SYLVANIA SPONSORED

# RADIO SERVICING MADE EASY

VOLUME I

SYLVANIA SPONSORED

# RADIO SERVICING MADE EASY

*By*

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*TV Servicing Made Easy*

*Transistor Servicing Made Easy*

*Industrial Electronics Made Easy*

THIS COURSE HAS BEEN PREPARED IN COOPERATION WITH

**SYLVANIA ELECTRIC PRODUCTS, INC.**

IN ORDER TO MAKE RADIO SERVICING INFORMATION MORE READILY AVAILABLE TO INDEPENDENT SERVICE TECHNICIANS

VOLUME 1

# contents

## Troubleshooting Charts

# Introduction

WELCOME to the ranks of those who want to earn more by servicing radio receivers.

We could let you jump right in with both feet, give you a complete circuit of a radio receiver and say: "Here. Do this and that . . . and the set will be fixed." That's a cook-book method. A few technicians might think that's good, but what do you do when the chief cook is out . . . and you have a collection of sets with troubles not described in the book?

With our approach you'll be able to look any radio set right in the face and say, "See here. No nonsense out of you or else . . ." What's more, you'll really mean it.

For many years radio service technicians fixed nothing but radios. There were all sorts of radios. Big ones. Little ones. Sets with 15 tubes. Sets with one tube.

But then, along came television and radio took a back seat. Practically all radio receivers were of the 4 or 5-tube ac–dc-type. If you could fix one, you could fix them all. Television was the big thing. People weren't too anxious to spend any money fixing their little sets since they were so cheap to begin with.

People have now become accustomed to television. Many homes have two television sets. And then people discovered radio all over again, after the novelty of television wore off. There is a big demand for radio again.

What sort of radio? All sorts! Clock radios, personal portable radios, short-wave receivers, marine radio receivers, police and airplane receivers, console receivers for the home, FM receivers for the home, FM receivers for use in automobiles. Just in the automobile alone, we have, in addition to AM and FM types, sets that fit into the dashboard, sets that fit into the glove compartment, sets that fit onto the rear-view mirror, sets that fasten to the floorboard (in sports cars).

Radio receivers now come in all shapes and sizes. Some are so tiny that they fit into a vest pocket—or will, just as soon as vests come back into style. Most come equipped with a hearing aid type of earphone so you can walk down the street listening to your favorite program.

And some sets are so big that they need a large console cabinet to hold them.

What does all this mean to you? Just this. These sets are going to break down—get out of order. The time to learn how to fix these sets is now—not when the set is sitting on your bench with the customer breathing down the back of your neck.

The day of the old "know one—know them all" is gone. Today we have such a large variety, that you can't "pick up your servicing knowledge as you go along."

Here is one cheerful note. In many cases, if you study one particular circuit, you will find it used in a number of sets, all of which look different. Just as an example, consider a transistor if stage. You will find it in personal portables, in home receivers, in auto radios. There will be some differences but many similarities. You won't find a *completely* new if stage with every new type of receiver.

We hope we haven't painted too dark a picture for you. We're just anxious that you should be fully prepared. Troubleshooting techniques learned here can be used on any electronic circuit. A dead stage will give the same wrong indications in a radio as in an amplifier. Noise interference must be traced with the same procedures and instruments in an automobile radio or an industrial installation. Once the principles are understood the solutions will come much easier.

Just one last word. We have tried to make this book as readable as possible, but that doesn't mean that you should consider it as a novel. By all means, read both Volumes 1 and 2, and read them often. But keep them around as reference books. The troubleshooting charts were prepared especially to help you. Take advantage of them.

LEONARD C. LANE

CHAPTER 1

# working with transistors

WE'RE GOING TO START our work with transistors. There's good reason for our doing so.

Transistors are being used more and more. Some sets have transistors only. Others, known as hybrid receivers, use both tubes and transistors. You may have had quite a lot of experience with tubes, but transistors are different.

## Getting started with transistors

Did you ever see a father with a new-born baby? From the way proud papa handles the infant you might get the idea the child is made of glass.

It isn't such a big jump from the nursery to the radio workbench as you might think. Have you watched the way some radio technicians handle a transistor? Right! They're practically afraid to breathe on it.

As you go through these volumes, you will learn that the transistor is not a little namby-pamby. For its size, and what it can do, the transistor is a tough item. It will outlive batteries. It will outlast resistors. You will replace transformers and coils while the original transistors will sit in their sockets waiting for a signal to come along.

Then what are all these stories you've been hearing? Someone having fun at your expense? Not quite! The whole problem lies in the fact that, when transistors were first introduced, technicians decided to handle them just like tubes.

Transistors weren't going to stand for that sort of nonsense.

Transistors wanted to be treated like transistors.

Transistors weren't going to be pushed around.

Transistors are quite willing to amplify and oscillate, but they insist on doing it on their terms.

Our job, then, is to learn what we can and what we can't do with transistors. Once we do that, all we need do is to wait for the receivers to come into the shop. And we don't mean wait and worry, either. We mean wait with confidence!

## What is a reference point?

Here's a simple little experiment you might like to try. Stand in the middle of the room and point east, then west. After you have done this, point north and then south (Fig. 101).

What does it mean when you point east? Wouldn't you say that

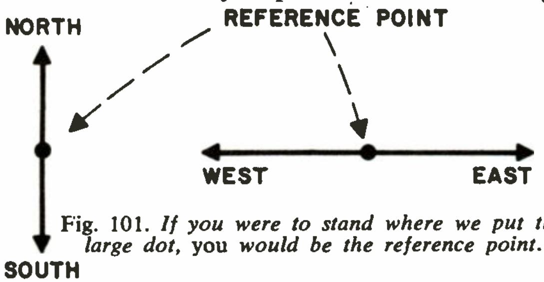



Fig. 101. *If you were to stand where we put the large dot, you would be the reference point.*

everything in front of your hand is east? But east of what? You're the one doing the pointing, so it must be east of *you!*

Now what happens when you make an about-face and point in the opposite direction? This time, everything in front of your hand is west. Once again, west of what? You're the one doing the pointing, so it must be west of you!

What were you in this little experiment? Since you could point in any direction, wouldn't you say you were a *reference point?*

## A practical example

A compass is a good example of a way in which we use reference points. Another very practical device is the ordinary thermometer. Two types are in general use, just as shown in Fig. 102, but they both work the same way.

One type, called the Fahrenheit, has a little mark on it at 32°. We call this the freezing point. At temperatures below 32° water starts to become a solid–ice. Above 32° the ice starts to become a liquid–water. In the Centigrade thermometer, the reference point is at 0°.

In either case, whether we use 32° or 0°, these temperature points are important as a reference.

## Other examples

There are many examples of reference points. Your home is a reference point. You leave home in the morning, come back at night. If you travel 3 miles to your job, then the 3 miles is the distance between the reference point (your home) and your job.

The surface of the earth (at sea level) is a reference point. We can either fly above it (as in an airplane) or travel below it (as in a submarine). The plane uses an altimeter to determine how high it is above sea level (its reference point). The submarine uses a

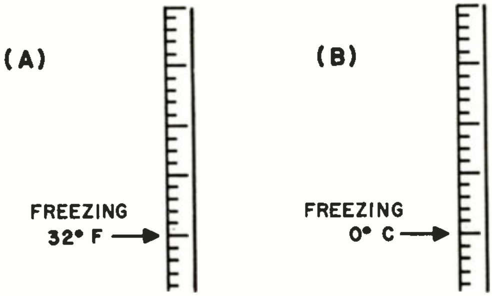



Fig. 102. *The Fahrenheit thermometer uses 32° as its reference point. The Centigrade thermometer uses 0° as its reference point.*

depth gauge to determine how far it is below sea level (its reference point). Both the plane and submarine (Fig. 103) use the same reference point.

Reference points are used all the time. A graph helps keep track of the progress of a business. You will see graphs almost every day in the business section of newspapers.

When you first learned electronic theory, you probably studied a few graphs like those shown in Fig. 104. In Fig. 104-A we show an alternating voltage.

Note how important the reference line is. We couldn't draw the graph without it. The reference line is the one marked zero. All voltages above zero are plus; all those below it are minus.

Even though our voltage might be all negative (as in Fig. 104-B) or all positive (as in Fig. 104-C), we still need a reference line. The graphs not only tell us whether a voltage is positive or negative (with reference to zero) but also by how much.

## Back to radio

In any circuit the chassis or B-minus line is often used as a reference point. In measuring the plate or screen voltage of a tube you connect one test lead to the correct pin on the tube base. The other test lead connects to chassis or B-minus. Just as you could live in a town east of a river (using the river as a reference) or north of Market Street (using Market Street as a reference), so we measure voltages (Fig. 105) using the chassis or B-minus as a reference.

## The ground is all around

Our reference point in a radio set has more than one name. (That isn't too surprising. You have a first and a second name.) The reference point is sometimes called the chassis and sometimes B-minus. But very often it is known as ground. The reason for this is that, in old-time radio sets, the chassis was actually connected to the earth (ground) with the help of a long wire. We don't usually do that any more, but the word ground has remained with us.

## Moving the reference point

When we asked you to help with our experiment, you stood in the middle of a room. Suppose, though, that you decide to take a walk. Are you—personally—still a reference point? Couldn't you still raise your arm and point wherever you wanted to?

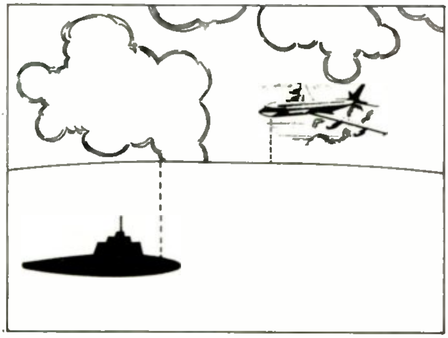


Fig. 103. *Both the plane and the submarine have the same reference point.*

This can be done with our reference point in a radio circuit. In Fig. 106-A, a 9-volt battery is shunted across a resistor. In Fig. 106-B, a ground is connected at point 2. Have we really changed the circuit? If we use exactly the same parts as in Fig. 106-A, wouldn't the same amount of current flow in both circuits?

In Fig. 106-C the ground connection is moved to position 1 of the circuit. Our reference point is in a different spot, but have we changed the circuit? The same amount of current flows. The reference point could be put right in the middle of the resistor, as in Fig. 106-D, without affecting the circuit.

## Bring on those questions

Your first question should be: Why are you doing this? If moving the reference point around doesn't change the circuit, why bother?

As a start, examine Fig. 106-B. What is the voltage at point 1? Obviously, it's 9 volts. But 9 volts what? Haven't we forgotten something? All voltage has polarity, so our answer isn't really wrong—it's just not complete. In Fig. 106-B, point 1 is 9 volts

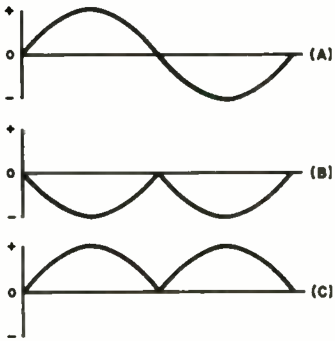



Fig. 104. *A graph is often used to show whether a voltage is positive or negative or both. The line marked zero is the reference line.*

positive. But with respect to what? Our *complete* answer must be: "Point 1 is 9 volts positive with respect to ground."

In Fig. 106-C, what can we say about point 2? The *complete* answer in this case must be that point 2 is 9 volts negative with respect to ground.

## We take a giant step

We hope you have noticed the importance of Figs. 106-B and C. Just by moving the reference point we can have either a positive voltage (with respect to ground) or a negative voltage (with respect to ground).

That isn't all. We can have both polarities, as shown in Fig. 106-D. Point 1 is positive with respect to ground while point 2 is negative.

Now do you see how easy it is, in any radio set with just a single battery, to have both positive and negative voltages?

## But is it practical?

Transistor radios use batteries and, although the circuits in Fig. 106 are very simple, they show us exactly what to expect in receivers.

For example, we might not want the full 9 volts supplied by the battery in Fig. 106. We can solve this problem in a nice, easy way: just move the reference point. In Fig. 106-D (if the reference point is at the exact center of the resistor), our voltages are 4.5 volts positive (with respect to ground) and 4.5 volts negative (with respect to ground).

The reference point can be moved anywhere along the resistor and get any combination of positive and negative voltages that add up to the voltage supplied by the battery.

## Follow the arrows

Did you ever see the big white arrows painted on highways to guide motorists? We can use arrows here, and they are just as practical.

Fig. 107 shows what we mean. In this circuit we have two equal resistors whose total value is the same as that of the resistor used

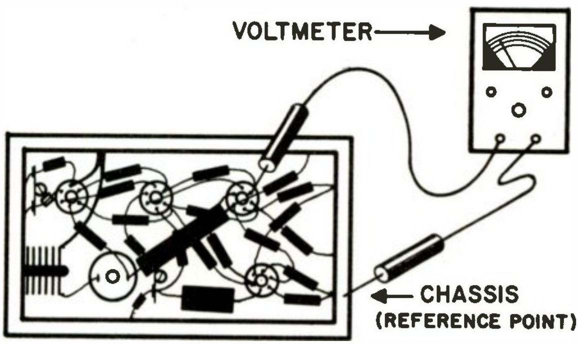



Fig. 105. *When making voltage measurements, the chassis is often used as a reference point. Sometimes a wire, running the length of the chassis, is used as the reference point instead of the chassis.*

in Fig. 106. We have a voltage drop of 4.5 volts across each resistor.

The arrows tell us the direction of current flow. What good are they? Knowing the direction of current flow tells us the polarity of the voltages across the resistors.

Knowing how to draw the arrows is very simple. An electron current always flows from minus to plus. All we need do, then, is to think of the direction of the current. The head end of the arrow (pointing in the direction the current is moving) is plus; the tail end is minus.

We hope you aren't going to be fooled for one little minute by the fact that this theory isn't difficult. You would be surprised at how many technicians get tripped up by it . . . especially in working with transistor radios, where polarity is so very important.

## The common line

If you've worked with vacuum-tube receivers, you are probably accustomed to the idea that B-minus is grounded. Another way of saying the same thing is that you probably always have used B-minus as the common line or reference point.

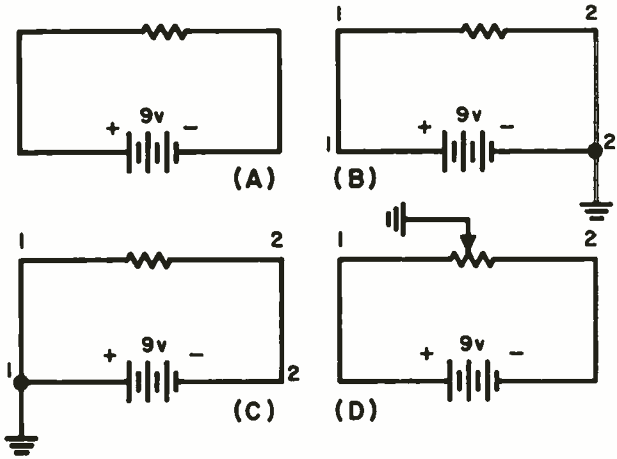



Fig. 106. *We can put the reference point anywhere we want. It will not change the voltage, the resistance or the amount of current flowing.*

In transistor receivers this isn't always so. In some transistor sets the B-plus of the battery is the common line and the B-plus may or may not be grounded. You may have a bus (a wire) running through the set to which connections are made. This bus is a reference point from which most checks are made.

In Fig. 108-A, note the electrolytic capacitor, C1. In this case the plus side of the capacitor is connected to ground.

Fig. 108-B shows the wiring that you might find in a transistor receiver but which is also very common in vacuum-tube sets. If you will look at C1, you will see that the electrolytic has been turned around.

## The great divide

Getting back to Fig. 107, what would you say about the polarity at the junction of the two resistors? Is it plus? Or is it minus? If you're paying attention then we won't be able to trip you up on this one. Aren't we really back to the idea of pointing north and then south?

The polarity at the common point of the two resistors depends on which way we are looking. It is minus with respect to point 1 and plus with respect to point 2.

### The forward-biased diode

With a few basic facts clearly in mind, let's move along to diodes. Fig. 109 shows the two types—semiconductor and vacuum tube.

The semiconductor diode in Fig. 109-A could be germanium or

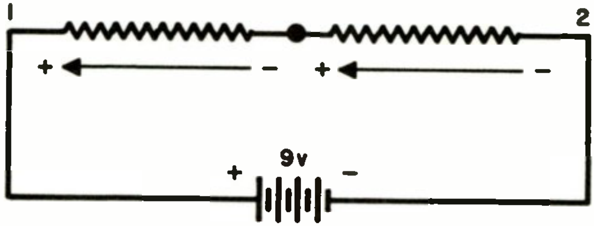



Fig. 107. *Note that the connecting point of the two resistors is plus and minus at the same time.*

silicon or any other semiconductor material. The supply voltage for the diode is called a bias battery. When we say that the semiconductor is biased, all we mean is that it is connected across a voltage source.

The circuit of Fig. 109-A shows a current flowing, but when we turn the diode around, as in Fig. 109-C, the current stops. Our diode acts like a switch. When the switch is closed, current flows. When the switch is opened, current stops.

Once again we have a few special names. Because the diode in Fig. 109-A is connected to let current flow, we say that it is forward-biased. It lets current move forward. And what is the opposite of forward? Wouldn't you say reverse? That is what we call the circuit of Fig. 109-C—reverse-biased.

If you're a little more familiar with tubes than with semiconductors, don't let it bother you. Fig. 109-A is similar to Fig. 109-B; Figs. 109-C and 109-D are also alike.

### Approaching the transistor

Perhaps you are a little worried about transistors and think them strange and mysterious. You certainly don't think about diodes that way because you run across them in every radio set you work on.

What applies to diodes, applies to transistors. The transistor is similar to a pair of diodes placed back to back.

In Fig. 110 we have a p-n-p transistor. The parts we are interested in—the emitter and the base—are just a forward-biased diode. Note the direction of current flow. Wouldn't you say that Fig. 109-A is similar to Fig. 110-A?

## A few relations

We now have a p-n-p transistor with the base–emitter circuit forward-biased. That's quite a mouthful to say but, at this point,

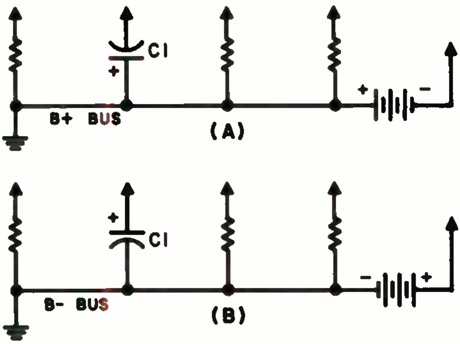



Fig. 108. *In some transistor receivers, B-plus is the common return and all measurements are made with respect to the B-plus bus. In other transistor receivers, B-minus is the common line and all measurements are taken with respect to B-minus. In both cases, though, voltage checks are made to ground. Note that in A, ground is connected to B-plus while in B ground is connected to B-minus.*

you know what it means. Current is going to flow from the negative terminal of the battery, through the base and emitter connections and back to the plus terminal of the battery. The arrows show the direction of current flow.

*I have an aunt,*
*an uncle too,*
*the closest of my relatives, just about*
*but the brother of the cousin*
*of the sister of my aunt,*
*is something I can't*
*even understand or figure out!*

You have relatives. So do we. But we're not the only ones. Each element of a transistor is related. Lucky for us, though, the transistor has only three elements, so remembering how they are related to each other won't be too difficult to remember.

How are the base and emitter related? Substitute a resistor in the p-n-p transistor, as in Fig. 110-B, and you'll have your answer. The base is negative with respect to the emitter. Another way of saying exactly the same thing is that the emitter is positive with respect to the base.

Let's see just what we know. We're using this resistor in Fig. 110-B as a substitute for the forward-biased diode part of a transistor. Keep in mind what we mean by forward-biasing. The diode is connected so that current flows through it fairly easily. What kind of an answer does this give us? Couldn't we say that the resistance used in place of the diode has a low value?

Suppose we add a few resistors to the circuit, as shown in Fig. 111-A. Our first step is to decide the direction of current flow (it moves the way the arrows point).

We can make life a bit easier by redrawing the circuit as in Fig. 111-B. Now what have we got? Three resistors in series! Who said transistors are difficult?

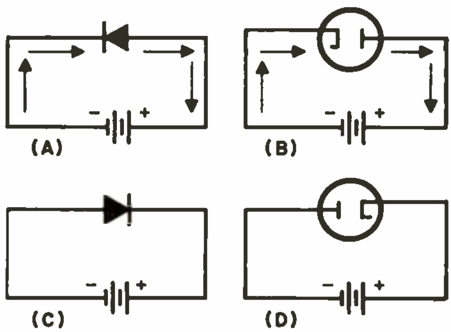



Fig. 109. *Semiconductor diodes are just like vacuum diodes. When diodes are forward-biased they conduct. When they are reverse-biased, they conduct very little (practically not at all).*

The only difference between Fig. 110 and Fig. 111 is a few added resistors. How will this change the circuit? What effect will it have? Begin with the current. We know that resistors can't change the direction of current flow, but one thing always happens when current goes through a resistor. We get an IR drop. Call it a voltage drop if you like—it means the same.

So we lose some voltage across the resistors. As a result we have less voltage between base and the emitter. However, the direction of current didn't change, the polarity didn't change and we still have a base that is negative with respect to the emitter.

## Pairs of diodes

The transistor in Fig. 111-A is a p-n-p unit. Here's how it gets its name:

| | |
|---|---|
| p (p-type material) | emitter |
| n (n-type material) | base |
| p (p-type material) | collector |

Look at this carefully. The first letter (p) does two things.

1. It stands for *emitter*.
2. It tells the type of semiconductor material used for the emitter.

That's quite a load of information for just one little letter.

What about the other letters? They work in the same way and just as hard. Examine the second letter (n).

1. It stands for *base*.
2. It tells us the type material used in the base.

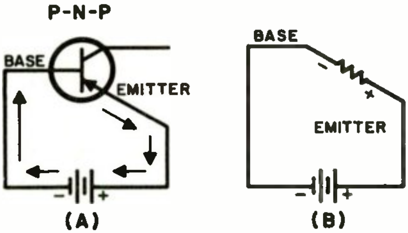



Fig. 110. *Note how similar the transistor is to the ordinary diode.*

The last letter (p) is the easiest of all. It is made of the same type of material as the emitter. The last letter is always the *collector*.

## P-n-p and n-p-n

Do you remember that old brain-teaser about which came first—the chicken or the egg? Maybe we can't answer that one, but if

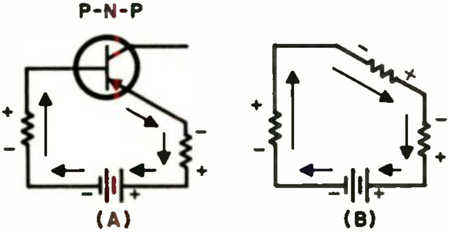



Fig. 111. *If we know the direction of current flow, we know the polarity of the voltages across the resistors.*

you're ever asked, "Which comes first—P-type or N-type material?" you can answer immediately—both.

Fig. 112 shows this clearly. In Fig. 112-A and Fig. 112-B, we have two diodes. Note that both are forward-biased. One diode is a p-n; the other is an n-p.

How did we manage to get forward biasing, even though the diodes are different? Easy enough: we turned the batteries around.

We could make the same diodes reverse-biased once more by turning the batteries around.

What do we need to remember for forward biasing?

P-type (positive type) germanium or silicon connects to the positive terminal of the battery.

N-type (negative type) transistor element connects to the negative terminal of the battery.

Perhaps you think this is too easy. But just because it is easy

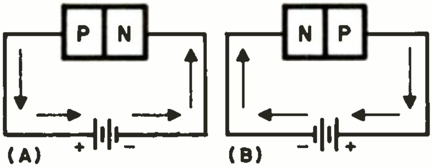



Fig. 112. *Current will flow when diodes are forward-biased.*

doesn't mean that it isn't important. With this little bit of information, we can have two different types of transistors–p-n-p and n-p-n.

Our first step in getting an n-p-n transistor is shown in Fig. 113. Now compare Fig. 113 with Fig. 110. What is the difference between them? Look carefully, because they are almost alike. If you want a clue, examine the arrows used in the transistor symbols.

In the n-p-n transistor, the current flow is exactly the opposite to that of the p-n-p. But is this such a big surprise? Not if you examine Fig. 112. What we have in Fig. 112 is a pair of forward-biased diodes. But isn't that exactly what we also have in Figs. 110 and 113?

## Adding the resistors again

A little earlier, we added some resistors to our p-n-p transistor. Suppose we borrow those resistors and use them again for our n-p-n unit in Fig. 114. Be careful. Watch the direction of current flow. Be sure. Compare Fig. 114 with Fig. 111. It wouldn't be a bad idea if you were to practice drawing both of these circuits. If you know them–really know them–you'll find it a big help in servicing transistor radios.

## Polarity again

Did you ever think that a two-way tunnel and transistors have something in common? Every time we drive through a tunnel and keep an eye on traffic moving both ways, we're nearly always reminded of p-n-p and n-p-n transistors. They have currents that move, just like traffic . . . in opposite directions.

Fig. 115 illustrates our diode-current "traffic control" system. Fig. 115-A shows a forward-biased diode. Transpose the battery and current stops (Fig. 115-B).

Fig. 115 shows two types of diodes—n-p and p-n. What is the difference between them? Just a matter of direction of current flow, isn't it?

## From the diode to the transistor

We have spent quite a bit of time explaining to you just how we can expect currents to flow in p-n and n-p diodes. If you have the

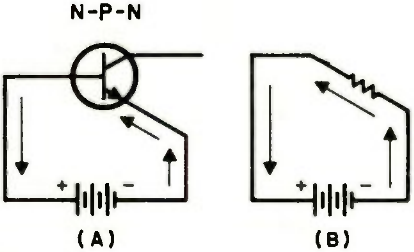



Fig. 113. *Current flow in an n-p-n transistor.*

slightest doubt about understanding it, go back over the text before going on.

Earlier we told you that a transistor is similar to a pair of diodes. Let's see how we can go about making a transistor out of them.

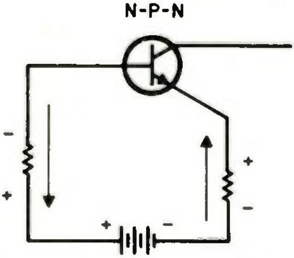



Fig. 114. *Note how useful the arrows are when working with circuits.*

Fig. 116 shows how we are going to do this. We can begin with Fig. 116-A. Here we have two diodes, connected back to back. How are these diodes biased? Let's make sure we agree. Diode 1 is forward-biased and diode 2 is reverse-biased.

## A little summary

Before we go any further, let's talk over some important facts we should have learned by now:

1. Voltages are measured with respect to a reference point.
2. A voltage can be positive with respect to a reference point.
3. A voltage can be negative with respect to a reference point.

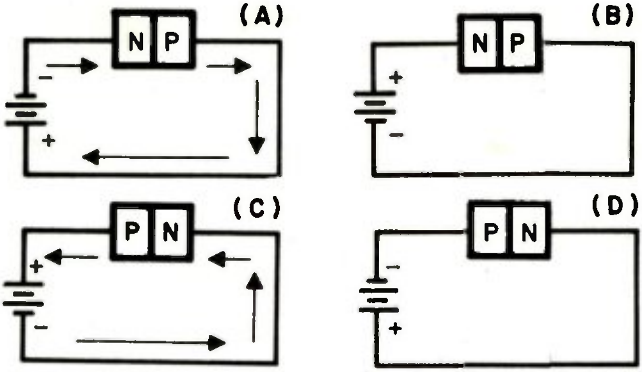



Fig. 115. *We can make current flow through n-p and p-n diodes by inserting the batteries the proper way. If we turn the batteries around, current flow will become so small that we can say it practically doesn't exist.*

4. In a receiver the chassis or ground is often used as a reference.

The reference can be a bus or some common connection point.

5. Current (electron movement) flows from minus to plus.
6. We can use an arrow to indicate direction of current flow.

The head of the arrow points in the direction in which the current is moving. The head of the arrow is marked plus (+). The tail of the arrow is marked minus (−).

7. Forward-biased means that current moves readily.
8. Reverse-biased means that very little current flows.
9. The elements of a transistor are the base, emitter and collector.

And now let's make the jump from diode to transistor. This is shown in Fig. 116-C. All we did, as you can see quite easily, is to take the two bits of p-type (and also n-type) material and combine them into one.

How could we do this? What gave us the right to do this? Stop for a moment and consider. We had two pieces of germanium or silicon. All we did was to join them. Actually, if you wanted to discuss the point, you might even say that we made no change at all. It's just as though we had two 1-lb weights on a scale and replaced them with a single 2-lb weight. How much difference does it make?

## Naming names

The transistor of Fig. 116-C looks like a sandwich. We have two slices of n- and one slice of p-type. The single section in the middle is called the *base*.

Did you ever buy a sandwich, separate the two slices to see if there was anything at all between them? That's the kind of economical transistor "sandwich" we have. The p-type material of the base is extremely thin.

Since the base is now shared by the emitter and the collector the base is a common element. And because it is, wouldn't the base make a good reference point for emitter and collector measurements?

The p-n-p transistor is made in the same way as the n-p-n, as shown in Figs. 116-B and 116-D.

## Taking the last step

Ever go on a hike? You can start out full of vim and pep and no distance seems too great. But which are the toughest steps to take? You guessed it. The last few on the way home.

We've been on an electronic hike but home is in sight. You can see it in Fig. 117. Start first with Fig. 117-A. Here we have our n-p-n transistor circuit, complete with batteries and resistors.

Fig. 117 should look familiar to you. Even though we are using the symbol for a transistor, it doesn't fool us a bit. And to make sure that it really isn't hiding any surprises, compare it with the vacuum-tube triode circuit shown in Fig. 117-B.

## A closer look

A circuit is like a movie. You have a door to go in and a door

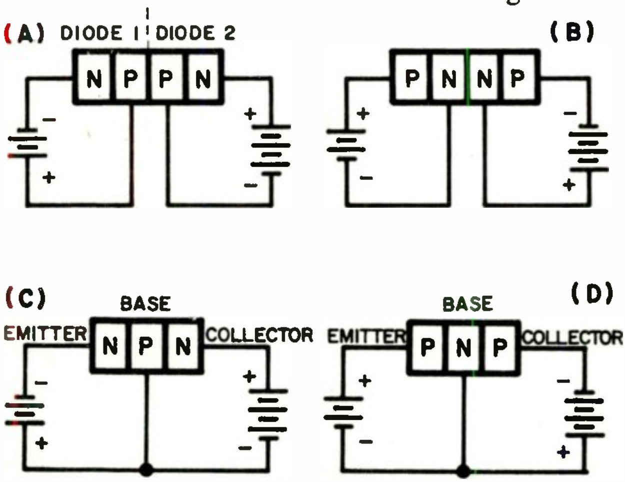



Fig. 116. *We can make a transistor from a pair of diodes. If you know how diodes work, you are well on your way to a good understanding of transistors.*

to go out. In a radio circuit, we let the signal go in and, if the circuit is working the way it should, we get a signal out.

Getting back to the movie for just a moment, we could eat some

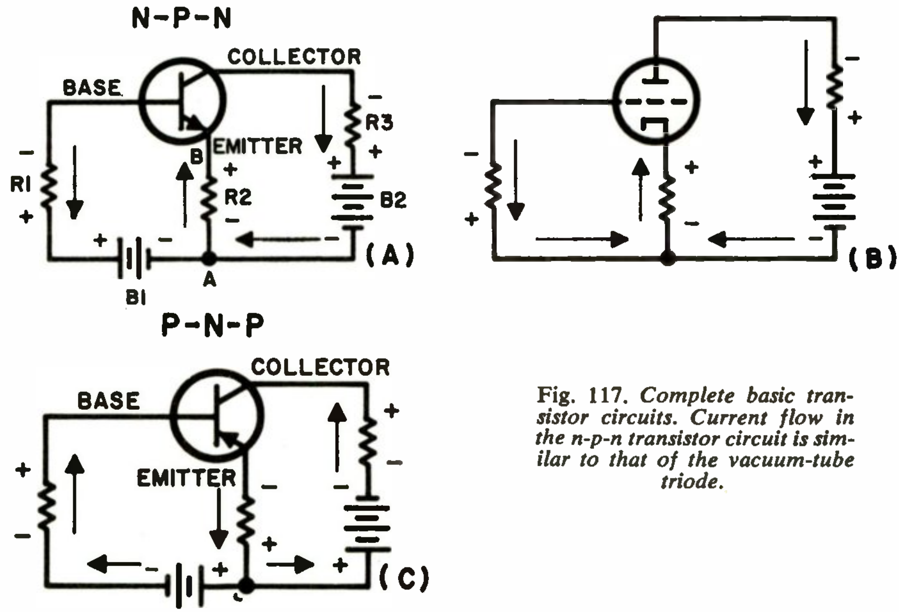



Fig. 117. *Complete basic transistor circuits. Current flow in the n-p-n transistor circuit is similar to that of the vacuum-tube triode.*

candy or other refreshments while watching, so we come out a bit bigger or heavier than when we went in. In a radio circuit this is what we want. We feed in a signal but we're usually anxious to get out a bigger one.

Fig. 118 shows just how we do this. The signal is injected or fed in between the base and the emitter. The output signal develops across the load resistor connected between the collector and the emitter. It is true that we show two batteries but ,with the kind help of a few resistors, we can use just one battery.

Fig. 119 shows the arrangement we have for an n-p-n transistor. Note how much alike Figs. 118 and 119 really are. But are our eyes sharp and our minds clear? What are the differences between the two?

Fig. 118 uses a p-n-p transistor. Note the polarity of the two batteries.

Fig. 119 uses an n-p-n transistor. Once again, note how the batteries are connected.

In certain ways the two circuits are alike. We feed the signal in the same way to both circuits. And we take the amplified signal out in the same way.

To see how very similar the tube and transistor are, let's set them up against each other.

| N-p-n Transistor | Triode Vacuum Tube |
|---|---|
| base current | grid current |
| collector current | plate current |
| emitter current | cathode current |

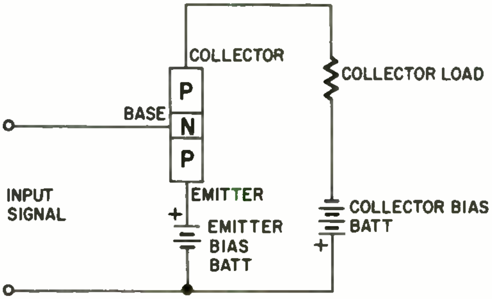



Fig. 118. *Just like a vacuum tube, a transistor triode circuit has an input and an output.*

Not only that, but the currents in both flow exactly in the same direction. What could be easier to remember!

What about the p-n-p transistor? We can't draw an equivalent vacuum-tube circuit for you because there isn't any we know of that

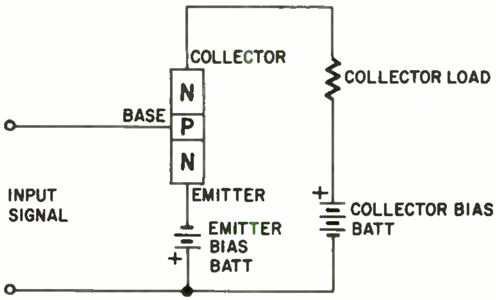



Fig. 119. *When working with transistors, be careful about battery polarity. Compare the battery arrangement shown here with that of Fig. 116.*

acts like the p-n-p. That won't bother us, though. The p-n-p is like the n-p-n but with currents flowing in the opposite direction.

## What about polarity?

We've been telling you this is so easy so often that you probably are beginning to believe it. It is really easy, but don't get the idea that you can know this without doing some working and thinking. Let's work together, then, on the subject of polarity. What about the polarity of the voltage drops across the resistors shown in Figs. 118 and 119? To help answer that question, let's check off the things we should do when working on a transistor circuit:

1. What type of transistor do we have? Is it p-n-p or n-p-n?
2. What part of the transistor is forward-biased?

To see how we go about answering these questions, take a look at Fig. 117-A. How do we know that it is an n-p-n transistor? In no less than three ways: First, the transistor symbol is marked. Next, the arrow of the emitter is pointing outward. Finally, we note that the emitter is connected to the negative terminal of the battery (B1) and the base to the positive terminal.

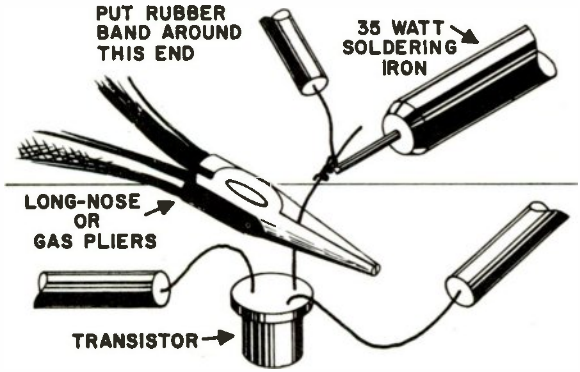



Fig. 120. *A pair of long-nose pliers make a good heat sink. Keep the tip of the iron away from the transistor. A rubber band can be used to hold the jaws of the pliers closed, freeing your hands for other work.*

Add one more little fact, and we have the whole story. Current flows from minus to plus. With all these clues you should never have any trouble in finding the polarity of the voltage across the resistors.

Finally, if you forget, just remember that in an n-p-n transistor the currents flow exactly as in a triode tube. And in a p-n-p unit the currents flow in the opposite way.

## How to handle transistors

All radio components need a certain amount of special handling. You shouldn't mount a wax-filled capacitor right next to a hot rectifier tube—not unless you want a chassis full of wax. You shouldn't connect a power transformer to a dc power line. In the same way, there are certain things we should not do to transistors.

1. Don't use excessive heat for soldering components to tran-

sistor leads. For most work a 35-watt iron is fine. This doesn't mean, though, that you can put the hot tip of a 35-watt iron to a transistor lead and then forget about it. Even with a 35-watt iron, enough heat can accumulate to damage a transistor. It's always best to use a heat sink, as shown in Fig. 120. This can be a pair of long-nose pliers or gas pliers. Kept closed with the help of a rubber band, your hands are free to work.

2. Heat damage is more of a problem with germanium transistors (or germanium diodes and rectifiers) than it is with silicon

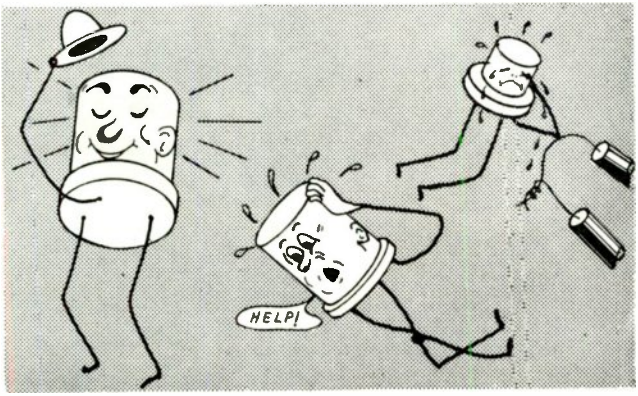



Fig. 121. *Make sure transistor leads don't touch each other or exposed wires of other components.*

units because of the higher permissible temperatures in silicon devices. The leads normally used are either Dumet or Kovar—either of which is a poor conductor of heat. Hence, if the full length of lead (usually about 1.5 inches) is used, and the solder connection is made within a few seconds, no heat "stealing" will be necessary. If the leads are to be short, or if it is necessary to apply the heat for a lengthy period of time (that is, more than just a few seconds), then it may be necessary to use some means of removing the heat which would be conducted by the component leads. Pliers can be used, as shown in Fig. 120, or it might be more convenient to utilize one of the following:

Dental tweezers which can be locked in place (also useful for holding parts together while soldering).

Alligator clips made of copper. If room permits, the normal clip (such as might be found at the end of a vtvm cable) can be used. Should space be limited, it might be necessary to "form" the ends of the clip by squeezing them with pliers or vise. A useful tool can be made by squeezing the clip and then bending the flattened portion at right angles. Or, if you don't wish to bother, you can buy ready-made clips.

Finally, you can wrap the transistor lead in cotton and dampen with water. A slotted felt pad will also work.

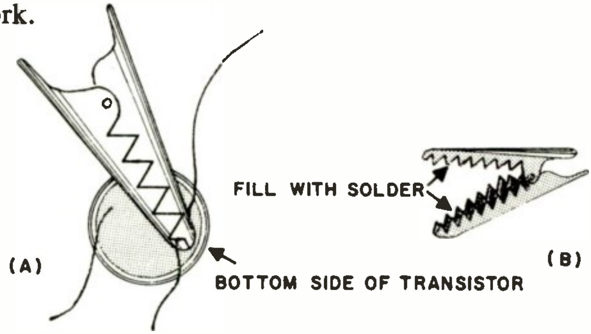



Fig. 122. *Ordinary size alligator clips can short transistor leads. The teeth can also bend and cut the transistor leads. Use small size clips. Fill the teeth with solder and then file the solder until it is smooth.*

3. When replacing a transistor, (if you cannot get an exact replacement) follow the manufacturer's recommendations for a substitute.

4. When checking transistor circuits, remove the transistor if it is mounted in a socket.

5. When putting transistors back into their sockets, make sure the receiver switch is off or the battery is disconnected.

6. If you must remove a transistor from a circuit, make sure the switch is turned off or the battery is disconnected.

7. Transistor leads are usually not insulated. Make sure the exposed transistor leads do not touch or short to each other or to other components (Fig. 121).

8. Do not install a battery whose voltage is higher than that of the original. A higher voltage does not mean the set will play louder. It does mean that you may end up with a handful of burned-out transistors.

9. Transistor leads can sometimes be damaged by alligator clips. Some clips have a very strong spring tension. To avoid damage fill the jaws of your test clips with solder (Fig. 122). File the solder until

the jaws can close smoothly. Select small-size clips for this modification. Large clips are often too big to work in the small space inside a transistor receiver. (These modified clips can also be used as heat sinks).

## The p-n-p amplifier

We can learn just a bit more about transistor amplifiers by looking at the circuit shown in Fig. 123. In the next chapter we are going to have another circuit, similar to this one, but at that time we will analyze it from a servicing viewpoint.

Unlike the usual vacuum-tube amplifier, this transistor circuit has a low input impedance and higher output impedance.

The input, or base-to-emitter circuit, has two components; one is C1, a 1-$\mu$f capacitor. This may seem like a fairly high value for a coupling unit but the reactance of this capacitor must be very low at audio frequencies. Bias voltage is applied to the base through R1.

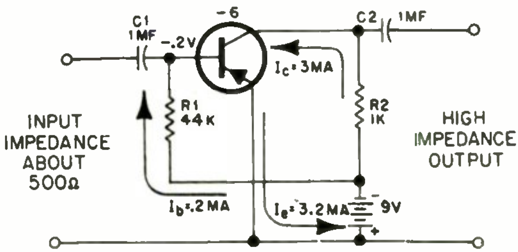



Fig. 123. *P-n-p transistor amplifier circuit. The voltage and currents are small.* (Admiral Corp.)

The output, or collector-to-emitter circuit has a 1,000-ohm resistor R2 and the output coupling capacitor C2.

What sort of currents can we expect? The base current is 0.2 milliampere (200 microamperes), while the collector current is 3 milliamperes. But what about the emitter current? This is the sum of the base and collector currents, or, in this case, 3.2 milliamperes.

## Voltage measurements

Note the voltages marked on the collector and base in the diagram (Fig. 123). We have −6 volts on the collector. But the battery is rated at 9 volts. Where have we lost 3 volts (the difference between the battery voltage and the voltage on the collector)?

We can find the lost voltage easily enough by using Ohm's Law:

$E = I \times R$. Since the collector current is 3-ma and the collector load resistor is 1,000-ohms the voltage drop across R2 is:

$$E = I \times R$$

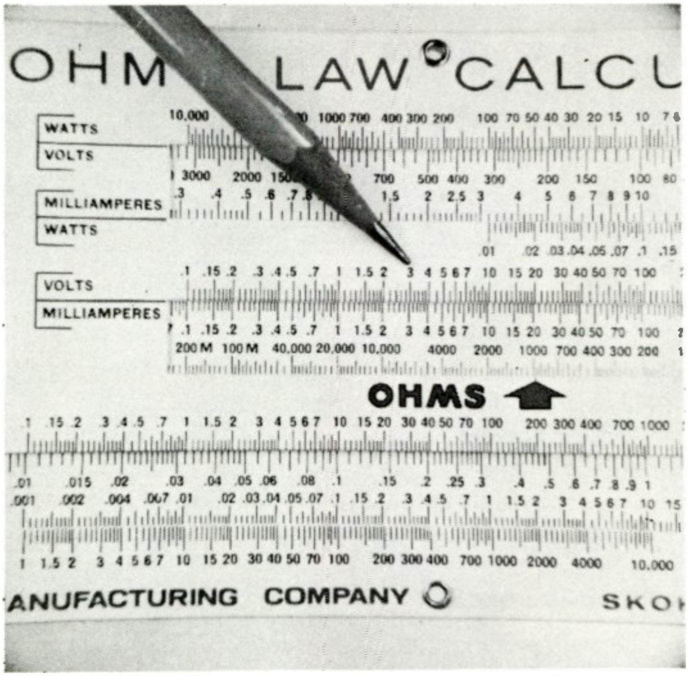
$$E = .003 \times 1{,}000 = 3 \text{ volts}$$

We can also find the voltage at the base by multiplying the base current by the value of R1.

Now what about the voltage at the emitter? This is usually very close in value to the base voltage, differing from it by just 0.1 or 0.2 volt. For example, the voltage on the base might be −0.1 volt.

## Voltage polarity

You've probably noticed that the voltages on the base and collector of this p-n-p transistor are negative. Is something wrong? Aren't we supposed to have a positive voltage on the emitter? Yes,




*If Ohm's Law calculations are difficult for you, use a special slide-rule. With any two known values the third can be found easily. Set 1000 over the Ohms arrow and 3 volts is found over 3 milliamperes (ma) as indicated by the pencil point. Wattage for the resistor (less than .01) is found under 3 ma on the next scale above.*
(Ohmite Mfg. Co.)

we are. Definitely. But positive with respect to what? Positive with respect to the base. If we have —0.1 volt on the emitter, we have met the requirement! —0.1 volt is less negative than —0.2 volt. Another way of saying exactly the same thing is to say that —0.1 volt is more positive than —0.2 volt.

Actually, though, the voltage on the emitter is zero, as shown in

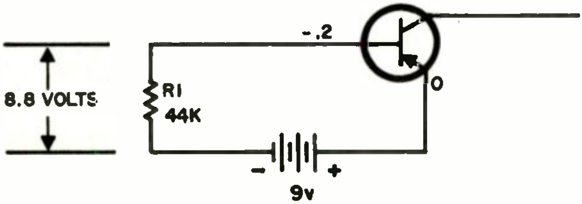



Fig. 124. *The base is negative with respect to the emitter by a small fraction of a volt.*

Fig. 124. By itself zero is just that—nothing. But we cannot consider it that way. We must consider zero with respect to the base. The base is more negative than the emitter by —0.2 volt. This is the same as saying that the emitter is more positive than the base by this amount.

Fig. 124 also shows how we get 0.2 volt for the base. We drop 8.8 volts across R1, the 44,000-ohm resistor.

## QUESTIONS

1. If the direction of current flow through a resistor is known can the polarity of the voltage across that resistor be found?
2. Do the *electron* currents flow from plus to minus within the battery?
3. Is the ground always the reference point in every electronic circuit?
4. Do all voltages have polarity?
5. Should the base-emitter circuit of a p-n-p transistor be forward-biased?
6. Should the base-emitter circuit of an n-p-n transistor be forward-biased?
7. What is the point from which almost all voltages are measured?
8. Do reverse-biased circuits have heavy current flowing through them?
9. Are all voltages positive with respect to the point from which they are measured?
10. What are the names of the three active parts of the transistor to which leads are connected?

CHAPTER 2

# testing transistors and printed circuits

DID YOU EVER watch a really good magician go through his routine? You know you are being fooled and it looks very mysterious. But to the magician it's old stuff. While he's doing his act he's probably thinking of a dozen different things that have nothing to do with magic.

In the first chapter we tried to take some of the mystery out of transistors. Now that you know how the electron currents flow, and the different polarities at the elements of the transistor, you will feel more confident when working on transistor receivers.

## Things to remember

Always remember:

You cannot treat the transistor like a tube.

You must adapt your servicing techniques to the transistor.

You must get used to working with smaller parts in smaller spaces.

## Checking transistors

What do you do if you want to test a tube? You can probably think of two ways immediately. Try the tube in a receiver. This is called the tube-substitution method. Or else you can use a tube tester.

Transistors are no different. If you want to know if a transistor is any good, try it in a set. Or else use a transistor checker.

Now all this sounds very nice, but is it practical? Are there any problems in the way? Let's see what they are.

To say that transistors and tubes are alike is like saying that, if you can drive a sports car, you can also drive a truck. Maybe. Just as cars and trucks are alike in some ways (and different in many others) so are transistors and tubes alike—yet different.

Here's our first problem in checking transistors. If the unit is soldered, removing it might mean damage to the transistor or to the printed-circuit board to which it is soldered. What we need to learn, then, is how to check transistors in the receiver.

## In-circuit transistor testing

Before we go one more step, we must tell you that *you know how* to test transistors while in the circuit.

To show that we mean what we say, let's look at Fig. 201, an n-p-n transistor circuit. Is the transistor working? You can't tell by looking at it, but we have a better way.

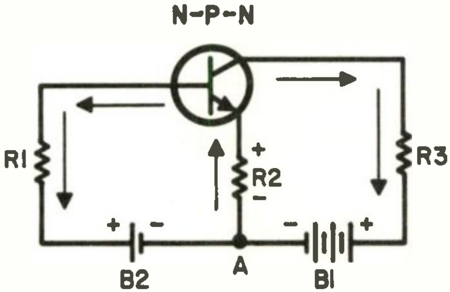



Fig. 201. *The first step in servicing is understanding the circuit.*

You'll need a vacuum-tube voltmeter for some of the tests. Suppose we start with the n-p-n transistor. There are quite a few checks we could make, but an easy one would be the voltage drop across R2, the emitter resistor. We know the polarity, so that's no problem. And the manufacturer's schematic will tell how much voltage to expect.

We've got three kinds of parts in Fig. 201—a transistor, some resistors and a pair of batteries. The only components that could possibly supply any current are the batteries.

Consider battery B1. How do we trace its path of current flow? This is easier than taking a walk around the block. There's no excuse for getting lost. We start—you guessed it—at the negative terminal of B1. We move along to point A. We go up through resistor R2 to the emitter of the transistor.

Now what about battery B2? Again we start at the minus terminal and move over to point A. Where do we go from here? Right up through emitter resistor R2.

If you think R2 is a favored resistor, you're absolutely right. It has the currents of the two batteries flowing through it.

What happens to our two currents? You don't have to worry about them because we aren't going to lose a single electron. Part of our current will come back through the base, and then through

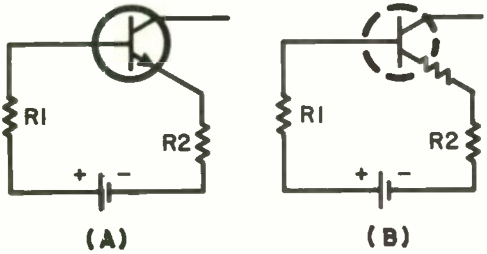



Fig. 202. *Transistor in circuit (A) can be replaced by a resistor in the simple series equivalent circuit (B). If the value of the base-to-emitter resistance decreases the current flowing through R1 and R2 will increase.*

R1. The remainder of the current will go through the collector, through R3 and back to battery B1.

## What if?

At this point, the almost instinctive protest is, "But what if . . .?" All right . . . what if? What if we get no voltage at all across R2? What if the voltage across R2 is too small?

## What could be wrong?

Suppose we start with the first question. What if we get no voltage across R2? What could be wrong?

Our first thought might be to suspect the batteries. We have two of those, though, so wouldn't it seem rather odd for both of them to become bad at the same time? Also, batteries don't give up quite so easily as you might imagine. Given a little rest, even a dead battery manages to push some current along.

Next we have the resistors. But which one of them? All three? Again, wouldn't you say that this would be very unlikely? Resistors can and do open, but how often do you think all the resistors in a circuit open at the same time?

Let's ask ourselves one last question. Through which part or parts must all of the current flow? Aren't there only two such parts —the transistor and R2?

Now that we have suspicion pointing in the right direction, what do we do next? Unsolder the transistor and then test it? That's quite a lot of work and could result in some damage. Wouldn't it be easier to make sure by checking the resistor?

We know—and you certainly do—that a resistance test is the easiest check to make. Before we rush ahead with our ohmmeter and its test leads, though, isn't there something we've forgotten? The resistor is in a circuit and up to now the circuit has been connected—it is live. You could argue that no current is flowing through R2 anyway, but why take a chance? Make sure. Turn the battery switch to the off position or else remove at least one lead to each battery.

We now have several possibilities. The resistor could be open or it could have increased to a very high value. In either case, we would have a higher than normal voltage across R2.

Is this the only possibility? Not quite. The resistor could be shorted. Again the answer is simple: replace the resistor.

But what if the resistor is good? What then? All we have left is the transistor. Wouldn't you say that this is exactly the opposite of the way in which we work with tube radios? In a radio set using

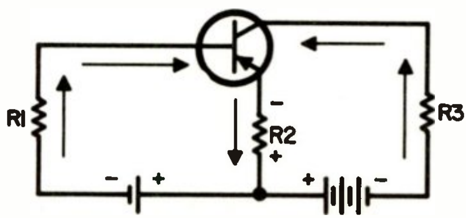



Fig. 203. *The p-n-p circuit is the same as the n-p-n. Note, though, that the batteries have been turned around. As a result, the current flows in a direction opposite to that of Fig. 201.*

tubes, the first thing to do is pull the tube out, substitute a new one for it or else test the suspect in a tube checker.

In a transistor radio, though, the transistor is the last item to check. Who would have thought that something that looks so delicate and tiny as a transistor could live longer than the other parts! It just shows you how all of us can make a wrong guess.

### Some more troubles

What else could happen to our transistor circuit in Fig. 201? We could have much more voltage across R2 than the schematic calls for if too much current is passing through R2.

Stop and think for a moment. What controls the flow of current in a circuit? Voltage and resistance? Right! We certainly can't expect the battery voltage to increase because dry-cell voltage can go in only one direction—down. Look at Fig. 202. What if the transistor were leaky or shorted from base to emitter? Wouldn't this be the same as a resistor whose value has gone down?

