an uncharged capacitor is used.

EXPERIMENT 67

Purpose: To show common causes of oscillation and how to locate them.

Introductory Discussion: Oscillation can be due to defective parts, to misplaced wiring, or to poorly soldered connections. If a part is defective, the trouble is usually easy to find.

Oscillation is the result of energy being fed back from the output of a stage to its input. This is called single-stage oscillation because only one stage in the receiver is involved. Overall oscillation occurs when the feedback path involves two or more stages. For example, from the plate of the 50C5 to the input of the 12AT6.

Oscillation can occur in either the af section or in the rf section. If turning the volume control down stops the oscillation, look for trouble in the af system. If tuning the receiver affects the oscillation, look for trouble in the rf section.

Oscillation does not always follow a fixed pattern. The defect that causes oscillation in one set may cause only regeneration or have no apparent effect in another. Regeneration is feedback in insufficient quantity to cause the receiver to squeal. Oscillation may result in a squeal, or it may cause motorboating. The position of the leads, the gain of the particular tubes used, and the Q of the tuned circuits determine the exact effects. These cannot always be predicted.

If your particular receiver is exceptionally stable, you may not get the results described. If not, go on to the next step, but remember the description of the effects so you will recognize them when you are doing servicing.

Experimental Procedure: To conduct the following steps, besides the receiver and your tvom, you will need:

1 0.25 μf or 0.27 μf capacitor
1 20 μf, 150-volt capacitor
1 120-ohm resistor
1 100k-ohm resistor
1 3k-ohm resistor

Step 1: To show that an open plate bypass capacitor for the power output tube and misplaced wiring may result in overall oscillation.

First, check your receiver to be sure it is operating normally. Now disconnect C8 from terminal DB1. Tune to a station, and turn the volume control up. If you hear a rushing, high-pitched squeal, the 50C5 has gone into oscillation. However, there may be no effect, especially if the grid and plate leads are well separated and are kept close to the chassis.

To give the effect of misplaced wiring, cut a piece of hookup wire about 9 inches long, and remove some of the insulation from one end of the wire only. Solder this lead to plate socket terminal 7 of the 50C5 tube. Bend the wire around until the insulation is against the grid lead of the 12AT6.

Now turn on the set again, and advance the volume control setting. You should hear a very loud squeal at a certain volume level. This indicates that energy is being fed back from the plate circuit of the 50C5 to the grid circuit of the 12AT6, resulting in overall oscillation. While the receiver is squealing, push the case of C8 so that the lead you disconnected is in good electrical contact with terminal DB1. This should stop or, at least, reduce the oscillation.

When replacing output transformers, be sure to keep the leads short and down close to the chassis. This will prevent radiation from the plate lead which might induce signal voltages in the input of the output tube or in the input of the first audio tube.

Turn the set off, unsolder the piece of hookup wire from the plate of the 50C5, and solder C8 firmly in place. Now try out the receiver to make sure that it is still operating normally.

Step 2: To show that the screen grid shields the plate from the control grid.

In this step you will install an unbypassed resistor in the screen supply of the i-f tube. In most ac-dc receivers the screen connects directly to B+, but in TV sets and in ac-operated receivers there is usually a resistor used to reduce the screen voltage, and a bypass capacitor between the screen and the chassis. If the bypass capacitor opens, oscillation will occur.

To demonstrate this, unsolder the three leads going to pin 6 of the 12BA6. Twist the three bare leads together and connect a 3k-ohm resistor between pin 6 of the 12BA6 tube socket and the junction of the three leads. Position these parts so nothing shorts out. Now turn on the receiver, and try tuning in stations. You will hear squeals as stations are tuned in. A signal voltage is developed across the screen supply resistor, and because of the capacity between the screen grid and the control grid, feedback takes place within the tube.

While the receiver is oscillating, touch one lead of a 0.27 μf capacitor to a B- point, and the other lead directly to the screen of the 12BA6 tube. Note that the oscillation stops. This is the method used by technicians to check suspected capacitors.

Now permit the receiver to oscillate, and bring your hand near the oscillator coil. Note that, as your hand approaches this coil, the pitch of the oscillation changes because you are changing the oscillator frequency by changing the capacity in the oscillator circuit. Exactly the same effect is produced by adjusting the tuning capacitor knob of the set. Many technicians are fooled by this effect; they assume that there is a defect in the oscillator circuit, when the trouble is really elsewhere in the receiver.

Step 3: To show that under some conditions a **high power factor in the output filter capacitor results in overall oscillation.**

Turn the set off, and remove the 3k-ohm resistor. Solder the three leads back to pin 6 of the 12BA6. Possibly you may be unable to get the three wires back through the hole in pin 6. In that case simply "tack" solder the three leads to pin 6. If the solder is allowed to flow smoothly over the joint, a good mechanical connection will result. Now try out the receiver to be sure that it is operating normally.

In the preceding experiment, you demonstrated that high power factor in the output filter capacitor produced hum. However, a small increase in power factor will not have any appreciable effect on the hum level. To demonstrate this, disconnect the positive lead of the output filter capacitor, C11B, from terminal DB3 and connect a 120-ohm resistor in series with this lead.