If we replace the base–emitter circuit with a resistor, we can see

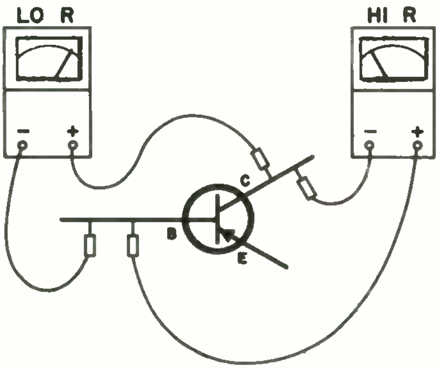



Fig. 204. *How to make a forward and reverse resistance check between the base and collector of a p-n-p transistor. Only one ohmmeter is used. It is shown in two different positions.*

right away how simple the circuit becomes. We have a battery and three resistors in series. If any of the resistors decrease in value, the current will go up. But if R1 and R2 test good, then what? We could suspect the transistor right away.

## Other measurements

While we have our vacuum-tube voltmeter handy, there are other checks we can make. We can measure the voltages across R1 and R3. We can measure the battery voltages under load. We can measure the voltage between base and emitter and between collector and emitter.

Don't be bothered by the fact that we have been working with an n-p-n transistor. The same tests apply to the p-n-p unit shown in Fig. 203. Remember *all* polarities will be reversed.

## Checking transistors out of the circuit

Just as we have tube testers, so too do we have transistor testers. But every piece of test equipment has its limitations and this goes for both tube and transistor testers.

Before we use a transistor tester, let's ask ourselves this question, "What do we expect out of a transistor?" You can give the answer in just one word—gain. We could use a larger word—amplification—but it would mean exactly the same. We want to put a small signal into the transistor and get out a bigger one.

What is our problem in working with transistors? Part of the question is a matter of frequency. Transistors work at different frequencies. We are going to want some of them to work at

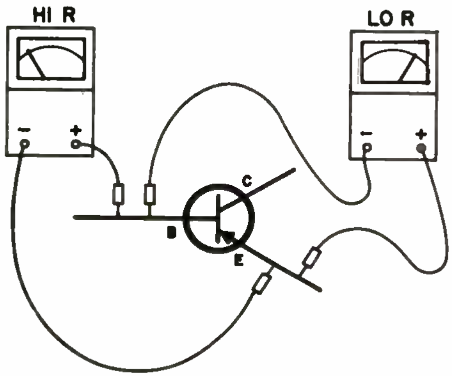



Fig. 205. *How to make a test between base and emitter of a p-n-p transistor.*

rf-signal frequencies; others to work as local oscillators, some as intermediate-frequency amplifiers and some as audio amplifiers.

Let's be practical! What does all this mean to us? Simply this! The fact that a transistor will work with dc voltages applied to it doesn't mean that it will work at 455 kilocycles. And if it works fine at 455 kc, what guarantee have we that it will do well as a local oscillator at 2,000 kc?

Does this mean, then, that transistor checkers are no good? That we shouldn't waste money on them? Not at all! They are fine if you know, understand and appreciate that, like tube testers, they have their limitations.

## Resistance-checking transistors

What have we around the shop that can be put to work testing transistors? How about that old standby, the multimeter? It has a small battery in it that's just about right for the job.

It shouldn't come as a shock that we can check transistors with the resistance section of a volt-ohm-milliammeter. All along we've been claiming that a transistor is nothing more than a couple of diodes.

Figs. 204, 205 and 206 show how to make resistance checks of a transistor. Have you noticed anything unusual or different? What about the base lead in each of the three drawings? Isn't it the only element that always has a test lead connected to it? What's the reason? The base is our reference point and all our resistance measurements—and we mean *all*—are made with respect to the base.

Let's star with Fig. 204. The position of the arrow on the emitter tells us that we have a p-n-p unit on our hands.

Look at the ohmmeter on the left-hand side of Fig. 204. The

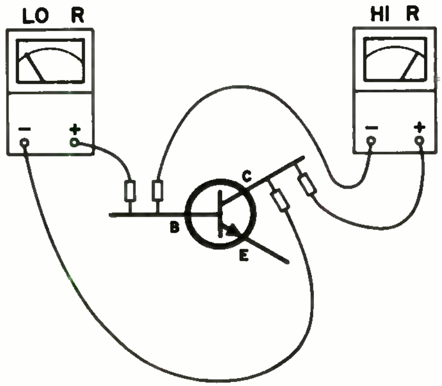



Fig. 206. *How to make forward and reverse resistance tests between base and collector of an n-p-n transistor.*

plus lead of the meter is attached to the collector and the minus or negative lead connected to the base. (The test leads must be checked to find out which connect to the plus and minus terminals of the battery inside the instrument.) The meter indicates a low amount of resistance.

How much resistance is low resistance? That depends on the transistor. Generally, you can figure on 40 to 50 ohms but please don't throw the transistor away if it reads 100 ohms. In some cases, the forward resistance (which is what we are measuring) will be as high as 500 ohms.

Our next step is to transpose the meter leads, as shown in Fig. 204: *we are not using two meters.* All we have done is shift the test leads.

We now have connected the positive lead to the base and the negative lead to the collector. Because the voltages are "wrong" for this part of the transistor, we are measuring the "reverse" resistance. The amount of resistance will vary from one transistor to the next, but anything over a megohm (1,000,000 ohms) can be considered good.

### The resistance ratio

We don't like to ask you to do arithmetic and we're going to try to avoid it as much as possible. However, just a little bit of it will come in very handy right now.

All you have to do is to divide the reverse resistance by the forward resistance. Suppose the transistor you check has a reverse resistance of 1,000,000 ohms and a forward resistance of 500 ohms. Divide the larger number by the smaller one. In this case we have:

$$\frac{1,000,000}{500} = 2,000$$

If you do the test and then the arithmetic, any answer you get that is above 100 would mean you have a good transistor. The number will usually be much higher than 100, just as in the sample problem.

Now that we've made a check between base and collector, make the same sort of test between base and emitter. This is shown in Fig. 205.

Test n-p-n transistors in exactly the same way (as shown in Figs. 206 and 207).

To help in making these tests, use Table I as a reminder on how to connect the ohmmeter and the results you should expect. The plus and minus signs in the table are same as the plus and minus signs marked on the meters in Figs. 204, 205, 206 and 207.

TABLE I

RESISTANCE CHECKS OF TRANSISTORS

| | | | resistance | |
|---|---|---|---|---|
| Base | Emitter | Collector | p-n-p | n-p-n |
| − | + | | low | high |
| + | − | | high | low |
| − | | + | low | high |
| + | | − | high | low |
| | − | + | high | high |
| | + | − | high | high |

We've added just one test to this chart that we haven't mentioned. This is the resistance check between emitter and collector. This shows a high resistance no matter which way we connect the test leads.

The resistance method of testing transistors gives a reasonable assurance that the transistor is good. This isn't quite the same thing as an iron-clad guarantee. All the test does is measure the two diode sections of the transistor.

Just one more word of caution: Some transistors have voltage and current ratings below that supplied by the ohmmeter. The maximum voltage across the test leads should be 3 volts. Make sure you know which is the plus lead and which is the minus lead of the meter.

When making the test, set the instrument on its highest resistance range. If it does not use more than 3 volts, turn the range control knob to a lower range until you get a deflection on the meter you can read easily. It isn't safe practice to go below the R × 10 range.

### In-circuit testing

Do you remember the first time you sat behind the wheel of a car?

Didn't it seem to you as though the street had suddenly become crowded with cars? Didn't you wonder whether you were ever going to learn how to read road signs, watch for pedestrians, look

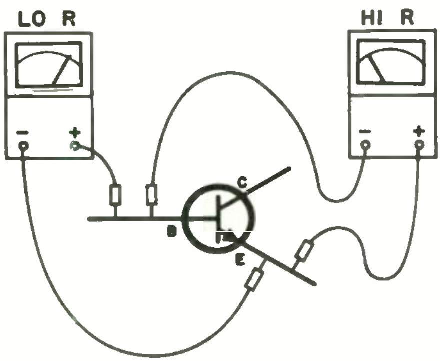



Fig. 207. *Connections for forward and reverse measurements between base and emitter of an n-p-n transistor*

out for traffic in front of you, alongside you, in back of you, and maybe shift gears too? And didn't you also wonder at other drivers doing all this so easily . . . almost without trying?

Working with radio receivers is like learning to drive. It takes a lot of instruction but, before you realize it, you've managed to pack away all the information, all the advice, all the do's and don'ts, and are busy servicing.

*There was once a technician who cried*
*"Every test you can name I have tried."*
*But the man was a boob,*
*Handled a transistor like a tube*
*So the transistor curled up and died.*

What is the best way to test a transistor? Right in the receiver with all of the voltages applied. No matter what we do, aren't we going to put the transistor back into the set sooner or later? We'll have to do this if we want the set to play.

We're going to find that transistor testing (and by this we mean circuit testing also) has certain advantages over tube testing. The voltages are low. We don't have to worry about a "hot" chassis or accidentally touching high B-plus voltages.

Does this mean we aren't going to have any problems? We managed to get quite a few advantages, but we've also managed to bring along a few new difficulties. We're going to be working in tight spots. Most transistor sets are compact. And we'll have to avoid shorting transistor leads to the common B-line to avoid damaging the transistor.

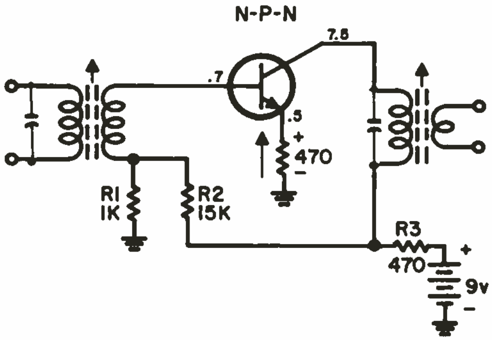



Fig. 208. *Simplified intermediate-frequency circuit of a transistor receiver.*

## Transistor testers

Just as we have tube testers of all sorts, so too do we have transistor testers. Some are very simple and do nothing more than give you some indication of the forward and reverse resistance of a transistor. Other transistor testers measure gain, shorts, etc.

A transistor tester will measure for leakage much in the same way as your vtvm. It will test both n-p-n and p-n-p transistors at the flick of a switch. Leakage is indicated as GOOD, FAIR or BAD and not in OHMS as the vtvm does.

## Let's get busy

In Fig. 208 we have a basic if (intermediate-frequency) stage. Let's see what measurements we can make. What do we do first? We must decide what sort of transistor we have. Is it p-n-p or n-p-n? Our emitter arrow tells us at once that we have an n-p-n transistor. Next, find the reference point. In this case, the reference point, as shown by the ground symbol, is very clear.

Do you see the voltages marked near the transistor leads? These are very important. The manufacturer is trying to tell us that if we have these voltages, the stage should be in working order.

But what are these voltages? How did we get them and how do we measure them? And what sort of voltages are they—positive or

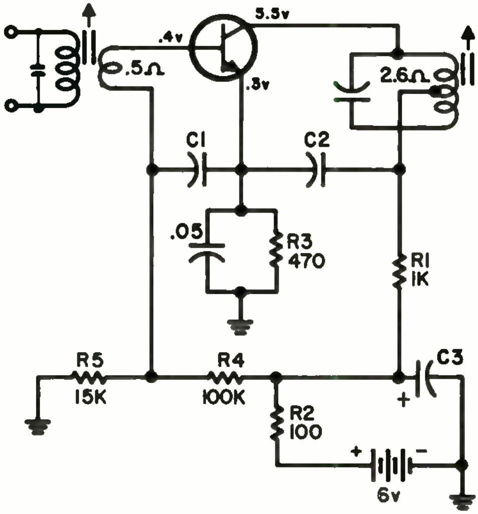



Fig. 209. *Ohm's Law can be used just as easily in transistor sets as in vacuum-tube radios.*

negative? Now the manufacturer isn't always going to tell us whether these are positive or negative. That may be up to us to figure out.

Look at the emitter. You will see that it is connected to the emitter resistor. Current flows up through the emitter resistor, making the emitter positive with respect to the ground. By how much? The circuit gives you that information. It's + 0.5 volt.

The base is marked 0.7 volt. Is this positive or negative? There are two ways of knowing. First, we are sure it is *positive* because, in an n-p-n transistor amplifier circuit the base is always positive with respect to the emitter.

Now what about the collector? Again we have two ways of knowing the polarity. In an n-p-n transistor amplifier circuit the collector is always positive with respect to the emitter. We can trace the collector circuit back to the positive terminal of the battery.

Let's list what we know about this circuit:

1. The emitter is 0.5 volt plus with respect to ground or the negative side of the battery.
2. The base is positive with respect to the emitter.
3. The collector is positive with respect to the emitter.

## Making voltage tests

Suppose we wanted to make some voltage tests, how would we go about it? With the receiver turned on:

1. Set the vtvm to its lowest *plus* dc voltage range. Connect the probe to the emitter and the common lead to the negative terminal of the battery or to ground. You should read +0.5 volt.
2. Keep the common lead of the vtvm connected to the negative terminal of the battery. Connect the probe to the base. You should read +0.7 volt here.
3. Now set the vtvm range selector to a scale that will read about 10 volts full scale. Touch the probe to the collector. This should be +7.5 volts.

Normally the + is not indicated. Any voltage not preceded with a minus (−) sign is positive (+) in relation to the reference point.

## And still more tests

You could also measure between base and emitter of the transistor.

4. Connect the common lead of the vtvm to the emitter and the probe to the base. (Remember—the base is positive with respect to the emitter.) You should read the difference between 0.7 and 0.5 volt, or 0.2 volt. (All we did was to subtract 0.5 from 0.7.)
5. You could also measure the voltage between collector and emitter. Put the probe of the vtvm on the collector lead and the

common lead of the meter on the emitter. Here you should get a reading of 7 volts. Note that this is the difference between 7.5 and 0.5 (that is, 7.5 minus 0.5 volt).

### Was that too easy?

The circuit in Fig. 208 was stripped for action. We omitted some of the parts to make it easy for you. But now that you have the general idea, let's move on to a complete circuit, such as the one in Fig. 209.

Start with the voltage on the collector. Here we have 5.5 volts. From the collector move along the wire until you come to the if transformer. From here travel through the 1K (1,000-ohm) resistor (R1), through the 100-ohm resistor (R2) until you arrive at the plus terminal of the battery.

What have we learned? The voltage on the collector is plus or

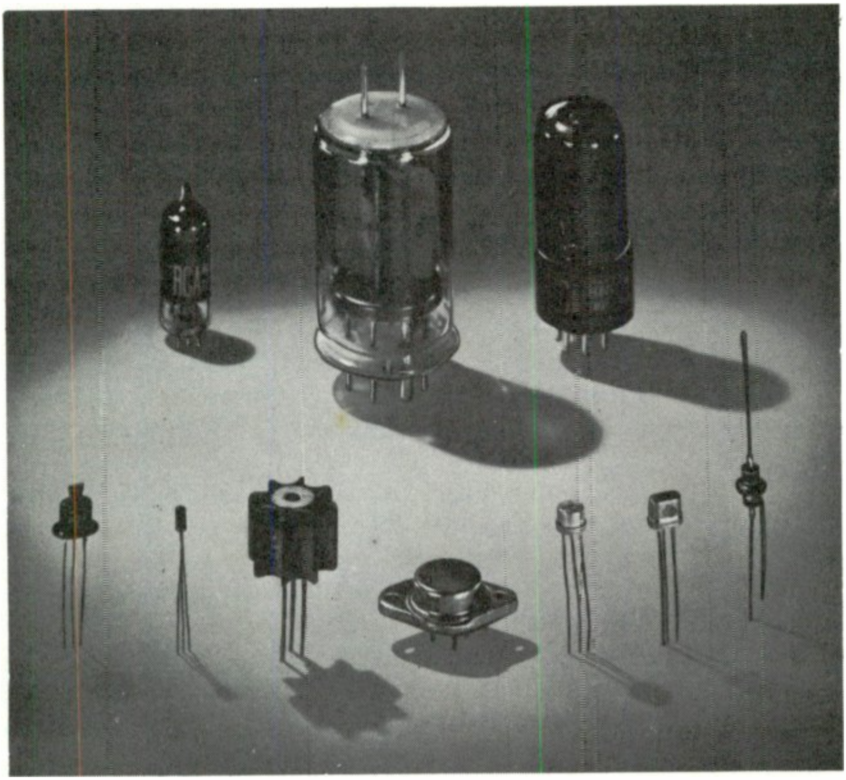



Fig. 210. *Because of their size, transistors make very small receivers possible.*

positive 5.5 volts. Positive with respect to what? Positive with respect to ground or the minus side of the battery.

Why is it that we have only 5.5 volts at the collector? Isn't the battery voltage 6 volts?

In taking this little trip, you went through R1 and R2. Current flowing through these resistors gives a voltage drop. We've lost half

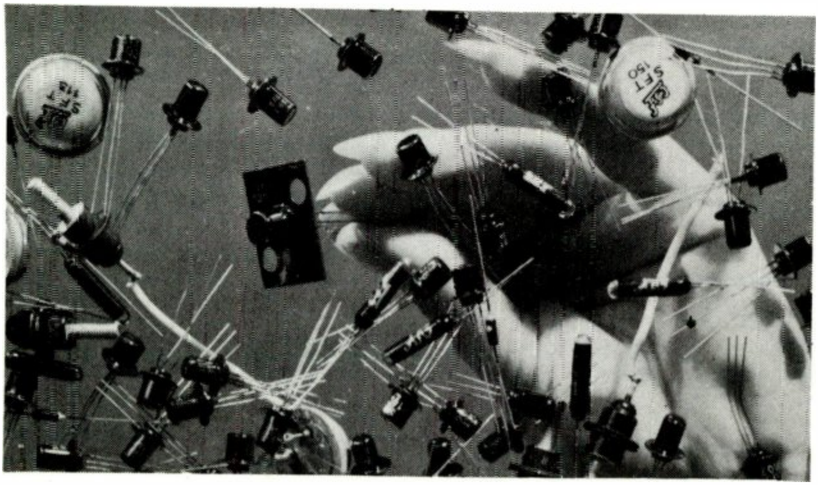


Fig. 211. *These are just a few of the numerous semiconductor types.* (Intercontinental Electronic Corp.)

of 1 volt. Most of the missing 0.5 volt appears across R1 as a voltage drop.

## Practical tests

There are quite a few tests we can make in the collector circuit. We can measure the collector voltage. The collector is 5.5 volts plus with respect to ground. We can check this with a vtvm very easily.

What other tests can we make in the collector circuit? How about measuring the voltage drop across R1? This voltage doesn't appear on the circuit diagram, but it must be very close to 0.5 volt.

Could we measure any voltage across R2? R2 is only one-tenth as large as R1. This means that it will have only one-tenth of the voltage across R2. But R2 has less than 0.5 volt, so do you think we would measure anything across R2? The amount is so small a meter needle will barely move.

## Some more "what-if's"

What if you measured the voltage at the collector and found that it was 6 volts? What then? Wouldn't this indicate no current flowing through the transistor? To check this, make a voltage measurement across R1! We're supposed to lose about 0.5 volt there. Our vtvm across R1 proves what we suspected—that no current is flowing through R1.

Let's follow through. We have a full 6 volts on the collector and no voltage across R1. What is the trouble? Should we replace the battery? Wouldn't that be useless? We are getting a full 6 volts. Should we measure the battery voltage? Again, wouldn't that be a waste of time? We did measure the full voltage at the collector and that should be enough.

Could it be an open circuit somewhere between collector and battery? Again we must rule this out since we're getting voltage at the collector.

It is possible that R1 is completely shorted, but this is not too likely. What about the if transformer? Since this is in series between the battery and the collector, we can rule out the possibility of its being open.

What if C2 were open? That certainly wouldn't prevent current from flowing in the collector circuit. What if C2 were shorted? If that were the case, then we would get no voltage at the collector and almost a full 6 volts across R1.

Where do we go from here? There are two possibilities. The transistor might be biased beyond cutoff. Another possibility is that the emitter resistor, R3, might be open.

This may seem a little odd, so let us consider it for a moment. If R3 is open, all action stops. No current flows to the base or to the collector.

## The emitter circuit

In Fig. 209 we show 0.3 volt at the emitter. Where does this come from? By now you're probably reaching for your hat ready to take another trip with us. As usual, when we go on these hunting trips our big "game" is the battery. The easiest path to the battery is down through R3 to ground. But ground is connected to the negative terminal of the battery. That was a short trip.

This still doesn't answer our question about the 0.3 volt at the emitter. The problem is solved, though, when we ask ourselves, "How does the electron current flow?" Always minus to plus. Our current begins at the negative terminal of the battery and moves through R3 to the emitter.

In passing through R3, we get a voltage drop of—you guessed it—0.3 volt. What the manufacturer is trying to tell you is that, if you make a measurement across R3, you should read 0.3 volt.

What else does Fig. 209 tell us? The base is marked 0.4 volt. If we're going to service transistor circuits quickly and easily, we should know what this voltage is and how we got it.

We can get the answer by tracing the circuit. We start at the base and move through the low-resistance secondary winding

Fig. 212. *Printed-circuit boards come in a large variety of sizes and shapes. They are used in AM, FM and TV receivers, test equipment and components like rotary switches, commutators, loop antennas, meter coils and motor armatures.* (Keil Products)

(marked 0.5 ohm) down to the junction of R4 and R5. But what have we here? Wouldn't you say that R2, R4 and R5 form a voltage divider connected across the battery?

There is something else. The base lead is "tapped up" on this voltage divider. Since ground is our reference point, the tap at the junction of R4 and R5 is positive with respect to ground. This means that the base is also positive with respect to ground.

## Adding up the answers

What have we learned about the transistor's voltages? All of the transistor's voltages are positive. But this is an n-p-n transistor! Isn't the emitter of an n-p-n transistor supposed to be negative? We can answer both questions easily enough. The emitter is positive with respect to ground and it is negative with respect to the base.

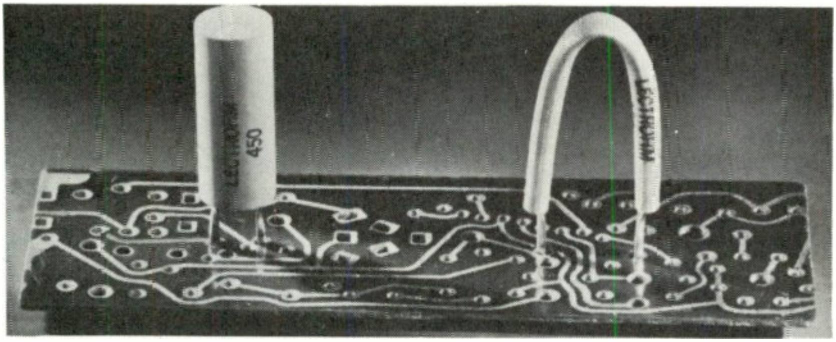
## A little comparison

As soon as transistors reached commercial production, there was a rush to manufacture small receivers. This had been tried earlier with vacuum tubes, but even miniature tubes are much bigger than transistors. Together with printed-circuit boards, transistors made a combination that produced radios that could fit into a pocket or purse.

To get an idea of the size of transistors compared to tubes, look at Fig. 210.

## How many?

About 40 years ago, there was no such thing as a tube manual. Tube types were so limited that they could easily be remembered.




*Special shaped resistors make it easier to bridge portions of printed circuit boards. Wire-wound resistors like these are mounted above phenolic board to prevent possible heat damage.* (Lectrohm Inc.)

As time went on, though, so many tubes were developed that technicians just couldn't work without a tube manual.

Today we have the same situation with transistors. There are actually hundreds of types, only some of which are shown in Fig. 211.

## Printed circuits

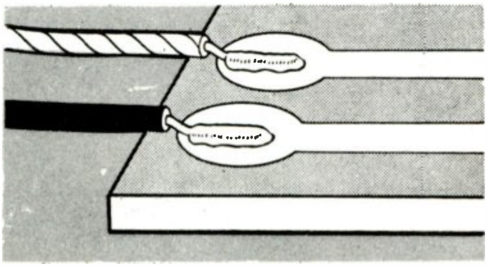
You've probably heard arguments about printed circuits and whether they should be put in receivers or not.

Our job, though, isn't to get mixed into any discussion about it. The fact is that tremendous quantities of receivers are being manufactured with printed-circuit boards—and these will need servicing.

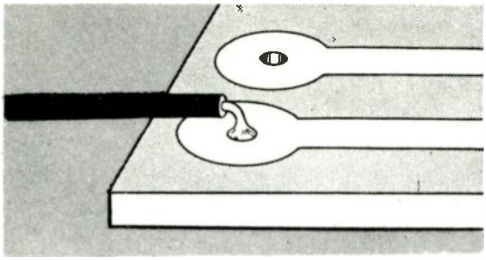
## What is a printed-circuit board?

A printed-circuit board consists of a plastic sheet with copper foil bonded to one or both sides. The board replaces most of the wiring in the receiver.

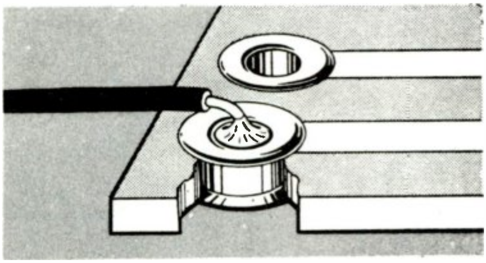
Quite often, a panel component, such as a volume control, will be mounted on the board. You will find parts, though, which are connected to the printed-circuit board through flexible wiring. Here again, variety is the rule. On this and the facing page are some methods for connecting these wires to the board.



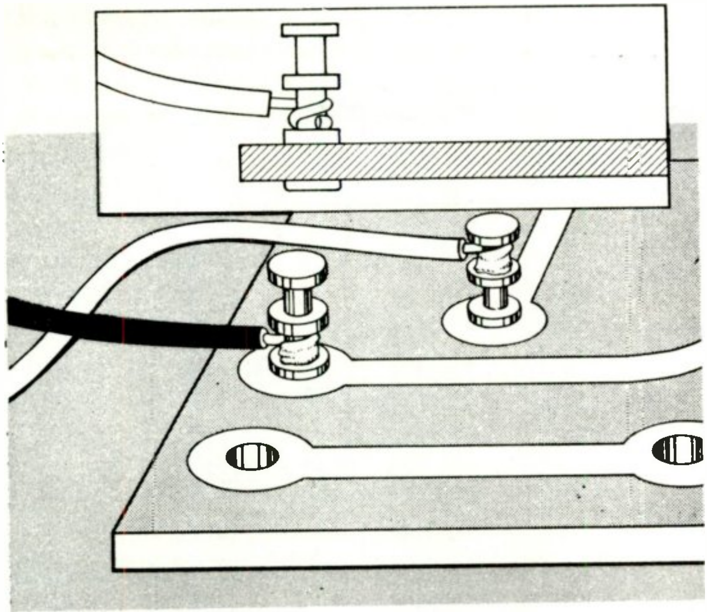
Direct soldering of leads to printed wiring is a simple, low-cost method of attachment. No drilling or slotting of the board is required. This type of connection does not provide a good mechanical connection. Also, repeated heating and removal of leads causes the printed circuit to separate from base material.



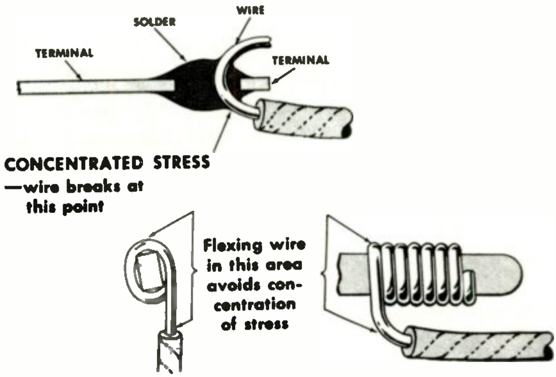
Tinned leads soldered in drilled holes eliminate the need of an electric connector, but the mechanical connection is poor.



Leads soldered in eyelets, which are swaged in printed-circuit boards, provide a good electrical contact and a low-cost connection. Here, too, it takes time to attach and remove leads.
*(Machine Design — Penton Publications)*



Terminals swaged to printed boards offer good mechanical and electrical connection with soldered-lead connections. This design allows termination of leads from areas of the board other than edges.
*(Machine Design — Penton Publications)*




Wire-wrap terminal connections are not soldered unless they are disturbed. Power-tool forms connection faster than soldering.
*(Gardner-Denver Co.)*

Printed-circuit boards are used in all types of equipment, small and large, transistor and tube. A few of the boards that you may meet in servicing are shown in Fig. 212.

Radio components—tubes, transistors, capacitors, resistors and

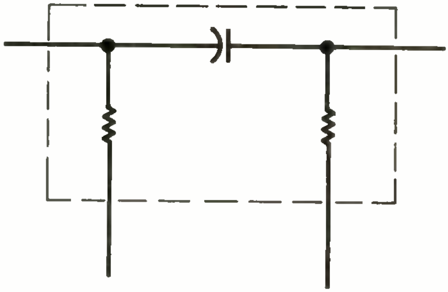


Fig. 213. *Circuit of a printed-circuit resistance-coupled unit. When you see the dashed lines around a component of this type in a circuit diagram, you will know that it is to be handled just as though it were a single component.*

coils—are usually mounted on one side of the board and then soldered into position. Once this is done, the radio part is automatically connected into the circuit by the copper foil molded into the board. We can regard the printed-circuit board as the chassis on which we mount parts. In working with printed-circuit boards (just as in working with transistors for the first time), we must learn special techniques and methods. These aren't difficult. All we need to remember is that there is a big difference between an aluminum chassis and a printed-circuit board. (Even the wired connections, as shown on pages 1-48 and 1-49, are different.) What is good for one will not do for the other.

## Printed-circuit components

In some receivers, you will find groups of parts molded into a single unit. For example, we could have the two resistors and capacitor of a resistance-coupled amplifier (Fig. 213). This unit is then regarded as one component even though it contains three parts. Thus, instead of replacing one part, you replace a whole section.

Printed-circuits come with many combinations of components. Some have groups of resistors only. Others have resistors and capacitors (Fig. 214). Some of them even have tubes or transistors.

## Soldering

You can replace components on a printed board very easily if you are careful not to use too much heat. Excessive heat will cause the conductor to break its bond to the board. This means that you should avoid the use of large soldering irons. In an emergency you can adapt your present heavy iron to printed-board work by wrapping some heavy copper wire around the metal body of the iron. Tin the end of the copper wire so that it will act as a soldering-iron tip.

If you would rather use your iron without modifying it, put a light bulb in series with it as shown in Fig. 215. Experiment with different sizes of bulbs until you get one that suits. Generally, the heavier the iron (larger wattage rating), the larger will be the wattage of the series bulb. Temperature-controlled irons are also available.

There will be times, though, when the conductive foil on the

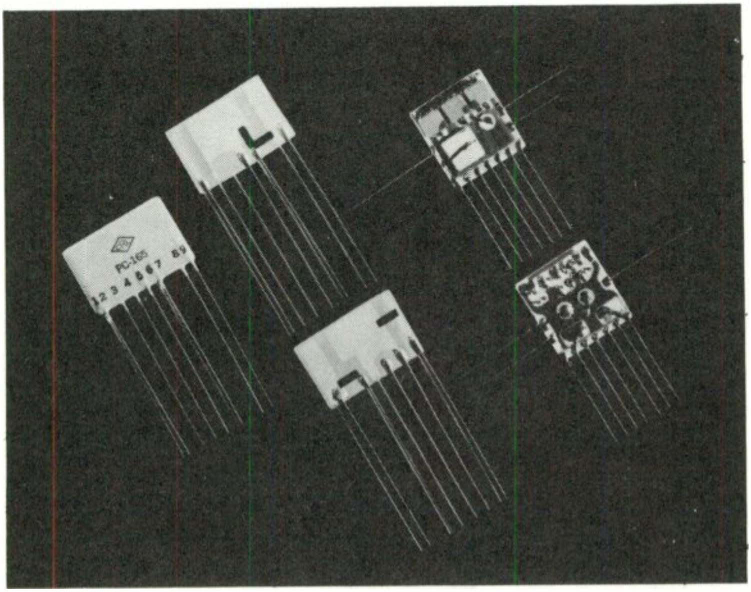
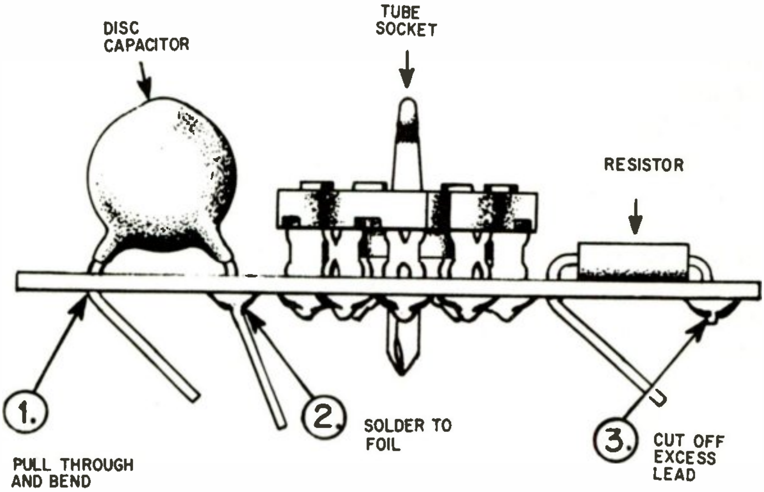
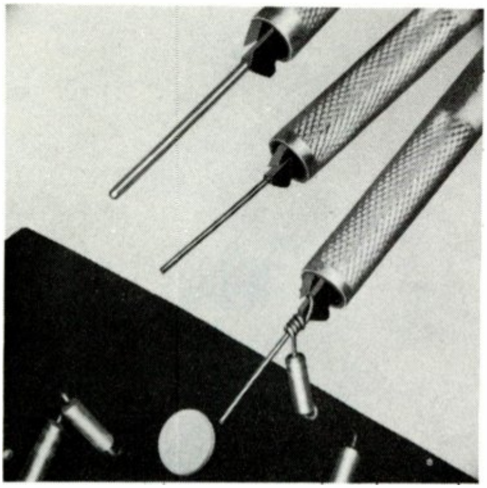



Fig. 214. *Some of the component printed-circuit modules have quite a number of parts mounted in them.* (Centralab)

printed-circuit board will come loose. You may have a defective board or you may have applied too much heat. When this happens, clip the defective section and replace it with a short section of wire as shown in Fig. 216.




Mounting components on the P-C board is simple and neat when done properly.
*(Knight Electronics Corp.)*



These special tools are used to form loops in the ends of replacement components that fit over the remaining lead ends when components are cut from a printed-circuit board. Old lead ends are straightened and inserted into center of coiled lead of new components
*(Twirl-con Tools)*

## Replacing resistors and capacitors

If a resistor or a capacitor on a printed board should become defective, don't try to unsolder the unit. Cut the leads as close to the body of the component as possible.

When you do this, you will have two leads soldered into position on the board. Straighten them with a pair of long-nose pliers. These two leads will now act as the supports and connectors for the new radio part.

Sometimes the defective component will be mounted so close and so tightly to the board that you will not be able to use this technique. When you run across a problem of this sort, get out your pliers and crush the body of the defective part. After you clean away the pieces, you will have two leads which will be long enough to work with. Straighten these leads and use them as the supports for the new part. (Special tools, as shown on page 1-52, are helpful.)

Mount the replacement component between the two leads, loop the wires and solder, as shown in Fig. 217.

## Replacing oscillator coils, if transformers, electrolytics (can type), variable capacitors

These components are similar in that they have a number of connections to the board. Use a 35-watt iron and a brush (a stiff bristle toothbrush will do). Heat each terminal, working on only one ter-

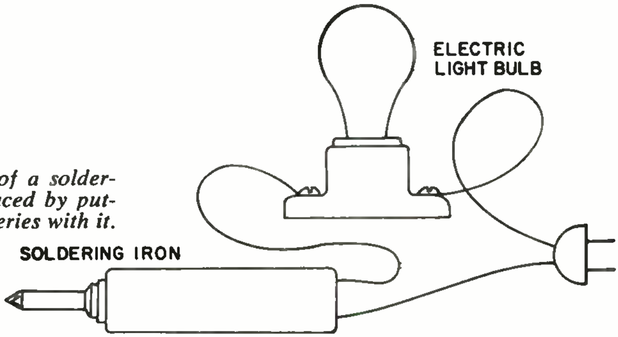



Fig. 215. *The heat of a soldering iron can be reduced by putting a light bulb in series with it.*

minal at a time. As you apply the iron, remove the loosened solder as quickly as possible. Try not to overheat.

There is one serious danger in removing solder this way. The conductors on the board are very close together and take to solder the way a 6-year-old boy takes to dirt. In both cases, they're hard to separate. So be careful. A little bit of solder can make a great big short.

After all the terminals of the component have been unsoldered, rock it back and forth slightly to free it from the board. Unless you have managed to remove all the solder from the terminals, you will find this difficult or impossible to do.

## What is connected to where?

When removing any part having a number of connections, always be sure to make a note of which connection goes where. If you don't

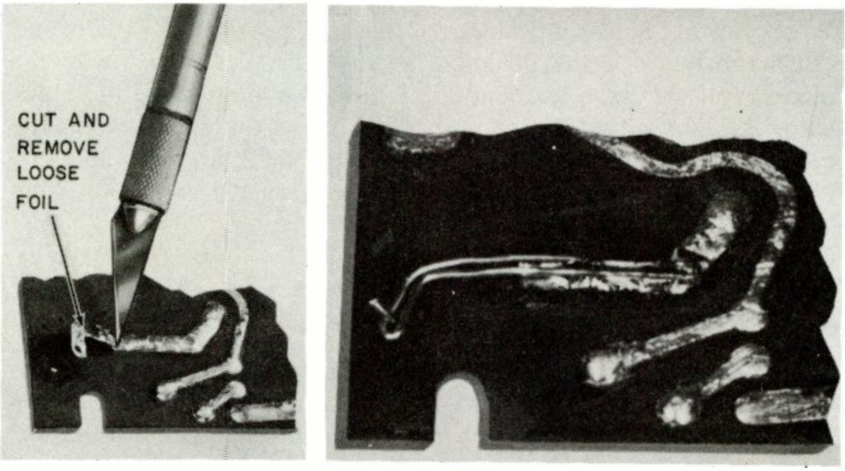



Fig. 216. *The foil on a printed-circuit board may pull away. When this happens, clip off the raised part and replace it with wire.*

do this, you'll be scratching your head for quite a while. This may be good for your scalp but it doesn't fix radios.

Don't use the manufacturer's numbers stamped on parts as your positioning guide. These can vary from one part to the next. And one final word of caution: keep solder from going into the part itself. You'll soon learn that solder has a habit of sticking best where it isn't wanted and of rolling into places where it has no right to be.

## Removing volume controls

You can remove these in the same manner as if transformers. Cut away the connecting leads. Heat the control lugs one at a time and brush away the solder. Straighten the lugs if they are bent. Rock the control back and forth until it comes loose. Don't force it. You are much stronger than the printed-circuit board and you will prove nothing if you break it. If the control doesn't want to come loose, inspect it to find out why. Fig. 218 shows how a control should be removed.

## Removing component boards

In Fig. 214 we showed you some samples of printed-circuit and component modules. Some of these are complete circuits. They can be removed in the same way in which you would remove an if transformer or a volume control.

Heat each lug. Remove the solder with a stiff bristle brush. If the component board is long (and some of them are), cut it with a

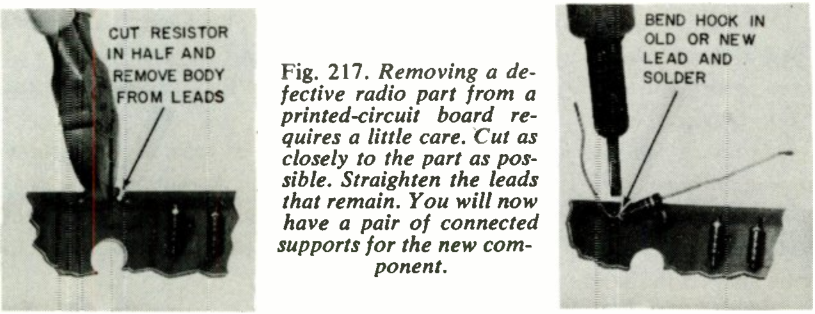



Fig. 217. *Removing a defective radio part from a printed-circuit board requires a little care. Cut as closely to the part as possible. Straighten the leads that remain. You will now have a pair of connected supports for the new component.*

pair of diagonal cutters (dykes) and remove one section at a time, as shown in Fig. 219.

## Testing

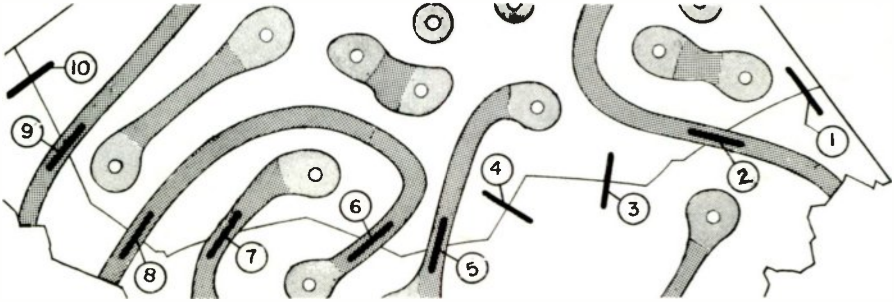
After replacing components on the printed-circuit board, check for in-circuit continuity. To make this test, set the vtvm on a suitable resistance scale and clip one test lead directly to the component. Touch the remaining probe to various points along the conductive foil on the printed-circuit board to make sure that a good electrical connection has been made.

The way in which this is done is shown in Fig. 220.

## Cracked boards

Sometimes one of the conductors will crack cross-wise. If the break is complete, you will have an open circuit. This will not be too difficult to check out with an ohmmeter. If the break is incomplete, you may end up with an intermittent or a high-resistance connection.

Sometimes one of the conductors on the board will split or break along its length. The effect will be as though resistance had been added to the circuit.




One method of repairing a broken board consists of drilling holes on both sides of a break, inserting wires through the holes and then twisting the wires to draw the board together at the break. This figure shows how such a board repair would appear upon completion.

First determine where the staple-like wires are to be located. They should span each break in a track (staples 2, 5, 6, 7, 8, 9). Additional staples (1, 3, 4, 10) should be located at those points where more support is needed. Drill the holes 3/16" on either side of the break. The holes should be the same size as the wire.

After all holes are drilled apply a non-conductive cement to the break and join the two sections. Insert part of the staples from the top of the board and part from the bottom, so that upon tightening they will draw evenly. Twist only enough to hold the two sections together.

Now solder all staples inserted in broken sections of track (staples 2, 5, 6, 7, 8, 9). This type of repair, while it fulfills all circuit electrical requirements, does not provide mechanical strength equivalent to the unbroken board. To provide a broken board with strength "like new" — or better:

First remove those components which are in the immediate vicinity of the break, leaving a cleared area on top of the board where the strengthening material is applied.

Locate the end of each crack and drill holes to prevent any extension of these cracks in the future.

Strengthening of the board is accomplished by a lamination process. Simply cut a piece of vinyl to fit the cleared area over the break. Coat both the cleared area on top of the board and the opposing surface of the vinyl with cement. Use the cement in the manner recommended by the manufacturer. It is not imperative that the vinyl be clamped to the board while the cement dries. However, clamping will result in maximum strength.

Allow 15 to 30 minutes for the cement to harden and then drill through the vinyl from the original mounting holes. Replace the components in their original locations and solder. All parts should have lead length sufficient to extend through the extra layer of thickness. *(Westinghouse Tech-Lit News)*

In either case, whether the break is cross-wise or length-wise, the trouble can be cured by soldering. Run a small amount of solder along the break. Don't pile on the solder since you will only short to an adjacent conductor.

Handling solder this way calls for some skill. An easier way is to put a length of wire along the break and solder it into place. To

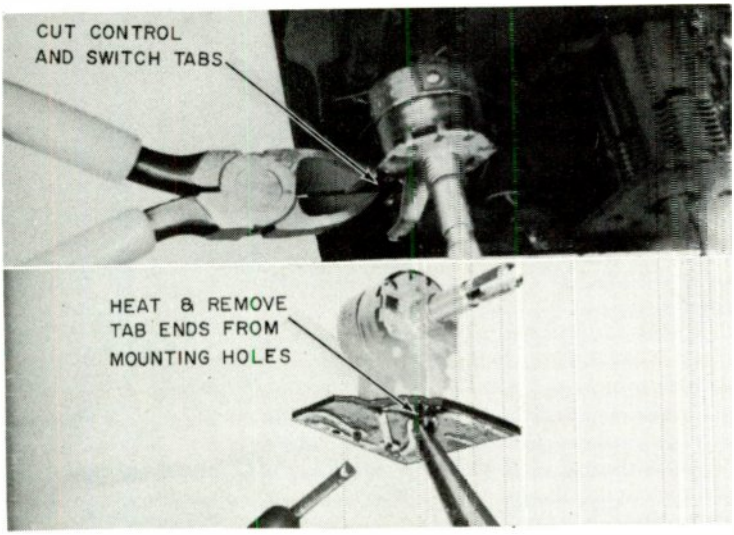



Fig. 218. *Method for removing a volume control from a printed-circuit board.*

make the job as easy as possible, cut a short length of copper wire to fit. Use bare copper wire. Avoid wire covered with enamel. Do not use very thin or fine wire or wire that is too thick. No. 22 wire should be about right. Wire that has been pretinned will take solder best. (See page 1-58 for more details.)

Lay the wire along the length of the break and solder into position. Use solder sparingly.

### Repairing broken boards

Yes — it can be done and it must be done. The only alternative is to junk the receiver. Even slight flexing of a broken board (and this happens all the time with portable transistor sets) means an intermittent or complete loss of sound. Repair details are described on page 1-56.

### Removing sockets

Use the same method as for if transformers and volume controls. Clean each socket pin of solder with the iron and a brush. Some

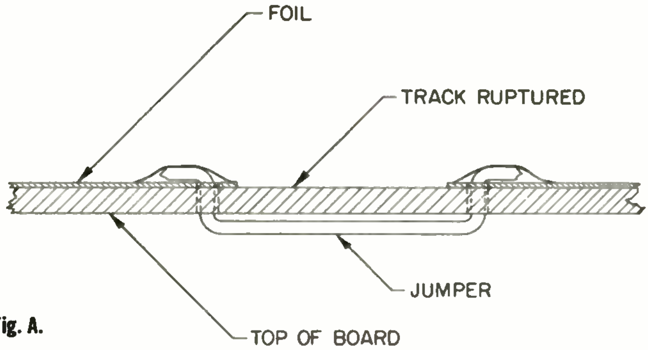



Fig. A.

1. *Fine cracks* — A hairline crack in the copper foil circuit can be located by holding a light source, such as a 60 watt lamp, on the top side and viewing the board from underneath. Flex the board slightly and watch for light to appear through the crack. Resistance measurement is another good method of locating minute cracks.

Flowing solder over these cracks is not a good repair, considering it takes only a few more seconds to solder a piece of bare wire across the break. Use a sharp blade or X-acto knife to scrape the solder resist off the foil. Place a ½" piece of bare wire directly across the crack and solder down quickly.

2. *Ruptures and large breaks* — Where there is extensive track damage such as might result from a short circuit burning out a section of the track or component burn-out, a combination of repair techniques may be necessary.

Small gaps may be repaired as shown in Figure A. Check first to see if there is space on top of the board for a jumper. Single conductor insulated (B) or bare wire may be used, depending upon the need for insulation in the particular situation. Drill through the board at the two broken ends of the track. Bend the wire as shown in Figure A and insert it into the holes from the top of the board. Hold the jumper tight against the top of the board while soldering it to each end of the broken track. This type of repair will hold the broken ends of the track tightly to the board, thus preventing raising of the track ends and peeling of the foil.

*(Westinghouse Tech-Lit News)*

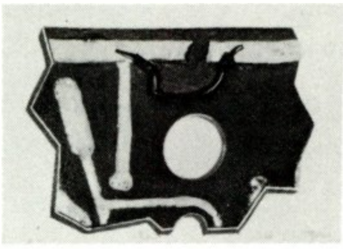


Fig. B. Insulated wire is used to bridge the gap after broken or loose foil has been removed.

soldering irons come equipped with circular adapters (circular soldering iron tip) which will permit you to unsolder all the pins at the same time.

## Arcing

This isn't a problem in portable transistor receivers but you will encounter it in auto radios and vacuum-tube receivers. The resistors mounted on printed-circuit boards are generally the nonfusible type —that is, they will open when current is excessive, rather than fuse.

Excessive heat, such as that caused by a burning resistor, will

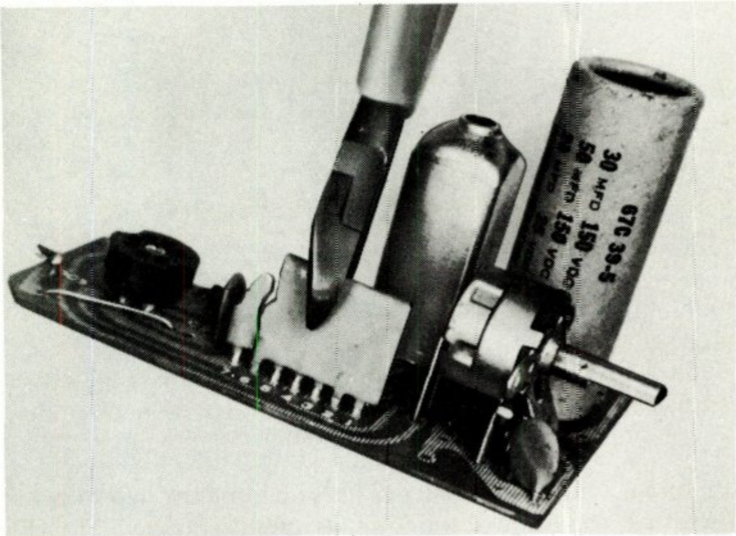


Fig. 219. *Removing a component section from a printed-circuit board. The component section is a subassembly and may consist of a complete circuit in itself. The component section is mounted on the main printed-circuit board in the same way as a single component, such as a volume control or an if transformer.*

cause the board to carbonize. This changes the board from an insulator to a resistor. Use a sharp penknife to clean away the carbon. Rinse with a non-oily cleaning fluid when finishing.

## The final check

More often than not, you will have the receiver out of the cabinet for repair. It really shouldn't make any difference whether the set is in the cabinet or not, but sometimes, in putting the receiver back, some wire or lead may become broken or disconnected. Slide-on clips are often used for speaker connections. These may become

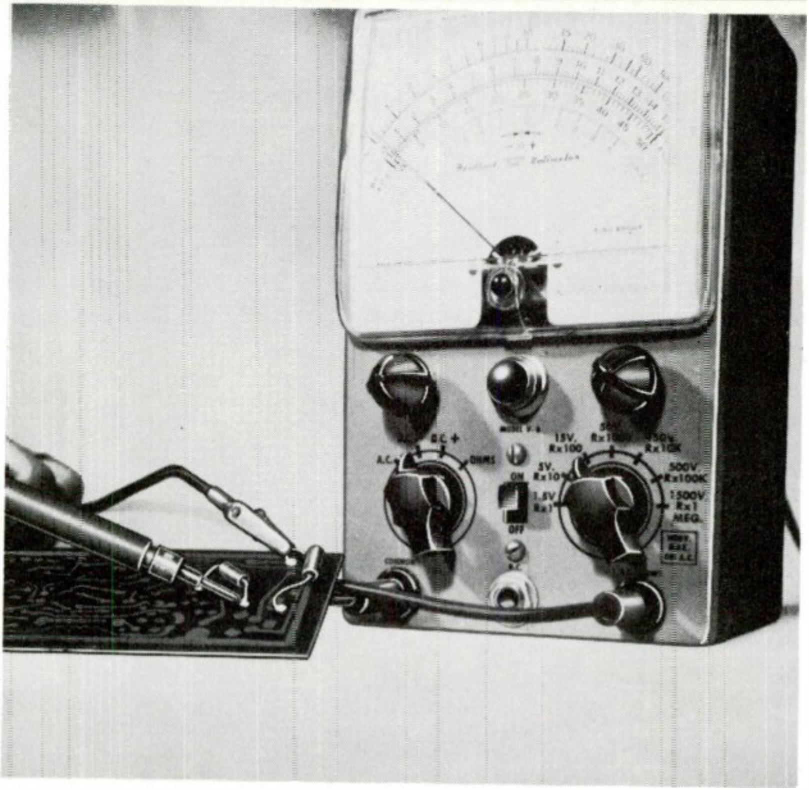


Fig. 220. *After replacing components on a printed circuit board check them for in-circuit connections.* (Heath Co.)

disconnected. The battery fastener may be loose enough to come off.

Make sure the set will work in its cabinet (Fig. 221). Knobs should be secure—not so loose they fall off the first time the set is played and yet not pushed so far forward that they rub against the cabinet. The dial of the receiver should turn smoothly from one end to the other.

Finally, if the cabinet is dirty, you can achieve miracles with just a damp sponge. You can be sure your customer won't ever remember the condition of the cabinet when he turned it over to you, but he will remember how nice and shiny it was when he first bought it. Try to keep him happy. It's good business!

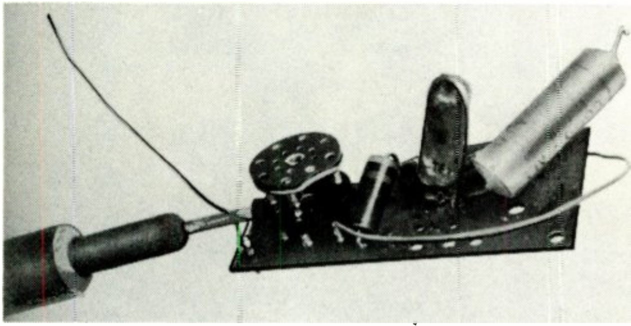
## Back to transistors

When working with transistor receivers, you will gradually get accustomed to the idea of low voltages and low currents. The voltage between the base and emitter will be less than 1 volt (and often less than 0.5 volt). The amount of current in the base-emitter circuit will be in the order of microamperes, and not too many of them, at that. A representative value would be approximately 30 $\mu$a.

Collector current will vary, depending on the transistor used, the voltage applied, etc. Values of collector current will be about 3 to 5 ma (but not in power output stages).

## Transistor types

There are two basic types of transistors, but we will be concerned with only one of them. The two types are the point contact and the junction. The point contact is obsolete (at least as far as radio re-



If there is sufficient "head-room" in the cabinet it is possible to solder replacement socket to old defective socket after removing top wafer. This will prevent possible damage to the printed circuit when removing old socket from board.

ceivers are concerned). The junction transistor is the name used for a large family group, including grown-diffused types, drift, alloy junction, etc. These transistors are all alike in their basic design—they use purified germanium or silicon plus controlled amounts of added impurities. The difference between them is the way in which they are manufactured and packaged.

A transistor is made by joining p- and n-types of material. The area where they join is called a junction—hence the name, junction transistor.

The type of junction is extremely important because it determines the transistor's characteristics—whether it will operate at high frequencies or not.

The frequency at which a transistor will work is determined by the speed with which current moves from the emitter to the collector. This "transit time" of the current is affected by the way in which the junction is made. In drift transistors, transit time is quite small, making this type of transistor suitable for intermediate-frequency stages, for converters and for radio-frequency amplifiers.

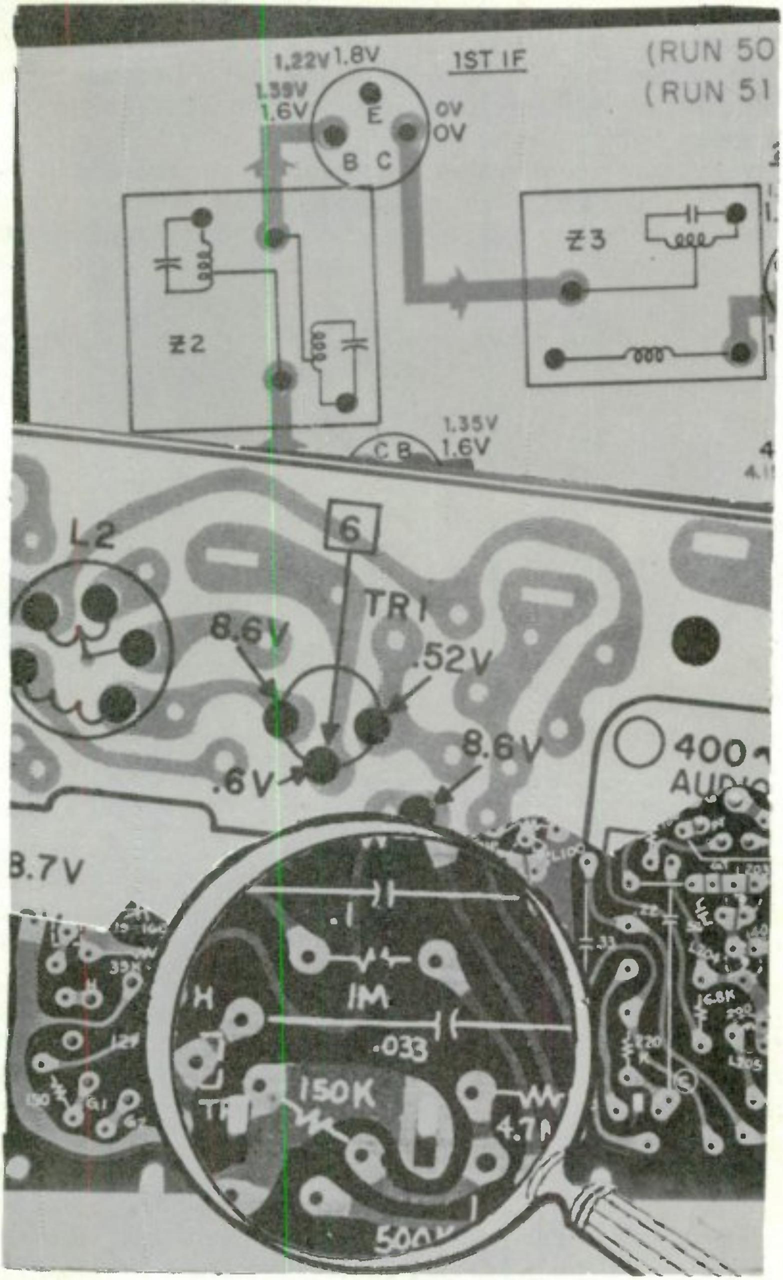
Fig. 221. *The last step in checking a receiver . . . an inspection to make sure the set is ready for the customer.* (Zenith Radio Corp.)

## Servicing do's and don'ts

In the next chapter we are going to start servicing transistor radios. We are going to learn about transistor troubles, stage by stage, circuit by circuit. But before we do, let's go over some servicing "do's and don'ts."

Remember what we have told you about soldering. If you must do any soldering near a transistor socket, it would be best to remove the transistor. If the circuit is the type that doesn't have sockets, put a thermal shunt across the transistor leads. You can make a thermal shunt by filling the jaws of an alligator clip with solder. Make a few of these—they will be very handy.

You will be working with a soldering iron having a low wattage rating. This doesn't give you much choice in the selection of solder. You will need a low-melting point type, such as 60/40. If you aren't sure just what type of solder you have available, connect




Perforated cards (top and center) identify test points and components, are necessary service aids. Additional printing on the circuit board (bottom) serves same purpose.
*(Philco, General Electric & Westinghouse)*

your 35-watt iron, let it heat and then see how quickly it melts the solder. If it seems to take a long time or if the solder seems to form a grayish mass instead of a silvery liquid, then the melting point of the solder is much too high.

When using your ohmmeter (the vtvm or vom) try to keep it on a high-resistance range. When making resistance checks, remove the transistors from their sockets. Also, keep in mind that electrolytics

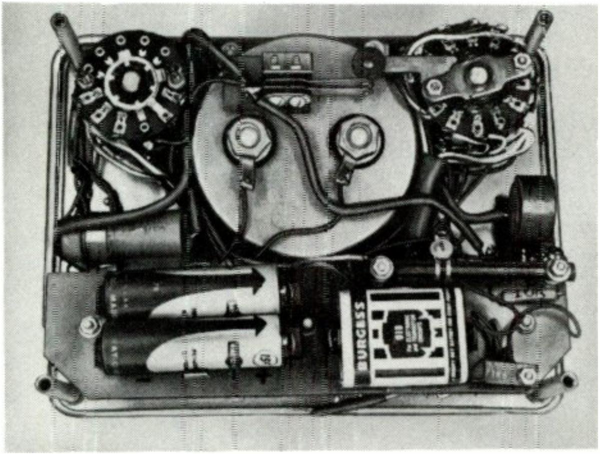



Fig. 222. *In this ohmmeter, the striped battery (lower right) used on the R x 10K range is 15 volts. This is added in series to the two 1.5-volt cells used on the lower resistance ranges. The total of 18 volts may exceed the ratings on many transistors or components.*

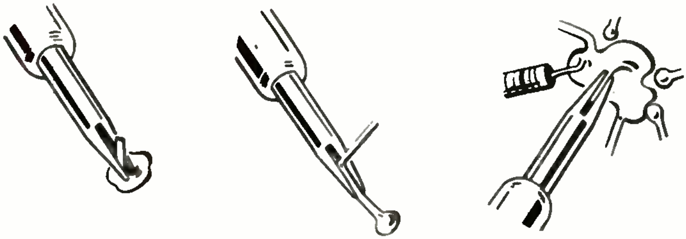
used in transistor sets have a very low voltage rating. Make sure that your ohmmeter's batteries don't have a voltage higher than the working voltage of the electrolytics (Fig. 222). Watch polarity when checking those electrolytics.

You will find that most battery connectors in transistor receivers are polarized, but where they are not, make sure that the batteries are connected properly. Sometimes B-plus is ground in transistor sets, so if you reverse batteries you may damage both transistors and electrolytics.

You must read quite a few low voltages when you work with transistor receivers. For this reason, you should become very familiar with the low-voltage dc scale of your vtvm. The scale should be wide enough so that the readings aren't crowded. Incidentally you will probably find that voltage checks are more useful than resistance checks. With a voltage check you do not have to worry about the voltage of the batteries in your ohmmeter or vtvm.

Also, with voltage checks you will not need to remove transistors from their sockets. Finally, voltage checks are much more conclusive, since a voltage check is a "live" test—it is made with battery voltage applied. Be sure to use needle-point test prods so that, when you touch a component or wire, you will get some gripping effect. This will help keep the test prod from slipping and possibly shorting wires or components.

Your troubles with transistors, for the most part, will be with



Special tiplet is used to melt solder and unbend tabs or leads at the same time. This is a common problem with printed circuit boards.

shorts rather than opens. A transistor can open by having broken leads or leads that have pulled away from the transistor header.

If you find a shorted transistor, don't just replace it. Find out why the short happened and then replace the component that caused it too.

A quick way to check if a set has a shorted or leaky component is to put a milliammeter in series with either the plus or minus terminal of the receiver's battery. Check the manufacturer's circuit diagram for the total amount of current flow. If your milliammeter reading is higher than this, look for a shorted transistor or component.

Finally (to make your servicing a little easier) some manufacturers supply perforated cards that will help you identify test points and components. (See page 1-63.)

The first two chapters have given us the background we need for troubleshooting transistor circuits. In the next one we are going to analyze transistor receiver troubles and supply you with servicing charts for your convenience.

## QUESTIONS

1. An n-p-n transistor has a resistor connected from emitter to ground. What is the polarity of the voltage at the emitter with respect to ground?
2. In an n-p-n transistor circuit is the base positive with respect to ground?
3. Does the current flow from the collector, through the load, toward the battery in an n-p-n transistor circuit?
4. Does the entire current flow through the emitter resistor also flow in the collector circuit?
5. Is the emitter of a p-n-p transistor positive with respect to the base?
6. Can collector current be measured by inserting a milliammeter in the emitter?
7. Are transistors only made from germanium?
8. Should the forward-to-reverse resistance ratio of the emitter–base ever be higher than 100?
9. Has the type of junction any effect on the transistor's characteristics?
10. Can printed circuits tolerate high soldering temperatures?

# CHAPTER 3 servicing transistor radios

## Moving ahead to servicing

*Working for hours and ready to faint,*
*A service man raised his voice in complaint,*
*At the transistor set he swore,*
*I've had it—and more,*
*Like an ac radio it ain't.*

LET'S LEAVE our poor friend to his misery. What he didn't know was that we just don't treat transistor radios as though they were ordinary radios with transistors substituted for tubes.

Transistor radios have troubles of their own. Let's see what they are! As a start, examine the block diagrams of two typical transistor receivers shown in Fig. 301. The average transistor receiver, like ac–dc sets, is a superheterodyne. It has a few extra added attractions of its own, though.

The block diagrams show us that the transistor receiver has two if stages. (Most ac–dc sets have just one if). The detector stage is a crystal. (In the ac–dc set we use the diode section of a diode-triode.) In the transistor receiver the output is often push-pull, although the cheaper sets have just a single-ended output. (Most ac–dc sets are single-ended.)

## Some differences

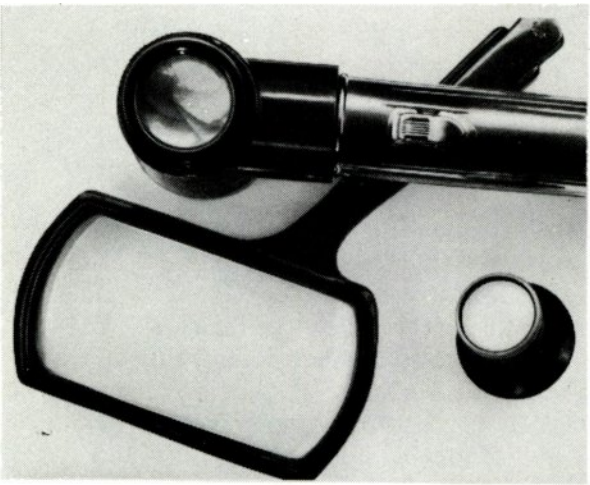
Most of the transistor receivers you will work on will be the types shown in Fig. 301-A or Fig. 301-B. But you will also find some that will be different. You may work on a set that will have push-pull output but no radio-frequency amplifier. This means that the receiver will be sort of halfway between that of Fig. 301-A and Fig. 301-B.

Some transistor sets will have added circuits, such as the one shown in Fig. 302. This set features an agc amplifier. The agc control current is amplified and fed back to the input to the first if amplifier. The sets in Fig. 301 will also have agc, but not the agc amplifier.

## Servicing the transistor receiver

No two service technicians repair receivers in the same way. You may have your own pet method or approach. If you do have a system, then by all means keep it. You've probably worked it out to your own satisfaction and it's best for you.

Our approach is going to be a little different since what we are doing is learning a general method of servicing. We are going to



Any of these magnifiers can be a help when hunting for printed-circuit board defects or bad connections in miniature receivers.
(Gem Electronics)

cover a few techniques and then work our way through the receiver, starting with the audio output and ending with the rf amplifier. We hope you will adapt what you learn to your own method of servicing.

## Look at the circuit

What do you do when you go on a long auto trip? You get out a map and you look over the whole area. Then you narrow your inspection down to the particular route you are going to travel.

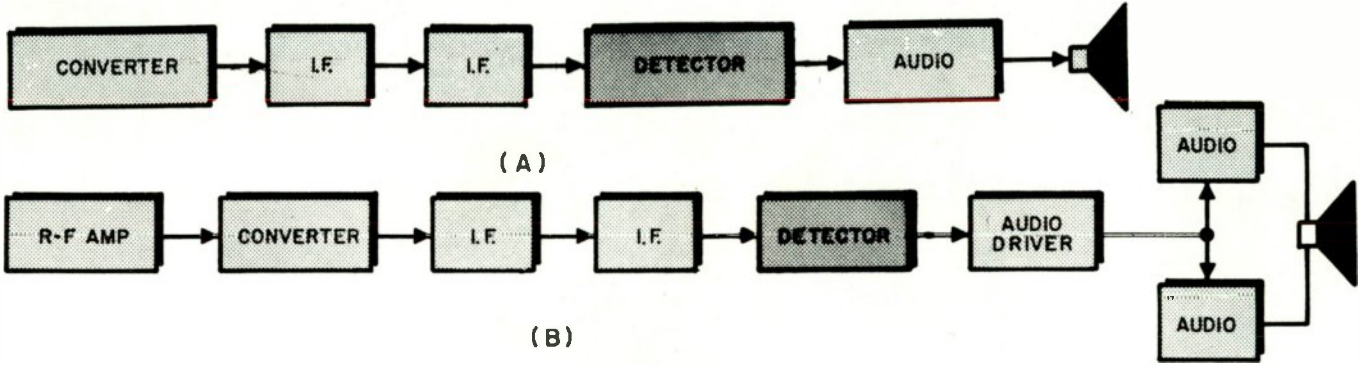



Fig. 301. *Transistor receivers can be fairly simple as shown in A or more elaborate as shown in B. The receiver in B is the same as A, except that it has an rf amplifier stage ahead of the converter, and push-pull instead of single-ended audio output.*

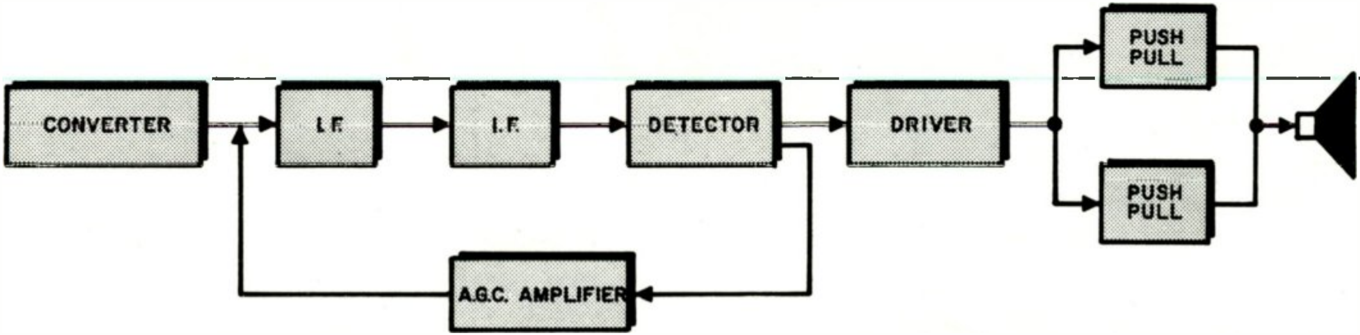


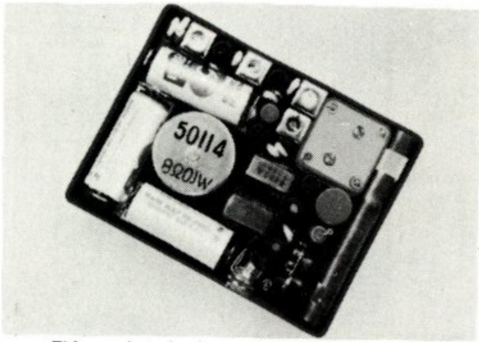

Fig. 302. *Not all transistor circuits are alike. This receiver does not have an rf amplifier stage but it does have push-pull audio output. It also has an additional transistor which works as an automatic gain control (agc) amplifier.*

Use the same approach here because it's a good one. In Fig. 303 we have the complete circuit of a transistor receiver. This corresponds to the block diagram of Fig. 301-A.

As we examine Fig. 303, we see right away that we have no rf amplifier stage. The signal is picked up by the antenna transformer and, before the signal knows what is happening, it is pushed right into the converter. The converter really works as a combined mixer and local oscillator.

Here is one big difference between tube and transistor receivers. In a vacuum-tube receiver we are accustomed to having either a pentode or a pentagrid converter. But what sort of converter do we have in the transistor set? The transistor converter is a triode.

The if (intermediate-frequency) signal coming out of the converter is fed into the first if transformer, T1. (The if is usually 455 kc.) The signal is then amplified by the transistor and sent along to




This pocket-sized transistor radio has such compact assembly it makes troubleshooting difficult.

the second if transformer, T2. Passing through several if stages, the signal reaches the detector. Note the volume control acting as a diode load across the detector.

Coupling capacitor C12 is generally an electrolytic. If we were working with a tube receiver, this capacitor would be a paper tubular since less capacitance would be needed.

Note the agc feedback circuit. Capacitors C9 and C7 are agc filter units.

Our next inspection point will be the emitters of all the transistors. In all cases, the emitters are connected to resistors which go to ground. These resistors supply self-bias. Where the resistors aren't bypassed, they produce negative feedback.

Capacitors C8, C10, C11 and C13 are rf bypass units.

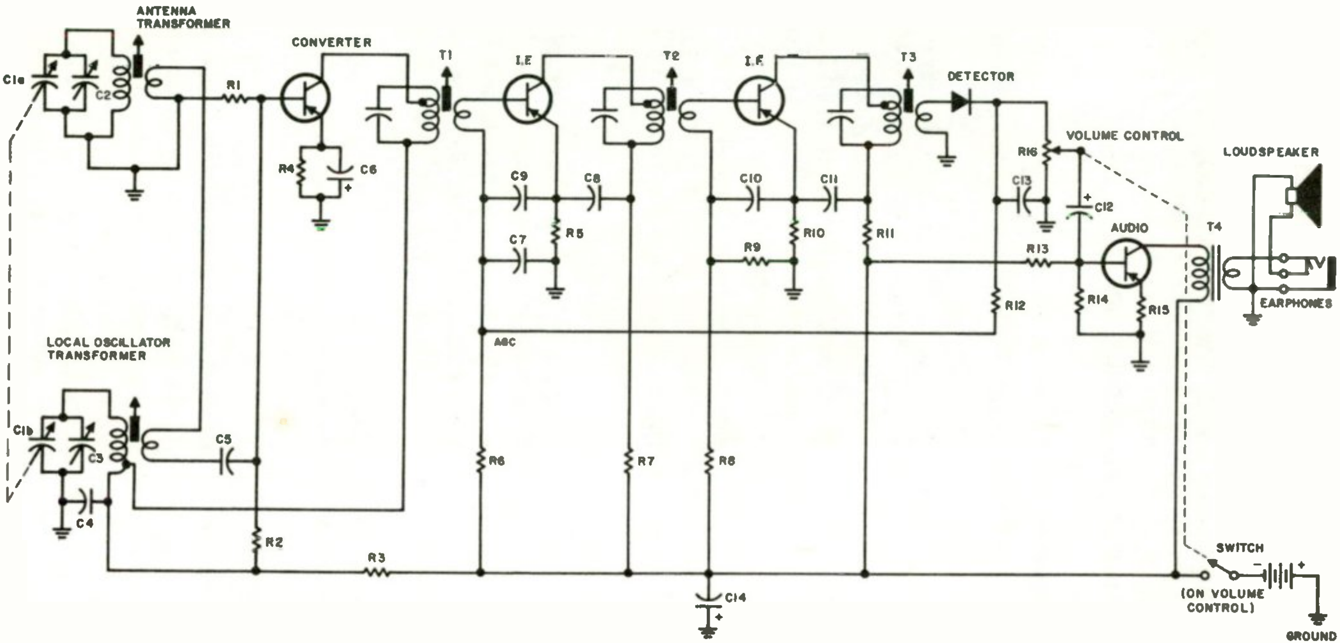



Fig. 303. *Circuit diagram of a transistor receiver. This is the type of circuit usually found in less expensive sets.*

## Another transistor circuit

In Fig. 304 we have another transistor circuit. If you will look at it carefully, you will see that it corresponds to the block diagram of Fig. 302. But there is also another and even more important difference. In this circuit the manufacturer has been very careful to include all the voltages and most parts values.

Note the heavy line marked + bus. All voltage measurements are made with respect to this common line.

## The first troublemaker

One component in the transistor receiver is always going to need attention. That component is the battery.

When does a battery start to go bad? The day it is manufactured! This doesn't mean battery manufacturers are cheating you and the public. It just means that's the way batteries behave. Keeping a battery on the shelf and not using it won't save it either. It will last longer that way but, whether you put a battery in the set or just keep it on your bench, it will have a definite life.

When a battery runs down, all sorts of things happen. Probably the first thing you'll notice is that the sound is distorted. Your customer may complain that favorite stations don't come in as nicely. Does the volume control need to be turned all the way up? Then check the battery.

How do we check batteries? Putting a voltmeter across them to measure their voltage isn't too helpful, since even a weak battery may show almost full voltage when the receiver is turned off. If you get distortion and the battery voltage is about 20% below normal (with the set turned on), you can be fairly sure that a new battery is called for.

But why do it the hard way? If you suspect the battery, replace it with one known to be in good condition. That way, you'll be sure!

## Battery types

Transistor radios use different types of batteries. The most popular are the zinc-carbon and the mercury. Mercury batteries will last longer but they also cost more. You can often interchange one for the other, but there is a precaution to follow.

The polarity of the center caps on mercury batteries is opposite that of penlight batteries. In a penlight battery, the center terminal

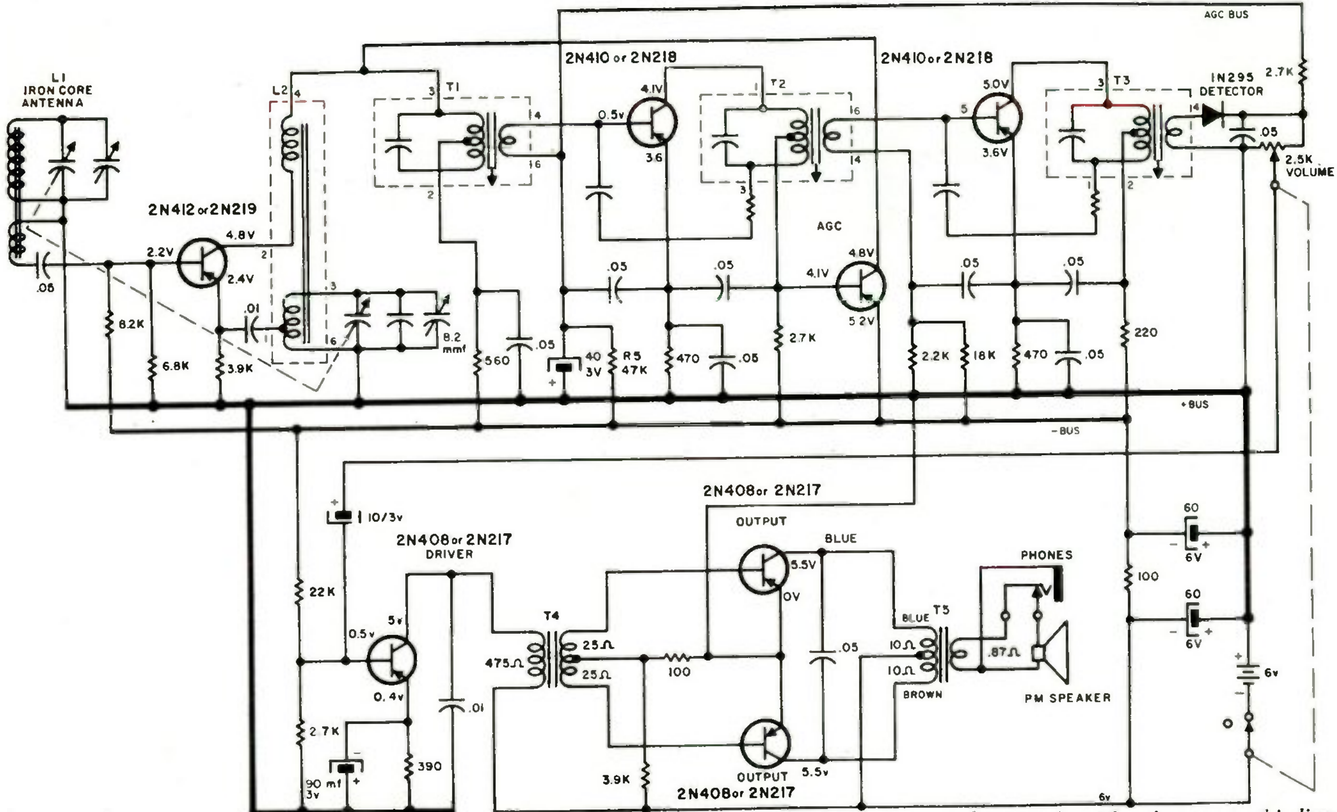



Fig. 304. *This set features an agc amplifier. The heavy line is the plus bus. Voltage measurements are made with reference to this line.*

on top of the battery is positive or plus. In a mercury battery, however, the center terminal is negative or minus. You can see these differences in Fig. 305.

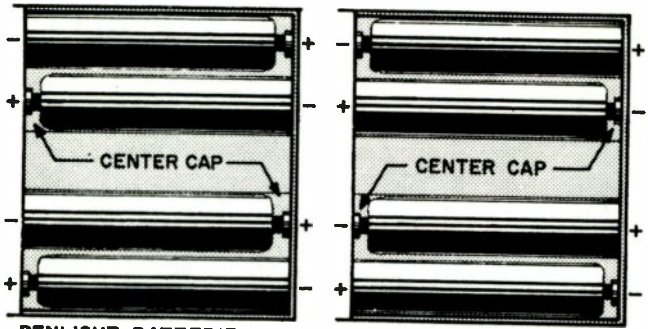



Fig. 305. *Mercury batteries and penlight batteries can be interchanged if you watch polarity carefully. The center cap on a penlight battery is plus. The center cap on a mercury battery is minus.*

In some receivers you will find a battery pack instead of individual cells. With battery packs the problem of polarity is eliminated since these come equipped with matching male and female connections. Since there is only one way of making the connection, the danger of reversed polarity is avoided. The disadvantage here, though, is that the battery pack must have an exact replacement.

## How long should batteries last?

This is a difficult question to answer. It depends on how fresh the battery is when installed and on how much the customer uses the set. Generally, zinc-carbon cells should give about 100 hours of working use. Mercury cells should last about 400 hours.

## Stage testing

How can we know if a transistor stage will amplify a signal? There is one way to find out. Feed a signal in, then see if the transistor circuit will do what it is supposed to do.

One way to do this is shown in Fig. 306. Use the 400-cycle modulating voltage of the signal generator. Measure the voltage output of your signal generator with your vacuum-tube voltmeter. (Set the vtvm to read low volts, ac). Then connect your vtvm to the output side of the transistor circuit and measure the output voltage.

Knowing the input and output voltages will give you a few choice bits of information. It will tell if the stage is working. It will also give you some idea of how well the stage is working.

## Gain per stage

When you compare output signal voltage with the input signal voltage, you are really measuring stage gain. If you feed in 1 volt and get out 5 volts, you have a gain of 5. If you feed in 2 volts and get out 20, you have a gain of 10. Just divide your output voltage by your input voltage and you have the answer.

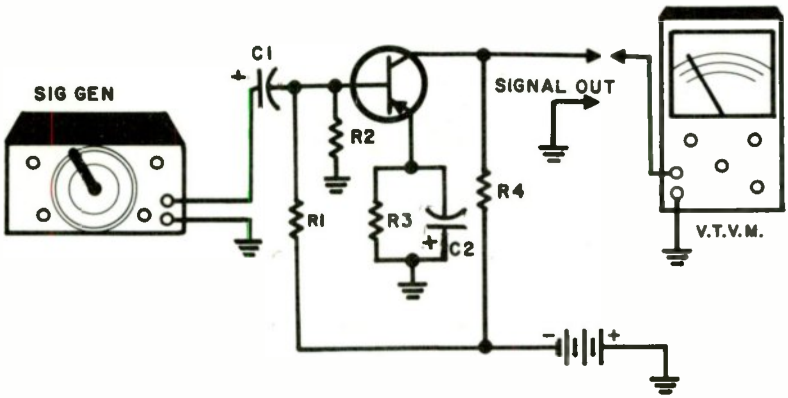



Fig. 306. *Method of testing a single resistance-coupled transistor stage.*

## Some limitations

The audio voltage of the average signal generator may not be a sine wave (Fig. 307). This means that you are not only getting the audio frequency, but quite a few harmonics as well. As a result, what your vtvm measures will not be quite correct. We're not going to worry too much about that since we're only making a comparison between input and output anyway.

In Fig. 308 we have a method of checking a transformer-coupled stage. As you can see, the general technique is the same as for the resistance-coupled stage of Fig. 306. While the vtvm is connected across the secondary of the second transformer, it could also have been connected in the collector-emitter output of the transistor circuit being checked.

## What are the parts?

If we're going to service receivers in a hurry, we should know what each component does in the circuit. There is no time like the present. What have we in Fig. 309? C1 is a coupling capacitor. How about R1 and R2? R1 and R2 are in series. These two resistors are shunted right across the battery. One side of R2 goes to ground. So does the plus side of the battery. And the other end of R1 is connected directly to battery minus. This connection makes R1 and R2 a voltage divider. Since ground is plus, the voltage drop

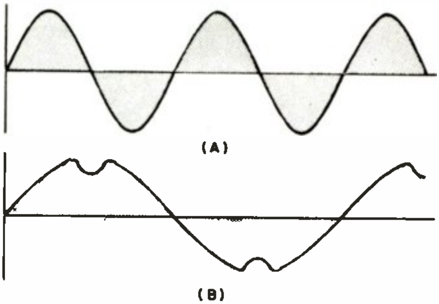



Fig. 307. *Most instruments (such as the volt-ohm-milliammeter and the vacuum-tube voltmeter) are designed to measure sine waves, such as the voltage wave shown in A. If the wave is distorted (as shown in B) the information supplied by the instrument will not be accurate.*

across R2 makes the base less than plus (or negative). R3 is the emitter resistor, shunted by emitter capacitor C2. Finally, the speaker is our load.

What we have here is a resistance-coupled stage but, if we had transformer coupling, our test would work in the same way, just as shown in Fig. 308.

## Stage-by-stage analysis

Now that we have covered general procedures, let's start at the output of the transistor receiver and work our way back through the set, stage by stage. We know that this is like eating a meal backwards, starting with dessert and coffee and working our way toward the beginning of the menu. Many technicians work this way and it's a very easy way to cover quite a lot of troubles.

Before we get started on transistor-stage work, let's become a little more familiar with some of the more common transistor shell types. In general (excluding power transistors) we have three types. These are shown in Fig. 310.

The first type (Fig. 310-A) is known as the nonsymmetrical. When you examine the transistor, you will see that the center lead isn't really at the exact center, but more to one side. Now hold the transistor so that the middle lead is toward the right. When the transistor is held in this way, the first lead (lead 1) is the collector,

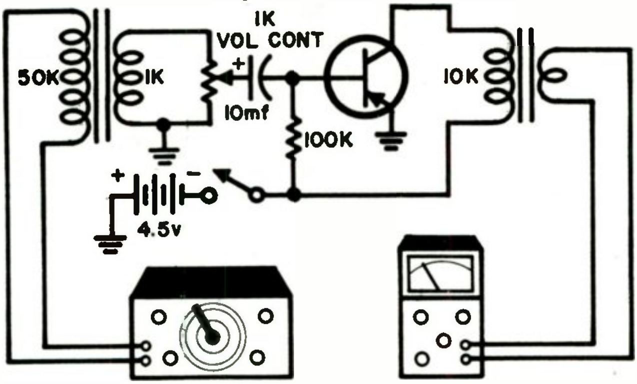



Fig. 308. *We test the transformer-coupled stage in the same way as the resistance-coupled stage of Fig. 306.*

lead 2 is the base and the remaining lead (No. 3) is the emitter.

The second type is shown in Fig. 310-B. Hold the transistor so that the leads are exactly as in the drawing. Once again, we have, reading from left to right, collector, base, emitter.

The remaining type has a little dot of color placed on the transistor. Hold the transistor so that the dot is at the left. When you do, the leads will be collector, base and emitter, in that order.

## Single-ended stage

A single-ended output stage is shown in Fig. 309. We know that the circuit looks easy to you, but that doesn't mean it can't be a real troublemaker.

The first thing to do is to make a quick check to see if the stage is working. Do this by connecting an audio generator to the input of the stage. If you don't have an audio generator, use the audio output of an rf signal generator.

With both the generator and the receiver turned on, you should hear an audio tone out of the speaker. (We hope you remembered to substitute a new battery or at least checked the old one.)

If you hear an audio tone, you will know the stage is working.

What about controlling the volume? We can't do it with the volume control because that part is in an earlier circuit.

## No sound

What if we get no sound at all during this test? Personally, we would think this is lucky. Maybe that sounds strange to you, but let's look at it this way. Here we ran just one test and we've managed to localize the trouble to the output stage.

So now we have a dead set on our hands. Let's check off all the possible things that could keep our output stage from working.

1. **Open voice coil.** This doesn't happen often but sometimes the voice-coil lead breaks away from its soldered connection or corrodes at that point.
2. **Open output transformer.** This could be in either the primary or the secondary winding. Don't expect the transformer windings to burn out. The currents that flow are too small for that. Corrosion and broken leads are a more probable cause. Pulling on transformer leads can cause them to come out.
3. **Shorted bypass capacitor.** Take a look at the bypass capacitor (C3) across the primary. This capacitor opens much more often than it shorts, but it is a possibility to keep in mind.

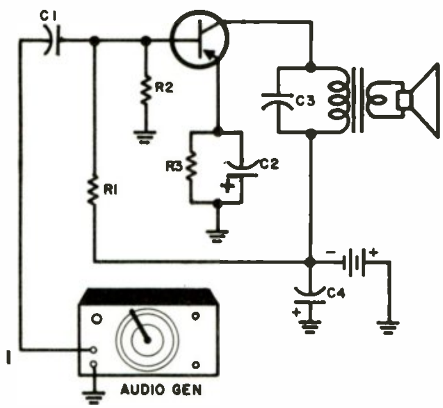



Fig. 309. *Testing single-ended transistor stage.*

Of course there are always odd troubles that never seem to happen to the other fellow, but inevitably to you and to us. We could have a broken transistor lead or a short between conductors on the printed-circuit board. Look for wires that act like kissin' cousins but which should really be separated. If the set has an output jack for earphones, take a good look at it. Try operating the set with and without the earphone.

### Weak output

The most common cause of trouble is the battery. The clue here is that, not only will the sound be weak, but it will be distorted as well.

Try making the audio generator test shown in Fig. 309 just to make sure that the trouble isn't in some earlier stage. If the output is still weak, check the emitter, base and collector voltages. If volt-

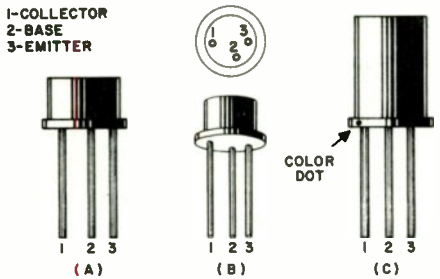



Fig. 310. *Method of identifying types of transistors.*

age is missing or incorrect, check the resistors. This should be easy to do since there are so few of them.

Once again, weak sound can be caused by troubles that aren't run-of-the-mill. A sticking or rubbing voice coil will discourage any speaker from working the way it should. A leaky audio bypass capacitor across the output transformer primary can cause this trouble. Has someone tried replacing the output transformer? The wrong transformer could produce this trouble. Check the emitter bypass capacitor. If it is open, nothing much will happen; but if it is leaky or shorted, it will produce weak output with distortion.

### A typical single-ended stage

Not all single-ended stages are identical but, as you've probably suspected, they are very much alike. There are a few small differences. Note capacitor C2 in Fig. 311. This is a neutralizing capacitor. Its job is to keep the output stage from oscillating.

Here is what we can do to keep the output stage working. (See Fig. 311.)

| Troubles in the Output Stage | And What To Do About Them. |
|---|---|
| **You are not sure the output stage is working.** | Inject an audio signal at the base of the audio output transistor. If you hear the signal in the earphones or speaker, the stage is working. |

| | |
|---|---|
| **No output signal.** | Check all the transistor voltages with a vacuum-tube voltmeter. Compare the voltages with those given by the manufacturer. They should be within 10% of those on the schematic. |
| | C1 may be open. This is an electrolytic coupling capacitor. Shunt it with a known good unit. Watch polarity. |
| | If this test starts the set working again, then the original coupling capacitor is probably defective. |
| **No sound or intermittent sound.** | Check the jack, the output transformer and the speaker. A shorted jack will kill sound in the speaker and earphones. |
| **Low volume.** | Check emitter bypass capacitor C3. Volume can decrease if this capacitor is open. Shunt with a high-capacitance electrolytic (40 μf or more). If volume is restored, original capacitor is open. |
| **Distortion.** | Capacitor C3 is very leaky. Open one capacitor lead (either one). If distortion disappears, replace capacitor. Also check emitter resistor R1. Check C3 and R1 if the voltage at the emitter is not correct. |

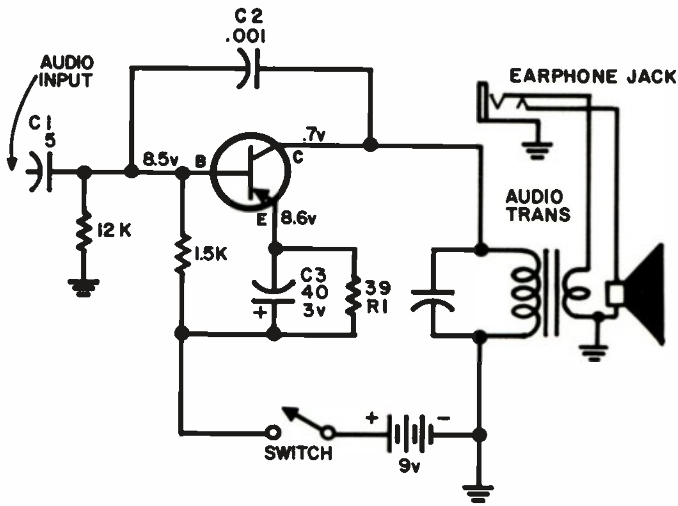



Fig. 311. *This single-ended stage is speaker- and earphone-operated.*

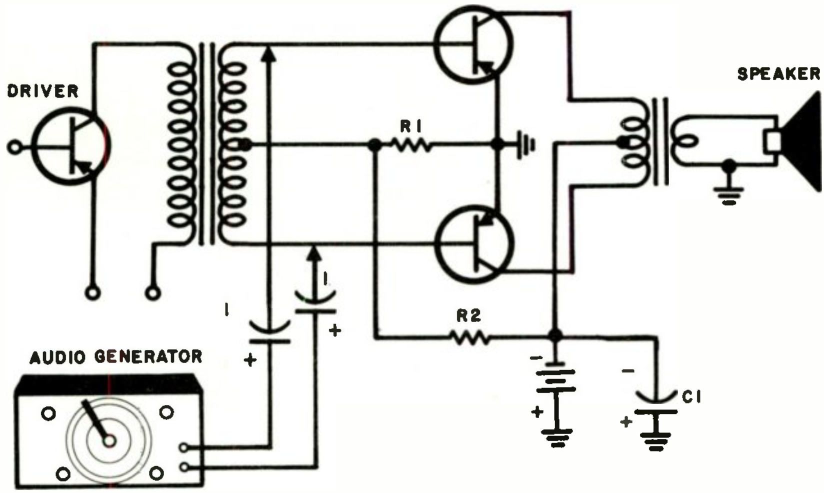



Fig. 312. *Testing a push-pull audio output stage. The stage is transformer-coupled at the input and the output.*

## The push-pull stage

*A designer built a set without enough sound,*
*At first he suspected a short or ground,*
*But then he made one transistor push*
*And he made the other transistor pull,*
*Now he has more than enough to go around.*

To get a little more volume out of the speaker and a little less distortion, many transistor receivers have a push-pull output stage, just as shown in Fig. 312.

The quick check for the push-pull output stage is a little bit different. Use the connections shown in Fig. 312.

Fig. 312 is a little unusual so follow the explanation carefully. We have two leads connected to the audio generator. Note that a pair of 1-$\mu$f capacitors are in series with each lead. One of these is the ground lead but it really makes no difference which lead is connected to the top transistor and which to the bottom one.

Here is the procedure for checking the push-pull stage quickly with this setup.

1. Turn on the receiver and the audio generator.
2. Connect the generator test leads to the voice coil of the speaker. If you get sound, the speaker is working.
3. Move the leads back to the primary of output transformer. If

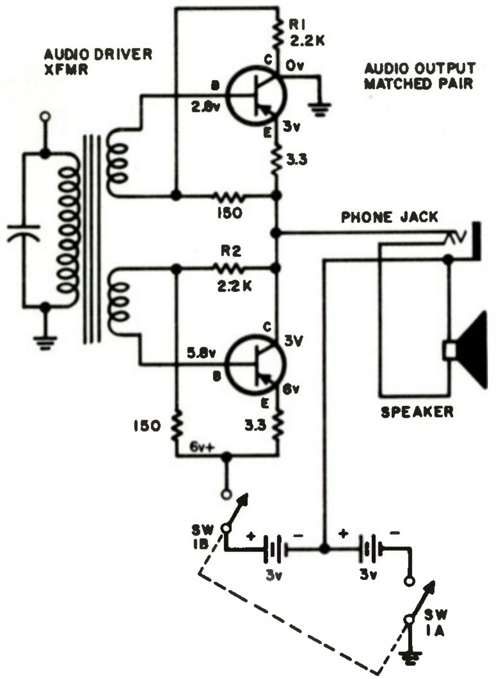



Fig. 313. *Push-pull output stage with direct coupling to speaker and phones.*

you get sound, both the transformer and speaker are good.

4. Finally, connect the leads as shown in Fig. 312. If the signal comes through, the entire stage is working.

## Looking for trouble

What sort of troubles can we expect in the push-pull output stage? Probably the most common is no output signal. Other troubles might be distortion and motorboating. Here are a few trouble-shooting ideas.

| Troubles in the Push-Pull Stage. | And What To Do About Them. |
|---|---|
| **No signal out of the speaker when the audio generator is connected as shown in Fig. 312.** | Look for a possible open circuit. This includes the voice coil, the output transformer, the transistors and bias resistors R1 and R2.<br>Try a new battery.<br>Sometimes a bypass capacitor is placed across the primary winding of the output transformer. |

| | |
|---|---|
| | Unsolder one end of the capacitor. If the set starts to work, install a new capacitor. |
| **Squealing, motor-boating, oscillation.** | Substitute a new capacitor for C1. Try a new battery. |
| **Sound is distorted. Speech is hard to understand. Music sounds poor.** | Make sure the speaker is in good condition. The cone might be torn. The voice coil may be rubbing against its pole piece. It's always a good idea to have a test speaker handy for quick substitution. Check resistors R1 and R2. If they have changed value, the bias will be incorrect. Distortion sometimes results if just one transistor of a pair is replaced. Use a matched pair. |

## A few changes

In one way all push-pull stages are alike—the job they are designed to do is the same. One that is really different is shown in Fig. 313.

When we compare the circuit of Fig. 313 with that of Fig. 312 we see that the output transformer has disappeared. The voice coil of the speaker gets the collector-to-emitter current of each transistor, in turn.

Does this circuit have any new servicing problems? The new

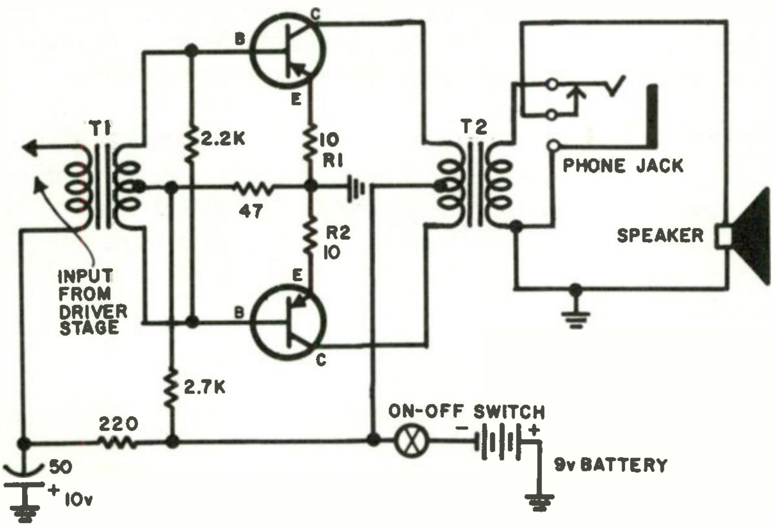
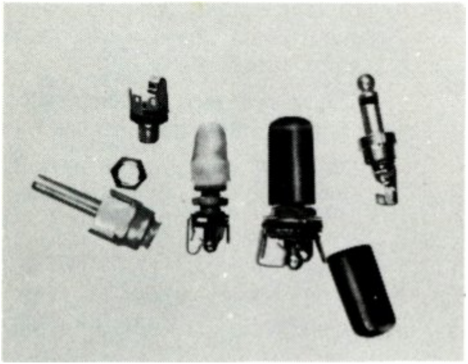



Fig. 314. *Typical push-pull output with parts values.*

items are the feedback resistors R1 and R2 and the earphone jack. If these feedback resistors change in value or become open, we might get some motorboating or squealing.

There is one other problem. Note how the voice coil of the speaker and the earphone jack are connected. When the earphones are removed, the closed-circuit jack automatically connects the



Components for transistor receivers are small and delicate. Earphone jacks and plugs are compared to the more common phono connector. All are to same scale—approximately actual size.
(Gem Electronics)

voice coil back into the circuit. But what if the jack contacts are dirty? Or what if the contacts don't touch? Several things could happen. The sound out of the speaker could be intermittent (dirty jack contacts) or disappear entirely (contacts not touching).

## A typical circuit

In Fig. 314 we have a typical push-pull output circuit with most of the parts values given. Many receivers you will service will have this sort of an arrangement. However, there are differences in push-pull transistor stages, depending on whether the set is intended for car or for portable use.

## Checking the transformers

All transformers used in transistor sets are stepdown types. This means that transformer T1 in Fig. 314 has a higher impedance in the primary than in the secondary. Similarly, transformer T2 has a primary with a higher impedance than the secondary.

We aren't going to bother measuring impedances, but with our vom and vtvm handy we can certainly measure resistance. Input transformer T1 (also known as a driver transformer) will have a primary resistance ranging between a few hundred to as much as several thousand ohms. The secondary will be much less, generally below 100 ohms.

To check the transformers, remove the driver and output transistors from their sockets. Make sure the receiver is turned off. Measure the resistances and compare with the manufacturer's values, often given on the schematic.

Output transformer, T2, will have lower resistances than the driver transformer. This will be about a few hundred ohms for the primary and a few ohms for the secondary.

Replace transformers with identical units or equivalent transformers recommended by the manufacturer. Do not interchange driver and output transformers. Transformer leads are color-coded. When replacing, follow the color code given on the schematic.

## Distortion

Just as in the case of push-pull tubes, match push-pull transistors

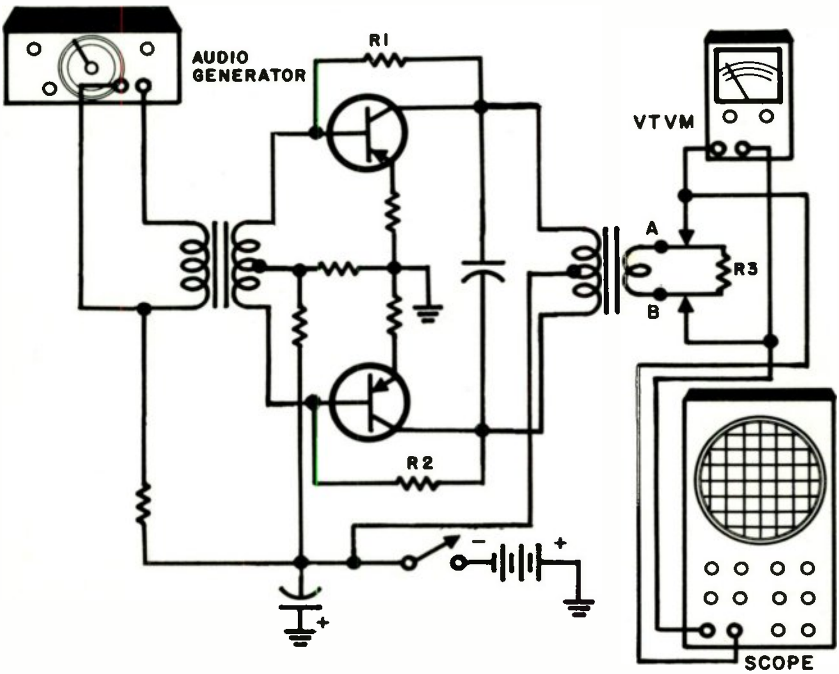



Fig. 315. *Circuit arrangements for measuring power output of a transistor receiver.*

if you expect a minimum amount of distortion. Test transistors right in the receiver to see if they are balanced.

As an example, let us check the circuit of Fig. 314. Feed a strong audio signal to the primary of the driver transformer. Measure the voltage drop across each emitter resistor (R1, R2) of the push-pull transistors. Do this with a vacuum-tube voltmeter set to read low volts dc (about 3 or 5 volts full scale). Both voltage readings should

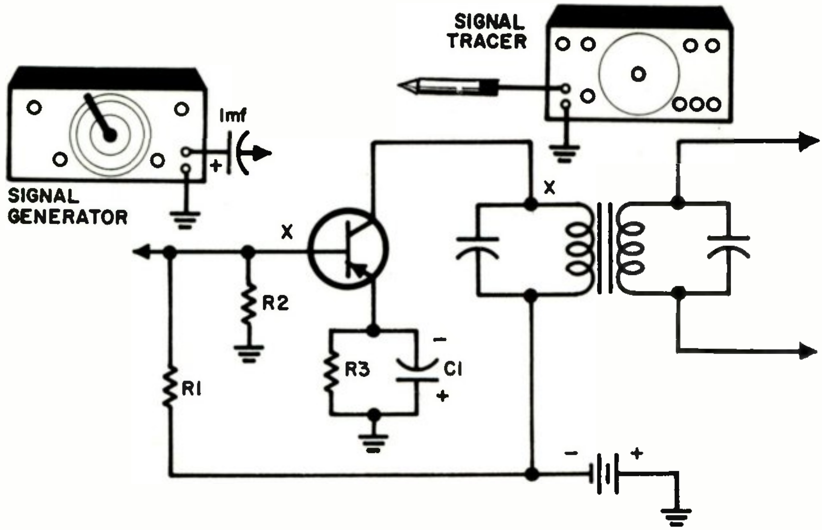



Fig. 316. *Check the driver stage quickly with a generator and a signal tracer. (X's indicate points for injecting signal generator signal.)*

be the same or very close to it. If you get a difference in the readings, the transistors aren't matched.

By using this test, you can match transistors. Incidentally, just because two transistors do not match does not mean they are defective. Keep the transistors for matching in another set.

There is still another way of matching transistors. Connect your oscilloscope across the voice-coil leads of the speaker. Feed an audio signal to the primary of the driver transformer. Now turn the volume control up until you get clipping of the waveform. If there is the same amount of clipping on the top and bottom of the wave, the transistors are balanced. If you get more clipping on one side of the wave, the transistors are not balanced.

## Measuring power output

After you get through testing and repairing a receiver, you may be interested in knowing just what its power output is.

But we should explain what these words mean. There are really two types of output power:

1. Maximum power output

   and

2. Maximum *undistorted* power output.

Do you see that word we have italicized? That's the word that makes the difference.

We can go about measuring both kinds of power output in the same way. Our first step is to replace the voice coil of the speaker with a resistor, R3 in Fig. 315. The resistor should have the same value as the impedance of the voice coil. If the set uses a 3-ohm speaker, replace it with a 3-ohm resistor. For small receivers, a carbon resistor having a rating of 2 watts will do.

Now connect a scope and a vtvm across the resistor. Set the vtvm to read ac volts. Use the 10-volt scale. Feed an audio signal into the primary of the driver transformer. Watch the waveform on the scope. Keep advancing the gain control on the generator until the waveform on the scope just begins to flatten.

## How to calculate maximum undistorted power

1. Note the ac voltage reading on the vtvm. Multiply this reading by itself.
2. Divide the voltage reading by the value of R3. This will give you the answer.

For example, suppose that R3 is 3 ohms. Let us also suppose that our vtvm gives us a reading of 4 volts.

*Step 1:* We multiply 4 × 4 and get 16.

*Step 2:* We divide our answer (16) by the resistance – in this case, 3 ohms.
16 divided by 3 equals 5.3.

Our answer is in watts.

Of course, in making this test, we must use a resistor rated 10 watts or more.