Turn the set on. If you notice any increase in hum, it will be very slight. However, there is another effect that would be noticeable if it were not for the 0.1 μf rf bypass capacitor. To demonstrate this, turn the set off, and disconnect this capacitor from the screen grid, pin 6, of the 50C5. Turn the set back on, turn up the volume, and tune over the dial. You will probably hear squeals and howls wherever a station should be received, because the electrolytic capacitor will not bypass rf signals, and signal voltage is built up in the B supply and is fed from one stage to another, resulting in oscillation.

To prove that the trouble is in the electrolytic, shunt your test electrolytic, the 20 μf capacitor, from DB3 to B- with the proper polarity. If you have trouble holding the leads in contact with the proper points in the circuit, turn the set off, solder the capacitor in place, and then turn the set back on to recheck it. You should get normal operation.

Now disconnect the test electrolytic, and let the receiver oscillate. Move the lead of the 0.1 μf rf plate bypass capacitor so that it is again in contact with the screen of the 50C5. As soon as you make contact, the oscillation will stop.

As an electrolytic capacitor ages, its ability to serve as an rf bypass decreases, and oscillation takes place. A paper bypass capacitor, even one as small as 0.01 μf, is used in parallel with the electrolytic output filter capacitor in well designed receivers to prevent this trouble. The set may play for months or years before the power factor in the electrolytic increases to the point where hum becomes a problem.

Remove the 120-ohm resistor from the circuit, and resolder the positive lead of the output filter capacitor to terminal DB3, and the 0.1 μf bypass to the screen of the 50C5 tube. Try out the set to be sure it is working normally.

Step 4: To show that single-stage rf oscillation can be due to misplaced wiring.

Solder a short length of wire to the control grid, pin 1 of the 12BA6. Gently push the wire down near the blue i-f transformer lead connecting to the plate of the 12BA6. Turn the set on, and after it warms up, try tuning in stations. You will find violent oscillation. If you do not get this oscillation, try moving the lead around and bring it even closer to the plate lead of the 12BA6. Do not, however, permit the end of the wire to come in contact with any parts or with the chassis.

The squeal may not be as loud as some of those you have formerly noticed, because the tremendous avc voltage being developed practically blocks all signals from the mixer. Check on this avc voltage by connecting the ground clip of the tvom to Pl of the volume control and touching the probe to the hot side of the volume control P3. The Function switch should be set to measure a negative dc voltage. You will measure from 3 to 15 volts across the volume control. Notice that this voltage does not vary as you tune the receiver throughout the tuning range. This avc voltage is being applied to the control grid of the mixer and also to the 12BA6 tube.

In a receiver, of course, you would not look for a piece of stray hookup wire hanging on the control grid of an i-f amplifier. However, the same effect would be produced if either of the i-f transformers had been replaced and the leads had not been cut to the proper lengths and kept close to the chassis. Therefore, when replacing i-f transformers, remember to keep the wiring neat and as much like the original as possible.

When you are satisfied that you have made the necessary observations in this experiment, turn the set off, and leave the lead connected to the control grid of the 12BA6. You will use it in the statement at the end of this experiment.

Discussion: In ac-dc receivers, oscillation can be caused by open bypass capacitors, defective output filter capacitors, and misplaced wiring.

In some cases, misalignment results in oscillation. Frequently, if a receiver is dead because of a defective oscillator, an inexperienced person may start adjusting the i-f transformers. He may turn them out far enough so that the i-f amplifier is actually tuned to a station at the low-frequency end of the broadcast band. Then the tuned circuit in the plate circuit of the mixer may be sufficiently near the tuned circuit in the grid circuit to permit feedback at the same frequency, resulting in oscillation. Therefore, in servicing a receiver, do not adjust the i-f transformers unless you have a good reason to.

In some receivers, oscillation will not occur when an i-f amplifier is peaked exactly. A slight detuning, however, may cause oscillation, because when one winding of an i-f transformer is detuned, the secondary winding absorbs less power from the primary, and the primary impedance rises. The voltage across the primary also rises, and stray coupling in the circuit may permit enough feedback into the grid circuit to cause oscillation.

Single-stage rf-if oscillation can often be controlled by increasing the bias. In your receiver, the cathode bias resistor for the i-f tube is 150 ohms. If there were uncontrollable oscillation, which could not otherwise be stopped, you could install a larger value resistor. Sometimes a resistor value will have to be as high as 300 or 400 ohms.

In your receiver, you have grounded the center shield on the rf-if tube sockets. If the ground (B–) connection were left off, feedback could occur between the plate and control grid, resulting in oscillation. This is a point you should watch in servicing receivers. The center shields in these stages should be grounded.

In servicing a set for oscillation, you should carefully examine the top of the chassis to see if all the tube shields are in place. Leaving off a tube shield frequently results in oscillation. The tubes requiring shields can be easily identified; their bases will have metal rings into which the shields should go.