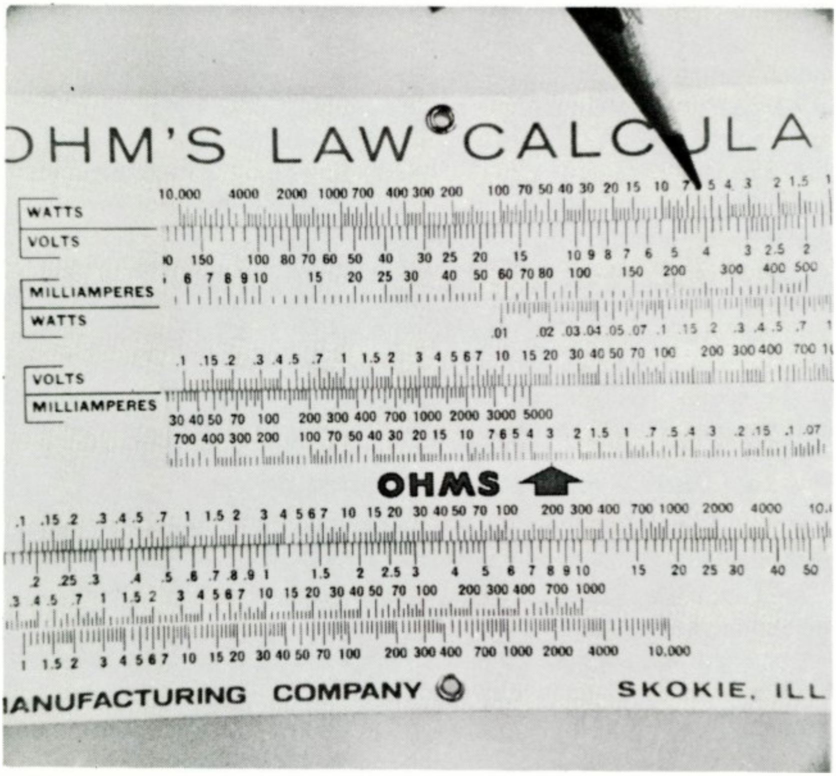
What have we done? In mathematical terms the 4 × 4 would be called "four squared". It would be written $4^2$. Since the 4 is the voltage it would be represented by the letter E. We divided this by the resistance (R). Written in mathematical language we have:

$$\frac{E^2}{R} = \frac{4 \times 4}{3} = \frac{16}{3} = 5.3 \text{ watts (P or W)}$$

That little bit of arithmetic wasn't so bad after all.

## The driver stage

The stage that comes right before the push-pull stage is called the driver. It's just an ordinary transistor audio amplifier.




Special Ohm's Law calculator (slide rule) is as helpful as a servicing tool. The resistance of the speaker (3 ohms) is set above the Ohms arrow. The answer (5.3 watts) is read above the 4 (volts) as indicated by the pencil tip. (Ohmite Manufacturing Co.)

There are several ways of checking the driver. The easiest and the quickest is shown in Fig. 316. Put in (inject) an audio signal at every point marked X. Start at the output, if you like, and work your way back to the input.

What is the output? It is just a transformer. We checked the secondary side of this transformer when we tested the output stage.

To check, touch the generator lead, in turn, to the collector and then to the base of the transistor. That's all there is to it. If you get good sound in both cases, the stage is working.

## Using a signal tracer

Some service technicians prefer using a signal tracer. It does have an advantage. You don't have to depend on the output stage. Just connect the test probe of the tracer to the collector of the transistor and the generator to the input.

## Driver troubles

We can get the same troubles in the driver that were found in

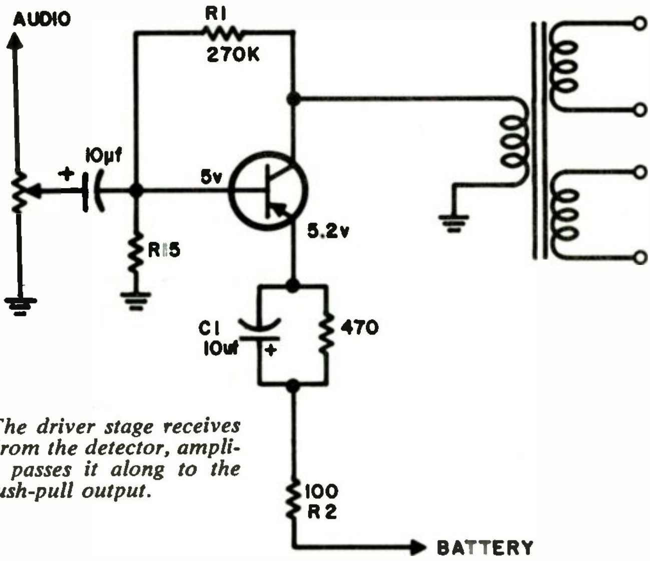



Fig. 317. *The driver stage receives the signal from the detector, amplifies it and passes it along to the push-pull output.*

the output stage. This isn't too surprising since both are audio amplifier circuits.

However, keep in mind that as you move the generator lead from the output end of the amplifier toward the input, the signal strength of the speaker should get stronger. You should be turning down the output of the generator.

In Fig. 316, R1 and R2 are the base bias resistors. If either of these become disconnected or open, the transistor will stop working. If they change value, the stage might distort the signal.

If emitter resistor R3 opens, the driver won't work.

Look at C1, the emitter bypass capacitor. A typical value for this unit would be 40 $\mu$f at 3 volts. If this capacitor is defective, it will reduce the volume. One way of checking is to shunt it with another unit of the same size. Watch the polarity. In the circuit of Fig. 316, the plus side of the electrolytic is grounded.

## More about the driver

As you can see from Fig. 317, the driver circuit has very few parts. The signal is picked off from the volume control and fed into the base. In some driver circuits you will find a fairly high value of resistance placed between collector and base. This is resistor R1. This is a feedback resistor and helps stabilize the transistor by supplying a small amount of negative feedback. We could

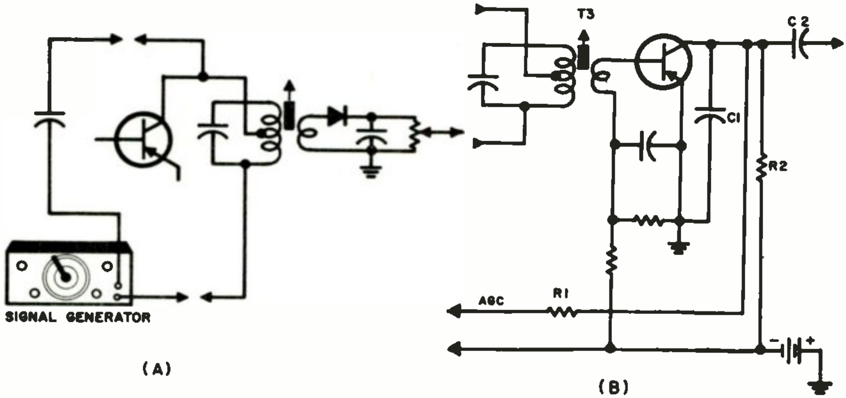



Fig. 318. *Signal-generator method of checking a diode detector (A). Signal heard from retceiver speaker indicates detector and audio circuits are working. Some receivers use a triode transistor (B) as detector.*

accomplish the same thing by omitting capacitor C1 across the emitter resistor.

## The detector

*Jumping from base to collector,*
*Was our hero service technician, Hector.*
*The set wouldn't squalk,*
*The speaker wouldn't talk,*
*The signal hadn't reached the detector.*

And from this little verse we learn a sad, sad story. If the signal doesn't reach the detector, there just isn't much use in looking at the audio driver and output stages for the troubles.

Most transistor sets use a diode detector circuit, as shown in Fig. 318-A, while some have a transistor for a detector.

Before we start to think about detector troubles, let's ask ourselves, "What does the detector do? Why should we use a transistor (Fig. 318-B) in place of the diode?"

Modern detectors have two jobs. They rectify the signal. If they didn't do this, we wouldn't be able to hear the signal. Also, the rectified detector current (when sent through a resistor) gives us our automatic gain control (we shorten this to agc) voltage. Another name for automatic gain control is automatic volume control (or avc).

Because we know what the detector does, we immediately have an idea of what sort of trouble to expect. No sound – check the detector. Very weak signal – check the detector. Blasting – check the detector.

## How do we know the detector is in trouble?

To learn if our detector stage is the troublemaker, feed a signal into the collector of the preceding transistor. Fig. 319 shows how we do this.

Now be careful and don't make a mistake. Up to now we've

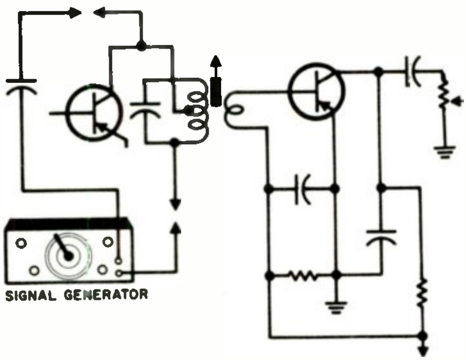



Fig. 319. *Signal-generator method of checking a transistor detector. A signal tracer connected across the detector load (usually the volume control) can substitute for receiver's audio stages.*

been working with audio stages. For that reason we have been using an audio signal for stage testing. But where are we now? Since we're trying to put a signal in right before the detector, shouldn't we use an if signal? Definitely! The if is 455 kc so we must make sure to set our generator to that frequency.

Anything else we might have forgotten? Yes. An if signal alone is not enough. It must be modulated. You can do this with the *mod on* control on your generator. Finally, put an .01 $\mu$f capacitor in series with the "hot" lead of the generator (this will keep collector voltage out of the generator) and we're ready to go.

If, with this test, we get a signal out of the speaker, the detector is working. If you prefer, you can connect your signal tracer across the detector load (the volume control).

What kind of trouble will the detector give us? Use the troubleshooting chart to help you. We have just one chart for diode and transistor detectors since you'll find the same sort of troubles whether the set has a diode or a transistor as a detector.

| **Troubles in the detector stage.** | **And What To Do About Them.** |
|---|---|
| **No signal output.** | Check for an open circuit, a short circuit, a defective diode or transistor detector. Check C1 and R1 in Fig. 320. Make sure the transistor detector is getting its voltage. The coupling capacitor (C2) may be open. A completely dead battery or one that is very weak might be responsible. |
| **Weak signal.** | Check rf bypass capacitor C1. Do not use any larger value capacitor than necessary. The larger the capacitance, the more audio signal we lose.<br>The if transformer feeding the detector may be misaligned. This is T3 in Fig. 320.<br>Weak signals sometimes indicate that the diode or transistor need replacement. |
| **Signal sounds good when low, distorts when it is loud.** | The agc filter capacitor (C3) may be leaky. Check rf bypass capacitor (C1). |
| **No agc voltage.** | Check agc resistor R1. Make sure components in agc line are not open or shorted. |

## Getting rid of agc voltage

During alignment, it is best to disable the agc. To do this, connect a 100-ohm resistor (½ or ¼ watt will do) between diode cathode and ground as shown in Fig. 320.

## How much voltage out of the detector?

This is a hard question to answer since it all depends on the amount of signal we have to begin with, whether or not we have an rf amplifier stage, and on the number of if stages. However, you can usually count on about 0.15 volt at the diode load.

What if we do not have this amount of voltage? Or, what if we have much more? Let's answer these two questions in the order in which you asked them.

A capacitor (rf bypass) is placed right across the output of the detector. If you don't get enough signal voltage, check this capacitor.

Sometimes one or more of the if stages will start to oscillate. This means, of course, that when they do this they are acting as generators, producing a signal voltage of their own. The diode

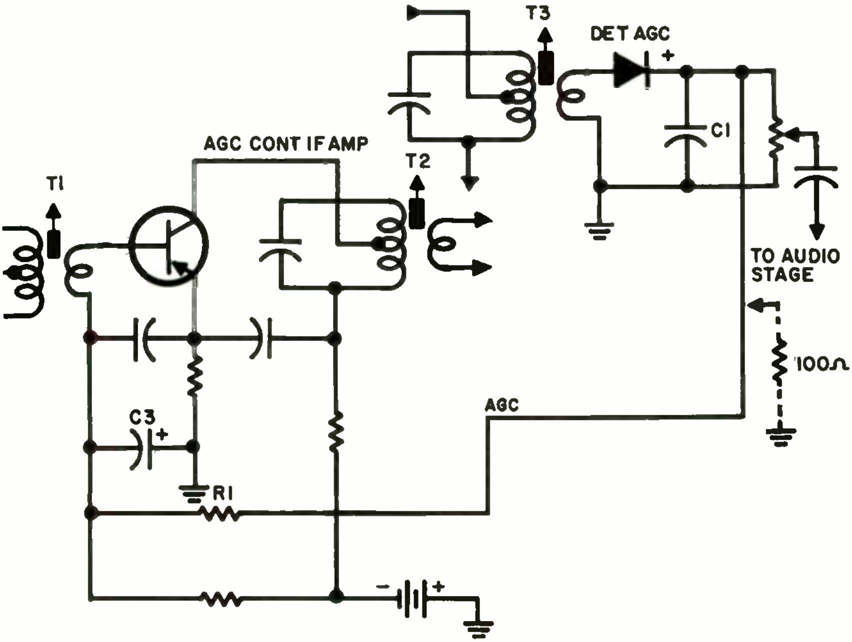



Fig. 320. *You can disable the agc line with a 100-ohm resistor.*

detector (or the transistor detector) won't know anything about this and will promptly proceed to rectify this artificial signal. Since this problem really belongs with the if stages, we will cover it in a later section.

## Checking the detector

If the receiver you are servicing uses a transistor detector and you suspect it, you can check it just as you would any other transistor by the methods we studied earlier.

If the detector is a diode, you can check it by measuring its forward and reverse resistances. Disconnect one side of the diode from the circuit. The reverse resistance should be more than ½ megohm. The forward resistance will range between 40 and 100 ohms.

## The agc line

In transistor receivers, automatic gain control is very simple. Fig. 321 shows the circuit. It consists of a resistor, R1, and a capacitor, C3. The value of R1 will vary from receiver to receiver, but it will have a range of 1,500 to about 3,300 ohms. The agc filter, C3, is

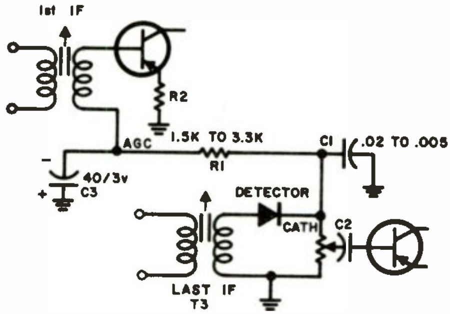



Fig. 321. *Agc network for a set using p-n-p transistors. For n-p-n types, the detector and C3 would be turned around.*

usually a 40-$\mu$f unit rated at 3 volts. (Capacitor C1 in the circuit is an rf bypass.)

Most transistor sets today use p-n-p transistors. However, you may find some that have n-p-n units. In such sets the diode detector will be connected in a manner opposite to that shown in Fig. 320—the cathode of the diode will be connected to the winding of the last if. Capacitor C3 will also be turned around so that its positive terminal goes to the agc bus and its negative terminal to ground.

## Agc operation

In Fig. 321, R2 is the emitter resistor for the first if stage. In the absence of a signal, the current through this resistor should be about 0.5 ma.

When a signal is received, the current through R2 will vary, in proportion to the strength of the signal. The stronger the signal, the smaller will be the current through R2.

But let us suppose that the current through R2 increases with the signal instead. The symptoms here would be in the agc line and would be caused by a reversed diode. Remember that the diode not only works to rectify the signal, but helps furnish bias for one or more stages (usually if) in the receiver. When checking controlled

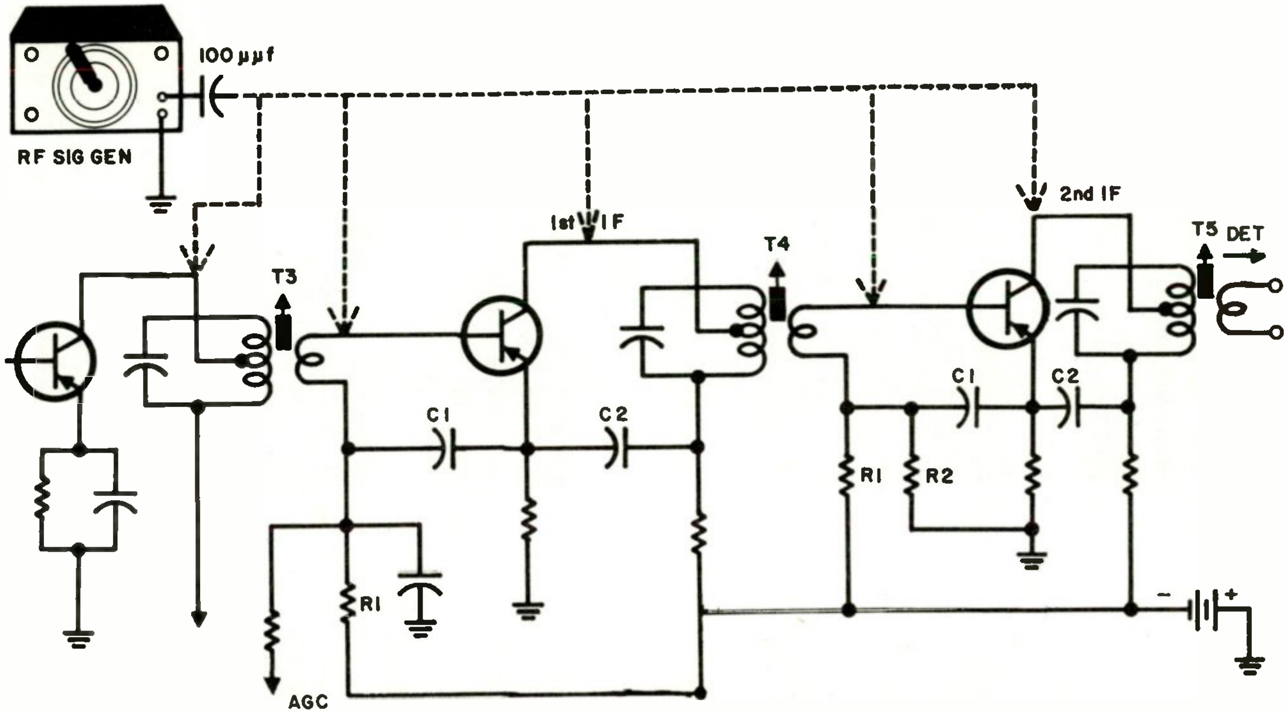



Fig. 322. *Method of signal tracing the second and the first if stages.*

stages, then, keep in mind that their behavior may be due to something over which they have no control.

*When you've checked the audio,*
*What else is there to do?*
*Perhaps the detector,*
*Could stand a look or two,*
*But if you're stuck, don't get in a rage,*
*Just move on back to the if stage.*

## The if stages

Perhaps you've been accustomed to working with vacuum-tube ac–dc receivers. If so, you may have become used to the idea of just a single if stage. Transistor radios, especially those used in automobiles, often have two if's although some of the cheaper portables have only one.

Does this mean any extra work? Not actually. If you can fix one you know how to fix two.

## Our first problem

Our first question is always the same: "Is the stage working? How can we tell if it is?"

Signal injection is still the answer. Put a signal in. Listen to hear if it comes out.

This method is shown in Fig. 322. To check the second if (the stage nearest the detector) feed a signal into the collector of the first if. If you get sound out of the speaker (or signal tracer), move the hot lead of the generator over to the collector of the converter or mixer. If the sound continues to come through, then both if stages are good.

When you checked the detector the generator was set to the if of the receiver. The generator modulation switch was turned on. Your only precaution now is to keep adjusting the gain control of the generator. As you move toward the front-end (tuner) of the receiver, stage by stage, the gain of the receiver increases the signal strength. This means you don't need as much output from the generator.

## How about the if?

An if amplifier is somewhat like an audio amplifier. A big difference is the frequency. As we go higher in frequency it becomes easier for an amplifier stage to oscillate. When this happens, the amplifier produces signals of its own—and they're certainly not pleasant to hear. They sound like whistling or squealing.

This is just one of the troubles we can expect in the if. Suppose we see what other sort of illness we can expect.

| Troubles in the if stages. | And What To Do About Them. |
|---|---|
| **No signal output.** | Resistance test the if transformers (primary and secondary windings). (Naturally, set must be off.)<br>Check the base bypass capacitors, C1 (Fig. 322). If this capacitor is shorted, the if stage won't work. |
| **Receiver is noisy.** | Check soldered contacts. If the set uses printed-circuit board, examine conductors for cracking or splitting.<br>Corroded windings in the if transformer produce noise. |
| **Signal is weak.** | If one or both if stages are misaligned (even partially), signal strength will be reduced.<br>Check the base bypass capacitor, C1, and the collector bypass, C2 (Fig. 322). If these are open, signal strength will be lowered. |
| **Distortion.** | If stage is agc-controlled, make sure it is receiving agc voltage.<br>Distortion is produced if transistors are being operated with wrong voltages.<br>Set will distort if battery voltage is weak.<br>Make sure the base biasing resistors, R1 and R2 (Fig. 322) haven't changed their value. The resistors should be within their tolerance. |

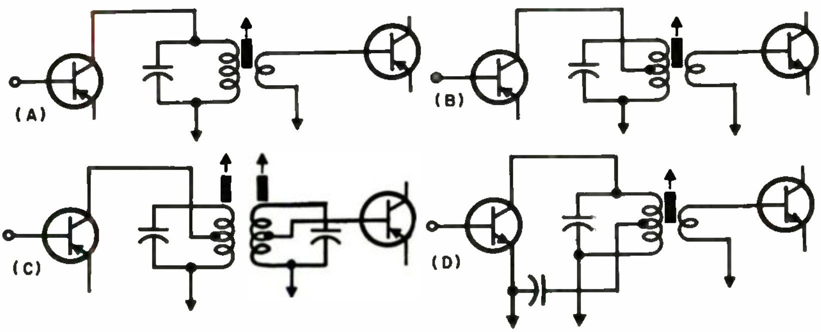



Fig. 323. *Four basic transistor if circuits. The dark rectangle and arrow between the transformer coils indicate adjustable slugs for tuning. Generally these are adjusted for maximum signal at 455 kc. Other if frequencies may be used.*

## If transformers

An if transformer acts as a connecting link, transferring the signal from one stage to the other.

But, like the little boy who carried the pitcher of cream upside down all the way from the grocery store, there are efficient and not-so-efficient means of transporting the signal.

For maximum transfer of signal, we must match impedances. This is why an audio output transformer is a stepdown device. It connects a high impedance (plate of a tube or collector of a transistor) to a much lower impedance (voice coil of the speaker).

If you were to call a transformer an impedance-matching device, you would be absolutely right! And the more closely impedances are matched, the more efficient is the transfer of signal energy.

When we go from the plate of a tube to the grid of the following tube, we are going from a lower to a higher impedance.

If stages in transistor receivers are exactly opposite to this. The impedance at the collector is much higher than that of the following base. Here we need stepdown if transformers.

We have three ways of getting what we want, as shown in Fig. 323. In Fig. 323-A we have a very common type of if transformer. The primary has more turns than the secondary, and that is that.

Some manufacturers try for better selectivity by using the method shown in Fig. 323-B. Here the collector connection isn't made to the top of the if primary winding (point of maximum impedance) but lower down on the winding (point of lower impedance).

Now you might argue that it would have been better to reduce the number of turns of the primary, but to do so would make it more difficult to resonate the primary (to 455 kc). It would also reduce the selectivity.

We can tap down on both primary and secondary, as shown in Fig. 323-C for impedance-matching purposes. Sometimes the emitter is tapped "up" on the primary winding (Fig. 323-D). The result is just the same as though we had tapped the collector "down".

## If transformer resistance

The resistance of the primary winding of a transistor if transformer is from about 1.4 to 3.5 ohms. The secondary winding, since it has fewer turns, has a lower resistance. A value of 0.5 ohm is common.

## Replacing transformers

In Fig. 323 we show four different transformer circuits. How-

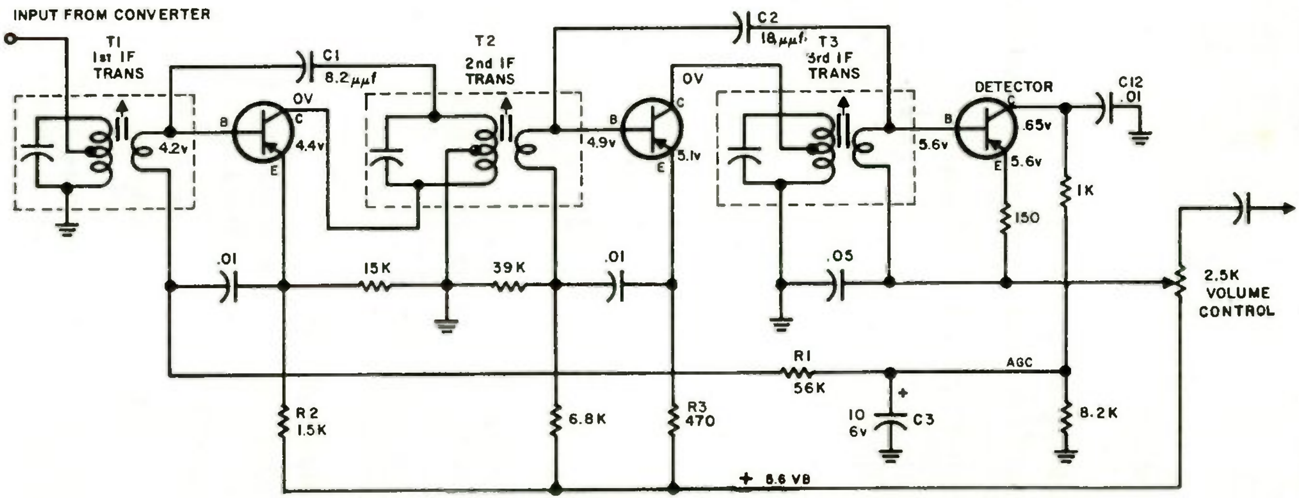



Fig. 324. *Two stages of if amplification are quite common in transistor sets.*

ever, the impedances of if transformer windings (quite a different thing than the resistance) varies considerably from one receiver to the next. For this reason, you cannot use just any old transformer that may be available. Use an exact replacement or an equivalent unit recommended by the manufacturer.

The if transformers used in transistor sets deserve care and respect. Keep screwdrivers away from them. These tools were never intended for alignment anyway. Use a nonmetallic alignment tool designed for that purpose.

## Removing if transformers

Use a low-wattage iron. A unit rated at about 35 watts will do.

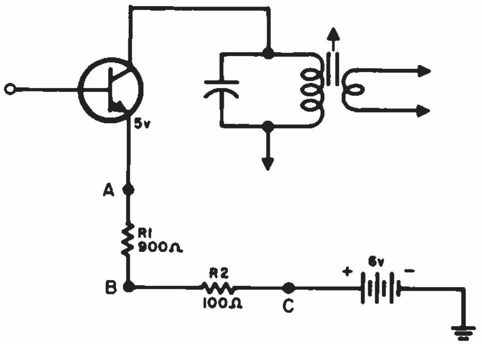



Fig. 325. *The emitter resistor supplies convenient check points for the if transistor.*

You will need the help of a small brush with stiff bristles. Heat the connection until the solder begins to melt then quickly brush the solder away. Don't keep the soldering iron at the lug any longer than necessary. Move the can from side to side gently until it comes loose.

## Examining the if

In Fig. 324 we have a two-stage if system and a transistor detector. This circuit has a few interesting features so let us examine them together.

Note capacitors C1 and C2. These are feedback capacitors (sometimes called neutralizing capacitors). Their purpose is to keep the if stage from oscillating.

The next item is the agc network. This comes from the collector output of the transistor detector and is fed back to the base of the first if transistor. The agc filter consists of R1, a 56,000-ohm resistor, and C3, a 10-$\mu$f electrolytic.

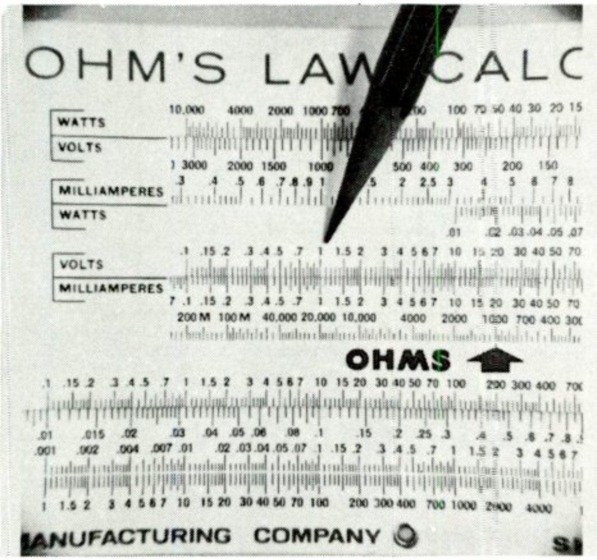
The emitter resistors, R2 and R3, are not bypassed. This supplies a small amount of negative feedback. Thus, R2 and R3 work together with C1 and C2 to keep the if system from oscillating.

## A little more arithmetic

You've probably noticed that we have avoided using arithmetic as much as possible. Sometimes, though, a little bit of it can help us in servicing a receiver.

Fig. 325 shows an example. Here we have an if stage. The emitter resistor is 900 ohms. On our way back to the battery, we see a decoupling resistor of 100 ohms. Thus, between the battery and the emitter, we have 900 plus 100 ohms, or a total of 1,000 ohms.

Now let's take a look at the emitter. The manufacturer has very kindly marked the emitter as 5 volts. This means that our resistance of 1,000 ohms has dropped 1 volt.




With the resistance (1,000 ohms) set over the arrow, 1 ma is found under 1 volt, pointed out by the pencil. (Ohmite Mfg. Co.)

With this little bit of information, we can now calculate the emitter current.

$$I = \frac{E}{R} = \frac{1}{1{,}000} = .001 \text{ ampere, or 1 ma}$$

This is all very nice, but suppose the voltage at the emitter doesn't measure 5 volts—what then? Your next step would be to check the resistance values of R1 and R2 (with the receiver turned off, of course).

It is possible, though, that both resistors will be good. Connect a vtvm between points A and B (in Fig. 325) or between points A and C.

Short the emitter to the base. You can do this with a clip lead

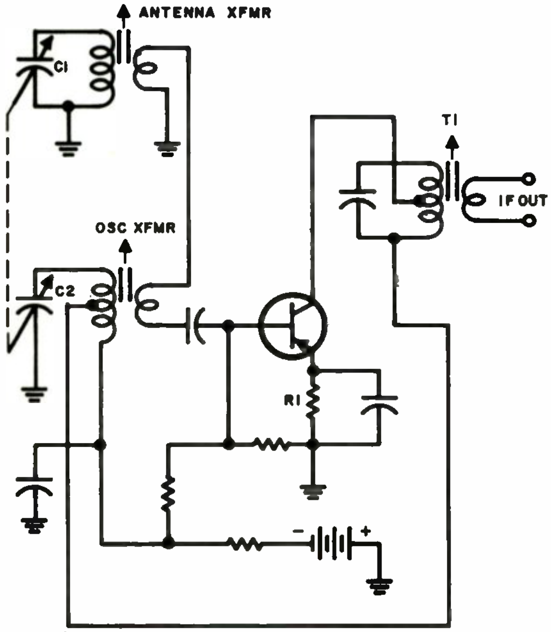



Fig. 326. *Converter stage of a transistor receiver. The converter transistor is a triode.*

but be careful not to damage the transistor leads. The voltage you are measuring between A and B or between A and C should drop to zero or very close to it. If it doesn't, the transistor is defective.

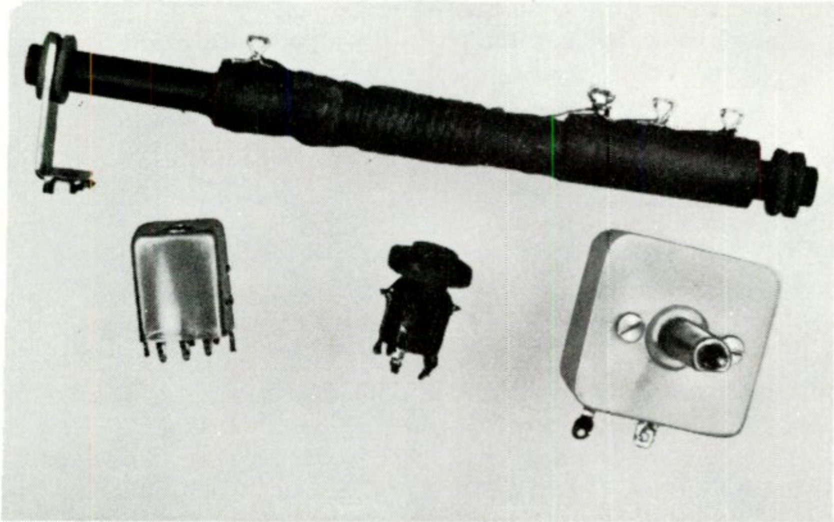
## Back at the front end

*There was once a converter*
*(It really needed fixing),*
*Very anti-social*
*It didn't enjoy mixing.*

We'll admit that it's taken us some time to reach the converter stage of our transistor receiver. If you had been working on a real set, you would have found the trouble long ago. What we're trying to do, though, is to learn to fix every section of the receiver.

A quick way to service any set is to divide the set into two parts (in your mind). From the front end (radio frequency or converter) to the detector is one half; from the detector to the speaker is the other half.

Let's see what good this does us. Put an audio signal across the detector diode load. If you get a signal out of the speaker, then you know that the second half of the set is working. Next, inject a signal at the receiver input and put your signal tracer across the



Ferrite loop (top) and (left to right) single-tuned if transformer, oscillator coil and tuning capacitor. Variable capacitor has plastic foil between plates to prevent shorting and increase capacitance value. It is sealed in plastic case to keep out dirt and moisture.

diode load. No signal, weak signal, distorted signal, etc. means that your trouble is in the first half.

Do you see what we're trying to do? We're trying to localize the trouble, pinpointing it to a particular stage. After we do that, we will then search for the particular part (or parts) that are defective.

### It's too easy!

Does this sound too easy? If it does, it's because it's a good way to work. We hope you will remember, though, that sometimes we can have troubles in both halves of the set at the same time. You may fix or replace some component in the audio amplifier only to find that the antenna coil is defective. It happens!

## The converter

You've probably had a good bit of your experience with vacuum-tube converters of the pentagrid type. Transistor converters are much simpler since they are triodes. Fig. 326 shows a typical transistor converter.

## How does it work?

What is a converter, anyway? Isn't it just a combined oscillator and amplifier? The amplifier part consists of the antenna transformer and the transistor. The oscillator is made up of the oscillator transformer and the same transistor.

The signal is fed into the transistor input (base–emitter) circuit

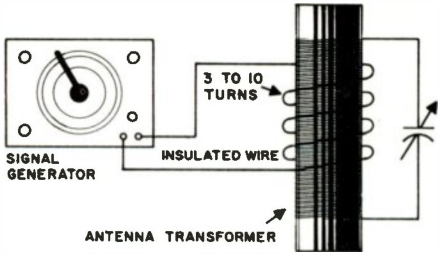



Fig. 327. *Method of coupling the signal generator to the antenna transformer of a transistor receiver.*

through the antenna transformer. The amplified signal appears in the collector (output).

The oscillator is tuned to a higher frequency than the incoming signal by the amount of the if. In other words, the difference between the incoming signal and the oscillator frequency is equal to the if. Here's an example:

| | |
|---|---|
| oscillator frequency | 1,455 kc |
| incoming signal | 1,000 kc |
| | 455 kc = value of the if |

Note that C1 and C2 (the tuning capacitors) are ganged (or are rotated at the same time). The dashed line shows that they are ganged or turn together.

## Quick check

Before we start to troubleshoot the converter, what do we want to know? As in the case of all the other circuits, we want to know if the converter stage is working. Let's see how we do this.

Take a length of insulated wire and wind a few turns of this wire around the antenna coil, just as shown in Fig. 327. You don't have to fasten the turns. Just keep them loose.

The reason we use an arrangement such as that shown in Fig. 327 is that we don't want to overload the converter transistor. Our generator can supply so much signal that this is easy to do. Also, keep your generator about 12 inches away from the receiver. Your coil can have a pair of connecting wires this long.

Now set the receiver and the signal generator to 600 kc and turn both of them on. Make sure the signal generator modulation switch is turned to the ON position. Keep the gain control of the generator low, since we don't need much signal.

It isn't too likely that the dials of the generator and receiver will match exactly, so turn the receiver tuning knob back and forth slightly. If you hear the modulation tone out of the speaker, the converter is working.

But what if the converter isn't working? What are the troubles we can expect? Use the chart to help you.

| Troubles in the Converter Stage. | And What To Do About Them. |
|---|---|
| No sound. | Look for shorted or open components and leads that have broken away from their joints.<br>The transistor could be defective.<br>Look for parts, especially resistors, that have changed value.<br>Check the battery, preferably by substitution. Are the battery clips making good contact? If the set uses two batteries, the fact that one of them is good is of no help. Both must be good. |
| You can tune in only one station. | If stages aren't aligned. The oscillator section of the converter isn't working. |
| Receiver cannot tune in stations at the high-frequency or the low-frequency end of the band. | Make sure capacitor plates aren't touching. Work the capacitor back and forth. If you hear a scratching noise, check the capacitor for shorts.<br>Antenna transformer may be defective.<br>Make sure emitter bypass capacitor isn't open. An open capacitor will cut down the gain. Weak station may not be picked up. |
| Poor sensitivity at low- or high-frequency end of the band. | Sometimes the antenna core gets cracked or broken. If it is, replace the core or entire transformer.<br>Misalignment of the oscillator coil or antenna transformer will cause this trouble. |
| Receiver is noisy. | Is the set noisy when being tuned, or when the volume control is being adjusted? Then these |

components (tuning capacitor or volume control) are probably causing the trouble.

Noise can be caused by a defective converter transistor. Only way to check is by substitution.

## Checking the local oscillator

What can we do if all the stages following the converter are good, but we get no sound out of the receiver?

One of the possible causes is that the local oscillator might not be working. Fortunately, we have a number of easy ways to check the oscillator.

The first step is to determine the transistor type. Is it p-n-p or n-p-n? For a p-n-p, connect the negative lead of the vtvm to the

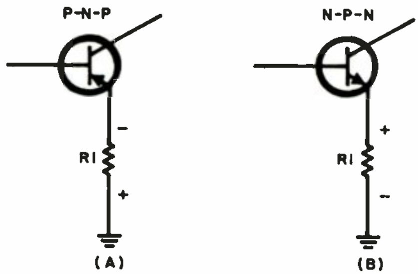



Fig. 328. *Methods for determining whether the oscillator section of the converter transistor is working.*

emitter, the positive lead to ground. Or, connect the leads across the emitter resistor of the converter, being careful to watch polarity.

Compare the voltage reading you get with that shown on the schematic. If your measurement shows the voltage at the emitter is more negative than normal, the oscillator isn't working.

You can make the same test with n-p-n converter transistors, except that the polarity is reversed, as shown in Fig. 328.

If the voltage at the emitter of the n-p-n transistor is above normal, the oscillator isn't working.

Another way of checking the oscillator is to use another receiver. Of course, the receiver you are going to use as a test unit must be in working order. Turn the receiver on and tune it to about 1500 kc. Turn on the receiver you are checking and adjust the dial until you are at about 1045 kc. Since it may be difficult to locate this frequency exactly on the dial, start at 1000 kc and turn the dial slowly toward 1100 kc. About halfway between these two points, you should hear a whistle out of the receiver you are checking. If you do, the local oscillator is working.

## The single-transistor converter

In Fig. 329 we have the circuit for a single-transistor converter. Inductive feedback is used between collector and emitter through oscillator transformer T2.

Bias is supplied by resistors R1 and R2, connected in series across the battery. Additional bias is also furnished by resistor R3, wired between the emitter and the battery.

The amount of feedback can be controlled by adjusting the slug in transformer T2.

## Mixer and local oscillator

In some sets you will find separate transistors used as the mixer and local oscillator. In Fig. 330, V1 is used as the mixer while V2 is used as the local oscillator. Note the difference between a converter and a mixer. A converter is a transistor (or a tube) that does a double job—it works both as a mixer and oscillator. A mixer, however, is a transistor (or a tube) that just mixes signals. It requires a separate transistor (or tube) for a local oscillator.

## Receiver test points

Did you ever take a trip in a plane? Unless you're very familiar with the area you fly over, you'll not be too sure of just where you are. A good way to check is to use a map and pick out large areas, such as lakes or big cities.

Servicing a radio is like taking this kind of a trip. Until you find the trouble, you really are "up in the air". Examine the typical transistor radio shown in Fig. 331. We've marked various test points with letters A, B, C, etc. For test points at the detector or after it, use an audio signal. For test points before the detector, use a modulated if or rf signal.

## More troubleshooting

*Once upon a time,*
*There was a very ambitious service technician*
*(A nice young fellow, very fine)*
*He advertised all his services, now and then*
*Told all his friends and neighbors how good he was*
*But while his prices were very fair*
*He knew very little about radio repair*
*And so the sets just piled up and up,*
*Up*
*Up.*

*Finally, the idea got through to his mind*
*That he had to do something about it*
*He did!*
*He moved!*
*And left all the unfixed sets behind.*

Please don't take this very sad poem too much to heart. After all, you are learning more and more about fixing sets.

We've covered the transistor receiver from stem to stern, from

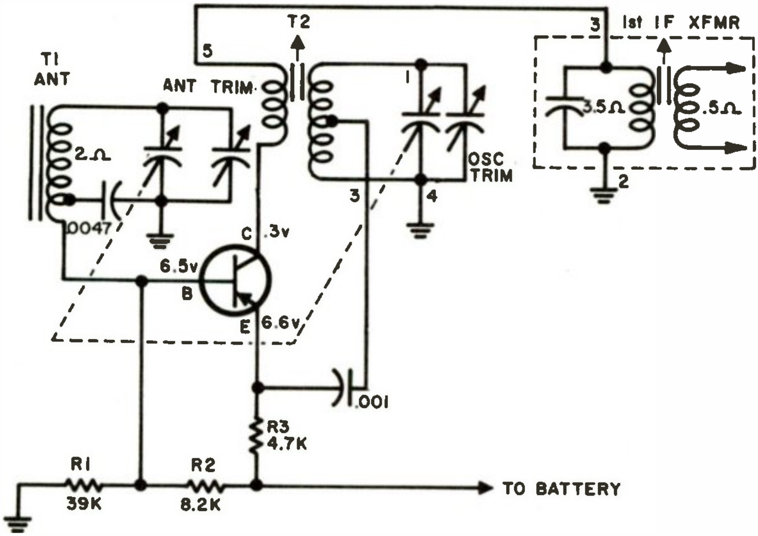



Fig. 329. *In this circuit, a single transistor is used as the mixer and local oscillator.*

the antenna to the speaker. Most of the transistor receiver troubles have been described but we do have a few more you should know about. We've included them for you in a general troubleshooting chart.

## TRANSISTOR RECEIVER SPEED SERVICING CHART

| Here are the Troubles. | And What To Do About Them. |
|---|---|
| The battery needs frequent replacement. | This is most often due to a shorted or a leaky component. Check transistor base-biasing resistors. If they have decreased in value, they will put a heavier current drain on the battery. |

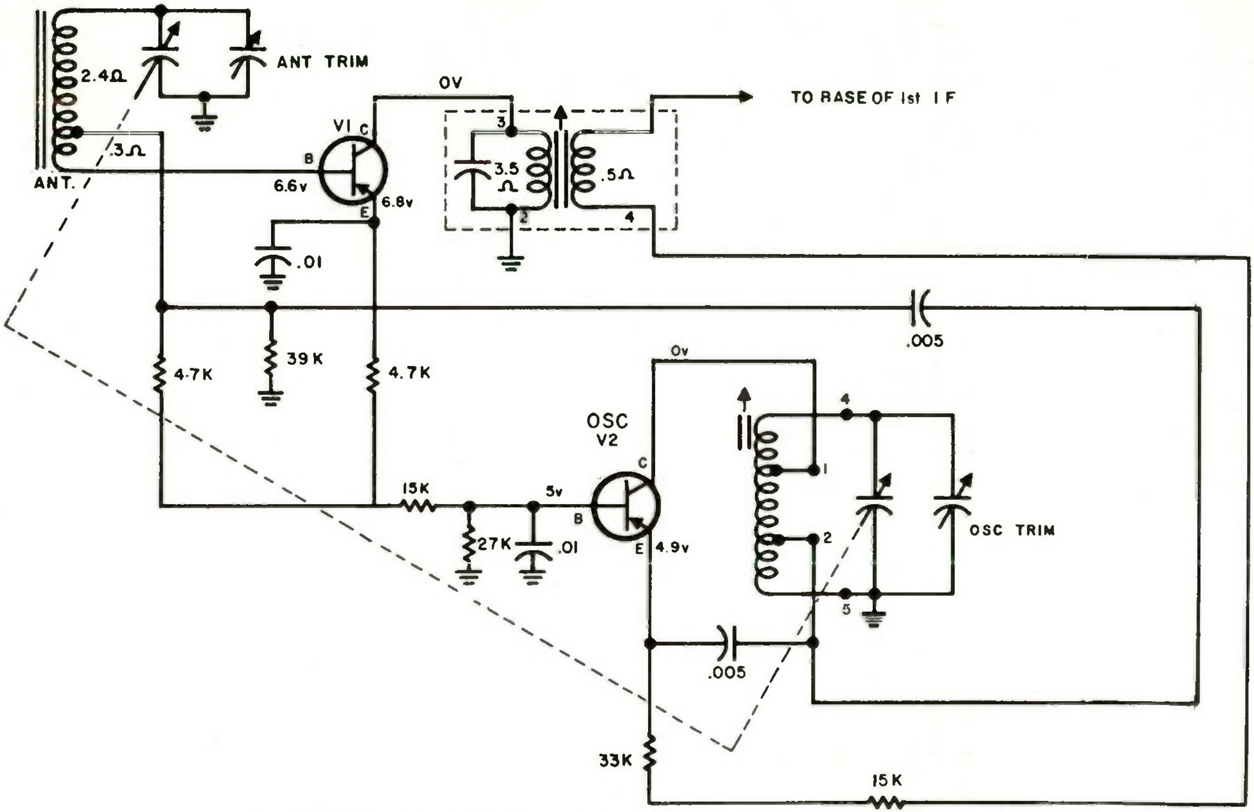



Fig. 330. *Front end of a transistor receiver using a mixer and a local oscillator.*

Check the ON–OFF switch. It may not switch off. This won't hurt the transistors, but it does put a continuous load on the battery.

You will find a high-value electrolytic shunted across the battery. If this capacitor's leakage increases, battery life will be shortened.

Check the current drain of the audio output transistor or transistors. Use a dc milliammeter for the test. Make sure these transistors do not draw more than normal current. If they do, either the transistors or associated components are at fault.

| | |
|---|---|
| **Sound is low. Setting volume control to maximum doesn't help.** | Usually caused by a rundown battery. Symptom is generally accompanied by distortion. Set may be misaligned. If these are not the troubles, check transistor bias voltages throughout. |
| **Sound is distorted.** | Try substituting a new battery. If set uses more than one battery, replace both. |

Is speaker cone torn? Does speaker voice coil slide back and forth without interference? If set uses earphones, try these to see if distortion disappears. If it does, fault is in speaker.

Leaky or shorted coupling capacitors will cause this trouble.

Unsolder one end of the emitter bypass capacitor (in each stage, one at a time). If distortion is lowered, bypass capacitor is defective. Replace.

In push-pull audio stages, matched transistors are needed. If one transistor of a matched pair becomes defective, distortion will result. Replace both.

Distortion may be natural characteristic of receiver. Some portables cannot have volume increased without increased distortion. This is in the receiver design.

Check agc filter bypass capacitors for short or leakage.

Receiver may be misaligned.

| | |
|---|---|
| **Receiver is intermittent.** | Look for dirty or worn contacts on moving components — volume control or switch. Battery fastener spreads sometimes, making poor contact. Make sure battery contacts aren't corroded or dirty.<br><br>Is set intermittent when tuning? Check tuning capacitor for short at a particular spot.<br><br>Look for a soldered connection that has come loose, making intermittent contact. Check printed-circuit board. Conductor on board may have broken away or may have opened along its length. If possible, hold printed board up to the light for examination. |
| **Set plays for a short while, then fades.** | Battery needs replacement. The receiver may play for a time then drift and finally become weak. |
| **Receiver whistles.** | Set may be misaligned.<br><br>This trouble is often caused by a weak battery. As a battery gets older its impedance increases, thus forming a common impedance for all stages.<br><br>Check filter capacitor across battery. Shunt with a known good unit of the same value. If whistling disappears, replace filter capacitor.<br><br>This trouble has been caused by defective cores in the antenna transformer or oscillator coil.<br><br>Check the neutralizing capacitor. (If more than one, check each in turn.) The capacitor should be replaced with a unit having the same value. Use a zero-temperature-coefficient type. |
| **Receiver volume keeps changing.** | Check agc circuit. Agc voltage may be lower than normal or missing entirely. |
| **Receiver does not receive stations at the high-frequency end of the broadcast band. Sometimes the set will not pick up stations at the low-frequency end of the band.** | Try replacing the battery. Some stations at the ends of the broadcast band (especially high end) are not as strong as other stations.<br><br>Front end of receiver may be misaligned.<br><br>Converter transistor may cause this trouble. |

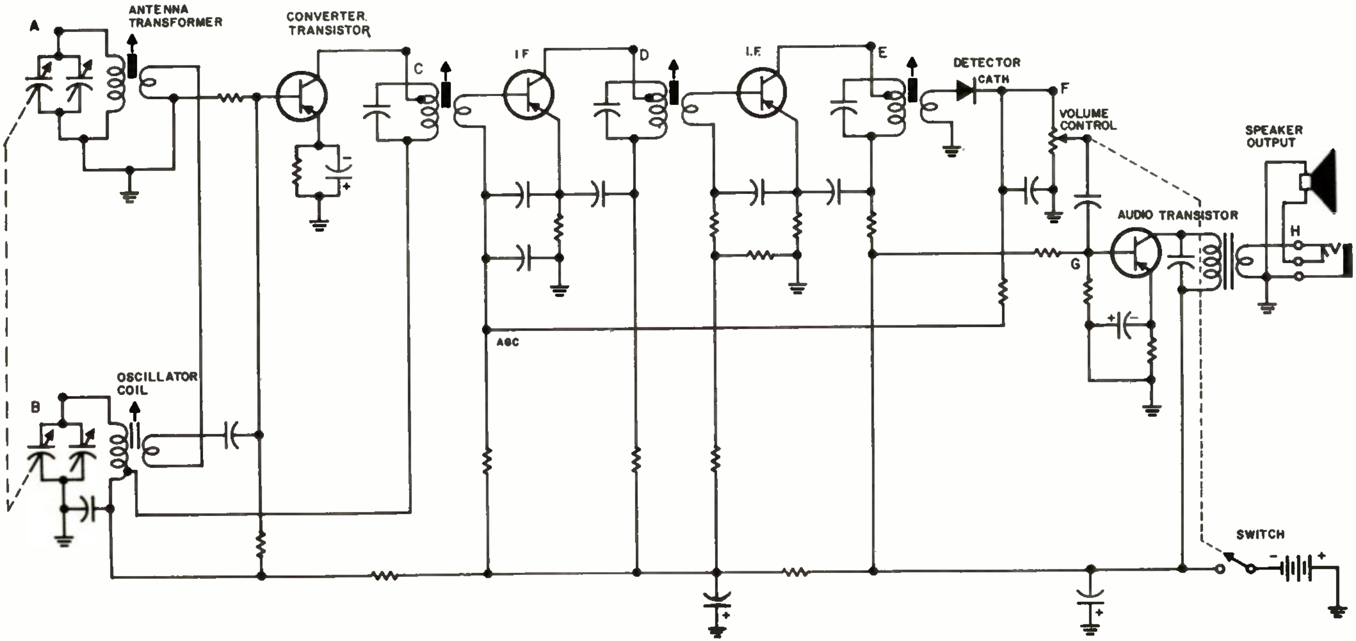



Fig. 331. *Test points in a typical transistor receiver.*

### The most common causes of trouble

Some troubles occur more often than others. In transistor receivers (but not in transistor auto receivers) we can expect servicing problems somewhat as follows:

1. Weak battery.
2. Battery completely dead.
3. Incorrect connections to the battery.
4. Defect in the printed-circuit board.
5. Broken connection.
6. Regeneration in some if or af stage.
7. Defect in some component, often an electrolytic capacitor.
8. Distortion due to unbalanced transistors in push-pull audio output stage.
9. Defective transistor.

## QUESTIONS

1. Does an unbypassed emitter produce positive feedback?

2. Can a weak battery cause excessive volume?

3. Will a shorted voice coil produce squealing, motorboating or other oscillation?

4. Do interstage transformers in a transistor receiver have a 1:1 ratio?

5. What is the normal (approximate) forward resistance of a diode? The reverse resistance?

6. Is an rf bypass capacitor wired across the output of the detector?

7. What is the usual intermediate frequency of a pocket transistor radio?

8. How is the impedance matching of an if transformer accomplished?

9. Is the detector a good place to obtain avc voltage?

10. Will the voltage measured across the detector load be higher or lower than normal if the converter isn't working?

CHAPTER 4

# servicing auto radios part 1

ARE YOU old enough to remember automobiles as they used to be? The most important thing about the old-time auto was that it should run. But what have we today? Autos with air-conditioning and built-in phonographs. We don't have to shift gears and some have powered window openers and seat adjusters.

We like to take our comfort with us. And when we say comfort, we mean pleasure too. That is why automobile radios are so important.

## Things have changed

Just as the modern car barely resembles the gas buggy of yesterday, so has the auto radio changed. You might say that a radio is a radio and let it go at that, but it isn't quite so simple. At one time the auto radio was quite ordinary. It used a vibrator type power supply. To help the driver keep his eyes on the road, the set had pushbutton tuning.

But what have we today? We still have some of the old style sets with us. But we also have sets without vibrators—using 12-volt tubes working directly from a 12-volt storage battery. We have hybrid sets using both tubes and transistors. These receivers use tubes for the rf and if stages and transistors for the audio output. And we have *all transistor* receivers.

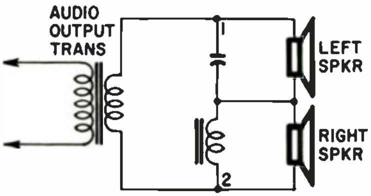
This isn't all. At one time car radios were for AM reception only. We now have FM receivers as well as converters that can be used with existing AM sets so that FM can be received.