Octal-base tubes were used in older ac-dc sets, and in many ac sets. These tubes may be either glass or metal. If oscillation is the complaint, try metal tubes in the rf-if stages. If you do this, ground pin 1, unless it is used as a tie point for other purposes. The No. 1 pins connect to the metal shell, which acts as a shield around the tube.

In older receivers using a three-gang tuning capacitor, check the wiper contacts used to ground the rotors to the capacitor frame. A dirty contact or a high resistance at this point will result in feedback between the sections, and oscillation in the rf stage. You will rarely find this difficulty in ac-dc sets, because practically no ac-dc receivers use a tuned rf stage.

Instructions for Statement 67: For this statement you will learn another method frequently used to eliminate oscillation. Turn your set on, and with your finger, move the short lead connected to the 12BA6 control grid away from the plate to the point where oscillation starts. In other words, if you move the lead farther, there will be no oscillation. With the receiver oscillating, turn off the set.

We will now proceed to lower the Q of the resonant circuit feeding the control grid of the 12BA6 and note the effect on the oscillation. Solder one end of your 100k-ohm resistor to the the control grid of the tube, and the other end to the avc line at terminal KB3. Do this without disturbing the position of the free lead connected to the control grid of the 12BA6. Now turn on the set, and try tuning in stations over the dial. You should now be able to answer the statement. Remove the 100k-ohm resistor and the short piece of wire from the circuit.

Statement No. 67: With the first i-f transformer secondary loaded by a 100k-ohm resistor, I found that the oscillation:

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

EXPERIMENT 68

Purpose: To show that distortion can be caused by a leaky coupling capacitor in an RC coupled amplifier stage, and if so, there will be a dc voltage drop across the grid resistor of the following stage.

Introductory Discussion: Up to the final audio stage, we are primarily interested in obtaining as high a voltage gain as possible without undesirable feedback, oscillation, or distortion. In the final stage, however, we must develop sufficient power to drive the loudspeaker. This is done by using power pentodes or beam power output tubes. Typical examples are the 3V4, 3S4, and 3Q5 tubes used in older battery sets, the 6BQ5, 6BK5, 6V6, and 6AQ5 tubes used in ac-operated sets using a power transformer, and the type 50C5, 35C5, and 50L6 tubes used in ac-dc sets.

All type 50C5 beam power amplifier tubes have rather high harmonic distortion when operated in single-ended (one tube) output stages at high audio output levels. To keep the distortion to a minimum, it is common to operate these tubes as class A amplifiers. This means that the bias for such a tube must be sufficient to keep it operating on the straight part of its Eg-Ip characteristic curve, and the input signal must be limited so that it will never drive the grid positive, and thus produce a grid current flow.

RC coupling is generally used between the plate of the voltage amplifier stage and the grid of the power output stage. The coupling capacitor is likely to have high voltage peaks applied to it. Thus, in some receivers, the capacitor is likely to become quite hot. It is not uncommon, therefore, for it to become leaky, or to break down completely after being in service for some time. When this happens, the plate voltage, which is positive with respect to ground, is applied to the control grid of the following stage, causing a large grid current to flow. If the grid current flow is allowed to continue for any great length of time, it will permanently damage the tube. The effect of such a breakdown on the operation will be severe distortion, because the stage is no longer operating as a class A amplifier. In this experiment you will demonstrate the effects of leakage in the coupling capacitor.

Experimental Procedure: Here you need the receiver and your tvom, plus:

1 1 meg resistor

Step 1: To simulate leakage in the coupling capacitor.

Solder one lead of the 1 meg resistor to the control grid, pin 2, of the 50C5 tube socket, and arrange the other lead so that it can be pushed into contact with plate pin 7 of the 12AT6 socket.

Step 2: To demonstrate the effects of a leaky coupling capacitor.

Turn on the set, tune in a station (preferably one presenting a musical program), set the volume at a fairly high level, and then push the 1 meg resistor into contact with plate pin 7 of the 12AT6 socket. Use the eraser end of a pencil, or a small wooden stick for this. The reproduction should be weak and distorted.

Tune to other stations, and repeat the foregoing procedure. Distortion should be produced in all instances.

To avoid damaging the 50C5 power output tube, release the 1 meg resistor from contact with plate pin 7 as soon as you have noted the effect of the simulated leakage.

Step 3: Measure the dc voltage across the 470k-ohm grid resistor R8, first with coupling capacitor C7 normal, then with leakage simulated.

Prepare your tvom for dc voltage measurements, and turn on the set. Tune in any local station, and adjust the volume to a comfortable level. Now see if you can measure a dc voltage across the 470k-ohm grid resistor. Enter the value for each test in Fig. 68-1. If you get no reading, write 0 in the space.

Without turning off the set or changing the position of the Function switch, set the Range switch at 12V, and push the free lead of the 1 meg resistor into contact with plate pin 7 of the 12AT6 tube socket. There should now be an appreciable dc voltage indicated by your meter. Enter the value you get in Fig. 68-1. Turn off the set, and disconnect the tvom. Also unsolder the 1 meg resistor from pin 2 of the 50C5 socket.