Mechanical variations add to this list. Not all car radios are built into the dash. For sports cars the radio may be mounted right on the floor. Some radios are designed to be slipped into the glove compartment and then removed for use as a personal portable. Some car radios are now part of the rear-view mirror and do a double job.

## Don't go away—we have more

We're not finished yet. Even the auto radio speaker has changed. Instead of having one speaker, we now may have two—one for the front of the car and one for the rear. In some arrangements the speakers can be controlled so that either the front or the rear speaker is on, or both.

This still isn't all. The input to the pair of speakers can be adjusted so that we get a sort of stereo sound in the car. It isn't




Pseudo-stereo system is used in automobiles. One speaker is in front and the other in the rear. Unless specific instructions are followed, or a kit is used, some experimenting may be necessary to separate lows from the highs.

true stereo (we call it pseudo-stereo) but the effect is very impressive.

## Mechanical changes

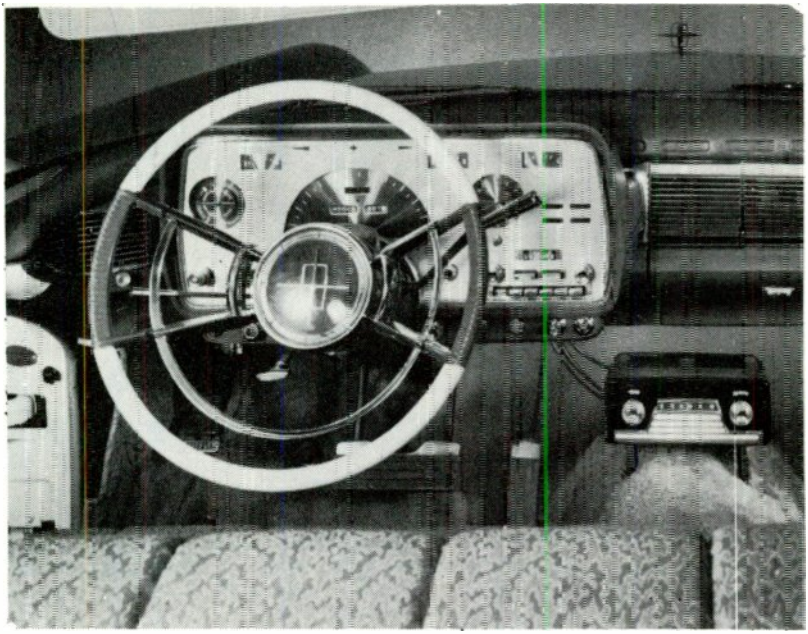
Not only has the electronic design of the car radio been changed but its mechanisms have changed also. Auto radios are equipped with search tuners so the driver no longer needs to bother punching a bunch of pushbuttons. The radio does the job for him.

## Where do we fit in?

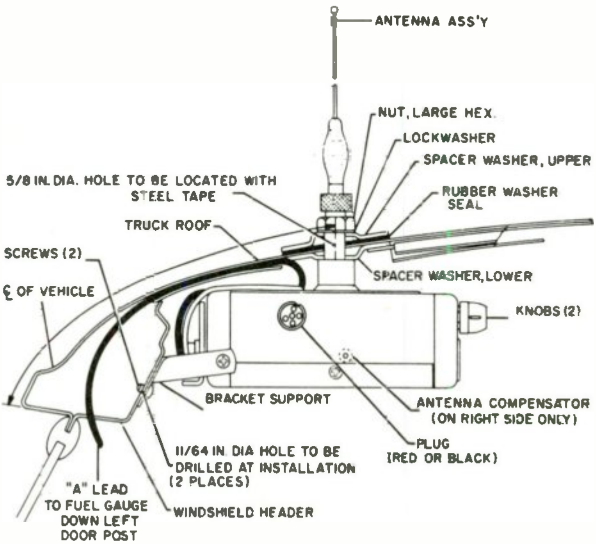
What has all this to do with us? The answer is this—if auto radios have made so many advances, you must stay up-to-date and be able to fix those sets.

## A few differences

The five-tube ac–dc home receiver was probably the most popular type ever made and sold. We know you're familiar with it so let's compare it to an auto radio. We can do this in block diagram form, as shown in Fig. 401.



Floor mounted FM tuner is much easier to service.
(The Bendix Corp.)




Radio installation in truck roof is used when dash space is too shallow for other types. Antenna connects directly to receiver without cables. (Philco Corp.)

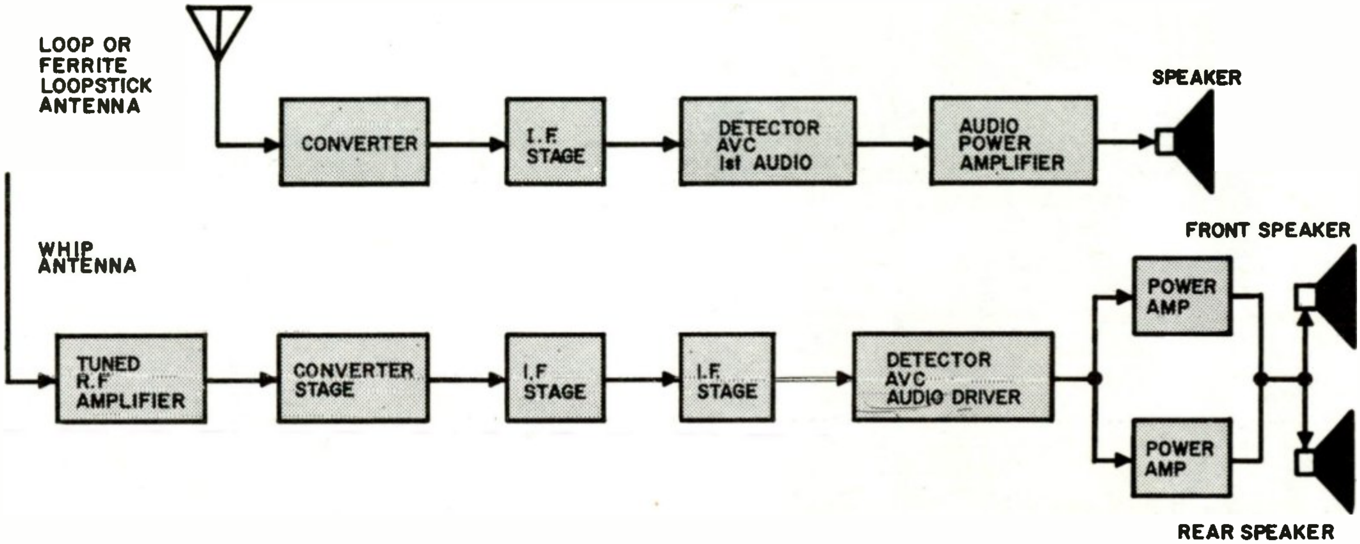
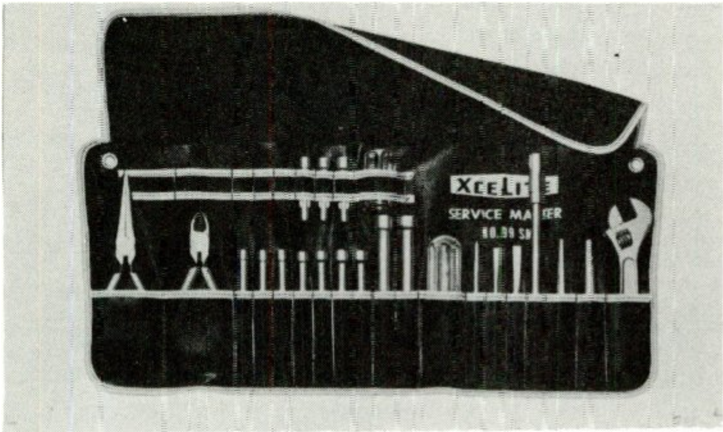



Fig. 401. *The auto radio (below) generally has more stages than the home ac-dc receiver (above).*

What are some of the differences? Has the auto radio more stages? Does it have more tubes or more transistors?

But what else is there? Take a look at the front end. Many auto radios have a tuned rf amplifier stage. In the home receiver we might not need it, but for auto radios we can't always be sure that we'll have lots of signal strength. Sometimes, when the car is traveling between cities, the signal gets very weak. An rf amplifier improves the receiver's sensitivity and selectivity.



You will need a tool set when installing or removing auto radios. Also, box-wrenches or automotive socket wrenches will be needed to reach some bracket fastenings. (Xcelite, Inc.)

Now let's look at the if section. The auto radio has two if amplifiers while the home set has just one. We have greater gain (supplied by the rf and if stages). We have push-pull output to handle the stronger audio signal.

What do we learn from this? The auto radio has more stages and is a more complicated receiver than the ones in our homes.

## Auto radio installation and removal

If a table radio has to be serviced in the shop, we just pick up the radio, tuck it under our arms and take it. The auto radio isn't quite so easy to handle. We must do two things:

1. Disconnect the auto radio from the electrical system of the car.

2. Remove the auto radio mechanically. The auto radio is part of the car and when we remove the radio we are removing a unit that must be securely mounted.

## Getting down to work

Now you have a sort of bird's-eye view of what we are going to cover in this part of the book. We know that some technicians have the idea that an auto radio is just the same as any other kind. But we are going to learn just how different auto radios are.

## The auto radio power supply

In any home the only source of power is the power outlet. In the auto radio, the only source of power is the car battery. That is

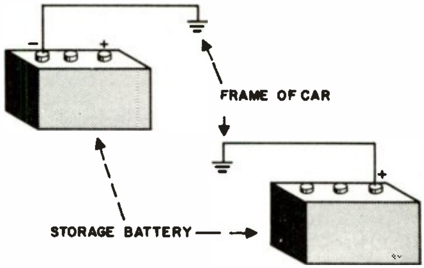



Fig. 402. *The basic source of power in the automobile is the storage battery. It can be either 6 or 12 volts (12 volts in more recent cars) and either its positive or the negative side can be grounded to the frame of the car.*

where we must start. Without the battery, radio operation isn't possible.

## We start at the beginning

What are the differences between power as supplied to the home and power in the car? We can set this up in the form of a little chart:

| **Home power** | **Car power** |
|---|---|
| ac | dc |
| 117 volts | 6 volts or 12 volts |
| one side grounded | either plus or minus grounded |
| needs no service | needs servicing |
| outlet never corrodes | battery terminals corrode |

We can learn more about these differences by looking at Fig. 402. Note that either the plus terminal of the car battery or the negative terminal can be grounded. Don't get into the habit of thinking the car "ground" is minus. In many cars it is plus (or positive).

## Direct and indirect power

The car battery supplies approximately 6 volts (in older cars) and 12 volts (in newer cars). The actual voltages are a little higher than these figures when the battery is new or freshly charged.

If the car radio uses tubes, the storage battery will supply filament voltage for all the tubes. No transformer or vibrator is needed or used. The tubes in the receiver, of course, will have filaments rated the same as the battery voltage.

If the car battery is 12 volts, then the auto receiver will have tubes with 12-volt filaments. If the car battery is 6 volts, then it will supply this voltage for filaments.

Thus, for tube filaments, we use the power of the battery directly. For screen and plate voltages, however, we can use the battery either directly or indirectly. If the set has 6 volt tubes, a vibrator power supply is required. If the set has tubes that work with 12 volts on the plate and screen, then the vibrator power supply is not needed and battery power is used directly.

## Filament systems

Let's start in an easy way and see how tubes get filament power. (We won't have to repeat this for transistor sets since transistors have no filaments.)

Fig. 403 shows the filament supply for a hybrid set. The battery

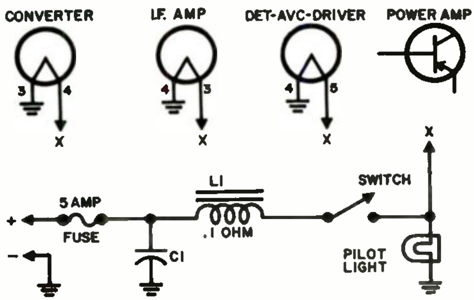



Fig. 403. *Typical filament supply circuit for a hybrid receiver.*

supplies the filaments of only three tubes since the output stage has a transistor.

What sort of troubles can we have in this circuit? Let's list them for easy reference.

| Troubles in the Filament Circuit. | And What To Do About Them. |
|---|---|
| **Open Fuse.** | This could be caused by a short anywhere in the receiver. Make sure the fuse is sitting firmly in its holder and is making good contact. Check to make sure that the fuse hasn't been replaced with one of a lower rating. If the set calls for a 5-ampere fuse, that is what should be used. |

**All filaments do not light.** If all the filaments do not light, look for an open fuse, an open filter coil L1 or a defect in the on-off switch or open in wiring. The switch is usually mounted on the volume control.

**One filament doesn't light.** Since the filaments are in parallel, one filament not lighting means that the tube or its socket pin connection is defective. The trouble is not in the power supply.


This small instrument is more convenient for testing filament continuity than an ohmmeter.
(Precision Apparatus Co., Inc.)

## The line filter

Getting power from a car battery is like living with a large family. You're bound to have noise sooner or later. The battery feeds the ignition system. This creates interference which rides right back along the line to the battery and from there through the filament connections into the receiver.

One way of reducing this interference is by using a filter. This is shown as L1 and C1 in Fig. 403. C1 is a filter capacitor, often called a spark plate (described later in more detail), while L1 is a filter choke. Sometimes the spark plate is made of selenium and acts more like a rectifier than a filter. You will sometimes find C1 drawn as a rectifier (diode symbol) instead of being shown as a capacitor.

The filter system in Fig. 403 is for an AM auto radio. For an FM receiver more filtering is needed. This is shown in Fig. 404. You are probably wondering why we need such a filter for an FM set. There are two reasons:

1. We need the filter to keep interference from coming into the filament line from the battery.

2. Just as important as item 1 above is the fact that we must keep each stage isolated. In an FM set we have high frequencies.

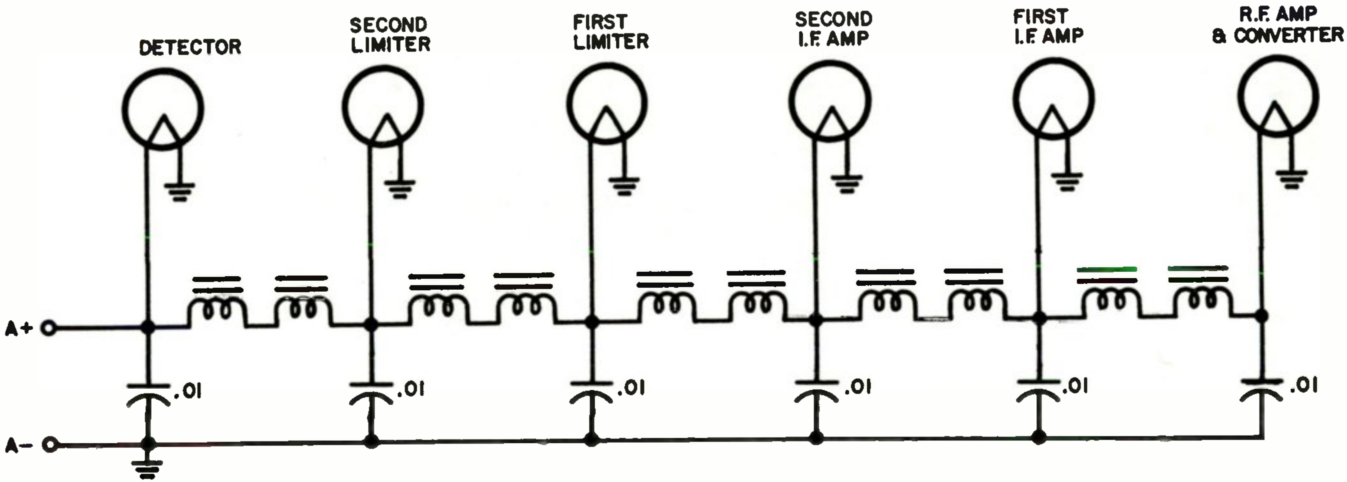



Fig. 404. *The filament system of an fm car radio usually has a large number of filter units.*

Therefore the filter shown in Fig. 404 works as a decoupling network. The filter keeps signal energy from being fed back from one stage to the other. Without the help of the filter the various amplifier stages might start to oscillate.

## Let's look for trouble

*The service technician is a peaceable guy, a good Joe,*
*Always being asked to fix a set "on the double,"*
*But he's the only one we know,*
*Who goes out looking for trouble.*

What sort of trouble can we expect from the filter circuit of Fig. 404? The tubes are all connected in parallel so, if the filament of one tube goes out, the other tubes should remain lighted.

If a particular tube doesn't light, you can be fairly sure the tube

Resistor-capacitor analyzer and capacitor decade boxes are useful in finding and substituting defective filters and bypass networks.
(Cornell-Dubilier Electronics)

is at fault. If not, make sure the filter choke for that filament is in good condition. With the receiver turned off, make a continuity check, using your ohmmeter.

There are a few other troubles we can expect. If the .01-$\mu$f capacitors open, we might get oscillation in the receiver. This could cause a whistle in the receiver, or squealing. If one of these capacitors shorts, the fuse will blow. If a capacitor is leaky, it could cause oscillation. It could also result in a fuse popping, but the set will play when a new fuse is put in.

## 12-volt tubes

At one time a 12-volt tube was understood to mean a tube with 12 volts on the filament. Not any more. It can also mean a tube working with 12 volts on the screen and plate, so we should describe such tubes just a little more carefully.

If we want to be very exact about it, none of the elements of these so-called 12-volt tubes work with 12 volts. The filaments may be anywhere between 10.0 and 15.9 volts; the lower voltage from

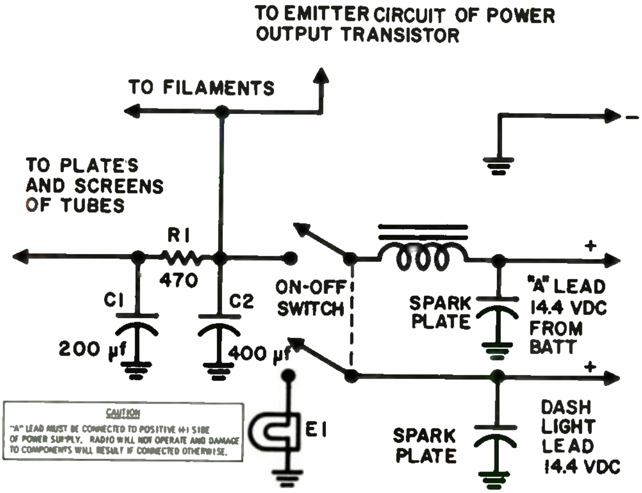



Fig. 405. *Only one wire is run to the filaments. One side of the filament of each tube is grounded to the chassis. So is one terminal of the storage battery.*

a weak battery and the higher voltage from the charging generator. The plate and screen voltages will generally be lower than the filaments because of the use of decoupling resistors in most circuits.

Power supplies (both filament and plate) for hybrid sets are about as simple as they can be. Actually, there is no power supply since we work almost directly from the battery itself as shown in Fig. 405.

The filter consists of R1, C1 and C2. C2 acts as a filter for the line going to the emitter of the power output transistor, for the tube filaments, and as the input filter capacitor for the plates and screens. Since this capacitor is common to every circuit in the set, it is a good unit to keep your eyes on.

R1 in Fig. 405 is only a ½-watt resistor. This resistor certainly isn't overrated, so if it starts to burn and char, check C1 for excessive leakage or a short in any circuit except the power output transistor stage.

## Spark plates

These are simply line filters and are used to keep out interference picked up by the leads going to the battery. The spark plate is a capacitor, as shown in Fig. 405.

Sometimes a selenium plate is used as the spark-plate capacitor. The symbol for this spark plate is the same as a diode (see Fig. 406). Diode D1 acts as a short for high-voltage interference pulses.

If the receiver works well but gets noisy when the car engine is started, take a look at the spark plates. Shunt with a capacitor rated at about 100 $\mu$f. If the noise gets weaker or disappears, the spark plate is defective.

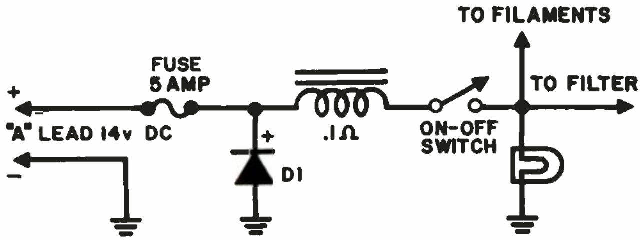



Fig. 406. *Sometimes a selenium diode is used as a spark plate.*

## Power supplies

Now that we have studied the filament circuit, let's move on to the power supply section.

What do we need in the way of B-plus for plate and screen voltage? In a home receiver we have ac which we can step up with a transformer and rectify. But in an auto we start with low-voltage dc. Let's see how we go about solving that problem.

Actually, we have quite a few ways of getting our plate and screen voltages (if we use tubes) and our base, emitter and collector voltages (if we use transistors). Here are the methods:

1. We can use a nonsynchronous vibrator to change smooth dc

(from the storage battery) into pulsating dc (with the help of the vibrator). We can then feed the pulsating dc into a transformer, step up the voltage, rectify and filter it. This will give us the voltage we need for plates and screens.

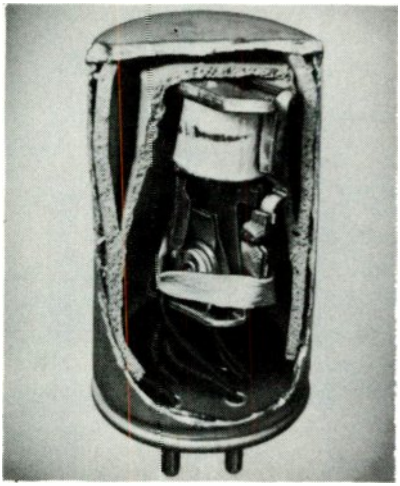
2. We can use a synchronous vibrator. The operation is about the same as above. With a synchronous vibrator we don't need a rectifier tube.

3. We have the transistor dc–dc converter. This is just a substitute for the synchronous vibrator.

4. Finally, we can eliminate the power supply completely by using 12-volt tubes, or with transistors.

### The nonsynchronous vibrator

Using the 12-volt storage battery directly with 12-volt tubes is undoubtedly the best system, so why bother with other methods when the direct-operation method (described as item 4) is so easy. There are definite limitations with 12-volt tubes, particularly in FM



Cutaway of vibrator shows molded foam rubber used to silence vibrator. Leads are kept in place with a rubber band. (Gem Electronics)

receivers. Also, at that low voltage, power output is low and transistors are used instead in the audio power amplifier. Finally, tremendous quantities of auto radios were made using vibrators and we are going to have them with us for a long time to come. We don't want you turning away jobs from your shop just because something new has been developed.

Fig. 407 shows the circuit of a non-synchronous vibrator supply. As a start, let us ask ourselves one little question. What is a vibrator? It's just a single-pole, double-throw automatic switch, isn't it? All that it does is to let the current from the storage battery flow in one half of the transformer (T1) primary and then in the other half of the transformer primary. It keeps switching the current back and forth through the primary winding. The transformer steps up the voltage and delivers it to the rectifier tube. The output of the rectifier tube is about 230 volts dc. This is then filtered and sent off to the plates and screens of the tubes.

## Here comes trouble!

What sort of trouble can we expect from this power supply? The easiest way to discuss this is with the help of a check list. But let's do more than just talk about it. Use this check list in your work.

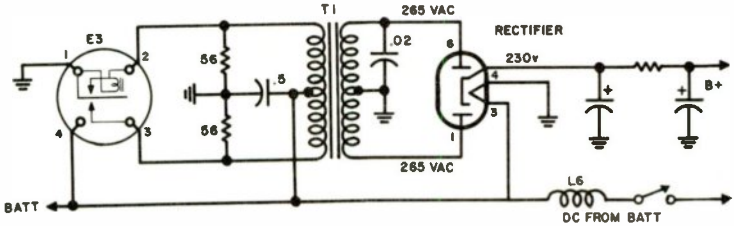



Fig. 407. *The vibrator (nonsynchronous type in this case) is just an automatic switch. It keeps interrupting the flow of dc to the transformer (thus permitting the use of a transformer on dc).*

| **Troubles in the Nonsynchronous Power Supply.** | **And What To Do About Them.** |
|---|---|
| **Receiver has a bad hum.** | Shunt a 20-μf capacitor across each of the filter capacitors in turn. If the hum decreases, replace the filter capacitor. Your test capacitor must have a working voltage rating of at least 300 volts. Be sure to discharge the test capacitor when you are finished. |
| **B-plus voltage is low.** | Try replacing the rectifier tube. If low B-plus is accompanied by hum, check the filter capacitors. Remove tubes one at a time and note if B-plus voltage goes up. If it rises sharply when removing a particular tube, you may have a short. The storage battery may be run down. This trouble is sometimes due to the vibrator. |
| **No B-plus voltage.** | Check to see if voltage is being delivered to rectifier plates. If it is, then trouble exists between output (cathode) of rectifier tube and other tubes in the set. Replace rectifier tube. |

**No B-plus voltage. (Cont.)**

Make sure the on-off switch is in good condition. Disconnect the battery lead and check the switch with ohmmeter. Check the vibrator buffer capacitor by substitution. **Important**—use a capacitor having identical capacitance and working voltage rating as original unit.

The power transformer may be defective. Make a continuity check. Also try replacing the vibrator.

If the tube filaments are not lighted, then check fuse.


Battery eliminator has voltmeter and ammeter to monitor output voltage and current.
(Precision Apparatus Co. Inc.)

**Fuse keeps opening.**

Fuse may be wrong size. Check the service manual to be sure. This trouble is often due to sticking vibrator contact. Don't try to repair vibrators. This requires specialized skill and tools. Also look for heater-to-cathode short in rectifier.

**Weak sound, with or without distortion.**

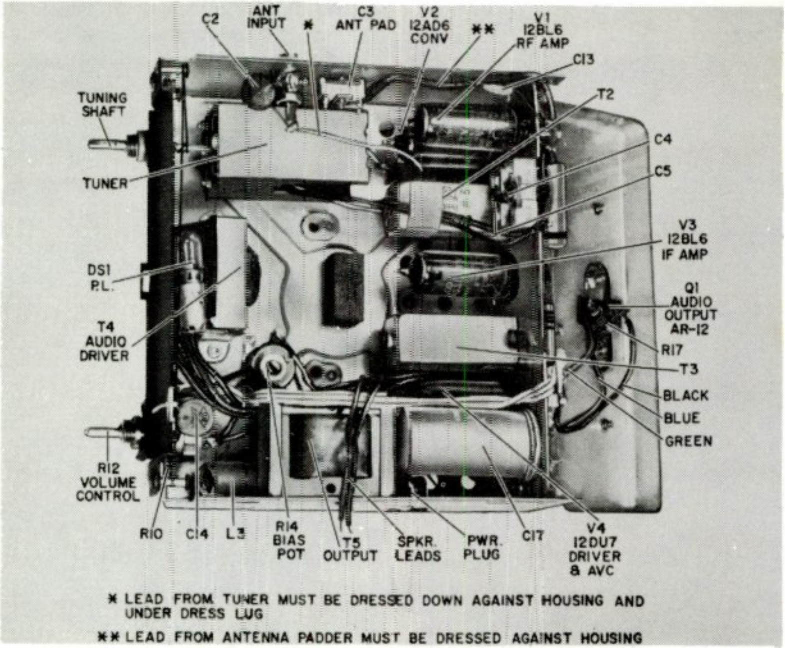
Check B-plus voltage. If low, follow tests as described for the symptom "B-plus voltage is low."

**Receiver oscillates.**

If you have oscillation together with noise, replace the output filter and then the input filter capacitor. Make sure filter capacitors in the filament line aren't open.

**Too much hash.**

If set sounds excessively noisy, make sure the vibrator is firmly in position. Try a new vibrator.




This view of auto radio is typical in most service manuals. Callouts correspond with those on schematic and make parts location easier. (Philco Corp.)

(Dirty vibrator contacts will produce this trouble.) Buffer capacitor may be defective. Some sets use a gas rectifier tube instead of a vacuum type. Gas rectifiers produce noise. Try a new tube.

If rectifier tube is metal-type gas rectifier, make sure shell is grounded. Shell is wired to tube pin (which connects to chassis) but sometimes internal tube connection to pin is broken. If rectifier tube is glass-type gas rectifier, make sure external shield is in place. Just having the shield sit on the tube isn't enough. The shield must be grounded.

**Vibrator doesn't work.**

If the fuse is also open, it's quite possible the vibrator contacts are stuck. Replace the vibrator and the fuse. If the new vibrator doesn't work, check back through the line to the storage battery.

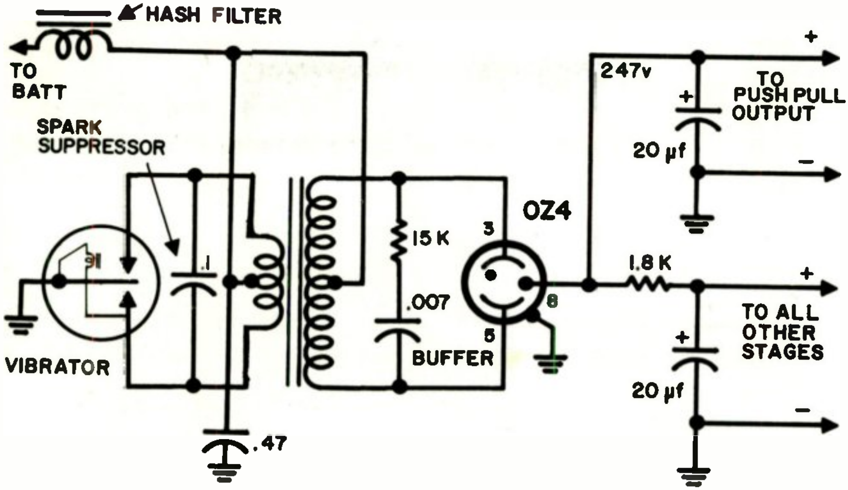



Fig. 408. *This auto radio power supply uses a gas rectifier tube.*

| | |
|---|---|
| **Rectifier tube plates glow, then fuse opens.** | One of the filter capacitors (usually the filter connected to the cathode of the rectifier tube) is shorted. |
| **B-plus voltage keeps changing.** | Storage battery defective. Vibrator pins dirty, making poor contact. |
| | Rectifier tube intermittent. |
| | Intermittent short in receiver or power supply. |
| **Vibrator is very noisy.** | Rubber is packed into the vibrator. Rubber is a vegetable product and decays. When this happens, the vibrator becomes noisy. Make sure the vibrator can isn't touching some other piece of metal which then amplifies the sound. |

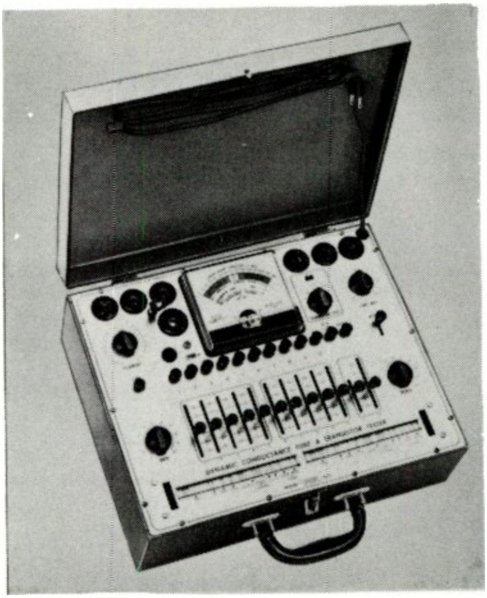
In the check list we mentioned a gas tube as a rectifier. This is shown in the nonsynchronous vibrator power supply circuit in Fig. 408. Note the 1.8 K filter resistor. If this should open, all stages (except the output stages) would lose their plate and screen voltages.

## The synchronous vibrator

The word vibrator is a good one! The word vibrate means to shake and that's exactly what any vibrator does – shake. And so, if you are ever in any doubt as to whether a vibrator is working, just rest your hand on the vibrator can. If it's working, you'll feel it. Most often, though, you won't be in any doubt. You'll be able to hear the vibrator.

A little earlier we mentioned nonsynchronous and synchronous vibrators. The difference between them is very simple. The nonsynchronous vibrator has one job. The synchronous vibrator has two:

| Nonsynchronous vibrator | Synchronous vibrator |
|---|---|
| 1. changes straight (unvarying) dc to pulsating dc. | 1. changes straight (unvarying) dc to pulsating dc. |
| | 2. acts as a rectifier. |



Combination tube and transistor tester is especially useful when servicing hybrid auto radios (EICO)

## What's the story?

As you have probably noted by now, we're trying to give you the greatest amount of practical information while keeping theory to a minimum. The synchronous vibrator interrupts the current coming from the storage battery. This changes it from dc to pulsating dc. The transformer steps up these pulses. The increased voltage is then fed back to the vibrator. The vibrator rectifies the voltage, which is then filtered.

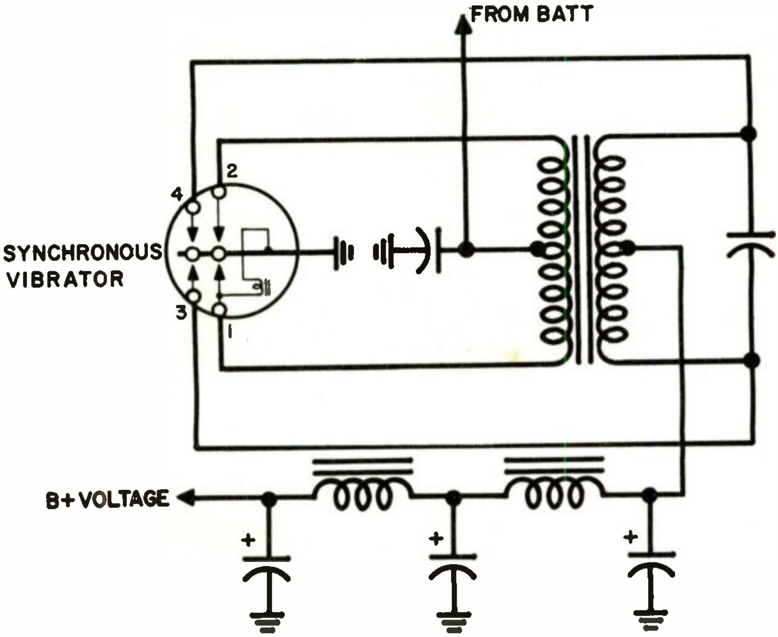



Fig. 409. *Circuit diagram of an auto radio power supply using a synchronous vibrator. This circuit does not need a rectifier tube.*

We have a synchronous vibrator circuit in Fig. 409. It's almost the same as the circuit shown in Fig. 408.

What is the difference between the two circuits? Our rectifier tube has disappeared. This is the major change.

## Bring on those troubles

Now what about troubles in the synchronous vibrator circuit? These are the same as those we covered for the nonsynchronous type so there is no use in repeating the list. Just keep one little fact in mind: A vibrator (of any kind) is a mechanical device. It has moving parts. Moving parts wear out, get dirty and noisy, and have to be replaced. This is especially true in the synchronous vibrator because we now have an extra set of contacts (inside the vibrator) that can become pitted or dirty.

## The transistor dc-to-dc converter

Suppose you had a very noisy neighbor. What could you do about it? You might move, get the neighbor to move or try living

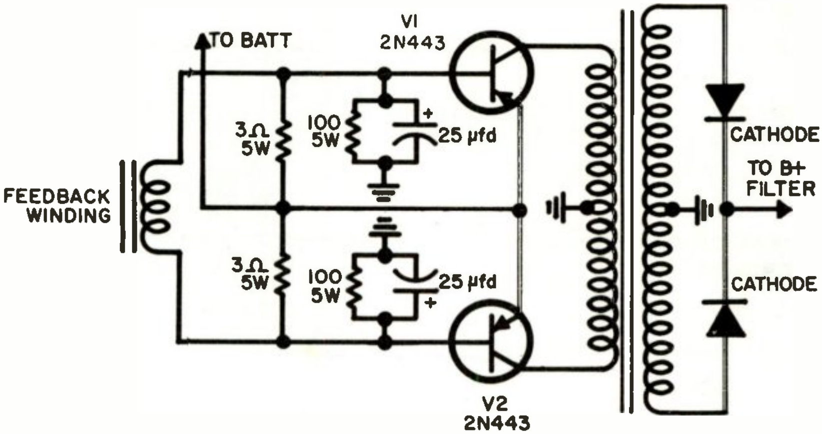



Fig. 410. *Transistor dc-to-dc converter. This is a multivibrator type.*

with all the windows closed. You would do whatever you could to get rid of the noise.

A vibrator is just like a noisy neighbor, so we aren't too surprised to learn that we have two ways for doing without this nuisance. One way is to use tubes that work with 12 volts on plates and screens. This is just about the easiest way.

A transistor dc-to-dc converter is a quiet substitute for the vibrator. In some receivers you can actually use a transistor dc-to-dc converter as a replacement for the vibrator.

This sounds like a good forward step, so let's investigate it a bit further.

A typical transistor dc-to-dc converter power supply is shown in Fig. 410. By working on it together we will be able to see how it works, quickly!

Whenever you get a circuit, such as this one, that seems a little strange, look around for a part that seems familiar. What can we recognize? Wouldn't you say that the step-up power transformer and full-wave rectifier (using semiconductor diodes) are old friends?

The filament circuit wiring and its filter are also old-timers, so what have we left? Just the transistors. The two transistors form a multivibrator.

## What's that?

We've had the synchronous vibrator, nonsynchronous vibrator and now we have another member of the family – a multivibrator. But do you remember what we said about vibrators? Give them any kind of a first name you like, but all they can possibly ever be is just a switch.

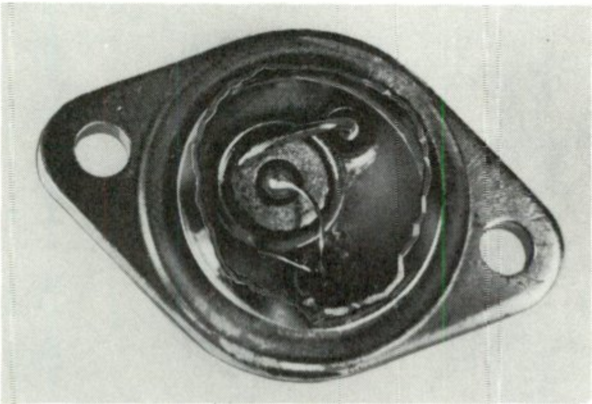
And so a multivibrator is a switch. But we have a pair of them. This is perfectly all right. All that it means is that we have two single-pole single-throw switches instead of one double-throw switch. When transistor V1 is turned on (it does so automatically, like any vibrator), transistor V2 is off. And when V2 is off, V1 is on.

Each transistor controls current through one half of the transformer primary. This is exactly the same as our nonsynchronous vibrator?

## Learn one—learn them all

One of the nicest things about electronics is that if you learn something about a circuit, you can use the same information over and over again.

To show what we mean, let's ask ourselves this question: "What

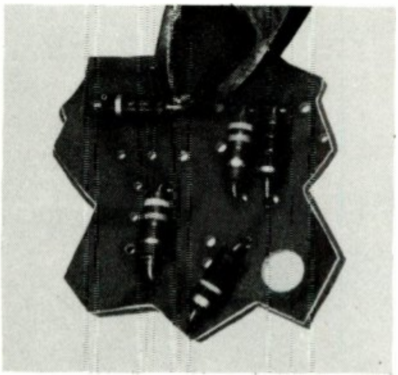


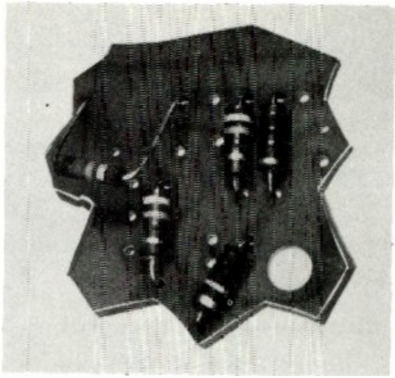
Type of transistor used in dc-to-dc converter. With the top of the case cut away the semiconductor wafer and its connections are exposed. About twice actual size. (Clevite Transistor).

have we changed in all of the auto radio power supplies?" The filter remains the same. The power transformer remains the same. All we do is use different vibrator circuits. Can you see the advantage now? Learn the troubles for one circuit and you've learned them for a whole group.

## Transistor dc-to-dc converter troubles

Although the power supply in Fig. 410 has no moving parts, we can still have trouble. By now you've realized that electronic circuits and servicing go hand in hand, so telling you that this cir-





Don't be afraid to destroy defective components to remove them from P-C power-supply board (left). When lead-holes have been cleaned it is easy to insert a new component (right).

cuit will need servicing surely doesn't come as a great big surprise.

What could go wrong? A common symptom is no B-plus output. This is easy to check quickly.

Set your vtvm to read dc voltage (select a suitable range) and

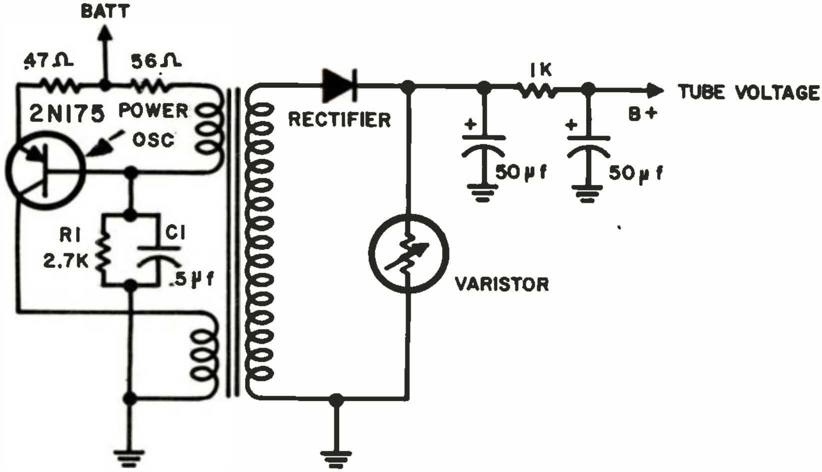
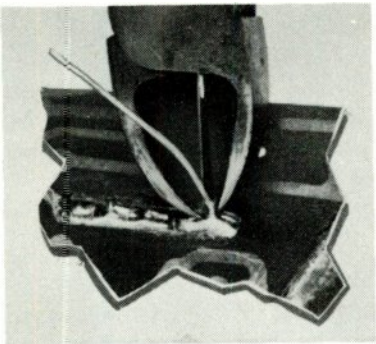



Fig. 411. *Transistor dc-to-dc converter. This is a blocking oscillator type.*

check for B-plus voltage starting at the output of the filter. If you have no B-plus, move the test prod over to the cathodes of the selenium rectifiers (either cathode). B-plus here means that your filter resistor is open.

We are sure that you are beginning to get the general idea of how this is done, but just to make it easy for everybody, let's set this up in the form of a progress chart:

| Here is how we check | Step by step |
|---|---|
| 1. Check for B-plus at filter output. | Voltage here indicates supply is working. If no voltage, move on to next step. |
| 2. Check for B-plus at either cathode of selenium rectifier. | B-plus here shows filter resistor is open. If no B-plus, take next step. |
| 3. Measure voltage from ground to anode of both semiconductor rectifiers. | Be careful. We're measuring ac here, so change the function selector switch on your vtvm. If you get voltage here, but you had no B-plus, the rectifiers are defective. If you get no voltage, move on to the next step. |
| 4. Measure emitter voltages. These voltages should be on manufacturer's circuit diagram. Measure other transistor voltages as indicated on the circuit. | If transistor voltages are absent, test back to the storage battery. Is battery delivering voltage? If not, fuse may be open. Lead to battery may be disconnected. <br><br> If transistors have abnormal voltages, shut receiver off and check all resistors, substitute base bypass capacitors with known good units. Do this for each transistor, one at a time. After making substitution, check for B-plus output. <br><br> If you still have no voltage, try switching the transistors. If this doesn't start the unit working, try new transistors. |



After soldering leads to circuit side of board trim them off close to the solder.

## Other troubles

This is a fairly long chart, but it covers only one trouble — absence of output voltage. We could have other problems, but these are the same as those in any type of power supply. For example, insufficient output could be due to a defective diode unit or to excessively leaky filter capacitors.

In Fig. 411 we have another type of transistor dc-to-dc converter. This one looks a little simpler than that of Fig. 410. It uses just one transistor in a blocking oscillator circuit. All that this means is that we have just one switch – the transistor – that goes on and off. The rectifier is also simpler. It is a half-wave unit instead of the full-wave rectifier shown in Fig. 410.

## Why make it complicated?

Are you wondering why manufacturers don't use the circuit of Fig. 411 all the time? It's easier than that of Fig. 410, so why should they go to extra trouble and expense?

It is true that the circuit of Fig. 411 is simpler, but it has more

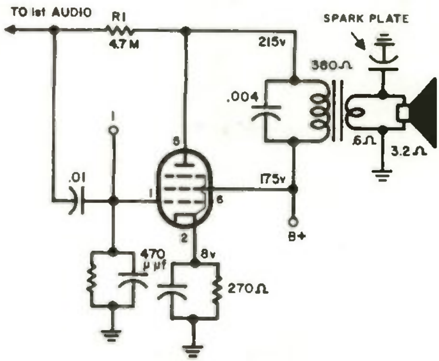



Fig. 412. *Single-ended vacuum-tube power amplifier stage for an auto radio.*

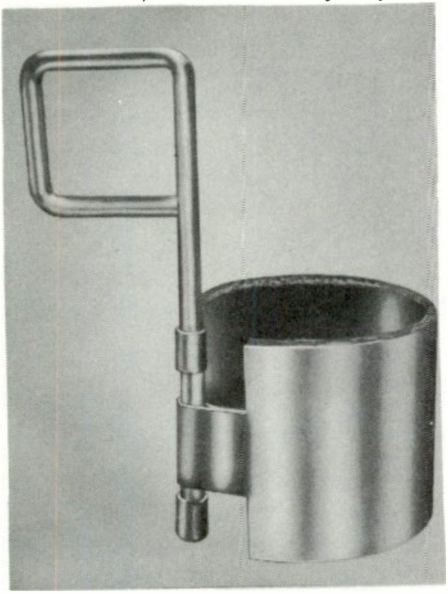
problems. The output voltage depends on how often the transistor switches on and off. This is controlled by resistor R1 and capacitor C1. If these change in value, the switching action of the transistor will get either faster or slower.

Is this any cause for alarm? It could very well be. An increase in voltage might damage the rectifier or the filter capacitors. To prevent such damage we put in a device known as a *varistor*. This is just a resistor with a fancy name. A varistor is a voltage sensitive resistor. If the voltage goes up, the varistor draws more current, and down goes the voltage.

Sometimes we use a diode (known as a Zener diode) for the same job. When the voltage becomes too high, the diode breaks down, conducts heavily and the voltage drops.

## Audio power amplifier output stage

One of the things to know is to be on a sharp lookout for differences among radio receivers. There is a good reason for this. If the circuit for an auto radio stage is exactly the same as that of a home receiver, we need study it just once. But if we come across



The vibrator puller locks around the body of the vibrator with a twist of the squared-loop handle making removal from compact chassis much easier. (Gem Electronics)

circuits that aren't alike, then we must know something about them to be able to fix them.

In auto radios you will find interesting differences in the audio amplifier power output stages. Here are the four basic types:

1. Single-ended vacuum-tube amplifier.
2. Push-pull vacuum tube amplifier.
3. Single-ended transistor amplifier.
4. Push-pull transistor amplifier.

As a start, let us examine the single-ended vacuum-tube amplifier shown in Fig. 412.

As usual, we have two questions. How can we tell if the circuit is working? What sort of troubles can we expect?

## Checking the single-ended stage

To test the circuit shown in Fig. 412, connect an audio generator to the control grid and listen for the signal out of the speaker. No signal means the stage is dead. A weak, noisy or distorted signal also means trouble.

## The fast test

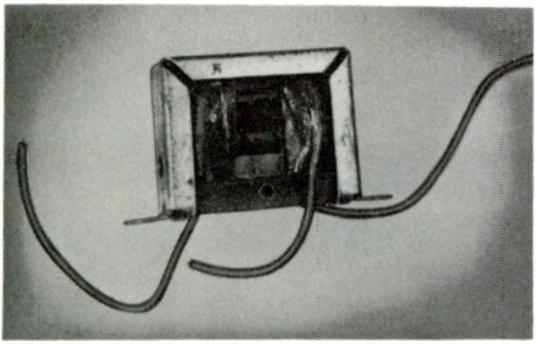
If you're in a hurry (and what service technician isn't?), you can test the stage without a generator. "Click-test" the stage by pulling the tube almost completely out of its socket and then adjust the tube until its pins just about make contact. A loud click out of the speaker will assure you the stage is working.

Another way is to touch the control grid with your finger. A loud hum or growl will answer your question as to whether the stage is operating. Another way is to short the grid to ground, quickly and intermittently, and listen for a loud click to come out of the speaker.

## Here comes trouble

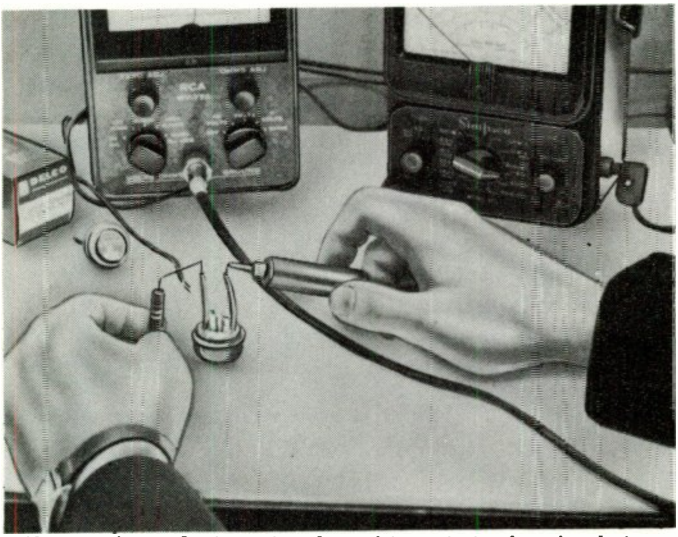
Now let's see what sort of troubles we can expect from the single-ended audio amplifier.

| Troubles in the Single-Ended Vacuum-Tube Stage. | And What to Do About Them. |
| --- | --- |
| **No sound out of speaker when signal is put in at the control grid.** | Tube is defective. |
| | No plate or screen voltage. |
| | Open cathode resistor. |
| | Capacitor across primary or secondary of output transformer is shorted. |
| | Defective output transformer. |
| | Defective speaker (voice coil open or leads not making contact). |
| | Shorted grid resistor. |



Cutaway of output transformer. Inner layer of heavy wire is the secondary. (Gem Electronics)

| | |
| --- | --- |
| **Weak sound.** | Tube may be weak. |
| | Lower than normal B-plus voltage. Try replacing the rectifier tube. |



Most vtvm's use 3-volts or less for resistance tests of semiconductors. Batteries of 15 volts and higher are often used in vom's.

**Weak sound** (Cont.)

Open dropping resistor to screen grid.

Trouble may be in driver stage; not enough signal being delivered to grid of output tube.

Wrong bias on tube can produce weak, distorted sound. Check cathode resistor and bypass capacitor.

**Oscillation.**

Check R1 in Fig. 412. This is a feedback resistor and minimizes the possibility of oscillation (and improves the quality of the sound).

Check lead dress. Make sure plate and grid leads are separated.

Check grid resistor.

Check screen grid bypass capacitor.

**Distorted sound.**

Make sure plate and screen have correct voltages.

Check bias.

Signal input to grid may be distorted.

Substitute new tube. Low emission of weak tube can cause distortion.

Plate bypass capacitor leaky.

Defective speaker (torn cone, rubbing voice coil).

## The push-pull stage

The push-pull stage is capable of handling a greater amount of signal drive and provides less distortion than the single-ended stage. You can test the stage (Fig. 413) to see if it is working by using the same methods we used for the single-ended stage.

We can expect all of the troubles of the single-ended stage plus a few extras. Here they are:

| Troubles in the Push-Pull Vacuum-Tube Stage. | And What To Do About Them. |
|---|---|
| **Distortion.** | Check cathode resistor. Bias may be incorrect. |
| | Push-pull tubes should be matched. Substitute matched pair. |
| | Part of output transformer primary may be open. B-plus on one tube only. |
| | Incorrect drive. One tube may be getting more signal than the other. Fault is in phase inverter (driver) stage. |
| | Unbalanced plate voltages. Voltages on both plates should be the same. |

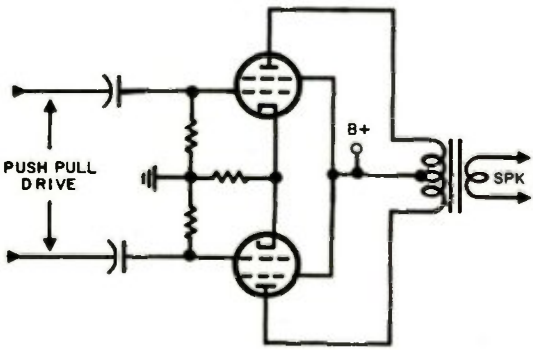


Fig. 413. *The push pull stage can have all the troubles of the single-ended stage plus a few of its own.*

| | |
|---|---|
| **No Sound.** | No input signal. |
| | No B-plus at center tap of primary of output transformer. |
| | Defective speaker. Leads broken. |
| | Open in secondary of output transformer. |

| | |
|---|---|
| **Sound gets distorted after auto radio is in operation for short time.** | Replace tubes. Can be caused by heater-to-cathode short or by grid emission. |
| **Weak sound.** | Try new tubes.<br>Check plate and screen voltages.<br>Signal from driver stage may be weak.<br>Bias on tubes too high. Check cathode resistor. |

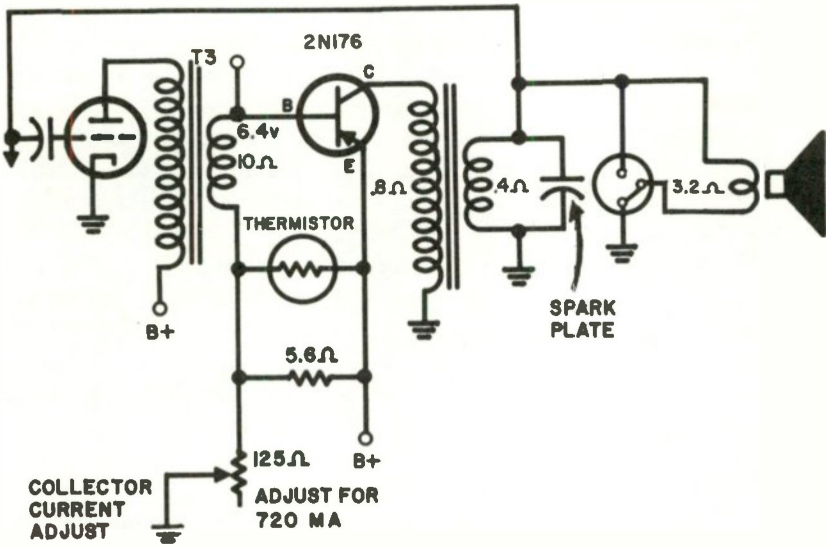



Fig. 414. *This single-ended transistor stage has a variable resistor for adjusting the collector current.*

| | |
|---|---|
| **Intermittent sound.** | Can be caused by the tubes.<br>Poorly soldered connection.<br>Broken wire.<br>Check components by pulling gently on leads. Lead may be making intermittent connection with component. |

## The single-ended transistor stage

The circuit is shown in Fig. 414. We studied this circuit in Chapter 3 but there are some differences between transistor audio output circuits used in auto radios and those in small, personal receivers. Basically, the circuits are the same, but let's examine the changes made for automobile operation.