CONDITION OF C7	READING
NORMAL	∅
LEAKY	12V

Fig. 68-1. Record your readings for Exp. 68 here.

Discussion: Since the 50C5 power output stage of your receiver is supposed to operate as a class A amplifier, you should get no voltage for either of the measurements when no leakage is simulated in the coupling capacitor C7. A -dc voltage reading could occur only if the tube were drawing grid current, which would happen only if there were no bias. However, you may get a small positive reading because there may be a slight amount of gas in the 50C5. If this is true, the voltage will remain when you disconnect C7.

When you simulate leakage by connecting the 1 meg resistor across C7, you should get an appreciable voltage. The leakage resistance you are using, together with grid resistor R8, constitutes a voltage divider for which the plate voltage of the first audio stage acts as a source. This voltage divides across the leakage resistance of the coupling capacitor and the grid resistor according to their values, and with such polarity that the grid of the output tube is now positive. This causes a flow of grid current and a tremendous increase in the plate current, and severe distortion takes place in the output.

Whenever you have a case of severe distortion in general service work, check for a positive dc voltage across the grid resistor of the power output tube. If there is voltage, and the set uses a power transformer for the filament supply, pull out the power output tube and again check for voltage across the grid resistor. If there is none now, the output tube is gassy and should be replaced. However, if the voltage does not disappear when the output tube is removed, the coupling capacitor is leaky, and should be replaced.

In ac-dc sets, the tube filaments are in series, so you cannot pull out the output tube. Here, you must disconnect the coupling capacitor and repeat your measurement. If the voltage disappears with the capacitor disconnected, you know the capacitor is leaky; otherwise, the tube is gassy.

Another defect you will find in your work as a technician is an open grid resistor in the first audio stage. You will simulate this defect in order to answer the statement for this experiment.

Instructions for Statement 68: It is not uncommon to find the grid resistor of the 12AT6 tube either open or increased greatly in value. You will determine the behavior of the receiver with an open grid resistor in the first audio stage.

Tune in a station and adjust the volume to a comfortable level. Unplug the receiver and unsolder the lead of the 10 meg resistor connected to pin 1 of the 12AT6. Leave the set turned off for about five minutes to allow the tubes to cool off. Then turn the set on and observe the sound as you turn the volume control up and down. Continue listening to the sound for about five minutes then answer the statement below and on your Report Sheet.

Statement No. 68: I found that, with an open resistor in the grid of the 12AT6, the audio output at first distorted:

(1) at low volume
(2) at high volume
(3) at all volume

control settings and, after a short time, the sound

(1) improved.
(2) disappeared.
(3) faded to a very low level.

Reconnect the lead of the 10 meg resistor to pin 1 of the 12AT6 and check to make sure the receiver is operating properly.

EXPERIMENT 69

Purpose: To show that noise can be localized by a stage-blocking technique, even though blocking is so incomplete that some noise can still be heard.

Introductory Discussion: The circuit disturbance test that you demonstrated in a previous experiment is based on the fact that any sudden irregular current change will produce a noise in the loudspeaker. In a circuit disturbance test, these current changes are deliberately produced for the purpose of localizing the source of trouble when a receiver is dead.

There are many things that will create the sudden current changes that produce noise in the output of a receiver. These may be within the set itself, such as poor contact in a volume control or a partial or intermittent open in an rf or af transformer, or external to the set, such as arcing electric motor brushes and defective neon signs. In this experiment, you will deal only with noise that originates within the set itself.

After creating a source of noise, you will demonstrate the stage-blocking technique in which you will make each stage in turn inoperative, and note if the noise is still present in the output. In an ac-operated set, this can be done by pulling out the tubes one by one. Since you cannot pull out the tubes in ac-dc receivers, technicians generally short-circuit the input and output of each stage in turn. This is the method you will follow in this experiment.

Experimental Procedure: For this experiment you will need:

1 20 μf electrolytic capacitor

Step 1: To create an intermittent open in the plate circuit of the 12BE6 converter stage.

Unsolder the blue i-f transformer lead from pin 5 of the 12BE6 tube socket. Remove all solder from the hole in this pin, and any excess solder that may be on the end of the blue wire.

Now, push the blue lead back into the hole, and if possible, place it so that striking the chassis or table forcibly with your hand will produce an intermittent contact between the plate lead and the pin. Turn on the set and try this effect. If you find it difficult to get the correct adjustment of this lead, the noise pulses can be produced by striking the loose lead with the eraser end of a pencil.

Step 2: To block the input to the mixer-oscillator stage.

Solder the negative lead of the 20 μf capacitor to the ground terminal in the center of the 12BA6 socket. Turn on the receiver, set the volume control for a high output, create noise pulses by striking the chassis or by moving the loose plate lead, and note that noise is plainly audible in the loudspeaker. Touch the positive lead of your blocking capacitor to pin 7 of the 12BE6 tube to block the input to the mixer oscillator stage. Continue creating noise pulses and note they are still plainly audible in the output. It is not necessary for the receiver to be tuned to a station for these tests.