1. Auto radios must be capable of supplying a much greater amount of volume than a portable. The auto receiver works under conditions of greater electrical noise pickup and ordinary sound noise. Fortunately, auto batteries can supply large amounts of current – far greater than that of small penlight batteries or mercury batteries. Special output transistors are used, designed to work with large amounts of current. Transistors of this type are shown in Fig. 415.
2. Some audio stages come equipped with a variable resistor so the collector current of the ouput transistor can be adjusted.
3. You may find a thermistor connected in the output stage. A thermistor is a temperature-sensitive device. The thermistor is mounted close to the transistor. If the temperature of the transistor goes up, the resistance of the thermistor goes down. In Fig. 414, the thermistor is connected between base and emitter. If the thermistor resistance decreases, so does the base bias. When this happens, collector current decreases.

When the temperature of a transistor rises, so does its collector current. But an increase in collector current increases temperature. This gets to be a sort of run-away merry-go-round. In the transistor this condition is known as thermal runaway. The thermistor prevents this from happening.

### Heat sink

The power output transistor (or transistors, in the case of push-pull output stages) gets hot. To get rid of the heat, the power transistor is mounted on a metal chassis. In the auto radio you will find a bit of metal having a wavy shape being used as a radiator. This has a large surface area, enabling the heat to escape into the air.

In some cases it might seem as though the transistor is mounted directly on the chassis when actually there will be some insulation between the two. The insulator is usually a very thin washer having a thickness of little more than 1/1,000 inch. To make good contact and better conduction of heat the washer is coated with silicone grease. If the transistor you are replacing has such a washer, make sure you use it for the new transistor.

The washer is not needed if the circuit calls for a grounded collector.

### The push-pull transistor stage

The push-pull stage is like the man who went up to the bar and

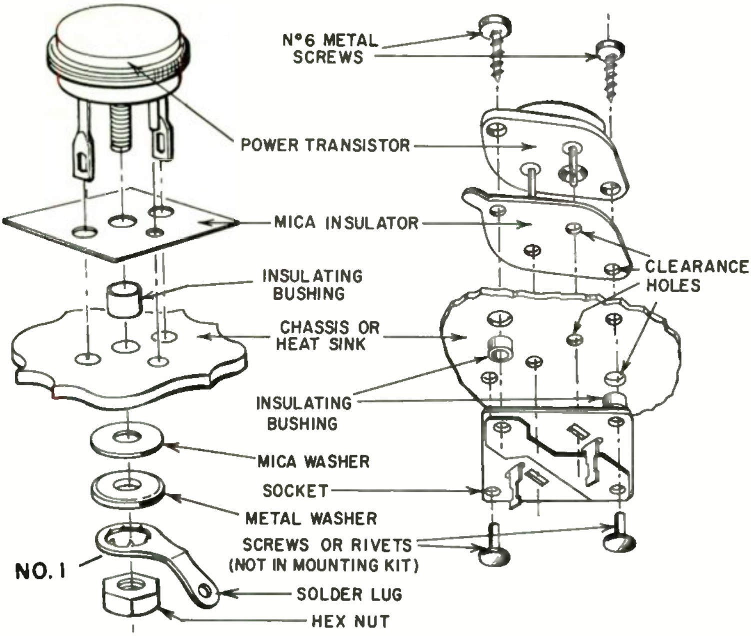



Fig. 415. *Two types of power transistors. Power-transistor mounting must insulate for electricity but conduct heat away from the case.* (Motorola Semiconductor Prod. Inc.)

ordered an extra "one" just for the road. He probably felt twice as good. The extra transistor is also "one for the road."

The push-pull stage shown in Fig. 416 doesn't have any new servicing problems for us, but there are a few points we should study.

The push-pull stage has a variable resistor, R1. The output transformer winding has a special tap where you can connect a milliammeter. The amount of current to be taken by the transistors will be specified by the manufacturer and will be supplied on the schematic. If you get a set for servicing, don't take for granted that the adjustment is correct. You can use a vom to read dc milliamperes and make the adjustment very quickly.

## Speaker control

The modern trend in auto radios is to use two speakers, one front and the other rear. Switches or variable resistors are supplied to control the speakers.

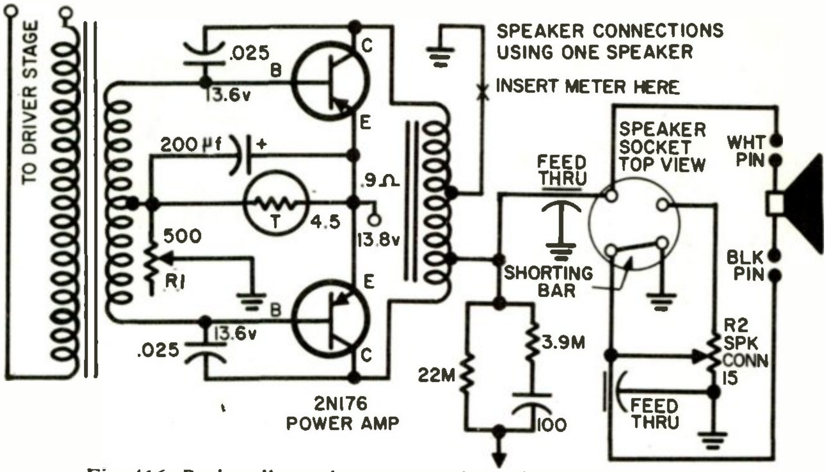



Fig. 416. *Push-pull transistor output circuit for an auto radio.*

You will also find a number of different switching arrangements. In Fig. 417 the auto radio operates two speakers, but with only one speaker working at any one time. When servicing a set with this arrangement, check the switch if neither speaker works.

In Fig. 418, the front speaker works all the time. A switch per-

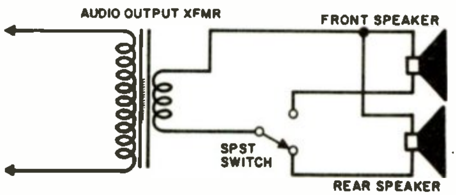



Fig. 417. *With this arrangement, only one speaker (either front or rear) works at a time.*

mits the rear speaker to be put in operation. Check the switch if the front speaker works but the rear speaker does not.

Sometimes a variable resistor is used in place of the speaker switches, as in Fig. 419. The resistor is known as a fader control. With the fader control, either speaker, or both, can be on. We can also adjust the amount of volume from each speaker.

## Adding a speaker

When you install a radio, or repair one, look to see if it has a special connection for a rear speaker. Generally you will find this on the side or the back of the receiver. Known as a rear-speaker jack, it comes equipped with a shorting plug or bar. Sometimes the customer will tamper with this bar and remove it. When this happens, the speaker stops working because the connection to the speaker is open. The circuit for the rear-speaker jack is shown in Fig. 420.

## Multiple speakers

If you want to add another speaker to the auto radio, you can use the speaker jack (shown in Fig. 420) in two different ways.

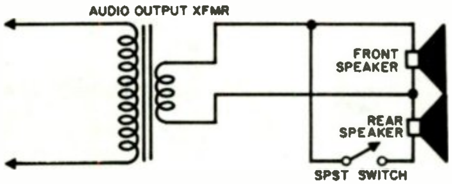



Fig. 418. *The front speaker is permanently connected. The rear speaker can be switched in or out.*

Connect the extra speaker to terminals 1 and 3 of the jack, and you will have the two speakers in parallel. The shorting plug must remain in position for this.

If you want the two speakers in series, remove the shorting plug. Run one lead from the rear speaker to pin 3 on the jack, and the other lead to pin 2.

## Four terminal jack

The jack shown in Fig. 420 is a three-terminal jack. Sometimes

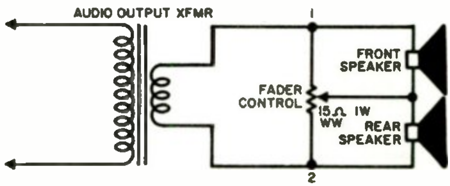



Fig. 419. *The variable resistor controls the volume out of the front and rear speakers. When the arm is in the center, the same volume comes out of both speakers. As the arm moves up toward 1, the front speaker is gradually cut out. As the arm moves toward 2, the rear speaker is gradually cut out.*

a four-terminal jack is used, as shown in Fig. 421. With the four-terminal jack, the shorting plug is always used, but it is moved into different positions, depending on whether we want to use one or two speakers.

## The mysterious case of the output transformer

We are so accustomed to the idea of having a two-winding output transformer between the amplifier and the speaker that the circuit shown in Fig. 422 (and Fig. 416) may come as a surprise.

Although it has only three leads, T1 is still a transformer, except that it is called an autotransformer. The entire primary extends from point 1 to point 3. The secondary is from the tap (point 2) to point 3 (Fig. 422).

In a circuit of this type, the collector current flows through the transformer and also through the voice coil of the speaker. A polarized plug is used to connect the speaker.

You can check a transformer of this type by making a resistance

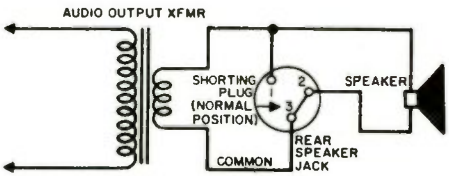



Fig. 420. *A three-pin jack is used on some sets. The jack is to be used when you want to install a rear speaker. If a rear speaker is not used, the shorting plug must be in position. If not, the front speaker will not work.*

check. Test across the entire winding since the resistance between the tap and ground is so small you may not be able to read the measurement on the meter.

You can replace the autotransformer with the ordinary four-

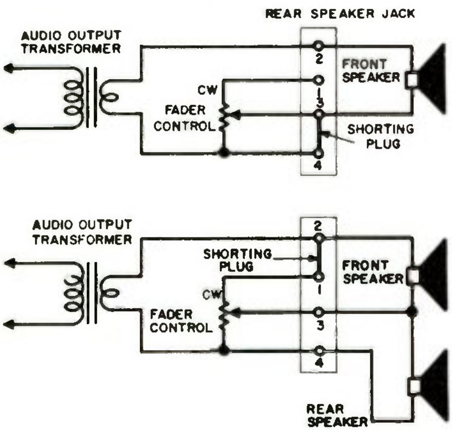



Fig. 421. *Circuit arrangement for a four-pin rear-speaker jack.*

terminal type, provided it matches the impedance of the transistor and the voice coil of the speaker.

## Negative feedback

Negative feedback is used to keep the output stage stable. This can be done with the help of a resistor R1 (Fig. 423). This set uses an autotransformer with R1 connected from the "hot" side of the voice coil to the grid of the driver tube.

If the set oscillates or whistles, check to make sure R1 is connected. Also make certain that R1 is attached to the correct voice coil lead.

In some auto receivers, a special winding is used to supply the feedback. Fig. 424 shows how this is done. The output transformer

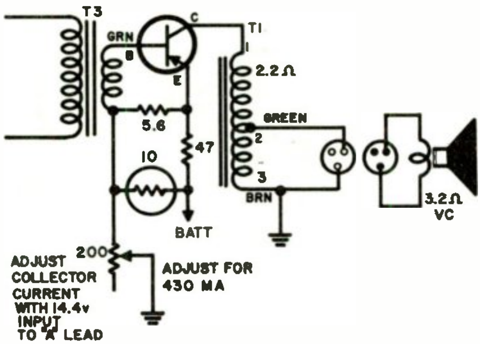



Fig. 422. *This auto radio uses an autotransformer to connect the output transistor to the speaker.*

is the autotransformer type. It has an additional winding which is part of the cathode circuit of the first audio amplifier.

The signal current flows through the autotransformer to the collector of the output transistor. The magnetic field of this current induces a voltage across feedback winding A. This current is out of phase with the current normally flowing through the first triode audio amplifier.

This is feedback over several stages, instead of between two adjoining stages as in Fig. 423.

The receiver will oscillate if connections to primaries or secondaries of either transformer T1 or T2 are reversed. If the output transformer becomes defective, it will need an *exact* replacement.

## Thermistor and varistor

A little earlier we told you about the use of a thermistor and how it works to keep the temperature rise of the output transistor from running away. Sometimes an additional unit, known as a *varistor*, is used. (The varistor was also discussed earlier in connection with Fig. 411.) This is shown in Fig. 425.

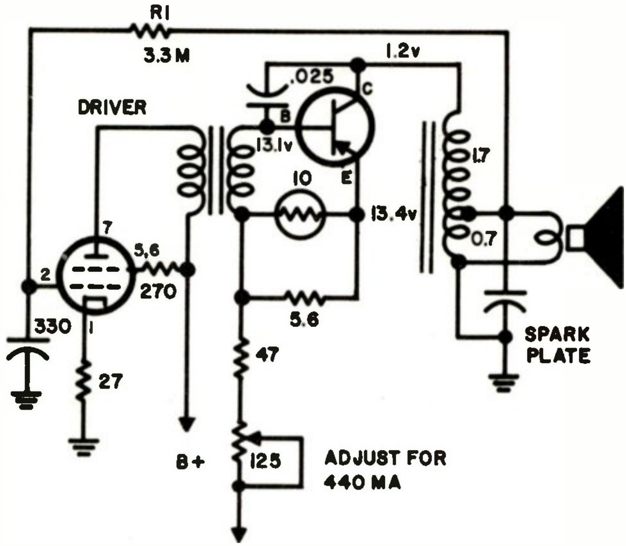



Fig. 423. *Single-ended transistor stage in hybrid auto receiver.*

A varistor is a voltage-sensitive device. (The thermistor is temperature-sensitive.) The resistance of the varistor varies inversely with the voltage. All that this means is that its resistance goes down when the voltage tries to rise.

If the voltage at the collector in Fig. 425 should go up, the resistance of the varistor would decrease. As a result, it would

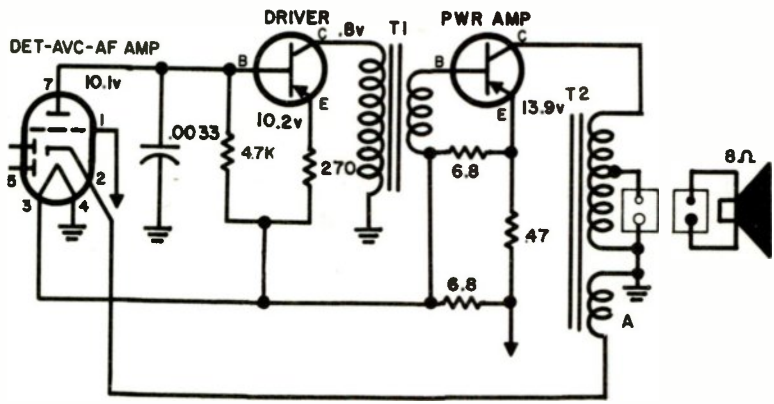



Fig. 424. *Some auto radios have a feedback winding as part of the output transformer.*

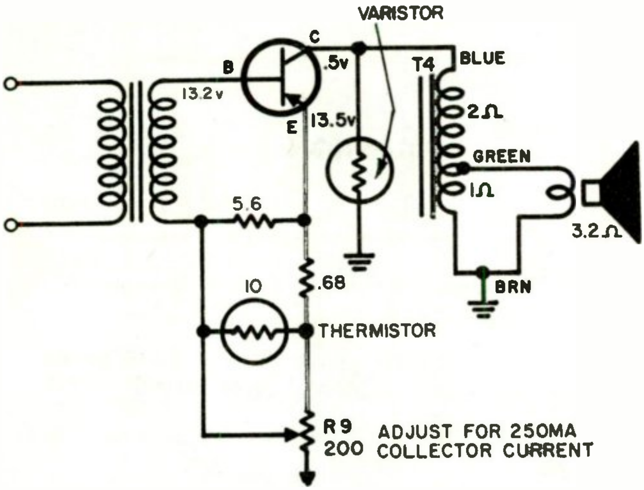



Fig. 425. *The thermistor and the varistor are both used to prevent excessive collector current.*

draw more current, loading the voltage supply. This would decrease the voltage and keep it within safe limits.

If the set you are working on has a history of burned-out power transistors, make sure that the thermistor (and also the varistor, if used) has not been removed from the circuit.

## QUESTIONS

1. What is a thermistor? A varistor? What is the difference between them?
2. What could cause oscillation in a transistor amplifier? How is it prevented?
3. What is a spark plate? What does it do? What two symbols are used to represent spark plates?
4. What is the difference between a synchronous and a nonsynchronous vibrator?
5. Why does a power transistor require a heat sink?
6. What is the purpose of a line filter in an auto radio?
7. What could cause a vibrator to become noisy? What quick check can you make to determine if the vibrator is working? What component should you check if the vibrator doesn't operate?
8. What is a dc-to-dc converter? Where is it used? What are its advantages? Name two circuits used by these converters.
9. What is a fader control? In what circuit is it used? What is the advantage of such a control?
10. Name two types of output transformers used in auto radios.
11. What is negative feedback? Why is it used?
12. In checking a receiver having a nonsynchronous power supply you note a bad hum. What should you do? What should you do if such a set has low low B-plus voltage? What might be the trouble if the fuse keeps opening?

# CHAPTER 5 servicing auto radios (part II)

REMEMBER some of the told-time automobiles? Perhaps you've seen pictures of them. All that any owner ever asked (or prayed for) was to be able to keep going once he managed to get the car started—and getting it started was a job in itself.

Once the mechanical bugs were licked, however, we soon wanted more than just a made-over buggy seat mounted on a horse-and-carriage spring. And, as we told you at the beginning of Chapter 4, we wanted comfort and style to be part of the car.

The auto radio is part of that comfort. And just as you can have your choice of many different makes, styles and costs when you buy a car, so too is there a big choice of auto radios. You might, somewhere, find a home without a radio, but it's less likely that you would find a car without one. That is why servicing auto radios is such good business.

## The driver stage

In Chapter 4 we talked about power supplies and different types of audio power amplifiers. But a power amplifier is like a car. It needs someone or something to drive it.

In any radio set, the tube or transistor that amplifies the audio signal and feeds it into the power amplifier is known as the driver. In Fig. 501 we have a transistor driver. This driver requires an input signal of 0.15 volt. In turn this will allow the power amplifier to produce 1 watt of audio output from the speaker.

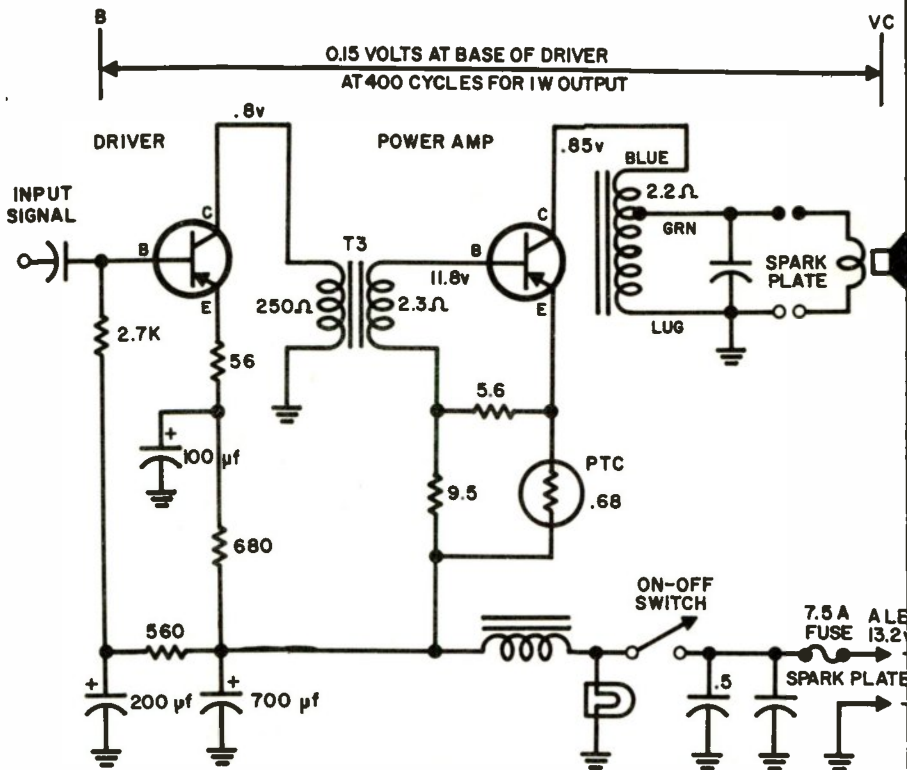



Fig. 501. *Driver stage in an auto radio. The driver is transformer-coupled to the audio power amplifier.*

The driver stage of Fig. 501 has just a few parts. But these few parts can be troublesome.

*Some people look back to the good old days,*
*Keep thinking about them, singing their praise,*
*But what about troubles in the old-time car?*
*Couldn't get started, couldn't go far,*
*But while they may have been a bag of tricks,*
*None of them had an auto set to fix.*

In an earlier chapter we learned how to service driver stages in portable receivers. We can repair driver stages in auto sets in the same way.

Put your finger on the base of the driver transistor for your first quick check. A growl or squawk out of the speaker tells you that the driver and the power amplifier are both on the job.

If this doesn't produce results, touch the base of the power amplifier transistor. If you get a squawk now, then you can be sure the driver is not working. Check the transistor's voltages for a clue as to the trouble. Check the emitter resistor and its bypass capacitor, and also the transformer between the two stages.

## Driver for push-pull output

The driver for a push-pull stage (Fig. 502), is almost the same as the circuit shown in Fig. 501. Actually, though, it is a little

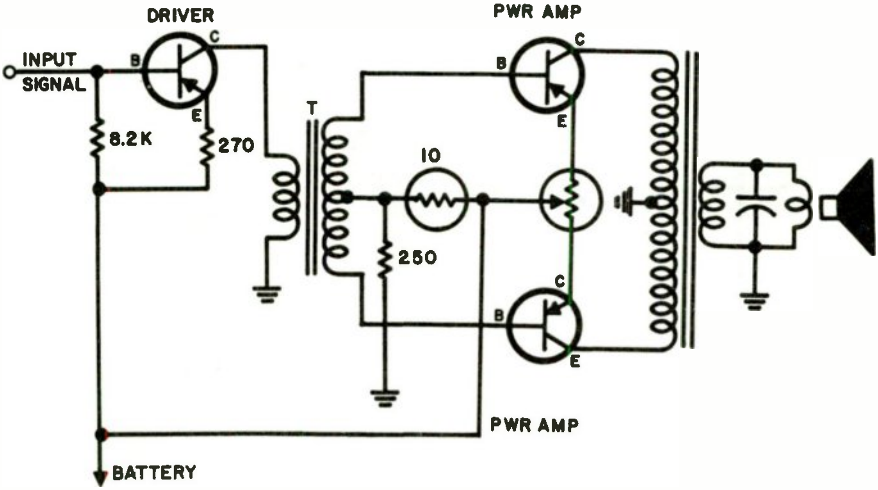



Fig. 502. *The driver for a push-pull stage has just a few parts.*

simpler. We have no emitter bypass capacitor. The main difference is in the interstage transformer (T). The secondary of this transformer is designed for push-pull output.

Servicing of this driver is the same as for all transistor drivers. First check to see if the driver is working, then check the components. Since there are so few, this is easy to do.

## Vacuum-tube driver

Do you remember reading about hybrid sets in an earlier chapter? At that time we told you that a hybrid set was one that used both tubes and transistors. The tubes are 12-volt types. This is the approximate voltage, not only on the filaments, but on screen and plate as well.

Fig. 503 shows one of these tubes used as a driver. The input is resistance coupled from the first audio amplifier. The output is transformer-coupled (we call it an interstage transformer) to the power amplifier.

What can go wrong with this circuit? One of the probable trouble spots is the tube. If it's dead, the stage won't operate. A weak tube (low emission) means weak or distorted sound output.

Check the tube first, by substitution if possible. Then make voltage checks at the tube socket. If you get voltage at the screen, but not at the plate, the primary winding is open.

A good check for proper tube operation is to measure the bias

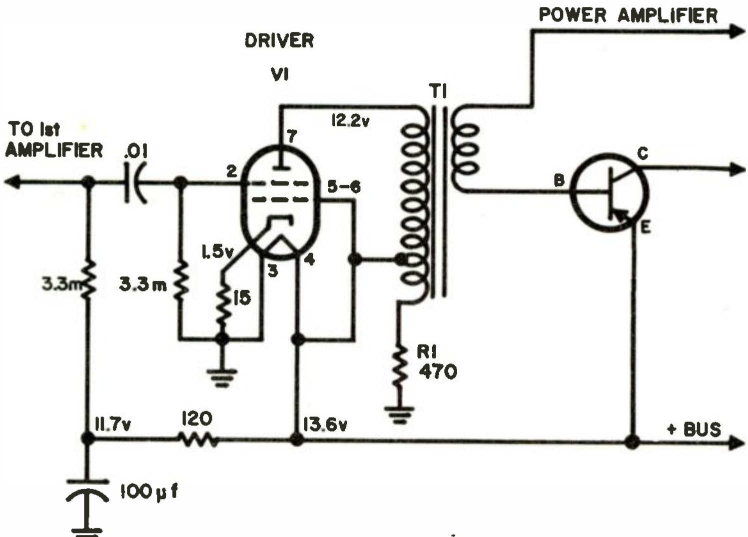



Fig. 503. *Not all interstage transformers (T1) are alike. This one has a tapped primary. If the transformer is defective, it will need an exact replacement.*

voltage. Set the vtvm to read low volts dc. Connect the plus probe to the cathode of the tube and the common probe to ground. In the circuit in Fig. 503 the bias should be 1.5 volts.

If the bias is incorrect, try a new tube. If this doesn't help, check the cathode resistor.

What if you just want to know if the stage is good? Put an audio signal in at the control grid. If you're in a hurry, touch the grid with your finger. A loud squawk out of the speaker is your answer if the driver is working.

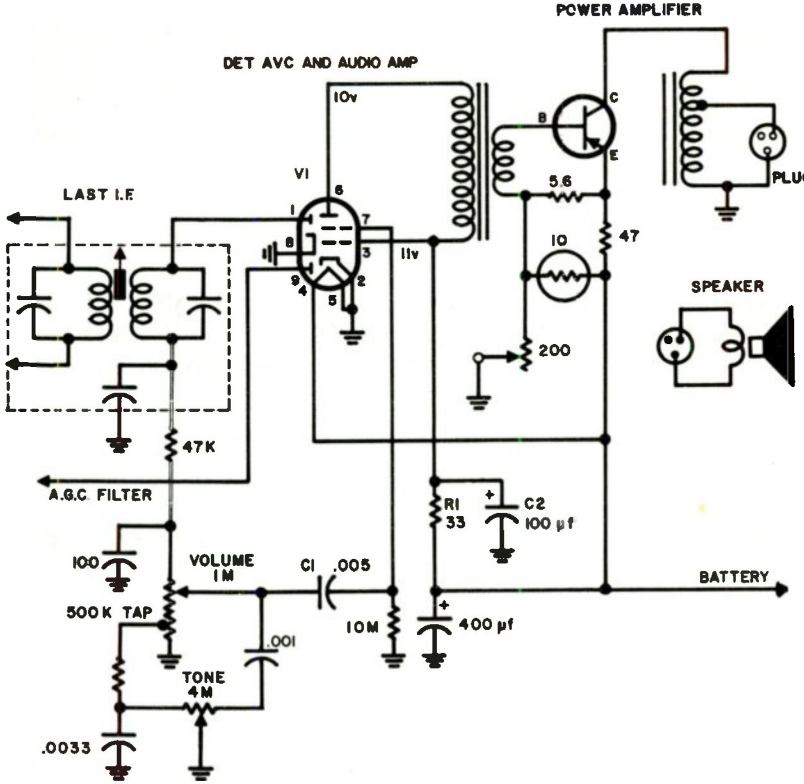



Fig. 504. *Sometimes the first audio amplifier works as the driver stage.*

## Where's the driver?

Do you remember the story of the farmer who decided to save money by feeding his horse fewer and fewer oats each day? It worked fine until the animal got "fed up," turned over and died. This applies to radios too. Some of your customers will buy auto radios for as little money as possible, but they just aren't going to get as many tubes. Fig. 504 shows just what we mean. Here we have a double diode, tetrode working as detector, avc and first audio.

And the first audio is also the driver.

The driver tube in Fig. 504 is a bit unusual. Note the odd transposition of control grid and screen grid. Known as a space-charge tetrode, the tube gets its bias through the 10-megohm resistor hanging on to the control grid. Because of the large value of this resistor, just a very small current through it (in the order of microamperes) produces the bias. The amount is dependent on signal strength, but 2 volts is typical. In the absence of signal, the bias developed (contact bias) is about 0.5 volt.

Now from your experience with ac-dc sets you might think this is just fine. However, the auto radio works under worse conditions than a home radio.

Does this make it more difficult for us to service this stage? Not at all! As far as we are concerned, it is just another driver stage and we can service it in the same way.

As our first quick check, put an audio signal into the control grid of the tube, V1. The center arm of the volume control is a convenient spot. You can use the finger test if you like without worrying about a shock. All the voltages are small.

If you get no signal output, move directly to the control grid of the tube. Signal output here means that coupling capacitor C1 is open. If you get no sound output, try a new tube.

It's about time that we collected our facts so that they are handy for servicing. Here's our check list for vacuum-tube drivers.

| Troubles in the Driver Stage. | And What To Do About Them. |
|---|---|
| No sound output. | Defective tube. |
| | Open cathode resistor (when one is used). Cathode lead disconnected from ground (when cathode resistor is not used). |
| | Open in winding of interstage transformer. No B-plus voltage. |
| | No signal input from earlier stage. |
| Intermittent. | Tube can cause this trouble. Tap tube gently. If set stops playing after it has been on for a while, substitute a new tube. |
| | Can be caused by defective component, such as coupling capacitor. Check volume control. It may have a worn spot. |
| Motorboating. | Check decoupling filter, such as R1 and C2 in Figure 504. |
| | Check lead dress. Keep plate and control grid leads separated. |
| | Battery may be run down. |

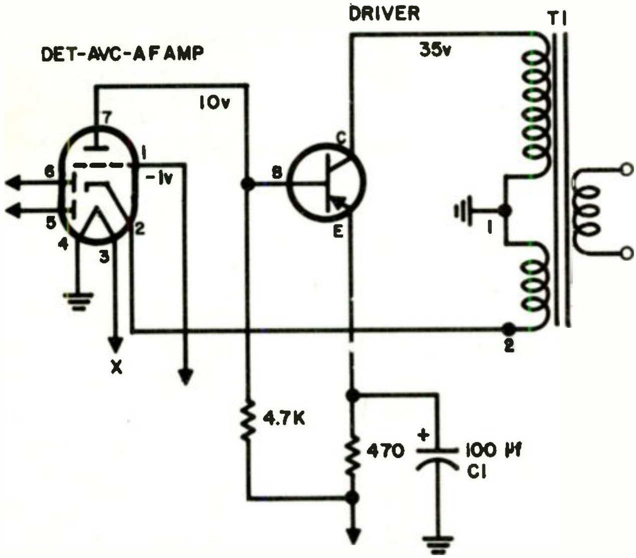


Fig. 505. *The interstage transformer in this driver circuit has a feedback winding.*

**Weak sound.**

Try a new tube.

Check plate and screen voltages.

Storage battery may need recharging.

Input signal may be weak. Try different station.

Check bias.

Check coupling capacitor for leakage.

## Driver-stage feedback

When they are very young, some girls (and boys, too) go through a stage known as the giggles. Just looking at them is enough to get them started.

Triode tubes and transistors (and most transistors we're working with are triodes) belong to the giggle class. Give them half a chance and they'll oscillate. We keep a strict check on that sort of thing by using negative feedback.

One way of doing this is shown in Fig: 505. Part of the winding of interstage transformer T1 feeds an out-of-phase signal back to the cathode of the first audio amplifier.

What does this mean to us? First, we cannot use just any old

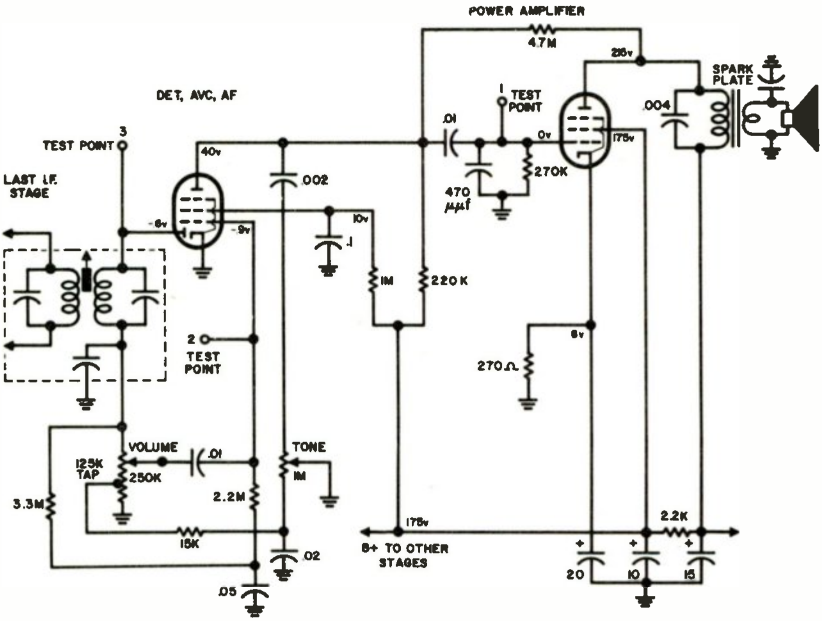



Fig. 506. *Driver and output stage of older type receivers.*

interstage transformer when making a replacement. And second, even if we do use an exact replacement, we must be careful of our connections. If we should accidentally transpose leads 1 and 2 on transformer T1, the receiver would oscillate strongly.

If you're sure that you've made your connections properly, but the receiver wants to oscillate, especially on strong signals, try disconnecting C1. The price we pay for this cure is reduced volume.

## The old-timers

Tremendous numbers of auto radio receivers were made using a vibrator supply and high-voltage (100 to 300 volts) tubes. These are going out of style but you will still come across them on your service bench. They will gradually disappear since the hybrids and all-transistor sets are so much quieter, use less power and, in the case of all-transistor sets, instant starting.

You can service these sets in the same way as any hybrid or vacuum-tube receiver. The troubles are the same. The tube voltages are higher, so using your finger for a squawk test may not be such a good idea. It's too easy to touch the wrong tube pin. For a quick check, click the control grid of the driver or the power amplifier to ground. If you prefer, use an audio signal generator.

In most cases the troubles are caused by the tubes. If the tubes are good, check at the tube pins for proper voltages. If any voltage is low, or missing at any tube pin, work back along the connection to that pin until you find the defective component. A typical driver and power amplifier are shown in Fig. 506.

## The odd-ball

When servicing auto radios, you can run across some strange circuit combinations. One of these is shown in Fig. 507. The set is a hybrid but, unlike most such sets, uses ordinary tubes (instead of special low-voltage tubes). The set has two power supplies. One is the battery supply and filter for the output transistor. The other is a dc-to-dc converter that furnishes about 66 volts for the tubes.

Servicing a set of this type is exactly the same as for any hybrid. The double power supply will be confusing unless you've been warned about it and you know enough to look for it.

Loss of B-plus for the driver (and earlier tubes) is usually due to failure in the transistor power supply. This is the blocking oscillator type that we studied earlier.

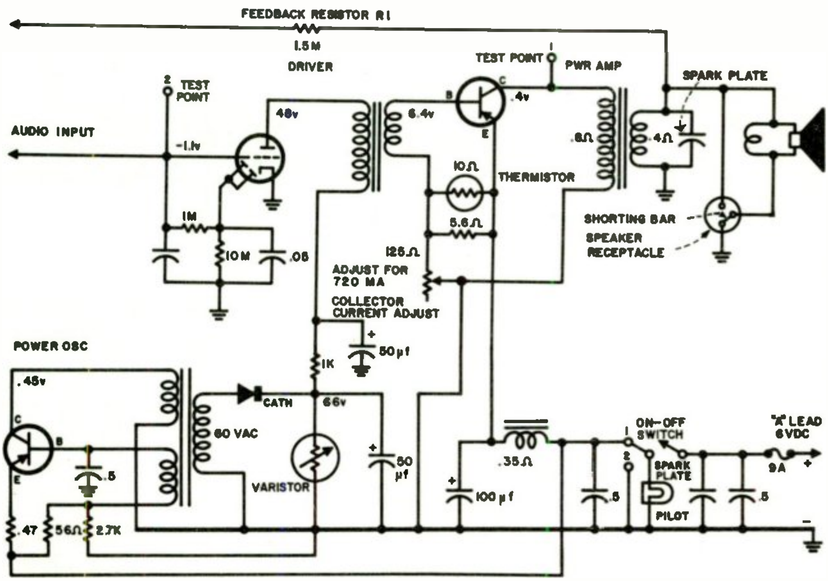



Fig. 507. *This type of hybrid auto radio uses a double power supply.*

The on-off switch (mounted on the volume control) turns on both power supplies at the same time. No heating time is required for the power supplies.

Servicing this type of set will be a little easier for you if you consider the power amplifier and its power supply as separate and independent units.

The circuit in Fig. 507 has a few points of interest that will help us in servicing. Note test point 1. This could be a closed-circuit jack for insertion of an ammeter to check collector current. Set your meter to read 1-ampere full-scale deflection and adjust the 125-ohm potentiometer until the meter reads 720 milliamperes. This check is made in the absence of signal. A good method is to ground the grid of the driver since this will eliminate both noise and signal voltages.

Note the low voltage on the plate of the driver. If you get no voltage here, check the primary of the interstage transformer and the 1,000-ohm resistor for continuity. If you get plate voltage but it is too low, check the decoupling network (1,000-ohm resistor and the 50-$\mu$f capacitor) connected to the primary of the interstage transformer. The voltage drop across the 1,000-ohm resistor should be less than 18 volts (allowing for a small voltage drop across the primary). If it is more than 18 volts, disconnect the 50-$\mu$f capacitor. If this brings the voltage back to normal, the 50-$\mu$f capacitor is excessively leaky.

The driver in Fig. 507 uses contact bias. A 10-megohm resistor is part of the bias network. Check to make sure the resistor is within its tolerance rating if the complaint is distortion. A quick check on driver bias is to make a voltage measurement at test point 2 with your vtvm.

## Servicing if and detector stages

Ever take a long bus ride? The people who run the bus lines are smart enough to know that it's a good idea to have a rest point about halfway along the route.

It's also a good idea in servicing radio receivers to have a halfway point—and what better circuit could we have for this than the detector.

Two things happen at the detector. The detector demodulates or slices the signal in half. Either the top or the bottom half of the signal is rejected. What is left is half the carrier and the audio signal. With the help of a bypass capacitor, the remaining carrier is junked while the audio signal is sent into the driver stage.

What sort of troubles can the detector give us? The usual kind —no signal, weak signal, distorted signal, etc.

Before we settle down to examining these troubles, our first question, as always, is: Before we point the finger of suspicion at the detector, how do we know the detector is working?

Fig. 508 shows a typical if and detector arrangement in a hybrid receiver. To make a quick check, set your generator to the if of the receiver. Make sure the modulation is turned on. Connect

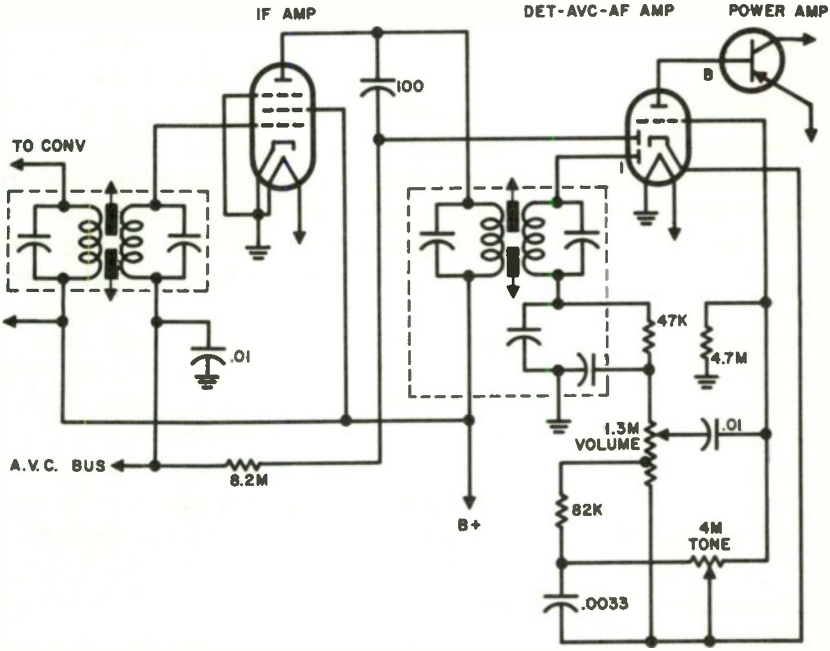



Fig. 508. *The if and detector stages in a hybrid set using low-voltage tubes.*

the test lead to point 1 of the detector diode and listen for the tone out of the speaker.

If you don't hear the tone, don't assume the detector is bad. You may have the wrong if. Some are 455 kc; other sets use 262.5 kc. Try both. The one that works is the right one.

If neither of these frequencies produces results, set the dial of your signal generator to 200 kc, with modulation on, gain control at or near maximum. Turn the generator dial slowly toward the higher frequency range. The secondary of the last if transformer may be very badly misaligned. You can be sure of this if the signal wants to come through somewhat near 262.5 or 455 kc.

Now if you hear the signal, you know the detector is operating. If you don't, put an audio signal across the volume control. If the signal comes through, you've narrowed the trouble down to the detector.

If the detector passes the signal, move your signal generator test lead to the control grid of the first if amplifier tube. Don't change the controls on the generator. If the signal out of the speaker comes through loud and strong, then you know the if is working and any trouble you may have is in the converter.

## Detector types

Vacuum-tube detector diodes are used in hybrid receivers. For the most part these diodes will be in multi-element tubes, such as diode triodes, duo-diode triodes and diode-pentodes.

In the all-transistor auto radio there would be no point in having a vacuum-tube diode. In such sets, semiconductor detectors are used, as shown in Fig. 509.

Servicing the if and detector stages in a transistor auto radio is the same as the servicing procedure we learned earlier. In Fig. 509 there is one difference to note. This is the use of a separate diode for automatic gain control.

But how different is this? Isn't it really the same idea that we have in vacuum-tube circuits when a double diode is used—one diode for detection and the other for automatic volume control?

## Detector and avc troubles

Since we have already had a troubleshooting chart for transistor if, detector and avc circuits, let's set one up for vacuum tubes. Although the chart refers to auto radios, you should be able to use it for any AM receiver using vacuum tubes.

| Troubles in the Detector and Avc Stages. | And What To Do About Them. |
|---|---|
| Receiver is noisy. | Ground the grid of the last if. If noise continues, the trouble is after this point. |
| | Check the volume control. This component is usually the diode load. A worn spot on the control can produce noise. |
| | Look for corroded connections. |

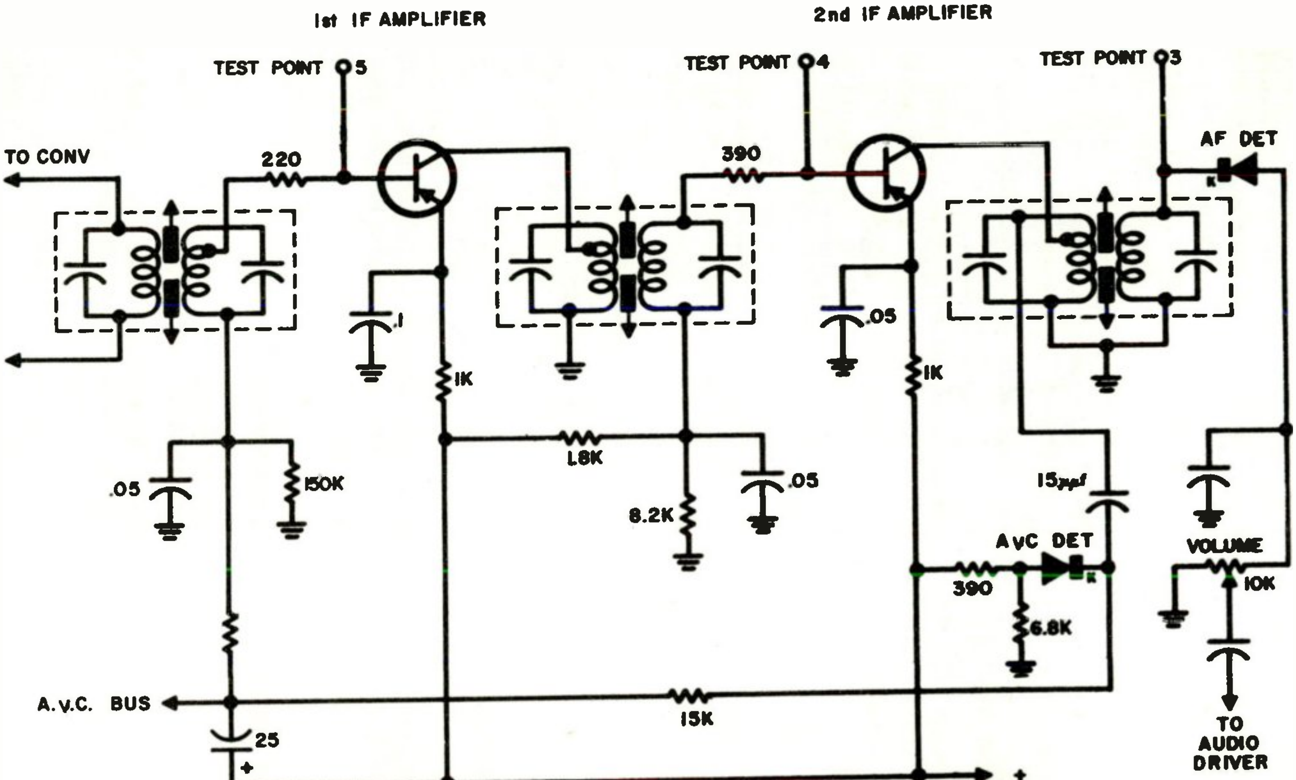



Fig. 509. *All-transistor auto radios use a semiconductor diode as the detector. A separate semiconductor diode is used for automatic gain control.*

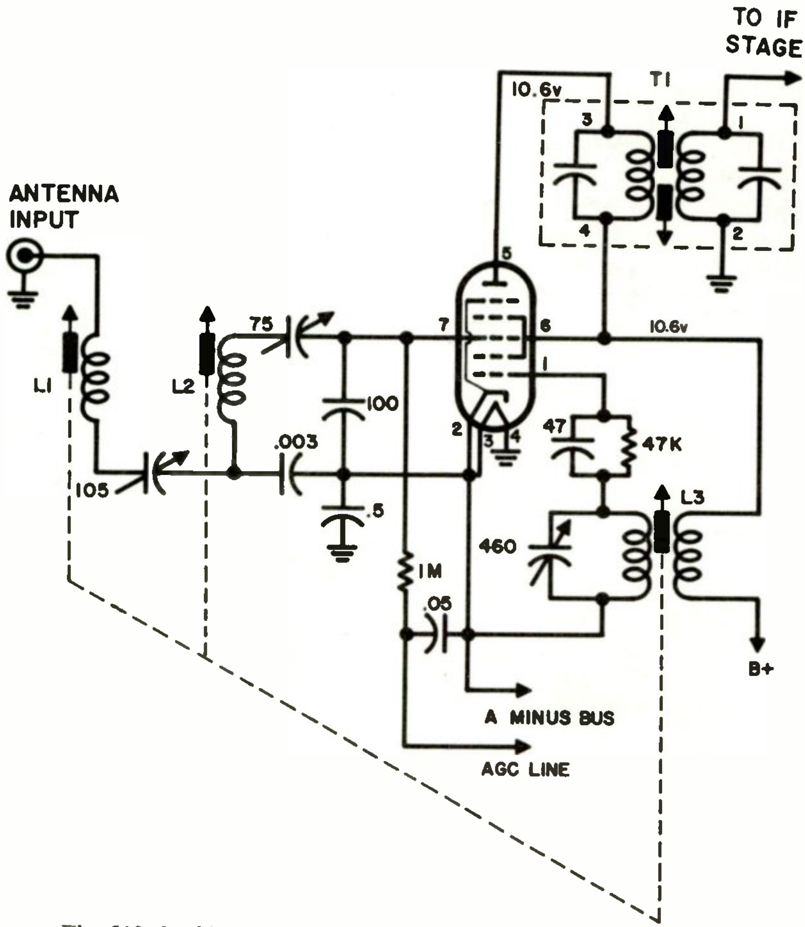



Fig. 510. *In this auto radio, the signal is fed directly into the converter. Auto radios of the better type use an rf amplifier ahead of the converter.*

| | |
|---|---|
| **No sound output.** | Try a new detector tube. |
| | No signal input from last if stage. |
| | Secondary of last if may be open. |
| | Coupling capacitor between volume control and first audio stage may be open. |
| **Oscillation or distortion.** | Check avc filter capacitor (or capacitors). If leaky, affects bias on controlled tubes. |

| | |
|---|---|
| **Signals are weak on all stations.** | Secondary of last if may be badly misaligned. Can be caused by detector tube having weak emission. |

## Some more troubles

Transistor auto radios usually have more if stages than home receivers. Two or more stages are very common. Once again, the reason for this can be found in the conditions under which we expect the auto radio to work. The auto radio is jammed in against an engine that radiates interference. It is in a car, often moving in weak signal areas. These are just a few of the reasons why you'll find more circuits, more tubes or transistors in auto radios.

However, you will find that while transistor auto radios have two if stages, vacuum tube auto sets usually have only one. You can see this quite easily by comparing Figs. 508 and 509.


Fig. 511. *Signal tracer is extremely useful in servicing receivers.* (Allied Radio Corp.)

What are the troubles we can expect to find in the if stages of a vacuum tube auto radio? You will find it easier to anticipate the kind of troubles if you will remember that an if amplifier and an audio amplifier are very closely related. The big difference between them is the frequencies at which they work.

Here is our check list for vacuum tube if stages. Before you use the chart, though, make sure the stage is working. Feed a modulated if signal into the grid of the first if amplifier tube. (Make sure the generator is set on the correct frequency.) You should get a strong tone.

| Troubles in the if Stages. | And What to Do About Them. |
|---|---|
| **No sound.** | Inject modulated if signal at grids and plates of each if to learn where signal disappears. |
| | Try substituting new if tube (or tubes). |
| | Check B-plus voltages on plate and screen of if tubes. If missing, trace circuit. |
| | Open in primary or secondary of if transformer. |
| | If transformer is misaligned. |
| | Slug in if transformer may be shorting windings. |
| | If winding may be shorting against metal can. |
| | Plate and screen may be connected to decoupling circuit. Check for open. |
| | Make sure tube hasn't pushed out of the socket. |
| **Weak sound.** | Defective tube. |
| | Low B-plus on plate or screen. Check series dropping resistors, if any. |
| | If transformer is misaligned. |
| | Open capacitor in the avc line. |
| | Signal from converter is weak. |
| **Oscillation.** | If tube is shielded, make sure shield is on and that it is grounded. |
| | Decoupling capacitor open. |
| | Check screen bypass capacitor. |
| **Intermittent operation of set.** | Make sure each tube is seated firmly in socket. Tube pins may be bent. |
| | Connect vtvm to each screen grid. Grid voltage should be steady. If not, check screen bypass capacitors and screen dropping resistors, if any. |

## Back at the front end

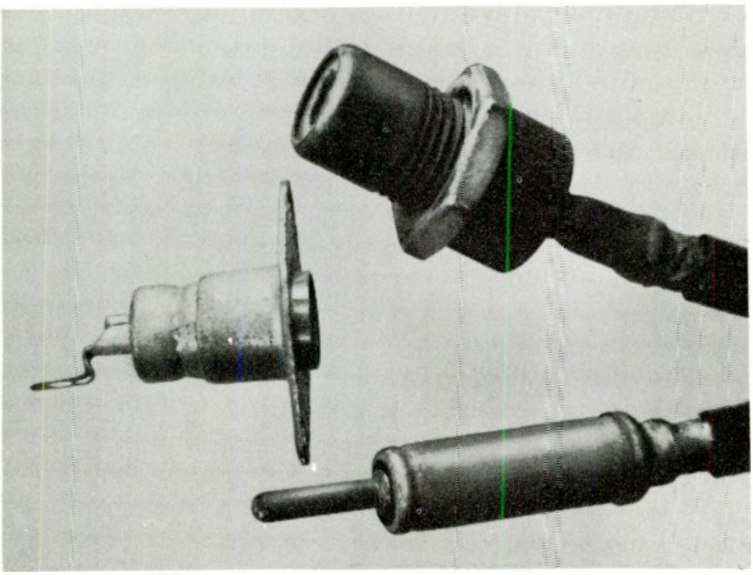
Did you ever try to buy a 5¢ newspaper with a $10 bill? This is a basic problem in conversion. It may not happen very often to you or to us, but we have a similar problem every time we tune in a radio station.

The mixer or converter takes the high frequency of the radio station and (with the help of the local oscillator) "changes" it into a much lower frequency—the intermediate frequency.

Sometimes, though, the converter runs into trouble and, when that happens, our signal can disappear. But before we get into that, let's examine a circuit and see what it looks like.

Start with Fig. 510. This shows a pentagrid converter. Slug tuning is used for the rf and local oscillator. Mixing action takes place in the tube and the output is fed into the first if.

A quick check of this stage can be made by tapping the signal grid of the converter with your finger while listening to the speaker. A better method is to feed in a modulated signal (somewhere in the broadcast-band range). You can check at the output of the converter with a signal tracer. A test unit of this type is shown in Fig. 511. With the signal fed in at the antenna, touch the demodulator probe (shown in the photo) to the plate of the converter tube. If the converter is working properly, you should be able to



Antenna connector (top), chassis-mount jack (center) and lead-in plug (bottom) are all possible sources of intermittent reception and noise.

hear the signal in the speaker of the signal tracer. But what if you don't hear the signal? Or what if the signal is weak or distorted? Let's consult our check list to see what we can do about servicing the converter stage.

| Troubles in the Converter Stage. | And What To Do About Them. |
|---|---|
| No sound. | Check the tube by substitution. |
| | No B-plus voltage on one or more elements of the tube. |
| | B-plus voltage may be too low. Check components from tube pins to the power supply or battery. |
| | No station on the air or set not tuned to a station. |
| | Local oscillator not working. Check oscillator coil, oscillator tuning slug, grid leak and grid capacitor. Oscillator slug may be broken or not moving in or out of the coil. |
| | Primary of first if transformer may be open. |
| Set works over part of broadcast band only. | Check oscillator tuning coil and slug. Slug may be shorting the coil. |
| | Check B-plus voltage on oscillator anode grid. |
| Whistling; birdies. | Try aligning rf and local oscillator sections. If misaligned, whistles can be caused by image interference. |
| Noise; weak signals. | Try a new converter tube. |
| | Front end may be misaligned. |
| | Look for broken connections, corroded soldered joints. |
| | Examine rf and local oscillator coils for broken strands of wire. |

## The rf amplifier

Did you ever see a mirror that magnifies? Look in one of these mirrors and suddenly everything is giant size. When you shave, you get the feeling that you're covering a lot of territory.

An rf amplifier in an auto radio is like this mirror. It makes the signal bigger. But it does a little more than that. The antenna of the car radio is very close to a big source of electrical noise. When this electrical noise is sent into the converter, the poor con-


Excessive electrode gap in the spark-plug (left) or corroded top connector can help generate excessive noise just as wear and burning of the rotor tip or a dirty or poor contact will at the center contact of the rotor. These normal-wear points can create noise before hard-starting or engine performance is affected.

verter has no choice but to send it along to the if section where it is amplified. Finally, we hear the noise as annoying crackles and scratches coming out of the speaker.

An rf amplifier gives the radio signal a fighting chance to overcome the noise.

In Fig. 512 we have the rf amplifier used in the front end of an auto radio. Our rf amplifier also has a sensitivity control so that we can adjust the set for best operation.

The sensitivity control is a variable resistor in the cathode circuit of the rf amplifier and controls its gain. Sometimes all that is needed in servicing a set of this type is to adjust the control properly. As the rf amplifier tube gets older, its gain becomes less, so some adjustment is needed.

For a quick check of the rf amplifier, touch the control grid. Listen for sound out of the speaker. Better yet, feed in a modulated signal and then put the probe of your signal tracer on the plate of the rf amplifier tube.

Just because the rf amplifier is a simple circuit doesn't mean that it can't have its share of troubles for you to work on. Here's our check list.

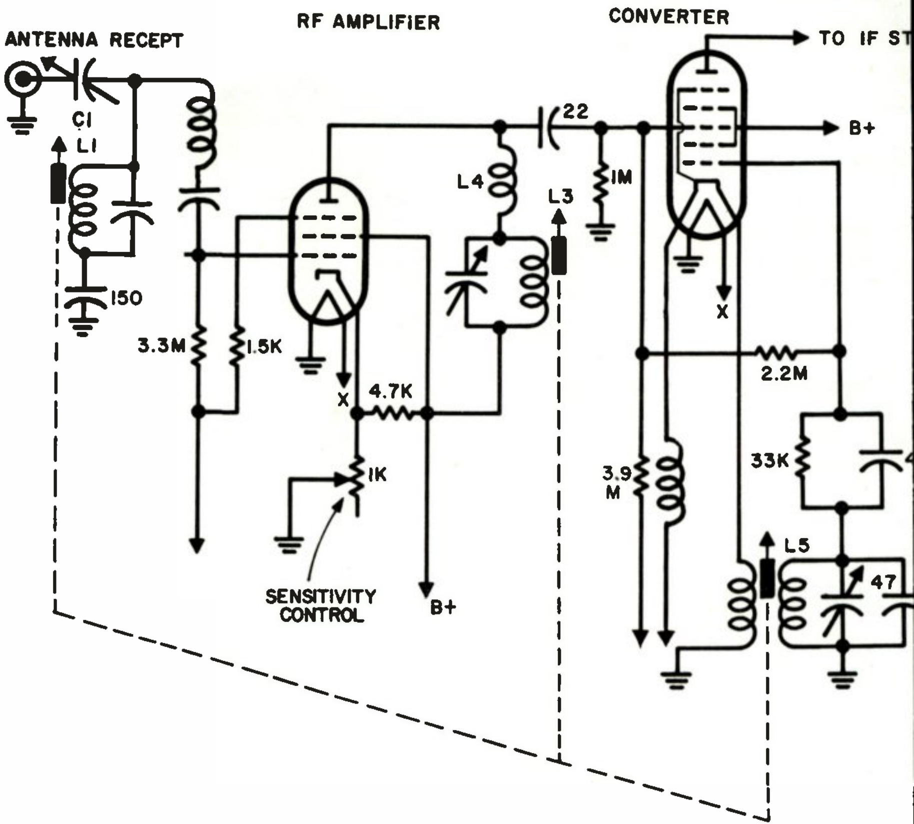



Fig. 512. *For best operation, the auto radio should have an rf amplifier ahead of the converter.*

| Troubles in the Rf Amplifier Stage. | And What To Do About Them. |
|---|---|
| No sginal. | Tube is dead. Try a new one. |
| | Check voltages on screen and plate. If voltage is missing, trace back along B-plus lead. |
| | No signal input. Antenna may be shorted to body of car. Antenna cable may be disconnected. Hot lead of antenna cable may be shorting to braid of cable. |
| | Filter circuit between antenna connector and control grid may be open. |
| | Cathode resistor (or sensitivity control) may be open. |

| | |
|---|---|
| **Weak signal.** | Low emission in tube.<br>Low plate or screen voltage. Check all components connected to plate and screen.<br>Slug may not be moving in and out of rf coil. Slug may be broken or severely chipped.<br>Input circuit trimmer (C1 in Fig. 512) may not be properly adjusted. |
| **Intermittent signal. Signal fades in and out.** | Tube may be intermittent.<br>Antenna connection may be loose or corroded.<br>If rf tube is avc-controlled, check avc filter capacitors. |

## The transistor rf amplifier

Every time we see a transistor rf amplifier stage we are reminded of that old song

*Anything you can do,*
*I can do better.*

Perhaps a transistor rf stage is better than a vacuum-tube type. At the present time, it's a bit difficult to say. But since both types are being manufactured, we need to work with both.

To test the rf stage, feed a weak signal into the antenna circuit using the method described earlier with transistors.

Unlike the tube rf amplifier, the transistor is the last item to suspect. Make sure the battery is fully charged. Check the voltages at the transistor elements. If any of these do not agree with the information given on the manufacturer's schematic, check back along the lines going to the transistor elements.

A good test of the rf transistor is to measure the voltage drop across the emitter resistor. If the voltage is too high, the transistor may be excessively leaky. If too low, bias voltage between emitter and base needs looking into.

Some of the same troubles that we have with vacuum-tube rf amplifiers will show up with the transistor rf stage. You can expect weak sound if the stage is misaligned. You can expect noisy, intermittent reception if the antenna lead is corroded or shorting. Examine the slugs to make sure they move in and out of the rf and oscillator coils. See Fig. 513.

## Some final servicing notes

Ever watch a bunch of women in action on "bargain" day in

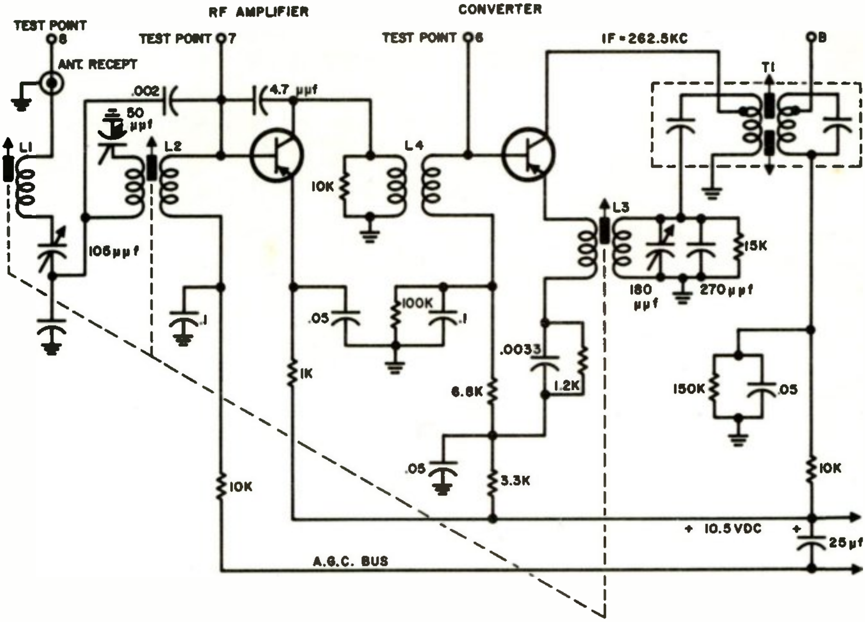



Fig. 513. *Transistor rf amplifier in an all-transistor auto radio.*

some department store basement? They tear through from one rack to the next in a matter of seconds. Reminds us of the way some service technicians work on radio sets. They jump like wildfire from stage to stage. Sometimes they even get sets fixed.

Although we prefer a more orderly method of servicing, working back from stage to stage, this doesn't mean that this is always the best way. Also, while we have given definite information about servicing each stage, there are still a few precautions to follow in servicing auto radios.

## Screwdriver servicing

Screwdriver testing—that is, probing from tube or transistor elements to the chassis with a screwdriver—can be risky. The energy in a storage battery can lift a ton of metal a mile into the sky. And while you can put both hands across a battery without getting hurt, a bit of metal (such as a screwdriver) across a battery can be very dangerous.

Now you are probably going to tell us that you would never do such a thing, you would never put a screwdriver across a bat-

Fig. 514. *Battery eliminator and eliminator with extra filter.* (EICO)

tery. But when you spark-test at different points in an auto radio, you are practically doing just that.

Storage batteries are designed to deliver current in amperes—many amperes—and this kind of current can burn wires and components quicker than a hamburger on a grille at a picnic.

Shorting the base of a transistor to ground is a good way to increase the sales of new transistors. When the transistor base is shorted, its bias is removed. When the bias is removed, the amount of current flowing through the transistor will fuse it.

## Testing the receiver

If you remove a radio from a car, you need a source of power to test it. Whether it is all-transistor or hybrid the best source is another storage battery.

A storage battery is a nuisance, however, since it must be kept clean, watered and charged. Don't try to use an ordinary battery eliminator, however, since the average eliminator isn't too well filtered. The ac ripple out of some eliminators runs between 15 to 25 volts—enough to retire most transistors for life.

This doesn't mean that the eliminator cannot be used. Filter attachments are made so that you can adapt your eliminator for use in servicing auto radios. A way of doing this is shown in Fig. 514.

## Polarity

Whether you use a storage battery or eliminator for powering the set, be sure to watch polarity. Two things will happen if you

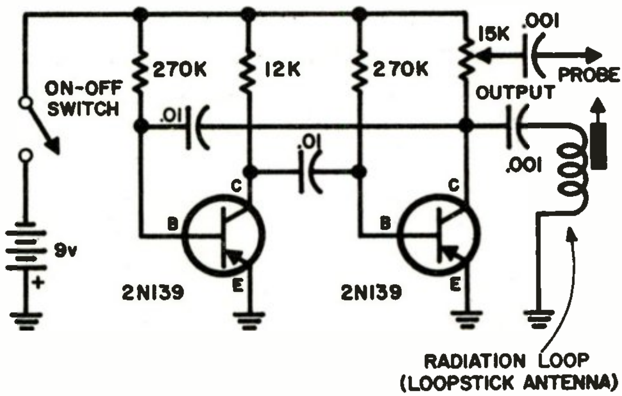



Fig. 515. *Harmonic generator can be used in place of a signal generator.*

connect wrong: The set will definitely not play and you may damage some parts. Check the schematic of the set if you have any doubt.

## Using the signal generator

The safest way to use a signal generator with all-transistor radios is to put 0.5-$\mu$f capacitors in series with both the hot and ground leads. You will avoid accidental shorting of components through the generator in this way.

If you want faster signal injecting than tuning your generator permits, try a harmonic generator.

The advantage of the harmonic generator is that you do not need to set it to any particular frequency. It has no adjustments to make.

A radiation loop can be used for checking front ends. Just bring the harmonic generator close to the front end of the receiver and listen for the signal.

For all other circuits, a direct probe can be used. This is just a wire inside a probe housing.

The circuit is shown in Fig. 515. As you can see, it is a transistor multivibrator. Basically, it puts out an audio signal, but the waveform is so distorted that it is rich in harmonics. These go right up to the broadcast band.

### Noise Suppression

The best noise suppressor we ever saw was when a mother shoved a bottle of milk in front of a baby. And the only thing that can compete with a baby for noise is an automobile. Milk won't work on a car but, fortunately, we have a few electronic gimmicks that are just as good.

When we say that certain parts connected with the engine produce noise, we don't mean the sort of noise that you can hear directly. The generator, the voltage regulator, the ignition coil, along

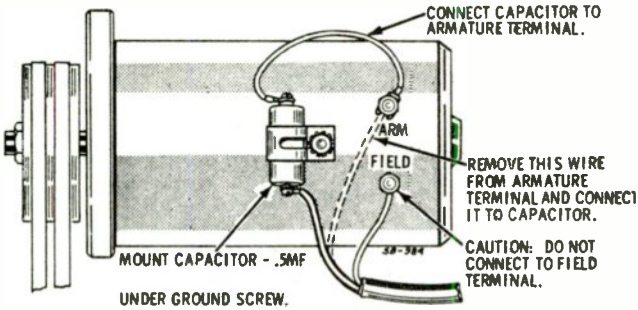



Fig. 516. *Method of mounting an interference-eliminating capacitor on the generator.* (Motorola Consumer Products, Inc.)

with the distributor and spark plugs, behave like small radio transmitters. Ordinarily, these devices wouldn't bother us, but the car radio is mounted so close to them that it just can't help picking up what we call "electrical noise."

### Installing a generator capacitor

Electrical noise is most often caused by sparking or by electrical contacts that make and break. Resistors and capacitors can be used to suppress the interference produced by the sparking or by the switching action of moving contacts.

Capacitors are made with special mounting brackets for use in cars. In Fig. 516 we have a 0.5-$\mu$f capacitor mounted right on the generator. You will find a ground screw in the generator metal frame. This is a tapped screw and can be easily removed. Use this screw for holding the mounting bracket of the capacitor.

On the generator you will find two terminals. One of these will be marked ARM (for armature) while the other will be marked FIELD. Do not touch the field terminal.

Disconnect the wire going to the terminal marked ARM. Connect this wire to one side of the capacitor. Connect the other side of the

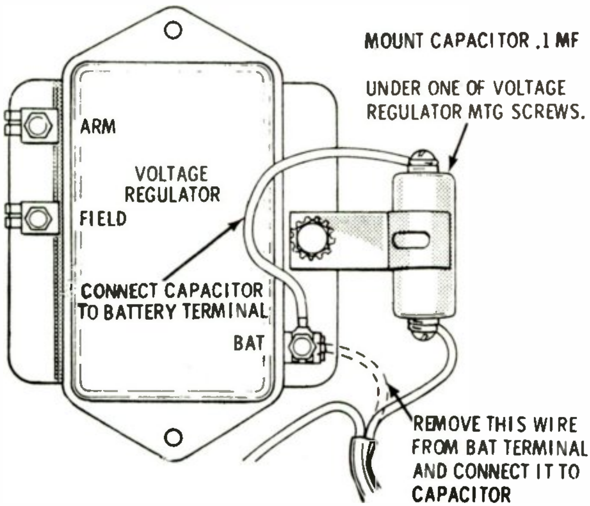



Fig. 517. *This drawing shows how the capacitor is mounted on the voltage regulator.* (Motorola Consumer Products, Inc.)

capacitor to the ARM terminal and the job is done. Make sure all the screws are tight.

## Installing a voltage-regulator capacitor

To install an interference-elimination capacitor on the voltage regulator (as shown in Fig. 517) remove one of the screws that holds the regulator in place and use it to hold the capacitor bracket.

On the regulator you will find three terminals marked ARM (for armature), FIELD and BAT (for battery). The BAT terminal is the one we are going to use. Disconnect the wire going to it and connect it to one side of the capacitor. Connect a wire between the other side of the capacitor and the BAT terminal and the job is done.

After you have installed the voltage regulator and the generator capacitors, turn the motor on and tune in a station. Note whether you have made an improvement. Tune the set from one end of the band to the other since the interference may concentrate at one end.

## Installing a capacitor on the ignition coil

On the ignition coil you will find two wires. One runs to the distributor and the other to the battery terminal. Mount the capacitor as shown in Fig. 518. Disconnect the wire going to the battery terminal and connect it to one side of the capacitor. Now connect the other side of the capacitor to the battery terminal and the job is finished.

## More noise suppression

The steps we have described so far should help eliminate most of the interference. But you can always expect to run into stubborn cases. This doesn't mean that you should recommend that your customer turn his car in for a bicycle. There are still a few more cures you can try.

One of the things you can do is to install more suppression capacitors on the voltage regulator. Fig. 519 shows just how we do this. Get a pair of capacitors and mount them near the voltage regulator. Remove the wire from the terminal marked ARM and connect

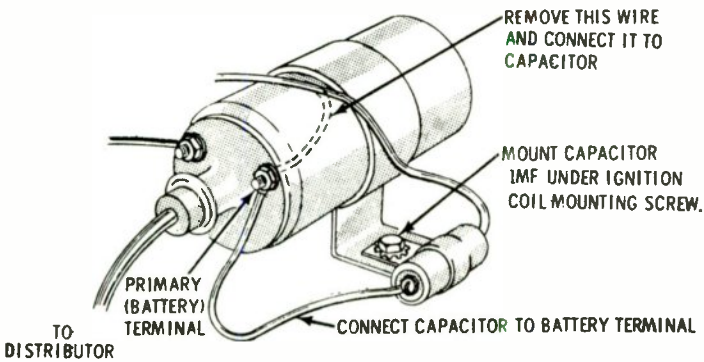



Fig. 518. *Method of mounting the capacitor on the ignition coil.* (Motorola Consumer Products, Inc.)

it to one of the capacitors. Connect the other side of this capacitor to the ARM terminal.

The other capacitor is a common type which has one connection automatically made to the "ground" or frame of your car when you mount the capacitor. This capacitor has just one lead. Connect this lead to the FIELD terminal on the voltage regulator.

## Other steps you can take to reduce interference

It is possible that you might still have some trouble with interference. Some makes of cars have special resistance ignition wiring

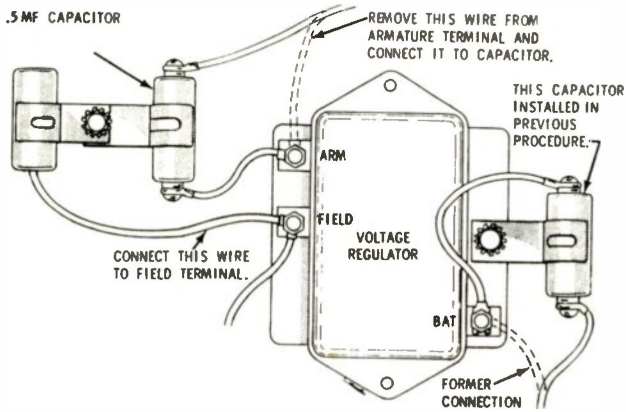



Fig. 519. *Additional capacitors can be used in cases where the interference is still annoying.* (Motorola Consumer Products, Inc.)

to eliminate interference. If the car you are working on doesn't have such wiring, you can replace the original wiring with resistance wiring.

Resistance wiring is obtainable from automotive parts dealers.

## Importance of grounds

The frame of the car is ground but it's a little less solid than the earth we walk on. Since the frame of the car isn't one piece, some rubbing action takes place and, since ground is part of the antenna system, it's just as though we had a poor connection to the antenna.

What are the things we can do to overcome this problem? Run a woven metal strap from the engine block to the firewall. In some cars you will find a support for the dash bolted to the firewall. Try connecting the ground strap to the firewall at this point.

Run a ground strap from one of the mounting screws on the voltage regulator to the grounded terminal of the car battery.

There are other methods you can try. Use spark plugs with built-in suppressor resistors. Install a suppressor resistor at the distributor. Use shielded ignition wiring. Make sure that the receiver is mounted securely. One way of doing this is to use star lockwashers on both sides of all metal contacts. The connections should be tight enough so that the washers bite into the metal.

Some radios are powered through the ignition switch. The contact resistance of the switch or the connections can help introduce ignition noise into the radio. If tightening the connections doesn't


This do-it-yourself ignition noise suppression kit can be used to advantage with any internal combustion engine where it interferes with the reception on broadcast, marine or Citizens bands. It includes suppressors, capacitors, an R-C network and shielded generator wiring. (Raytheon Company)

help, try running a wire directly to the battery's *hot* terminal. This will eliminate one more possibility.

Noise can be generated by such unlikely things as the wheels. Static electricity (a mild form of lightning) is created by friction. This is stored up (usually by the front wheels) until the voltage is high enough to arc over. This can be reduced by using special springs in the bearing covers or adding graphite to the wheel bearing lubricant to give a low resistance electrical path.

## Search tuners

The best way to drive an automobile is with two hands. But if a driver must tune a radio while trying to operate a car, the

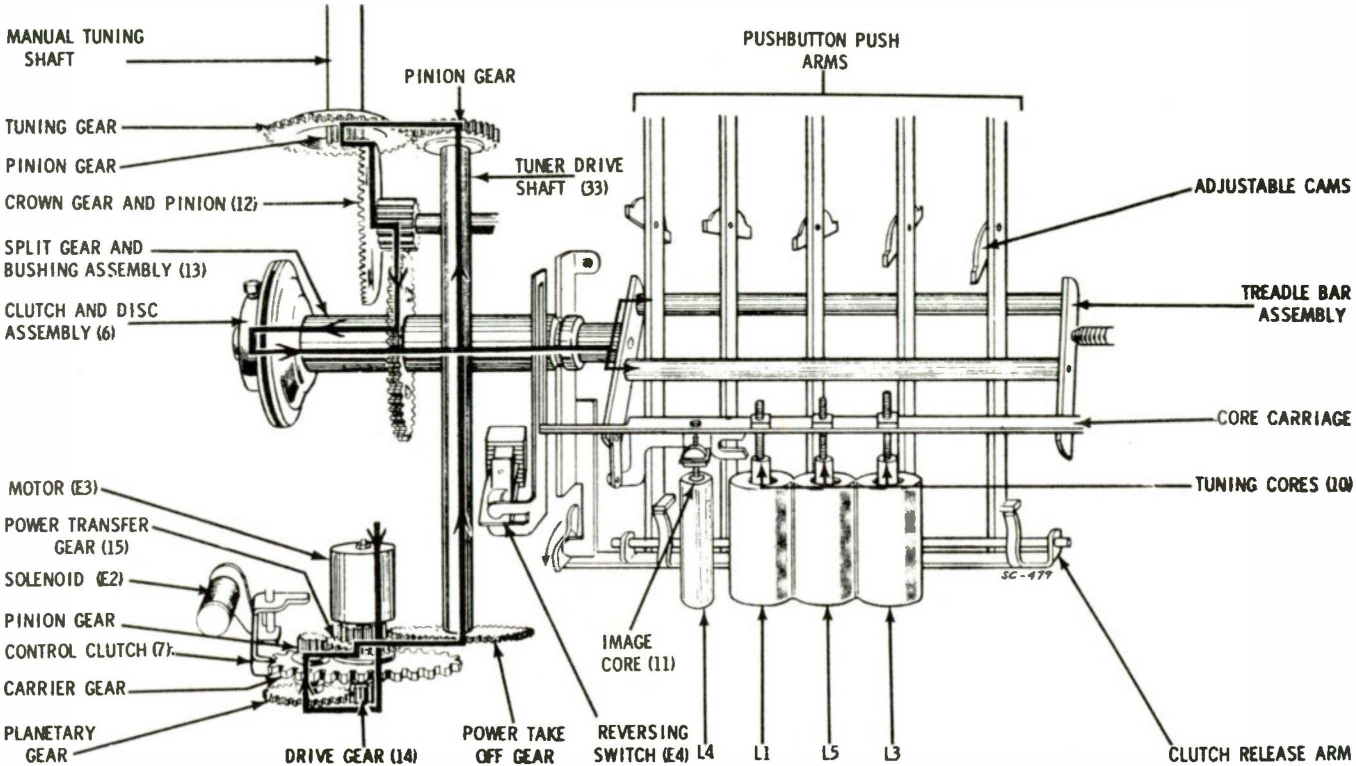



Fig. 520. *The tuning slugs in this search tuner are operated by gears which are driven by a motor.* (Motorola Consumer Products, Inc.)

chances for an accident becomes a little greater. That is why some auto radios come equipped with search tuners.

The search tuner may be operated by a foot pedal or by pushing a bar on the front of the set to start the search tuner into operation.

The search tuner has a small motor which operates the tuning slugs instead of the knobs or pushbuttons. The effect of this is to cover the broadcast band from the low-frequency to the high frequency end.

In some search tuners, a spring returns the tuning device to the low-frequency end (somewhat like a typewriter return spring) and then the search motor goes into operation once again.

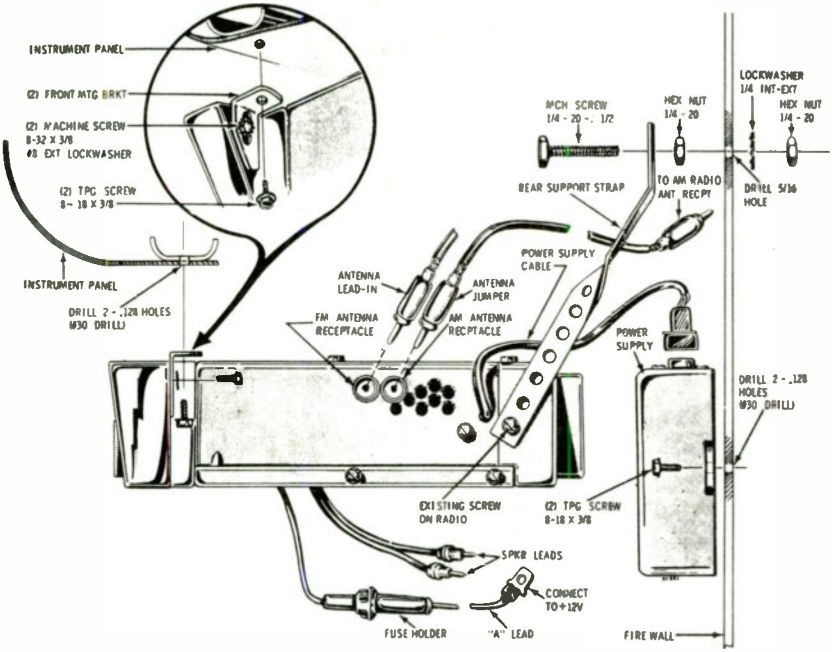



Fig. 521. *Mechanical and electrical connections for an auto radio.* (Motorola Consumer Products, Inc.)

In other search tuners, the motor is a reversing type so that the tuner sweeps in two directions—from low frequency to high and from high frequency to low.

## The search tuner in action

When the search pushbutton or bar is depressed, the search tuner goes into action. Between stations the speaker is muted so

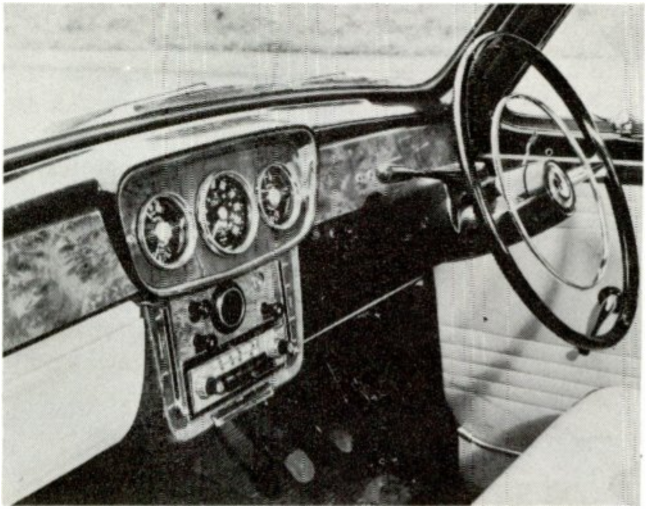


Fig. 522. *There are many ways of installing car radios. This shows an installation in a foreign car.* (Pye Corporation of America)

that the set is quiet. When a station is found, the search action stops and the speaker is permitted to operate. If the customer doesn't like the program all he needs to do is to touch the search pushbutton or bar once again.

## Servicing search tuners

Only the more expensive auto radios come equipped with search tuners. The search tuners are fairly complicated mechanisms and they vary somewhat from one model to the next.

If you have a receiver to service and the search tuner does not work, your best source of information is the service manual supplied by the manufacturer. These come equipped with detailed drawings of the mechanism plus full instructions on how to service that particular model.

A drawing of a search tuner is shown in Fig. 520. The drive motor operates a gear train which moves the slugs (tuning cores) in and out of their coils.

## Installation and removal of auto radios

You've probably heard that old saying, "The first million dollars are hard to make. After that, it's easy."

The same thinking could be applied to many auto radios. Once you have them out of the car, servicing isn't too difficult.

When you remove an auto radio, you are taking out part of a car, and the way some of them are installed, you could easily believe that they were never intended to come out.

## Types of installation

You will find auto radios installed practically everywhere in the car. You will find some in the glove compartment. In some cars the radio is mounted right on the floor. In many cases, it is installed behind the dash. And a recent transistor type acts as a combined radio and a rear-view mirror.

A complete book could be written just on installing and removing auto radios. For this reason many service technicians are not too anxious to get started in this particular branch of radio

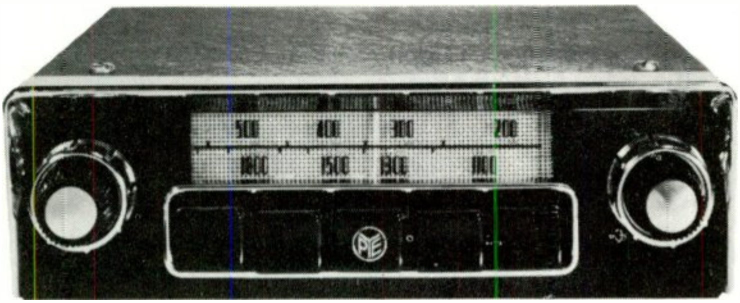



Fig. 523. *This auto radio is designed to slide in and out of special compartment.* (Pye Corporation of America)

repair. And yet servicing the electronic section of an auto radio requires far more thinking ability.

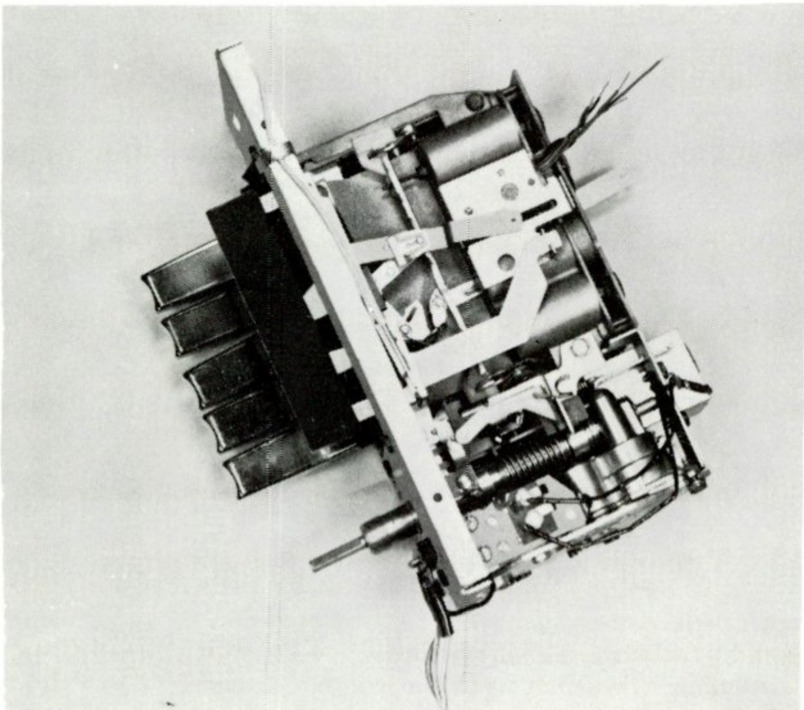
Installing and removing radios can be learned by doing. If you remove a set, make a mental note of the hardware and where each piece belongs. Note how the set is mounted before you remove it. Use the right tools. A socket wrench is much easier for removing nuts, and much more practical, even though a pair of gas pliers could be used.

Note how the washers are mounted on machine screws. Watch for screws that are cross-threaded or corroded and replace them.

Fig. 521 shows the installation details for an AM–FM auto radio. This radio is supported by the instrument panel and by a pair of rear support straps holding the receiver to the fire wall.

Not only must you remove hardware, but electrical connections as well. Make your electrical disconnections before you remove the brackets and other supports, otherwise you will have the receiver hanging by its wires—and that won't do either the receiver or the wires any good.

If you want to be absolutely sure about which wire goes where and you aren't too certain about your ability to remember the electrical connections, tag each one as you remove it. You can

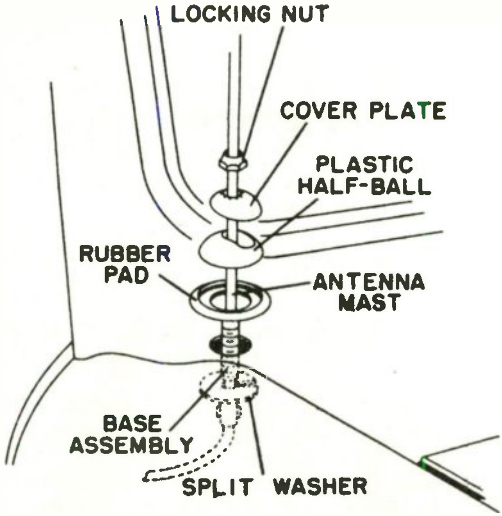


Search tuner troubles can be mechanical, electrical or electronic. A control amplifier (electronic) activates the motor-drive circuits (electrical) that move the tuning slugs (mechanical) that tune in the station. (Delco Radio, Div. General Motors Corp.)

get small tags with strings attached in most stationery stores.

The first wire to disconnect is the lead to the battery. This will avoid the possibility of accidentally shorting the hot battery lead to ground.

After disconnecting the set electrically, examine the way in which the set is mounted mechanically. As you loosen the machine




For antenna installation select the desired cowl mounting location, then center-punch and cut a hole. Feed the lead-in down through the hole. Insert one edge of the split washer into the hole, and twist the base assembly until the washer slips through the hole. Place the rubber pad on the mast, followed by the plastic half-ball, cover plate, and locking nut. Pull up on the mast, and tighten the locking nut while holding the mast in the desired position. (Philco Corp.)

screws, support the receiver so that it will not drop accidentally.

In some foreign cars, such as the one shown in Fig. 522, there is an arrangement for supporting the car radio in a small enclosure below the instrument panel. Here again, examination of the way the receiver is installed will give you the clue as to how it should be removed.

The same receiver is shown out of its compartment in Fig. 523.

## Antennas

Auto antennas have many enemies, few friends. It is exposed to vandalism, corrosion, vibration. Some antennas are of fixed length; most are of the telescoping variety. Moving the sliding parts in and out wears away the tight fit the antenna elements must make with each other. Unless the trouble is a minor one, it hardly pays to repair the antenna. A new one can be installed easily, quickly. A typical installation is described at the top of this page.

## QUESTIONS

1. What is a sensitivity control? Where would you expect to find it? What does it do?
2. What are some intermediate frequencies used in auto radios?
3. You have whistling and birdies due to trouble in the converter? What can you do to eliminate them?
4. After replacing an output transformer, the receiver whistles and howls? What is wrong?
5. The voltage drop across a decoupling resistor is excessive? What associated component might cause this?
6. A driver stage uses a cathode resistor. What is the effect if this resistor opens?
7. Name one possible cause of trouble in an intermittent vacuum-tube driver stage. What troubles could cause motorboating? Weak sound?
8. An interstage transformer has a primary and secondary winding, but sometimes a third winding is included. What is the purpose of this winding?
9. A receiver has a control marked "collector current adjust." How would you set this control properly?
10. What is a hybrid receiver?
11. What might be the effect of shorting the base of a transistor to ground?
12. What might be the effect if the avc filter capacitor [or capacitors] is leaky?

# INDEX

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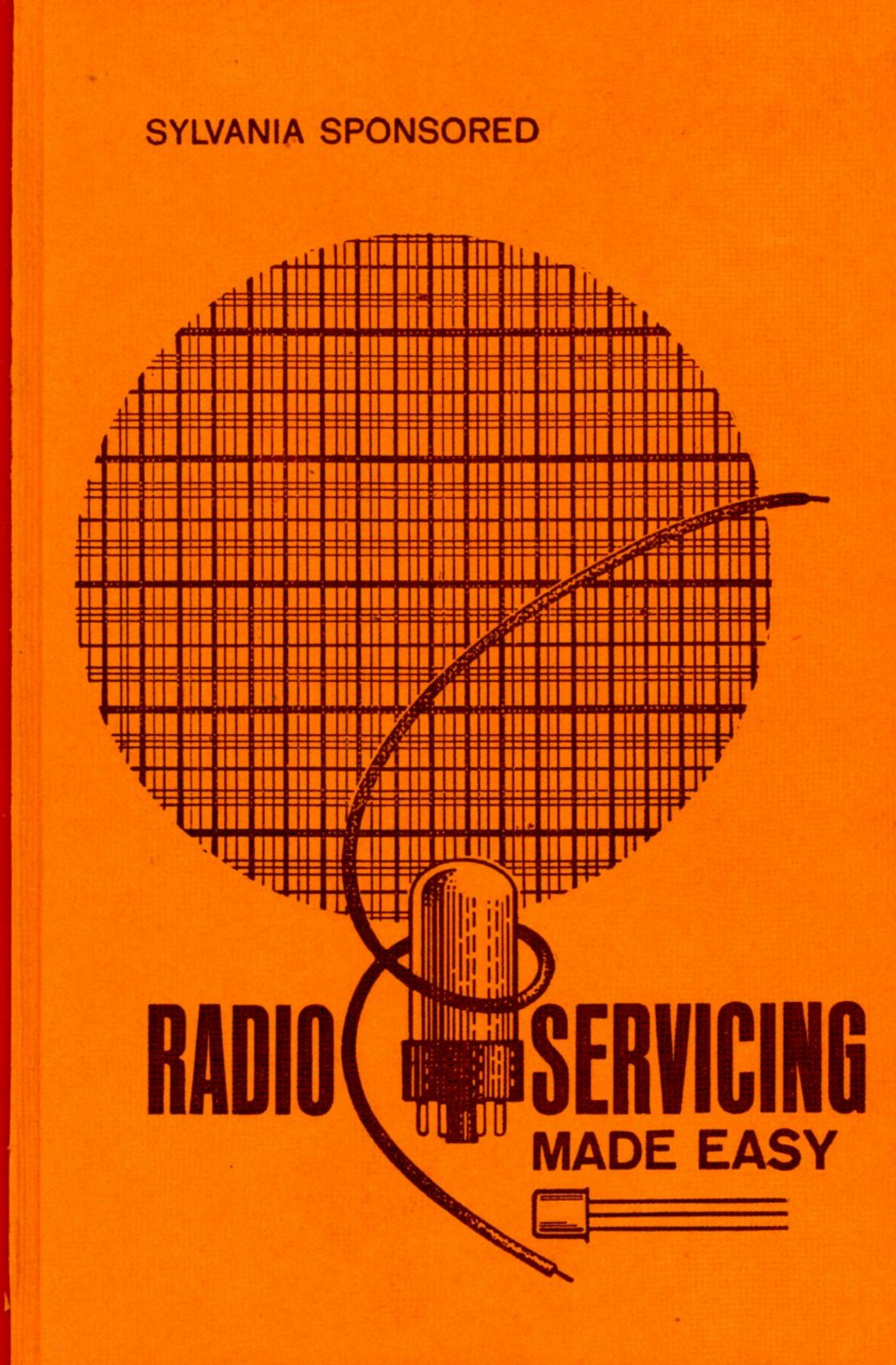

SYLVANIA SPONSORED
RADIO SERVICING
MADE EASY

VOLUME 2

SYLVANIA
SPONSORED

# RADIO SERVICING MADE EASY

*By*

*LEONARD C. LANE*

*Author of*

*TV Servicing Made Easy*

*Transistor Servicing Made Easy*

*Industrial Electronics Made Easy*

THIS COURSE HAS BEEN PREPARED IN COOPERATION WITH

**SYLVANIA ELECTRIC PRODUCTS, INC.**

IN ORDER TO MAKE RADIO SERVICING INFORMATION MORE READILY AVAILABLE TO INDEPENDENT SERVICE TECHNICIANS

VOLUME 2

# contents

## Troubleshooting Charts

# Introduction

WELCOME to the ranks of those who want to earn more by servicing radio receivers.

We could let you jump right in with both feet, give you a complete circuit of a radio receiver and say: "Here. Do this and that . . . and the set will be fixed." That's a cook-book method. A few technicians might think that's good, but what do you do when the chief cook is out . . . and you have a collection of sets with troubles not described in the book?

With our approach you'll be able to look any radio set right in the face and say, "See here. No nonsense out of you or else . . ." What's more, you'll really mean it.

For many years radio service technicians fixed nothing but radios. There were all sorts of radios. Big ones. Little ones. Sets with 15 tubes. Sets with one tube.

But then, along came television and radio took a back seat. Practically all radio receivers were of the 4 or 5-tube ac–dc-type. If you could fix one, you could fix them all. Television was the big thing. People weren't too anxious to spend any money fixing their little sets since they were so cheap to begin with.

People have now become accustomed to television. Many homes have two television sets. And then people discovered radio all over again, after the novelty of television wore off. There is a big demand for radio again.

What sort of radio? All sorts! Clock radios, personal portable radios, short-wave receivers, marine radio receivers, police and airplane receivers, console receivers for the home, FM receivers for the home, FM receivers for use in automobiles. Just in the automobile alone, we have, in addition to AM and FM types, sets that fit into the dashboard, sets that fit into the glove compartment, sets that fit onto the rear-view mirror, sets that fasten to the floorboard (in sports cars).

Radio receivers now come in all shapes and sizes. Some are so tiny that they fit into a vest pocket—or will, just as soon as vests come back into style. Most come equipped with a hearing aid type of earphone so you can walk down the street listening to your favorite program.

And some sets are so big that they need a large console cabinet to hold them.

What does all this mean to you? Just this. These sets are going to break down—get out of order. The time to learn how to fix these sets is now—not when the set is sitting on your bench with the customer breathing down the back of your neck.

The day of the old "know one—know them all" is gone. Today we have such a large variety, that you can't "pick up your servicing knowledge as you go along."

Here is one cheerful note. In many cases, if you study one particular circuit, you will find it used in a number of sets, all of which look different. Just as an example, consider a transistor if stage. You will find it in personal portables, in home receivers, in auto radios. There will be some differences but many similarities. You won't find a *completely* new if stage with every new type of receiver.

We hope we haven't painted too dark a picture for you. We're just anxious that you should be fully prepared. Troubleshooting techniques learned here can be used on any electronic circuit. A dead stage will give the same wrong indications in a radio as in an amplifier. Noise interference must be traced with the same procedures and instruments in an automobile radio or an industrial installation. Once the principles are understood the solutions will come much easier.

Just one last word. We have tried to make this book as readable as possible, but that doesn't mean that you should consider it as a novel. By all means, read both Volumes 1 and 2, and read them often. But keep them around as reference books. The troubleshooting charts were prepared especially to help you. Take advantage of them.

LEONARD C. LANE

CHAPTER 6

# AM receivers

WHAT DOES AM mean? It all depends on where you are and what sort of job you hold. If you are in bed and your alarm clock starts hammering away at about 6 in the morning, then you know that AM means any hour before noon.

If you are a radio service technician you know that AM also means amplitude modulation. But what is amplitude modulation? Amplitude modulation means that we change the height or the strength (or the amplitude) of the carrier with an audio signal. A receiver that can tune in such a signal (and use it) is known as an AM receiver. Just as we can load a truck by hand or by machine, so too can we put an audio signal on a carrier in different ways.

## The AM frequency range

Look at a map and you will see all sorts of roads shown on it. Some are super-highways, turnpikes and freeways. Then we have two- or four-lane highways, gravel roads and some roads that don't even deserve the name.

We have roads through the air, used by radio waves. We can't see these roads, but the space through which these waves travel has been divided just as surely and as definitely as the roads on the ground. Of course, we don't call them air roads or anything like that. Instead we call them bands.

Thus, we have television bands, short-wave bands, bands for marine radio communications, Citizens radio bands, etc. But the one we are interested in now is the broadcast band. This band covers the frequency range from 540 to 1600 kilocycles. All stations in this band are AM stations.

## The power supply

How far do you think we would get if we tried to take a ride in a car with an empty gasoline tank? And just as gasoline supplies the power to move a car, so too must we have a unit in the receiver to get lazy electrons into motion. That unit is our power supply.

For transistor radios the power supply is a battery. For vacuum-tube receivers, the power supply begins outside the receiver at the power outlet. But outlets supply ac and our tubes need dc. Not only that, but seldom does an outlet furnish the correct amount of voltage for our tubes. It's either too much or too little, so we must do something about changing that also.

Fig. 601 shows the basic elements of a power supply. Let's see what we have. The two block diagrams cover practically every

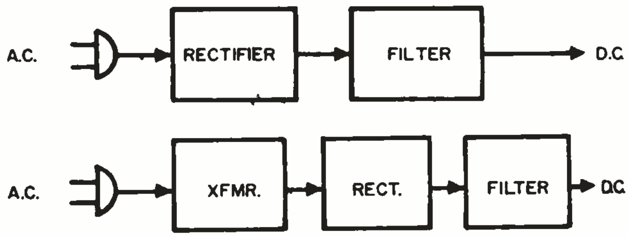



Fig. 601. *Two basic types of power supplies. Some power supplies have a transformer; others do not.*

type of power supply you will have in servicing AM receivers. The only difference between them is that one of them uses a power transformer.

## AC–DC power supplies

The supply that does not use a power transformer is called ac-dc. This means that it will work from outlets that deliver dc or ac. The fact that practically all power today is ac (when did you last see a dc power outlet?) makes no difference.

## The filament circuit

Did you ever join in a game called "snap-the-whip"? The players (on skates), hold hands and, as they travel faster and faster, some of them get "pushed" forward at pretty good speeds, but when this happens the line or the connection between players is broken.

This game reminds us of the filament circuit shown in Fig. 602.

The filaments are connected in series. But if one of the filaments opens, then none of them can work, since they are then all out of the game.

## Troubleshooting the filament circuit

If all the tubes are lit, then you know the filament circuit is not open and no troubleshooting is needed. Remember, though, just because a tube lights does not mean the rest of the tube is good.

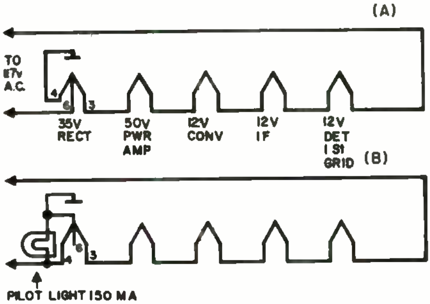



Fig. 602. *Two typical filament circuits. In ac-dc sets the filaments are connected in series. Some older sets use a pilot light connected across one half of the filament.*

But what if none of the tubes light? How do we know which one of the tubes is in trouble?

We have several ways of finding out. Use whichever one of these methods you prefer.

1. Test all the tubes in a tube tester. This is slow, but you might also locate some tubes that are weak, intermittent or open.
2. Remove each tube and check each filament for continuity with an ohmmeter. This method can be used if you don't have a tube tester and don't want to bother removing the chassis from its cabinet.
3. For this next method you will need to take the set out of its cabinet, but in most modern sets you can do this very easily and quickly. Set your vom or vtvm to read ac volts. The range switch should be set so that full-scale deflection is more than 125 volts. Connect the test leads (Fig. 603) across each set of filament pins, in turn. (For this test the line cord must be plugged into the outlet and the receiver switch turned on.) If you get no voltage reading, the tube you are checking has a good filament. When you measure across a tube's filament pins and you read the full line voltage, remove the tube. Its filament is more open than a baby's mouth at feeding time.

4. Tube-substitution method. Some service technicians keep a set of tubes on hand. These tubes (known to be in perfect condition) are their "test tubes" and are never sold or used for any other purpose. The tubes are substituted for those in the set, one at a time, until the defective tube is found.
5. You can use a neon-tester. This inexpensive unit can be bought in radio parts stores or hardware stores. Just put the test leads across the filament terminals of each tube. When the neon bulb lights, you have the tube with the open filament.

## Make a continuity tester

You can make your own tester using a porcelain socket, a 10-watt bulb, some wire and a pair of alligator clips as shown in Fig. 604-A. Use the tester in the same way as the neon tester described above.

Another continuity tester you can make is illustrated in Fig. 604-B. Insert a 10-watt bulb in a porcelain socket. Put the bulb in series between an outlet and the power line. To test any ac-dc

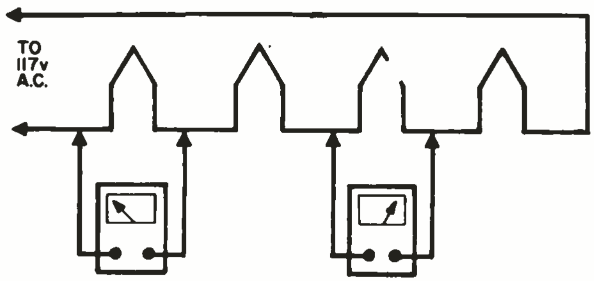



Fig. 603. *Ac voltmeter method of locating an open filament. If the filament is good, the meter will read zero. If the filament is open, the meter will give a reading.*

set, plug it into the bench outlet instead of directly into the power line. If the bulb lights, you know that the tube filament circuit is unbroken. Of course, if the bulb doesn't light, you must still check through the receiver, using any one of the methods we have described so far.

Whichever servicing system you use depends on you. No method is best, since they all have disadvantages and advantages. The best one is the one you like the best.

In some older sets you will find a pilot light connected across two of the filament pins of the rectifier. Normally, the pilot light causes no trouble, but this doesn't mean that it can't. If the light flickers, you may have poor contact between the light and its socket. This can produce noise in the receiver, aside from the fact that a flickering light is annoying. If the set has a pilot light (but the light isn't working) replace the bulb. If a circuit is wired for a pilot lamp it must be used. Without the lamp in the circuit excessive current will soon burn out that portion of the rectifier tube filament.

## Other filament troubles

Don't jump to the conclusion that the set has a defective tube if the tube filaments don't light. The trouble might be in the outlet.

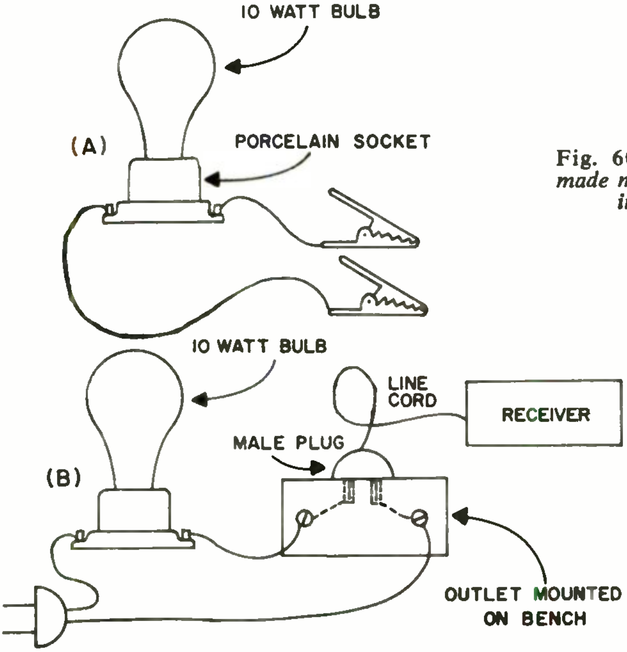



Fig. 604. *Some home-made methods for checking filaments.*

The quickest and easiest test is to connect a lamp or use a neon-lamp tester. Even if this shows power at the outlet, don't take it for granted. The contacts in the outlet may be spread, or else the male plug on the line cord may have its prongs pushed apart.

Check the interlock (Fig. 605). It may not be making contact. If you have any suspicion that line voltage isn't getting into the set, check with your vom or vtvm. Set the meter to read ac volts (on a high enough range) and check the two leads going to the interlock on the chassis side. If you have voltage here, then the outlet, line cord and interlock are good. If you do not have voltage, the trouble is in the interlock, line cord, male plug or outlet. Also consider the possibility that the house fuse may be open.

### The rectifier and filter

Do you know the old saying "One man's meat is another man's poison"? It applies, after a fashion, to radio sets also. The line

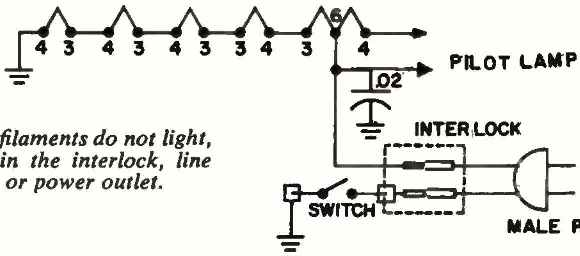



Fig. 605. *If the tube filaments do not light, the trouble can be in the interlock, line cord, male plug or power outlet.*

voltage is good enough for lighting electric light bulbs, heating toasters and running vacuum cleaners, but not quite satisfactory (as is) for radios.