Step 3: To block the input of the 12BA6 i-f amplifier stage.

Move the positive lead of your blocking capacitor to pin 1 of the 12BA6 and create the noise pulses. Note that although the noise is still audible, it is not nearly so loud.

Step 4: To block the output of the i-f amplifier stage.

Move the positive lead of the blocking capacitor to pin 5 of the 12BA6. Create the noise, and again note that although it is still audible, it is not nearly as loud.

Remove the stage block long enough to tune in a station. Then restore the block at pin 5, and again create the noise pulses. Although the incoming program is blocked, the noise pulses should still be audible in the speaker. This proves that the noise pulses are not getting into the output along the usual signal paths.

Now restore the receiver to normal operation. Securely solder the loose plate lead to pin 5 of the 12BE6 tube socket.

Discussion: As you found in Step 2, a stage block between the input of the set and the source of the noise will have no effect on the strength of the noise pulses in the output, because the normal signal path from the noise source to the loudspeaker is unobstructed.

However, the reason that the noise is still audible when the signal path is blocked anywhere between the noise source and the output is not so apparent. To understand this, you must remember that the noise is caused by a sudden current change. In this experiment, it is the plate current of the 12BE6 mixer-oscillator stage that is changing and producing the noise in the output. Since this changes the loading on the power supply unit, small changes occur in the plate and screen currents of other stages. This again produces noise; but since these changes are very small compared to the change that produces them, these noise pulses are comparatively weak.

You must also consider the fact that every time the contact at the plate pin of the tube socket is made and broken, a small electric arc is formed. This arc produces a pulse of rf energy, which can be picked up by unblocked rf stages by direct radiation from the arc, or the rf energy may travel along the intercircuit wiring to unblocked stages.

You may begin your stage-blocking procedure at either the input or the output of the set. In either case, the defective stage is indicated by a change in the noise level as you move the block along. Thus, in the experiment, you started at the input and worked toward the output. Noise was heard at the original loudness level until the defective stage was passed, then the noise level was much weaker. If you had started at the output stage and worked toward the input, the noise pulses would have been weak until you passed over the defect, then the noise pulses would have become much stronger.

Instructions for Statement 69: For your report on this experiment, you will simulate noise originating in the audio section of the set, block the following stage, and determine whether or not the results are the same as those observed in carrying out the experiment. Proceed as follows:

Solder a short piece of hookup wire to pin 7 of the 12AT6. Position the wire so you may easily touch it to terminal DB3. Turn on the set and make and break the contact between DB3 and the hookup wire. This should produce noise in the output.

Try a block ahead of the trouble by touching the positive lead of the blocking capacitor to pin 1 of the 12AT6. Again make and break the contact between pin 7 and terminal DB3 and note the effect on the noise.

Now block the output of the 50C5 by touching the positive lead of the blocking capacitor to pin 7 of the 50C5. If the capacitor leads do not reach this far conveniently, resolder the negative lead to a more convenient ground connection such as terminal DB1. Turn on the set and again create noise pulses. Note the effects, then answer the statement below and on the Report Sheet.

Restore the receiver to normal operation by removing the short wire and the blocking capacitor.

Statement No. 69: When I blocked the output stage, noise pulses, which were created by opening and closing the plate circuit of the first audio stage:

(1) could still be heard
(2) could not be heard

from the loudspeaker.

EXPERIMENT 70

Purpose: To show alignment problems; and to show how alignment can affect tracking.

Introductory Discussion: The i-f, rf, and mixer stages of the superheterodyne receiver are aligned to produce maximum signal strength at the second detector output for each station tuned in, so that the dial pointer indicates the frequencies of the various stations accurately.

Misalignment can have several effects. The local oscillator frequency may not be separated from the frequency of the rf tuned circuit by the i-f frequency over the entire tuning range, although stations will come in at about the right dial settings. In this case we say that the oscillator and preselector do not track. Another effect of misalignment might be that the oscillator and preselector track, but the dial readings are not correct at the lower frequencies.

To carry out this experiment successfully, you must be able to receive strong stations at both ends of the dial. You should have a station you can easily identify that operates between 1400 kHz and 1600 kHz, and one that operates between 550 kHz and 900 kHz. Preferably the station frequency should fall on a marked division of the dial, especially at the high-frequency end. At NRI we used stations at 1500 kHz and 630 kHz.

If you do not receive such stations in your locality, do only the first part of Step 1 and the Statement. Do not detune the i-f's.

Your results will depend on the ease with which you can spot stations on the dial, the condition of your receiver to start with, and the care with which you follow the instructions.

You will find it much easier to tune in the stations accurately if you use the rim of the tuning knob rather than the smaller center knob. In this way, you can tune in stations more easily.

A properly aligned i-f amplifier is the heart of the superheterodyne receiver. If the i-f amplifier is properly aligned, the oscillator and preselector trimmers can easily be adjusted using known broadcast station signals.

Experimental Procedure: You need only your receiver and the tvom.

To guarantee consistent results, it is important to set the antenna winding on the ferrite rod exactly in the center of the rod. Later, you may find you can peak up the low end of the band by slightly repositioning the winding.

Step 1: To check the tracking of the oscillator, preselector, and dial.

You have already made preliminary adjustments of the oscillator and preselector trimmers. You will now check the alignment of your receiver at the high end of the band.

Tune to a station at the high end of the band and make sure the dial setting is correct for this station. If the receiver has been jarred or banged while performing the experiments, the oscillator adjustment may be slightly off and the high frequency station may be at the wrong dial setting. If it is, turn the dial to the correct setting and adjust the oscillator trimmer CT2 to bring in the station. CT2 is the trimmer farthest from the front panel. Now adjust the preselector trimmer, CT1, for maximum volume.

With the receiver still tuned to the high frequency station, carefully adjust the i-f slugs for maximum volume beginning with T2. Make these adjustments very carefully since the slugs will need only very slight adjustment. Do the same thing with the adjustments on T1.

You will adjust your i-f transformers with the alignment tool provided. So that you can easily observe how far you have turned the tool, attach a piece of tape to the center of the alignment tool as shown in Fig. 70-1. The end nearest the tape "flag" is the end to use for all transformer adjustments. It is possible to adjust both the top and bottom slugs of the transformer from either the top or bottom hole. However, to avoid confusion, you should make all of your adjustments from the end closest to the

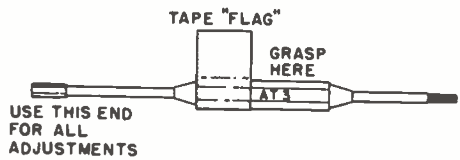

Fig. 70-1. Attaching a tape "flag" to the alignment tool.

slug that you are adjusting. Make sure that you insert the tip of the alignment tool into the transformer only far enough to reach the first slug.

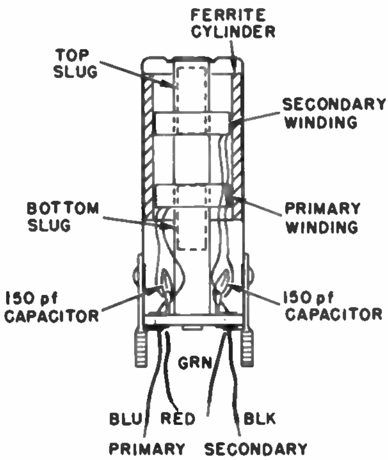

Fig. 70-2. Internal construction of the i-f transformers.

As you can see from Fig. 70-2, there is one powdered iron slug associated with each of the transformer coils. When you look at the transformer from the top, turning the top slug counterclockwise will move it toward the top of the transformer, and since the slug is moving away from the coil, the inductance of the coil will be decreased, so the resonant frequency will increase. Looking at the transformer from the bottom, turning the bottom slug counterclockwise will move it toward the bottom of the transformer, which will reduce the inductance of the bottom coil, and therefore raise the resonant frequency of that part of the transformer.

Next, detune the i-f's approximately 10 kHz by turning each of the i-f slugs one-eighth of a turn in a counterclockwise direction. This will raise the i-f about 10 kHz.

Instead of relying on your ear to indicate maximum volume while aligning the receiver, you will use your tvom to measure the avc voltage developed in the receiver. Clip the ground lead of your tvom to P1 of the volume control and the probe to P3. Set the meter to read -dc volts on the 3V range.

With the receiver still tuned to the highest frequency station and while watching the meter, adjust the rf trimmer CT1 on the front section of the tuning capacitor gang for maximum avc. Tune the receiver over the dial, noting how the avc reading increases as you tune to each moderately strong station. Weak stations will produce little avc.

Tune to the low-frequency end of the dial, and check the preselector and oscillator tracking by turning the dial knob to bring in a station for greatest avc. Do not touch the oscillator trimmer. Try adjusting the rf trimmer CT1 to see if the avc can be increased. If the receiver is tracking properly, no change, or less than half a turn of the trimmer should be necessary to pass through a maximum on the meter.

You will find that you have to tighten the rf trimmer almost all the way to get maximum avc and maximum volume. Leave the rf trimmer set for maximum volume, and tune back to the high-frequency station. Note how little avc is now produced. Readjust the rf trimmer for maximum avc. Naturally, something must be done, because the customer cannot readjust the rf trimmer each time he tunes in a new station.

Step 2: To show that poor tracking of the oscillator, preselector, and dial can be

due to incorrect alignment of the i-f amplifier.

You should have noticed that although the high-frequency station comes in at the correct dial setting, the low-frequency station comes in at a somewhat higher dial setting than called for by its operating frequency. The condition is not serious and would probably go unnoticed unless your attention were called to it. The receiver is not tracking its dial as well as it might, because the i-f amplifier is tuned to approximately 456 kHz, but the i-f frequency that should be used with the oscillator coil and dial is about 446 kHz.

Normally a serviceman would read the i-f value on the manufacturer's diagram and would realign the i-f amplifier to the specified frequency using a signal generator. If you have a signal generator, you can use it to check the i-f alignment after completing Experiment 70.

Now tune to the low-frequency station, and set the dial slightly below the point where maximum avc is received, but where the station can still be heard. Adjust the first i-f transformer, T1, and then the second i-f transformer, T2, for maximum avc. The slugs will have to be turned only a very small amount so make the adjustment carefully.

Again set the dial pointer toward the low-frequency end at a point where you can still hear the station. Readjust the first and second i-f transformer slugs for maximum avc. Repeat this procedure once more (three adjustments in all), remembering to reset the dial to a lower frequency and to adjust the first i-f transformer and then the second i-f transformer.

This procedure should lower the frequency of the i-f amplifier about 10 kHz, and the low-frequency station should be coming in at very nearly its right dial setting, or perhaps a little lower.

Now tune to the correct dial setting for the high-frequency station, and adjust the oscillator and rf trimmers, CT2 and CT1, for maximum avc. You may find that the trimmers do not need to be readjusted. Tune to the low-frequency station, and check the tracking by adjusting the rf trimmer. If it is already peaked and no further (not more than half a turn) adjustment is needed, the oscillator and preselector are tracking each other and the dial. If you still have to screw the trimmer rather tight, the i-f is still too high, and the procedure of lowering the i-f should be done once more. Don't go too far or the i-f will be too low. If you experience any difficulty in making these adjustments or if you do not get the proper tracking as described, return the i-f trimmers to the settings used in the beginning of this experiment.

Discussion: You probably wonder why readjustment of the i-f amplifier frequency three times changes the i-f by 10 kHz. The receiver has a band width of slightly less than 10 kHz; you can tune away from a desired station about 3-1/3 kHz, and still receive its signal. If you shift the frequency 3-1/3 kHz three times, and readjust the i-f each time, there will be an overall change of approximately 10 kHz in the i-f amplifier frequency.

Exact tracking between the rf and oscillator is possible, but is seldom achieved in commercial receivers. Usually some slight readjustment of the rf trimmer can be made to improve the tracking at a given frequency. If the necessary readjustment is small, the change in volume cannot be noticed by the ear.

Some manufacturers compromise on the adjustment by setting the oscillator at the highest dial marking, for example 1600 kHz, and adjusting the rf trimmer at 1400 kHz so that the tracking is equally good at the high and low ends of the dial.

Remember that in a well designed receiver using specially cut plates in the oscillator section of the tuning capacitor, poor tracking is an almost sure sign of incorrect i-f alignment. If you have to screw the rf trimmer in at the low-frequency end, the i-f is too high; if you have to loosen the rf trimmer at the low-frequency end, the i-f is too low. To lower the i-f, tune below a station, and readjust the i-f slugs. To raise the i-f, tune the receiver above a station, and readjust the i-f slugs. In both cases the job is easier if you use a station at the low-frequency end of the dial. A signal generator set to the particular value recommended by the manufacturer can be used to adjust the i-f, or you can use the methods outlined in this experiment.

Many different i-f values have been used in commercial receivers. Frequencies of 130 kHz, 175 kHz, 262 kHz, 455 kHz, 456 kHz, and 470 kHz have been commonly used in broadcast receivers. Other values can, of course, be used; for example, we used 446 kHz for this receiver.

Instructions for Statement 70: Strip 1/4" of insulation from both leads at one end of a 3" length of twisted wire. Make sure the insulated ends are not touching one another by slightly separating the two leads. You will use this length of twisted wire as a small capacitor of about 5 pf to slightly detune the rf input and the two i-f transformers.

Turn on the receiver and tune in a station at the low end of the band (550 kHz to 700 kHz). Clip the ground lead of your tvom to terminal P1 on the volume control and the probe to P3. Set the tvom to read -dc volts and note the avc voltage.

Turn off the receiver and solder one lead of the twisted pair to the center post of the 12BE6 tube. Solder the other lead to pin 7 of the same tube. Turn on the receiver and adjust the tuning knob for maximum avc voltage. Note the value of voltage. 6 → 8

Turn off the receiver and disconnect the leads from pin 7 and the center post of the 12BE6. Reconnect the leads to pins 5 and 6 of the 12BE6. Now the capacitor is across the primary of the input i-f transformer. Turn on the receiver and adjust the tuning knob for maximum avc voltage. Note the value of voltage. 6 → 7

Turn off the receiver and disconnect the leads from pins 5 and 6. Reconnect the leads to pin 6 and the center post of the 12AT6 tube. The capacitor is now across the secondary of the output i-f transformer. Turn on the receiver and adjust the tuning knob for maximum avc voltage. Note the voltage. You now have enough information to answer the statement. Turn off the receiver and disconnect the two leads from the 12AT6 tube. 3 → 5

Answer the statement below and on your Report Sheet.

Statement No. 70: I found the sensitivity of the receiver, as indicated by the avc voltage, was decreased most by detuning of the

(1) first i-f transformer.
~~(2)~~ second i-f transformer.
(3) preselector.

ALIGNING THE I-F WITH A SIGNAL GENERATOR

Here are some instructions on aligning the i-f amplifier section of the receiver, using a signal generator. If the rf signal from the generator is modulated by an audio signal, you can make your alignment adjustments by ear, adjusting the various slugs for maximum sound output. You can also use your tvom, connected across the volume control, to indicate when the transformers are peaked for maximum voltage output. Using a tvom will usually give better results; but if the input level is kept to a low value, your ear is quite sensitive to changes in volume.

The signal generator can be coupled to the receiver by connecting it between terminals C2 and C3 of the loop antenna. This will cause energy to flow through the second winding of the loop, and will induce the signal in the loop antenna. For i-f alignment, the receiver should be tuned to the low-frequency end of the dial, at a point where a squeal or a station is not received. If you cannot find such a point, you can stop the local oscillator by holding a screwdriver blade between the tuning capacitor plates to short it out. Adjust the i-f slugs to give maximum output at the setting of the signal generator. The signal generator should, of course, be tuned to the recommended i-f value (in this case, 446 kHz).

If a receiver has been badly misaligned, it is sometimes impossible to feed enough energy into the loop to get a reading on the output meter or to hear the signal. In this case, align the i-f transformers one at a time. Clip the ground lead of the signal generator to B– (clipping it to the chassis may result in hum modulation), and touch the hot lead of the signal generator to the control grid of the i-f tube. Adjust the second i-f transformer for maximum output.

You can then move the hot probe of the signal generator to the mixer grid of the detector-oscillator tube, and adjust the first i-f slugs. The exact order in which the slugs are adjusted is of no particular importance.

Clip the antenna and ground leads of the signal generator to the antenna and ground leads of the loop. The signal generator and the receiver should both be tuned to some setting at the high-frequency end of the dial such as 1600 kHz. If you do not receive a signal, adjust the oscillator trimmer for maximum signal. Next, tune the signal generator and receiver to a lower frequency, such as 1400 kHz, and adjust the rf trimmer for maximum output. Now tune to a station at the low-frequency end of the dial and see if adjustment of the rf trimmer improves the volume. If there is no noticeable improvement, the receiver is tracking properly.

CONCLUSION

This concludes the experiments in this kit. Check over your Report Sheet to see that you have answered all the Statements, and that your answers are just as you want them. Then send it to us for grading.

INSTALLING THE RECEIVER IN THE CHASSIS

Remove the power cord from both the receiver and the ac outlet. Slip one of the power cord clamps on the interlock connector as shown in Fig. 25. . . . . ( )

Fig. 25. Placement of first cord clamp on interlock.

Run the ac plug from the inside of the cabinet through the rectangular cutout marked "interlock." . . . . ( )

Draw the interlock portion of the cord into the cutout and push the second power cord clamp between the body of the interlock connector and the outside of the cabinet, as shown at "1" in Fig. 26. . . . . ( )

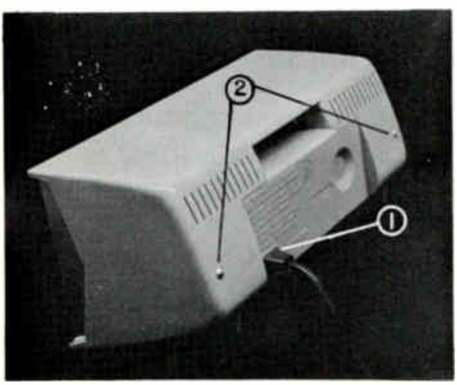

Fig. 26. Mounting the receiver in its cabinet.

With the cabinet right side up, position the chassis and panel so the chassis rests on the guide strips on either side of the cabinet. . . . . ( )

Slowly slide the chassis into the cabinet. Position the interlock connector so the interlock plug on the chassis will go into the female connector in the back of the cabinet. . . . . ( )

To make certain the interlock is correctly seated, plug in the receiver and turn it on. The receiver should operate. ( )

If it does not operate, pull the chassis forward and reseat the interlock connector. . . . . ( )

Place the two 4-1/4" screws through the two holes in the rear of the cabinet, as shown at "2" in Fig. 26. Tighten securely. . . . . ( )

The handsome 5-tube ac-dc superheterodyne receiver that you assembled in this kit is well worth keeping. You can use it on your servicing bench as a test set or use it in your home.

HELP YOUR MEMORY

Experience is a great teacher, providing you have a good memory! An unusual defect may take hours to locate the first time you meet it – but the next time, you should be able to spot the difficulty quickly. However, that "next time" may not occur for several months; by then you may have forgotten what you did.

You can aid your memory by keeping notes. Every time you meet an unusual trouble, write up a careful and complete description of its symptoms and your isolation procedure.

Also, draw schematics of any changes you may make in wiring. Even simple changes will make the circuit different from its original diagram and may give you puzzling test results at some later date, unless you are aware of the change.

After collecting this information, you'll never use it unless it is placed conveniently near your workbench. It is best to arrange your notes and sketches by make and model number in a file. In time, you will have a valuable assortment of service information – such as only YOU can collect!

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