How do we make the change from ac to dc? Just as easy as can be. We use a rectifier tube. This tube allows current to flow through

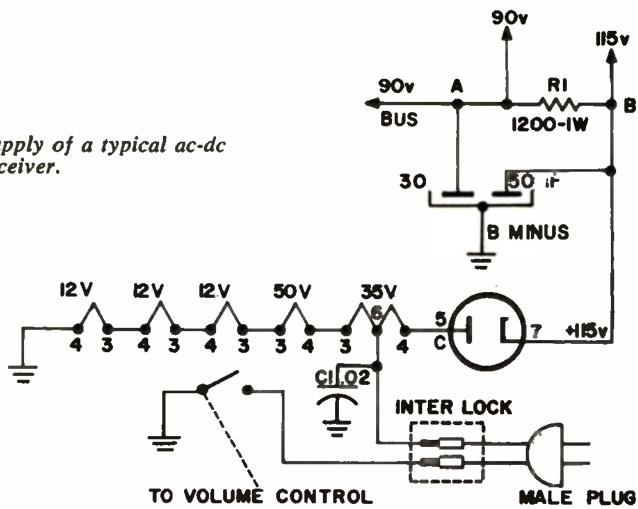



Fig. 606. *Power supply of a typical ac-dc receiver.*

it in only one direction. The result isn't pure dc but with the help of a filter, we get a voltage that's smooth enough for our tubes.

The way in which we do this is shown in Fig. 606. The input to the tube is ac. The output is dc. Now as we test the supply we will learn what sort of troubles to expect.

To check B-plus voltage, set your vtvm or vom on the dc scale with the range selector set to read about 200 volts full scale. Connect the negative test lead to B minus. Touch the test lead to point A in Fig. 606. You should read about 90 to 125 volts.

If you get no voltage at point A, move over to point B. If there is a voltage reading here, then you have found the trouble. Resistor R1 is open. If you get no voltage at point B, set the meter to read 200 to 300 ac volts and touch point C. If you get a voltage reading

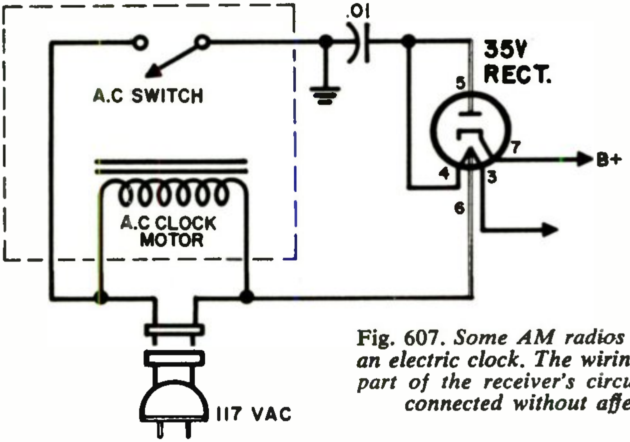



Fig. 607. *Some AM radios come equipped with an electric clock. The wiring of the clock is not part of the receiver's circuits and can be disconnected without affecting the radio.*

here, try a new rectifier tube since this test shows it isn't working.

If the filament of the rectifier tube isn't lit, don't bother with voltage tests since there will be no voltage.

What other troubles can we have? Suppose we go through our check list.

| **Troubles in the Ac-Dc Supply.** | **And What To Do About Them.** |
|---|---|
| **Filaments do not light.** | Make sure trouble is not in line cord, interlock, male plug or outlet. House fuse may be open. Receiver on–off switch may be defective. One or more tubes may have open filaments. |
| **No B-plus voltage. Filaments light.** | Open filter resistor or defective rectifier tube. |
| **Hum. B-plus voltage is lower than specified on manufacturer's schematic.** | Try a new tube. Rectifier emission may be too low. Check the filter capacitors. Shunt these capacitors (one at a time) with a known good unit. Watch polarity. Use capacitors having same (or higher) voltage rating. If hum disappears and voltage goes up, capacitor in set is defective. |

| | |
|---|---|
| **Hum** (Continued) | If one capacitor in a block of two becomes defective, you may get leakage between the two capacitors. |
| **Strong hum.** | Can be caused by heater-to-cathode leakage in any one of the tubes. Not always possible to detect with tube tester. Try tube substitution. |
| **When station is tuned in, set begins to hum.** | Reverse line plug in socket. Disconnect line filter capacitor (C1 in Fig. 606). If hum disappears, replace unit with a new capacitor. |

## Other troubles

In some sets the power supply of the ac–dc set is tied in with other units, such as an electric clock or a turntable. A set may have

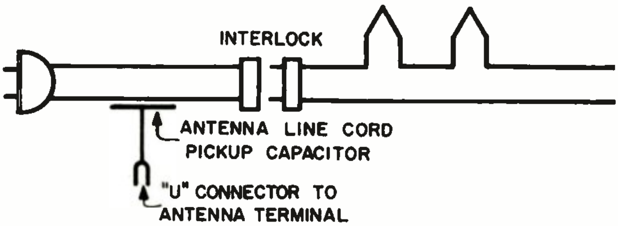



Fig. 608. *If the receiver uses the power line as an antenna, try reversing the power-line plug if you have a hum problem. Removing the U-connector from the antenna terminal may help.*

a turntable with the signal from the pickup playing through the audio amplifier of the receiver. If the receiver has a bad hum when the turntable is used, try replacing the line filter capacitor. This is usually .01 to .02 $\mu$f. Try a capacitor having a value of .05 $\mu$f. You may have to go as high as 0.1 $\mu$f, but use the smallest value of capacitance that will eliminate the hum.

Does the set have a clock? If so, the clock is always connected across the ac line and is independent of the on–off switch in the receiver. If, for some reason, the clock becomes defective and cannot be repaired or replaced, disconnect the clock's ac leads. The connections are simple, as shown in Fig. 607.

Some sets use the power line as an antenna. Fig. 608 shows how this is done. Metal is wrapped around one side of the line inside the set. There is no physical connection between the metal and the copper wire of the line cord, but there is a small amount of capacitance. Not much capacitance is needed. The power line acts as an antenna and transfers the signal to the antenna coil in the receiver.

Sometimes this connection produces hum or noise. To check, remove the U-connector from the antenna terminal on the receiver. If it has no effect, replace the connector. If it eliminates the hum, keep the connector removed or else replace it and try reversing the line plug in the outlet. Sometimes this is helpful.

### Semiconductor rectifiers

Some sets use a semiconductor diode in place of a rectifier tube. What sort of troubles can we expect? Just about the same as in the power supplies we have studied so far.

There is less of a voltage drop across a metallic rectifier than across a tube and so the B-plus voltage on the cathode side of the rectifier will be about 140 v. (Fig. 609.)

Most of the rectifiers in table radios are rated at 100 ma. Never replace with a unit having a lower rating. The same rating or a higher one is acceptable.

Semiconductor rectifiers (like tubes) give their highest voltage

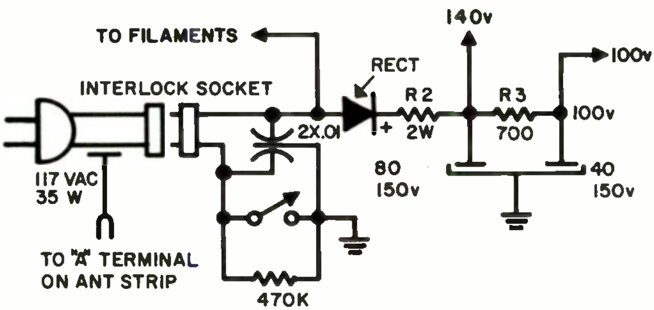



Fig. 609. *Semiconductor units are often used in place of rectifier tubes.*

output when they are new. The voltage gradually drops off with use. If the set sounds weak (or not as peppy as it should), check the voltage on the cathode side of the rectifier. If the voltage is down 15% or more, replace the rectifier. Your clue to the fact that the diode has seen its best days is when the set stops playing when a heavy-current drain appliance is plugged in.

If you suspect the rectifier, shunt it with a known good unit. You won't need to remove the old one or to unsolder its leads. If, after doing this, you note an improvement in the set's operation, replace the rectifier. If the set has a history of poor operation and the diode needs too frequent replacement, use one having a higher current rating.

Rectifiers are sometimes punctured by line transients. These are voltage pulses having a peak of more than 150 volts that ride in on the line. If the set does not have one, install a line shunting capacitor having a capacitance between .01 and .05 μf. This is shown in Fig. 610.

A current limiting surge resistor is required to reduce the current flow into the input filter capacitor. This initial current can be as high as several amperes into a completely discharged 50–μf electrolytic.

## The transformer supply

Some of the more expensive sets, especially console types, use a power transformer type supply, shown in Fig. 611.

Do the words "more expensive" mean that we won't have trouble? Not at all. The full-wave supply in Fig. 611 has its share of problems. First, though, let's run through the quick checks we can make to see what is working.

What about the rectifier tube filaments? These are independent of the other tubes and so, if the rectifier filaments do not light, the tube (or the transformer) is defective, or no power is being delivered to the transformer primary.

Set your vom or vtvm to read about 300 volts dc. Connect the negative test lead to ground (chassis) or B-minus. Touch the other

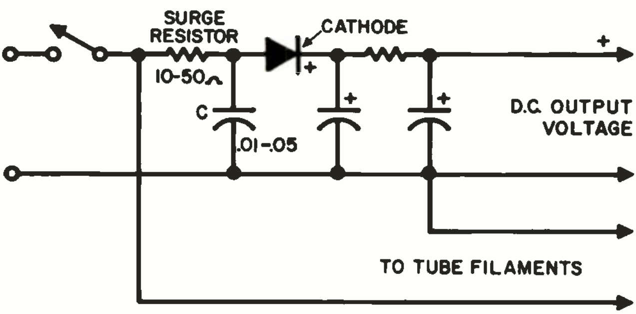



Fig. 610. *The addition of a bypass capacitor (C) will help protect the rectifier against line surges.*

test lead to point A (in Fig. 611). If you get the proper voltage at this point, the power supply is working.

If there is no voltage at point A, move the test lead over to point B. Voltage here indicates that filter resistor R1 is open. Sometimes a choke is used instead of the resistor, but the idea is the same.

If you get no B-plus at point B, what then? Set your test meter to read ac volts (300 to 500). Keep the minus test lead attached to chassis or B-minus. Touch the probe lead to one plate of the recti-

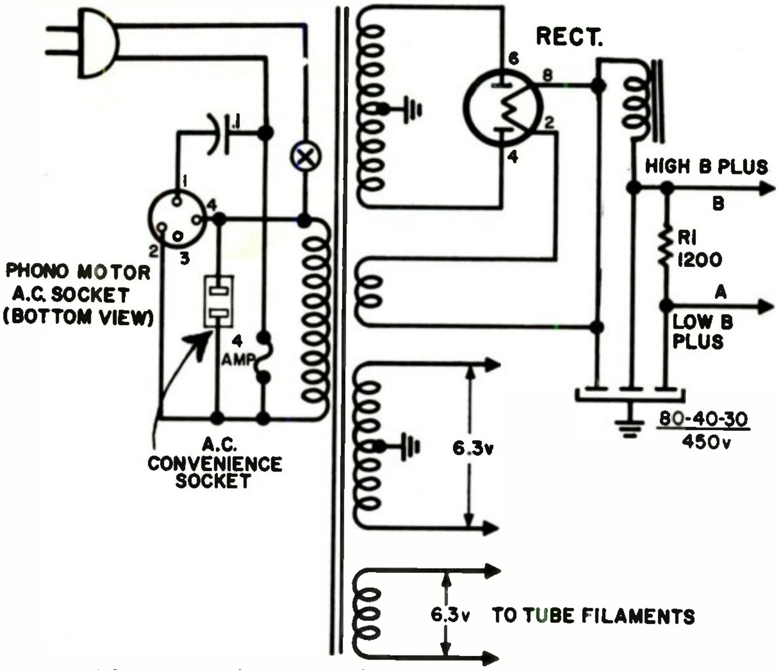



Fig. 611. *Full-wave rectifier supply of the type used in console receivers.*

fier tube and then to the other. Absence of voltage puts suspicion on the transformer.

If the rectifier tube filaments light, but you get no ac voltage on the rectifier plates, either the high-voltage winding is open or the return lead from the center tap of the high-voltage winding to ground has become disconnected.

Now what if the rectifier tube does not light and you have no ac voltage on the plates? Our next step is to check across the primary winding. If we get no ac voltage here, we must back track right on up to the power outlet.

What sort of troubles can we expect in the transformer power supply? Here's a list made up for you.

| **Troubles in the Transformer Power Supply.** | **And What To Do About Them.** |
|---|---|
| **None of the tubes in the receiver (including the rectifier) light.** | The trouble is in the primary circuit of the power transformer. Disconnect the plug and connect an ohmmeter across the plug terminals. Make sure the receiver switch is closed. |

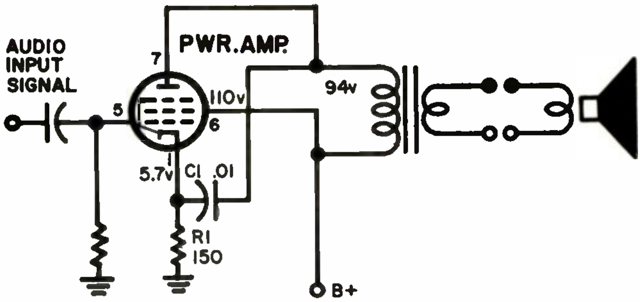



Fig. 612. *Typical circuit of an audio power amplifier in an ac-dc receiver.*

You should read the resistance of transformer primary. If not, check the fuse (if any) interlock, line cord, line plug and on–off switch.

Sniff transformer and see if you can detect odor of burning. If you can, transformer winding is shorted.

**No B-plus output. Rectifier lights.**

Try new rectifier tube. If rectifier tube has whitish deposit on inside of glass, near the base, or has a bright blue or purple glow when power is turned on, tube is gassy and must be replaced. If rectifier plates glow red, input filter capacitor is shorted.

If rectifier plates glow red and filter resistor (of filter choke) starts to smoke, output filter capacitor is shorted.

Make sure rectifier tube is seated well in its socket.

Check filter resistor or filter choke for open.

**Set hums.**

Shunt filter capacitors in the set with known good units. Watch polarity. Use capacitors with an adequate voltage rating.

If the filter capacitor is multiple unit in one can or container, there may be leakage from one capacitor to another.

**Set plays, then stops.**

Some rectifier tubes have a cathode. Set playing, then stopping, is often caused by short from heater to cathode. Replace the tube. This condition also happens if cathode emission is on borderline of being good and line voltage drops. Could be caused by heavy-current-drain appliance being turned on, especially in older homes whose line wiring wasn't intended for modern, heavy-current appliances.

| | |
|---|---|
| **Motorboating.** | Check filter capacitors—especially output filter unit. Check decoupling resistors and capacitors. Although these are not usually shown as part of the power supply, they are really added filtering units. |
| **Set sounds very weak. Some stations cannot be picked up.** | Weak rectifier tube. |

We've put in quite a bit of time on power supplies for the very good reason that power supplies can and do keep us busy. But what about the rest of the set? Let's follow our usual practice, start at the speaker end of the receiver and work our way back to the front end.

Is there any advantage to this method? Perhaps not from a servicing viewpoint, but we do it this way to make sure that we will not miss any circuit.

How should you service a set? Your first question should be—is the set getting its voltage? If you can answer that question, the next one should be: In which half of the set do we have the trouble? Is the trouble between the antenna and the detector or the detector and the speaker?

Your voltmeter will tell you at once if the power supply is working. Inject an audio signal across the volume control and that will tell you if the audio amplifiers and speaker are working. Note how just a few simple tests narrow the range of search to a few circuits in the receiver.

## The power amplifier and speaker

Now that we have a procedure for quick-checking the whole receiver, how do we go about checking it stage by stage?

This is easy. Fig. 612 shows an audio power amplifier. Put your

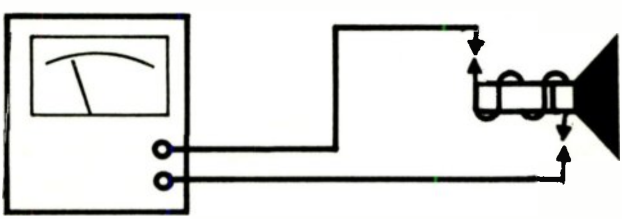


Fig. 613. *How to check a voice coil for an open circuit. Disconnect one lead of voice coil from secondary of output transformer. Rub test leads of an ohmmeter against the voice-coil leads. Scratching noise out of speaker indicates speaker is working.*

audio generator lead on the control grid and listen for the tone out of the speaker. Some service technicians prefer touching the control grid with a finger and listening for the growl or squawk.

This procedure is a good one if you don't accidentally touch the plate (94 volts) or the screen grid 110 volts). The shock may not hurt, but no one ever pulls his fingers away slowly from high B-plus. The chances of whacking your hand against a hard object become very good.

Another method is to click the control grid to chassis with a screwdriver. This method is OK except that you might short the plate or screen accidentally. Some technicians deliberately spark the screen and plate to chassis to see if the tube and the power supply are working. This method can damage tubes and components.

You can also use your soldering iron as a test instrument. Plug in the iron and touch it to the control grid of the audio power amplifier. If the speaker growls, your audio amplifier is working.

### Let's ask for trouble

Suppose that the audio power amplifier does not pass the signal, what then? You have the satisfaction of knowing that you have located the defective stage and all you need to do now is to find out which part is loafing on the job.

### Speaker troubles

In many receivers the voice-coil leads of the speaker aren't soldered into position but are connected to the secondary of the output transformer with a pair of slide clips. Check them. Have they become loose? Have they slipped out of position?

To test the speaker, disconnect one voice-coil lead from the output transformer secondary and rub your ohmmeter leads across the voice coil connections as shown in Fig. 613. You should hear a scratching noise out of the speaker. Examine the cone. Make sure it has no rips or tears. In time, cones get dry and brittle and fall apart.

Push against the cone gently with your fingers. Can the cone move back and forth without interference? If you feel some sort of obstruction, replace the speaker. Particles that get between the magnet and the voice coil are difficult to remove.

In cheaper-grade speakers, the permanent magnet turns out to be not so permanent. As the magnet gets weaker, the volume out of the speaker will become less. To check, feed an audio signal across the volume control or at the input to the power amplifier, as shown in Fig. 614.

Connect the voice coils of the old speaker and the new one to a double-pole double-throw switch. Switch back and forth from one speaker to the other. If you can hear a definite improvement, replace the old speaker.

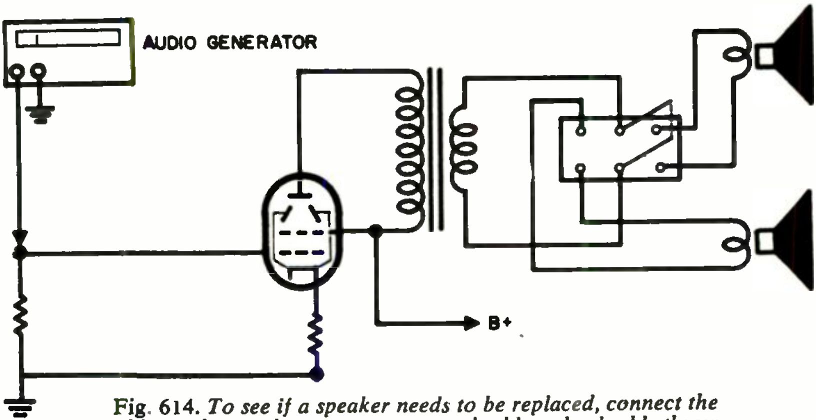



Fig. 614. *To see if a speaker needs to be replaced, connect the old speaker and a new one to a double-pole double-throw switch. Operate the switch and listen carefully. If you can hear a definite improvement, replace the old speaker.*

The speaker is an important radio part, for without it we hear nothing. Let's see what sort of troubles we should watch for.

| Troubles in the Speaker. | And What To Do About Them. |
|---|---|
| Distortion | Impedance mismatch between transformer and speaker. In cheap sets the output transformer produces considerable distortion. Replacement with a better unit is helpful. The voice coil may be rubbing the pole piece of the magnet. |
| Oscillation | The voice coil and output transformer secondary are sometimes part of a feed-back circuit. If either the primary or secondary connections should be transposed during replacement of the transformer, the audio amplifier may oscillate. Transpose one pair of leads—not both. See Fig. 615. |
| Rattling | Poorly centered voice coil. Torn cone. This is sometimes repaired with plastic tape, which gets dry and becomes loose. Spider, used for holding voice coil in position, may have broken or become loose. Spiders are glued into position or held in place with screws. Glue may have become dry or screws may have loosened. |

**No sound**

Open voice coil. Voice-coil lead (or both leads) may be broken, at solder connections.

**Distortion**

Voice coil rubbing against magnet. As paper cone gets older, it becomes dry. When it gets dry, it shrinks and gets out of shape, pulling the voice coil out of position.

If the set uses two speakers, both cones must move out and in at the same time. If not, they are out of phase. To check, connect a dry cell across the secondary of transformers. Do not make a permanent connection. Tap the lead to the dry cell and note movement of the cones. They should both move in the same direction. If not, transpose the connections to one of the speakers (not both). Method of making this test is shown in Fig. 616.

## Checking the audio power amplifier

If we put a signal into the audio power amplifier, but get no signal output, our next question is: What do we do now? The

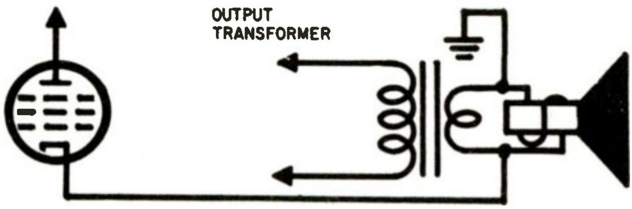



Fig. 615. *Sometimes the voice coil is part of a negative feedback system. Transposing the ground connection on the voice coil to the wrong side will cause the audio amplifier to oscillate.*

answer is simple. With no audio output, we've located the stage having trouble. Our only job is to find out which part has decided against working.

How do we find out? Take voltage measurements around the tube. Measure the cathode (bias) voltage. If you get no voltage reading, the tube isn't working. Either the tube is defective, or the primary of the audio output transformer is open. Next measure the plate voltage. If you have no plate voltage, the output transformer primary is open. If you have plate voltage, but no screen voltage, then the screen dropping resistor (if one is used) or the connection to B-plus is open.

There should be a small voltage difference between plate and screen with slightly more voltage on the screen than on the plate.

If both voltages are exactly the same, and the tube has no bias resistor voltage, the tube isn't working. Try a new tube.

With a signal tracer and an audio generator (or an rf generator with audio output), you can pinpoint the trouble fairly quickly. Connect the generator to the input (control grid). Touch the lead of the tracer to point A (Fig. 617) and then to point B. If you get a

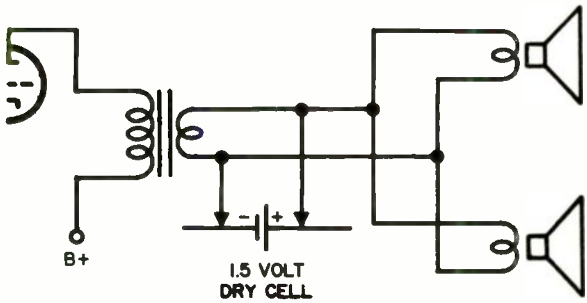



Fig. 616. *Method of checking phasing of speakers. Connect the dry cell. Tap one lead from the secondary winding of the transformer against one terminal of the cell while watching the movement of both cones. The cones should move in or out at the same time. Do not make a permanent connection to the dry cell.*

signal at point A, but no sound out of the speaker, the speaker is defective. If you pick up the signal at point B, but not at point A, the output transformer secondary is defective.

## Single-ended amplifier troubles

With Fig. 612 as a guide, let's see what sort of troubles we can expect out of the single-ended audio power amplifier stage.

| Troubles in the Audio Power Amplifier. | And What To Do About Them. |
|---|---|
| No sound out of the speaker | Voice coil leads open or voice coil defective. |
| | Voice coil unable to move. It may have jammed or popped out. |
| | Defective power amplifier tube. No B-plus voltage. |
| | Plate capacitor (C1) in Fig. 612, shorted. |
| | Open in primary or secondary of output transformer. |
| | No signal from earlier stage. |
| | Open grid-return resistor. |
| | Open cathode resistor. |

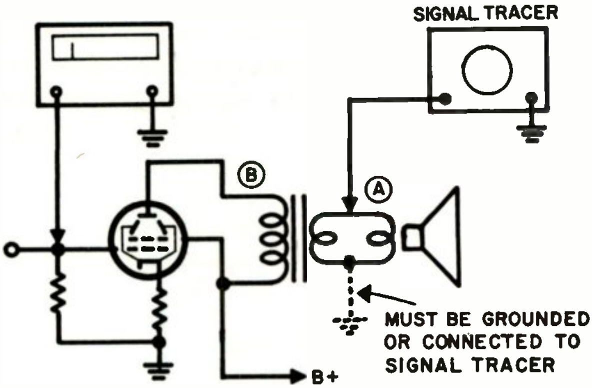


Fig. 617. *Signal-tracing the audio power amplifier stage.*

| | |
|---|---|
| **Sound is weak, may be distorted** | Weak tube.<br>Low B-plus voltage.<br>Defective speaker.<br>Changed value of grid-return resistor. Value is too low.<br>Excessive bias.<br>Leaky coupling capacitor connected to control grid. |
| **Distorted sound** | Defective tube.<br>Defective speaker.<br>Cathode bypass capacitor (if used) may be excessively leaky or shorted. Extreme condition needed since value of cathode resistor is usually very low.<br>Poor quality output transformer or severe mismatch between transformer and tube.<br>Leaky coupling capacitor connected to control grid.<br>Plate capacitor has partial internal short. |
| **Oscillation** | Check feedback network from speaker to earlier stage.<br>Check power supply and decoupling filter capacitors. |

## The push-pull output stage

Ever watch how trees are cut down? Today power saws are used and they seem to work fine. At one time (still used in some areas) a long saw with handles on both ends was the accepted method. It worked on the theory that two men could do a better job than one.

We have the same idea in radio sets. We use two tubes in push-pull (as shown in Fig. 618) instead of just one. With this circuit and a well designed output transformer, the audio sounds better because it is better. There is much less distortion.

We can't play favorites with the two tubes in Fig. 618. Each tube must receive the same amount of signal voltage. And the dc voltages on all the elements of the tubes must also be the same.

### Quick check of the push-pull stage

Do you remember how we checked the single-ended stage? There were quite a number of different tests you could make. You can use all of these on the push-pull stage.

Generally, then, we can service the push-pull stage just as

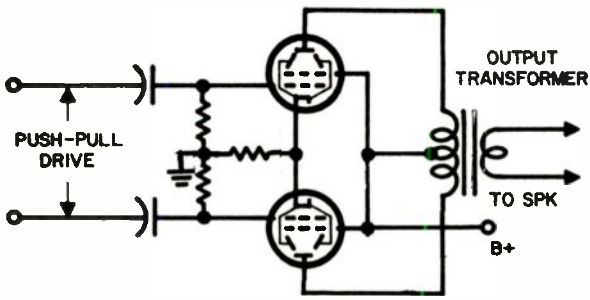



Fig. 618. *A properly designed push-pull stage produces less distortion than a single-ended audio amplifier.*

though it had one tube instead of two. But just to make sure, let's consult the troubleshooting chart.

| Troubles in the Push-Pull Output Stage. | And What To Do About Them. |
|---|---|
| Sound is weak. | One of the tubes may be weak. For best results, use matched tubes. |
| | Insufficient signal input from driver stage. |
| | B-plus voltages are too low. |
| | Push-pull tubes may receive bias from power supply, in addition to cathode bias. Check to make sure bias voltage is correct on both tubes by measuring between control grid and cathode of each tube. |

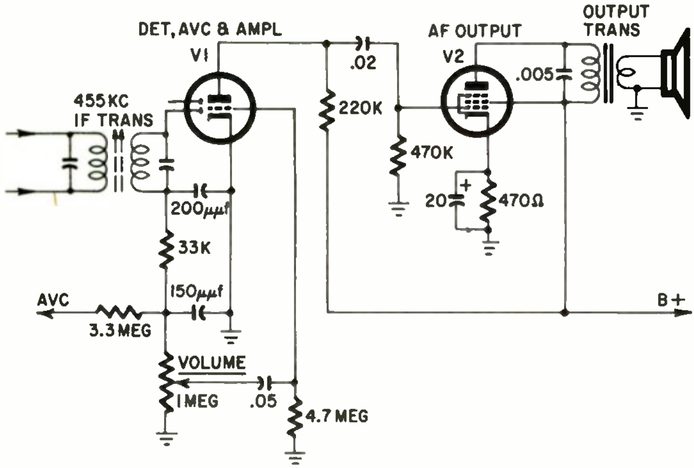



Fig. 619. *Audio amplifier section of a typical AM receiver.*

| | |
|---|---|
| **No sound.** | No B-plus voltage. |
| | Tubes not in sockets. |
| | No signal from driver stage. |
| | No filament voltage. |
| **Distortion.** | One grid receiving more signal voltage than the other grid. |
| | One tube weak, other normal. |
| | Improper bias. |
| | Original output transformer replaced with unit which does not match impedance of tubes. |
| | Input signal is distorted. |
| | Leaky coupling capacitor or capacitors to control grids. |

## Let's move backward

Let's continue our trip from the output end of the AM receiver to the tuner.

What sort of circuit do we have in front of the audio power amplifier? Usually, we have a multipurpose tube acting as a detector, automatic volume control (avc) and first audio amplifier (see Fig. 619).

What is our first question? How can we tell if the circuit is working? Feed in a signal to the control grid of the first audio amplifier and listen to the speaker.

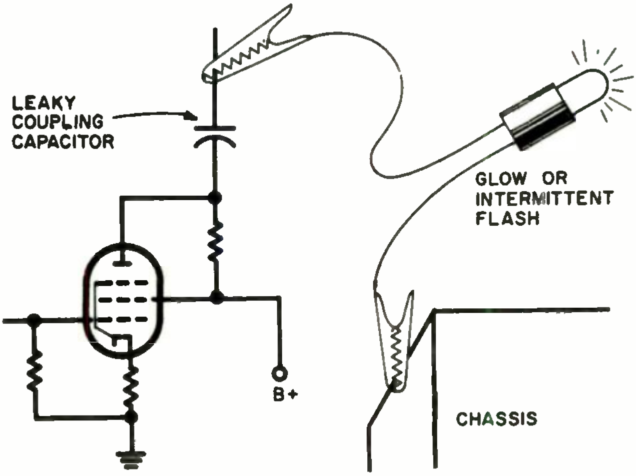



Fig. 620. *A neon lamp can be used to check for leaky coupling capacitors.*

Do you remember all the methods we used for putting a signal into the power amplifier? We can use them here. A convenient place is the volume control. The on-off switch is usually part of this control, so be careful not to touch the switch terminals when the set is plugged in.

Suppose the first audio amplifier will not pass a signal. Our next step would be to examine the check list for the possible causes of trouble.

| **Troubles in the First Audio Amplifier.** | **And What To Do About Them.** |
|---|---|
| **Signal will not pass through the amplifier.** | Tube is defective.<br>No B-plus on tube; the plate resistor is open.<br>Shorted volume control.<br>Open coupling capacitor to control grid.<br>Grid shorted to ground. |
| **Hum** | Hum pickup by grid lead. Try moving lead while listening to speaker.<br>Try a new tube. Heater-cathode leakage may have developed. |
| **Intermittent** | Defective tube.<br>Check coupling capacitor. Tap lightly and note effect.<br>Volume control may have a worn spot. |

| | |
|---|---|
| **Weak sound; possible distortion** | Input signal from detector may be distorted. Try another station. |
| | Plate voltage may be incorrect. |
| | Check load resistor; also B-plus voltage. |
| | Coupling capacitor between volume control and grid may be leaky. |
| | Tube bias may be wrong. Check bias resistor between control grid and ground. |
| **Oscillation** | Can be caused by faulty lead dress. Keep plate and grid leads away from each other. |
| | Stage may be part of feedback network. Make sure feedback winding leads have not been transposed. If feedback resistor is used, check for open or changed value. |

## Leaky coupling capacitors

Incorrect bias on a tube that is capacitor-coupled to an earlier stage is always reason to suspect the capacitor. If you note that the bias on the tube is much lower than normal, or if the voltage on the control grid is positive, replace the coupling capacitor.

You can use a neon lamp tester, as shown in Fig. 620. Disconnect the lead of the capacitor going to the control grid. Attach the neon tester. If the tester glows steadily, the capacitor is shorted. If the tester flashes on and off, the capacitor is leaky. If the lamp flashes just once (or extremely slowly), the capacitor is in good condition.

## The halfway point

On this trip through the AM receiver, we have reached the halfway point. While we have learned about the many troubles that can occur in a radio set, what other fact is just as important? Wouldn't you say that we are developing a method, a system for servicing?

Have you ever watched an inexperienced person working on a set, pushing wires here and there, making tests in no order or sequence. Wouldn't you think that it is better to have a servicing procedure to follow?

What is the detector, and what does it do? It slices the signal in half, much as you would slice a long loaf for making a hero sandwich. The detector is a rectifier, and like any other rectifier, it has a filter. In this case it is used for eliminating the carrier.

Fig. 619 shows our detector and avc circuit. What check can we use? A signal generator is easy and quick. Set the generator to the if of the receiver. Make sure modulation is turned on. Connect the hot lead of the generator to the diode detector plate and listen for the modulated tone out of the speaker.

If this test produces signal output, you know the detector is working. But do not change the setting of the generator, since we are going to need this test instrument for checking the if stages.

Some technicians feel that using a generator isn't fast enough. Perhaps they just don't want to be bothered. We can click test the detector (if the filament is part of a parallel network) by pulling the detector tube out of its socket and then inserting it so that the pins barely make contact. A loud click out of the speaker shows that the tube is working. If it is a series filament set, this must be done before

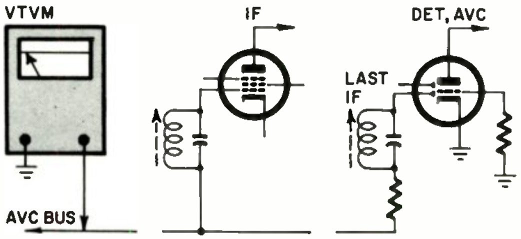



Fig. 621. *A check on the avc voltage will tell you quite a bit about the performance of the if and detector circuit.*

the other filaments get a chance to cool off. This test isn't recommended for series-connected tubes since it is possible to damage the filaments this way.

Most AM tube radios do not use germanium diodes as detectors. Mostly such diodes are found in FM and TV receivers.

Like the other circuits in the set, the detector and avc can have its own share of problems. The check list tells what these are.

| **Troubles in the Detector and Avc.** | **And What To Do About Them.** |
|---|---|
| **Signal very weak.** | Signal from if stage weak. |
| | Secondary of if transformer misaligned. |
| | Weak detector tube. |
| **No sound.** | Check the tube. |
| | No signal from if stage. |
| | Secondary of if transformer open. |
| | Short in if transformer. |

| | |
|---|---|
| **Hum. Signals weak or set may not work.** | Check avc filter resistor and capacitor. |
| **Sound too loud, no control.** | An open volume control element will usually have an abrupt increase in sound level to maximum. If break is at clockwise terminal, there will be no sound. |

## Checking the avc circuit

A quick way to check the operation of the receiver up to the detector is to measure the avc voltage, as shown in Fig. 621. Connect the probe of your vtvm (set to read minus low volts, dc) to the avc bus and the common to the B-minus bus. Tune in a strong station and note the amount of avc voltage.

If you do this test with the sets you service, and keep a record of the stations, you will soon arrive at some average figure that you can expect for your area. If the avc voltage is lower than normal, the set may be misaligned or it may have weak tubes in the converter, if and detector stages. A lower than normal avc voltage (plus distortion) can also mean trouble in the avc filter.

## The what and why of avc

Did you ever see someone sit at a table loaded with all sorts of good things to eat, and refuse to eat more than a small amount? That's self-discipline–not an easy thing to acquire.

Radio receivers have built-in self-discipline. If they get too much of a signal, more than they can digest, they refuse some of it. The circuit in the radio receiver that tells it to be careful about getting overstuffed with too much signal is the automatic volume-control circuit.

If the signal is too large, the avc rectifier develops a large voltage. This voltage is fed to earlier stages in the form of a negative bias. Bias helps keep the gain of a tube down. And the more bias, the less gain.

Of course, the reverse is also true. If the signal is very weak, the automatic volume-control bias is very low, and the tubes which are controlled by this bias have a higher gain.

What is the result of all this? As you tune from station to station, there is less chance of having a very weak sound out of the speaker, only to be followed by a loud blast. Also, if the signal tends to fade in and out a little bit, avc puts a stop to it. All in all, it is a very nice circuit to have . . . as long as it is working the way it should.

The first thing we would like to have for avc is a quick check. How can we tell, without too much trouble, if the avc is in good

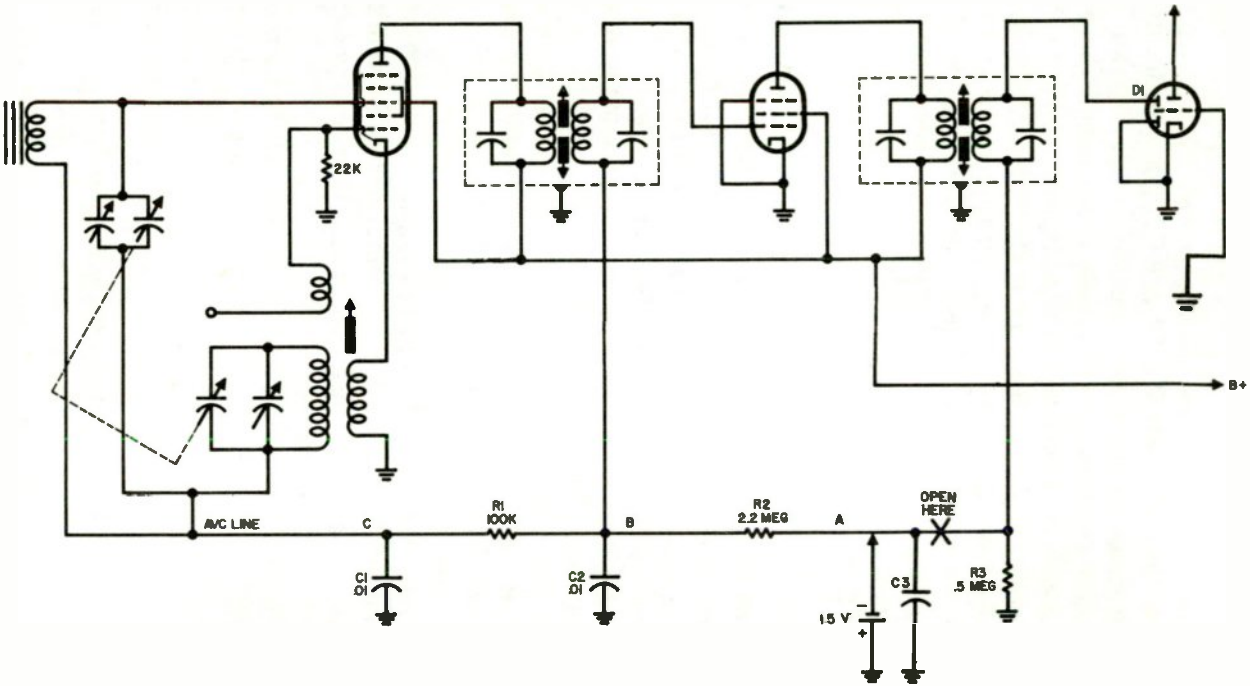



Fig. 622. *The avc circuit can be checked with the help of a battery.*

condition? Here's a simple test. Disconnect the avc bus, as shown in Fig. 622. Tune in a weak signal. Now connect the plus side of a 1.5-volt battery to ground. Attach a wire to the minus terminal of the battery, and then tap points A, B and C one after the other. If you get no improvement at A, but the sound becomes much better at B, check R2, C3 and the volume control. If the sound gets better when you tap at C, check R1, C1 and C2. (In some locations it may be better to us a 3-volt battery.)

Note how simple the avc line really is. We start at diode plate D1, move through the if transformer winding to the volume control. This is near point A. We continue along through R2 to point B. From here a wire goes up as far as the if transformer. The other side of the transformer is connected to the control grid. So this tube is controlled by avc.

Let's move back to point B. Continue along to C, and from there you can find your way easily enough to the grid of the first tube—so that tube is also controlled.

Now try to find the way in which the grids of these two tubes get to ground. You will have to come back, all the way through all the avc resistors and the volume control before you can get to ground.

This is a long journey, but what have we learned? If any resistor (such as R1, R2 or R3) should become open, we would have one (or possibly two) "floating" grids—that is, grids that have no connection to ground.

When this happens, the grids often block the flow of current through the tube and the set either stops playing or does so in a very intermittent way. Using the test battery stops this trouble and pinpoints the difficulty to the avc circuit.

C1 and C2 are avc decoupling capacitors. They provide a path to ground for the rf and if signals, preventing interaction (squealing or constant oscillation) between stages. They also prevent the avc voltage from changing too rapidly.

Isn't is strange that just a few little parts could keep a big radio from working? But this is something that happens all the time. Do you remember the famous poem:

*For want of a nail, the shoe was lost*
*For want of a shoe, the horse was lost,*
*For want of a horse, the rider was lost,*
*And for want of a rider, the battle was lost.*

## Servicing the if stages

Some sea creatures, such as certain crabs, can travel backward very rapidly. This may seem funny to us but, to a crab intent on getting away from danger, it is a very serious matter. We, too, like our friend the crab, have been moving backward—fast, because we have had so much to do. Our backward motion, though, has brought us to the if section.

What is the if? The letters mean intermediate frequency and, when we say if, we are talking about an amplifier.

The if receives the signal from the converter. It amplifies that signal, using one or more stages to do so, and then (possibly with a sigh of relief) turns the signal over to the detector.

## Trouble, trouble, nothing but trouble

Should you assume that the correct if is 455 kc? If you do, you may spend quite a lot of time trying to tune the if to a frequency for which it was never designed. If you don't know the if, connect your signal generator to the output of the converter. (We've described this technique before, but it is also applicable here.) Make sure the modulation is turned on. Start at about 200 kilocycles and move up to 500. Somewhere between these two, a strong tone out of the speaker will tell you that you have located the if.

This doesn't always work. The protruding screw of an if slug or the screw of a trimmer might have attracted the attention of a dyed-in-the-wool do-it-yourselfer who promptly turned it all the way. And don't think this hasn't happened or that it can't happen to you.

Now what should you do if no signal comes through? Move the output lead of the generator to the diode detector plate. If you get a signal, move to the primary of the output if transformer. If this produces a signal, transfer the generator lead to the control grid of the last if tube.

In this way, step by step, move toward the converter. Where the if signal disappears do a little more checking and looking.

Of course, not all troubles are clear cut. A single misaligned if, or a corroded connection or a broken slug, inside the transformer where they can't be seen can result in a servicing headache. But please don't reach for that aspirin bottle! At least, not yet. Take a few minutes to go over the if servicing chart. Even if you are a service expert, read the chart since just a single suggestion or idea will be worth the effort.

| Troubles in the if. | And What To Do About Them. |
|---|---|
| Sound weak. | One or more weak tubes.<br>Set might be tuned to a weak station.<br>Check avc bus. Line may be open.<br>One or more if transformers may be misaligned. Check B-plus voltages. |
| No sound. | One or more tubes defective.<br>No B-plus.<br>No input signal.<br>Open in if transformer.<br>The if stages badly misaligned.<br>Open in avc line.<br>Wrong tube in socket.<br>Shorted trimmer in if.<br>Shorted winding in if.<br>Open grid or cathode lead to if tubes.<br>Shorted screen bypass capacitor. |
| Intermittent sound. | Check avc components.<br>Examine soldered joints. Make sure no connection is corroded, or loose.<br>Some connections can be very close to each other and short when set vibrates.<br>Slugs or trimmers in if cans may be loose enough to move.<br>Tubes in if stages may be intermittent. Tap tubes lightly while listening to speaker. |
| Set oscillates. | Some if's will oscillate if you align them too exactly. Detune slightly until oscillation stops. Or, align exactly, and insert 100-ohm 1/2-watt resistor in series with lead to control grid of each if tube.<br>Shield can of if may not be making good contact with B minus or chassis.<br>If tubes have shields, make sure all shields are replaced and that metal makes good ground to ground contact.<br>Screen bypass capacitor may be open.<br>Watch lead dress. Keep plate and grid leads away from each other. |

## The converter (or mixer and oscillator)

Remember we told you in the introduction that no radio is completely new, that the circuits found in receivers will all have similarities. The converter of the auto radio in Chapter 5 is likely to have the same troubles as the converter in the home radio. The mechanical assembly of the front end will differ. The AM receiver for home operation will normally have a variable capacitor for tuning instead of the more stable, more expensive and less exposed variable inductor tuner found in the auto radio. The end result is the same, circuit operation is the same. The home radio does not rely on an antenna for its signal pickup. This is accomplished by a high-Q ferrite coil tuned to the rf signal of the broadcast station. This is another reason that inductance tuning is not used. The Q of the coil varies considerably when the core is moved in and out.

Rf amplifiers are seldom found in AM broadcast receivers. If a receiver does have one that appears to be troublesome refer to the rf amplifier test techniques of the auto radio in Chapter 5 or to the sections on all-wave and communications receivers in Chapter 9 of this volume.

## QUESTIONS

1. Describe two techniques for checking for an open filament in a series-connected filament circuit.
2. The filament of a rectifier tube in an ac-dc set lights, but there is no B-plus voltage at the cathode? What tests should you make?
3. What can you do to minimize the effects of line-voltage transients?
4. What is a power-line antenna? How is it connected? What trouble can it produce? How would you cure it?
5. How would you check a semiconductor rectifier?
6. What quick check can you make to test the entire primary circuit [including plug and line cord] of a power transformer?
7. In making a test, you get voltage at the screen of a power output tube, but not at the plate. What is the trouble?
8. How can you check a pair of speakers for phasing?
9. What troubles in the speaker could cause rattling? Distortion? No sound?
10. How is the output transformer used as part of the negative feedback system?
11. How can you check avc voltage?
12. You have oscillation in a receiver and you have localized this trouble to an if stage. Name two techniques you could use to eliminate the oscillation.

CHAPTER 7

# FM receivers

DID YOU ever watch a steamship being loaded? Next time, try to count the different ways in which freight and baggage are put on board. Some of it is carried by hand, some loaded by slings and winches. The freight is pushed, lifted, shoved, tossed, pulled.

In radio broadcasting we have a similar problem. We need to load the signal (voice or music) on the radio-frequency carrier. We have quite a few ways in which to do this. One method is called amplitude modulation which we shorten to AM. Another system is called frequency modulation, more popularly known as FM.

What is the difference between the two? Simply in the method of loading the transport – the carrier. In AM, the amplitude or the height of the carrier is varied. In FM, the frequency of the carrier is varied.

Naturally, since we load the carrier in AM and FM in two different ways, we are going to need two different ways for unloading that carrier. We need to know these differences since it will affect the way in which we service receivers.

## Alike—and yet different

The man (or men) who invented the automobile didn't start from scratch. He didn't sit down and say, "Let's throw away everything we know." Instead, he started with a wagon, unhitched the horse and put in an engine instead. With the exception of the horse, early automobiles looked just like wagons.

In the same way, an FM receiver uses many circuits that we see in AM receivers. There are some completely new circuits, but there are also many that (except for the value of the parts) could also be used in AM receivers.

## Strike up the band

When we speak of broadcast band, the average person thinks of AM. But we do have another band just for FM transmission. This band extends from 88.1 to 107.9 megacycles, but it is generally referred to as covering the range from 88 to 108 mc.

This gives us our first clue when we start thinking of our servicing problems. Since the FM band is so much higher in frequency than the AM band, our components and parts layout are going to be more critical. We are going to have more of a problem with bandwidth.

## Stop that noise

FM has been so widely publicized as being noise-free, static-free and high fidelity that some of us have come to believe it. Repeat something often enough and it sounds true.

FM can be static-free. FM can be noise-free. FM can be made to supply high fidelity. But just because a set is FM does not mean that it has these virtues automatically. There are cheap FM sets just as there are cheap AM sets.

## The overall view

To see where we will be going, let's begin with our electronic road map shown in Fig. 701. One difference in these block diagrams is in the detector circuits.

Three types of detectors or demodulators are used. The first one (and the oldest) is the *discriminator*. This type usually has one limiter and sometimes two (in cascade). The *ratio detector* and *gated beam detector* are not as sensitive to amplitude variations as the discriminator, hence do not use limiters. In a few sets, though, you will find a limiter stage used with a ratio detector.

## Power supplies in FM sets

What sort of power can we expect in the FM receiver? Think of almost every one you have and you will probably find it. You will have:

1. Transformerless type using a vacuum-tube rectifier.
2. Transformerless type using a semiconductor rectifier.
3. Transformer type with a half-wave supply and using either a semiconductor or vacuum-tube rectifier.
4. Transformer type with full-wave supply and using a vacuum-tube rectifier.

Does this present a problem? Actually, no – or at least, not different from the power supplies we have in other receivers.

## Bring on those troubles

In any radio receiver, sooner or later a filament will open. When that happens in a series string, such as that shown in Fig. 702, all the other filaments go along on a sort of sympathy strike and none of them light.

Do you remember that old game called, "Button, button, who's got the button?" That's the sort of a game we play now. Which filament is open? You can't tell just by looking. A very easy way, though, is to use a neon tester. Just connect the tester across each

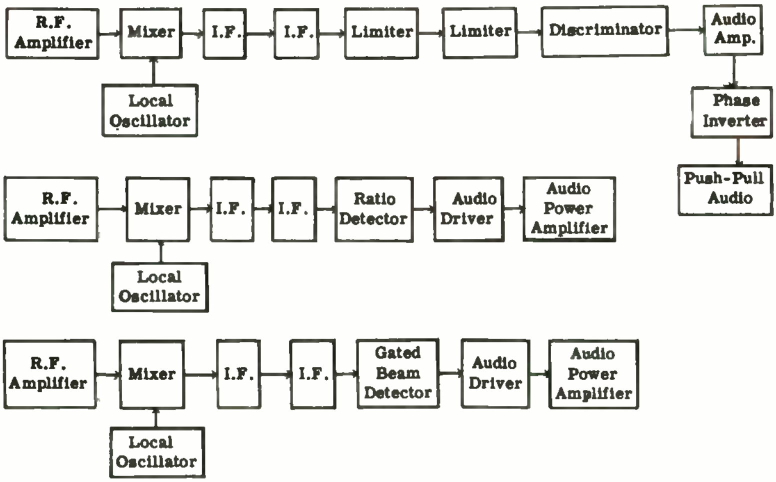



Fig. 701. *FM receivers can use a number of different detector circuits.*

pair of filament pins, in turn. When the neon bulb lights, you have found the tube with the open filament. (This technique, and others, was also described in connection with AM receivers and is covered in Chapter 6.

Which are the filament pins? Be careful! Don't get fooled. They aren't always pins 3 and 4, although these are the pin numbers very often for 7-pin miniature tubes. They could also be pins 4 and 5 for 9-pin types as shown in Fig. 702.

The circuit in Fig. 702 has some interesting features we should investigate. Coming off one side of the power line (connected to L2) is a lead marked LINE ANTENNA. In strong-signal areas a line antenna will do, but an outside antenna, designed for FM, will improve reception on both strong and weak stations. In weak-signal areas, an outside antenna is essential.

Sometimes, all that is wrong with an FM set is the lack of a good outside antenna. The FM signal is there – we should at least meet it halfway.

Note R17, the 1,000-ohm 10-watt resistor. That resistor is in series with the lamp. If the lamp lights (switch closed) you know immediately that you have line voltage on the other side of the interlock. R17 will get warm in operation – that's normal. If you must replace it, keep it away from radio parts that don't like heat, such as wax-filled capacitors, electrolytics.

The rectifier is marked 360 PIV. These letters stand for *Peak Inverse Volts*. This is one of the voltage ratings of the rectifier, so when making a replacement, get one having this value–or higher.

The 82-ohm resistor, R22, helps prevent surges from puncturing the rectifier. If you short this resistor, the set will work just as

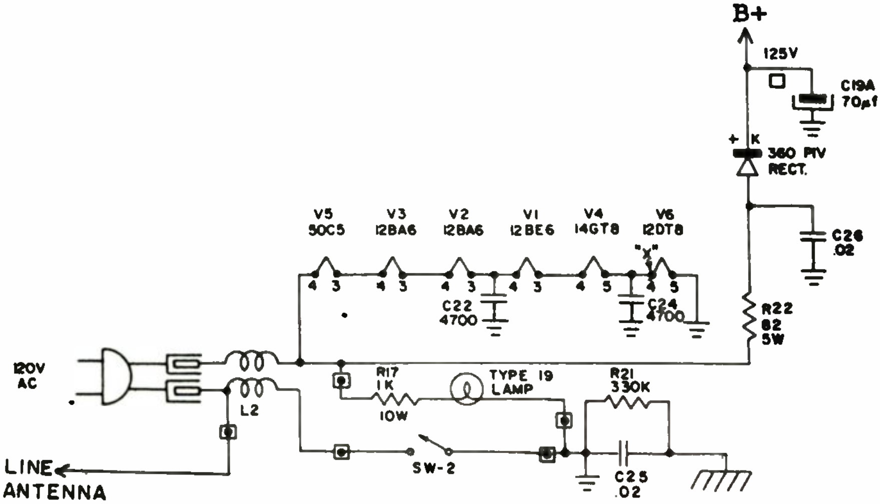



Fig. 702. *Transformerless supply. The series filaments are bypassed by two capacitors. Capacitor C26 protects the rectifier from transient surges in the power line.* (Arvin Industries, Inc.)

well, but sooner or later this current surge of several amperes will damage the rectifier and the input filter. When replacing this resistor, be sure to use a 5-watt unit – or one having a higher rating. If R22 happens to open, the set will lose all B-plus and that will be the end of that.

## Where is the B-plus?

Ever travel along a superhighway with a dividing line or barrier between the lanes? Is there any doubt in your mind as to which side you are to travel on? We have the same idea in a power supply. On one side of the rectifier we have ac. And on the other side we have dc.

But where is the dividing line? The cathode and everything beyond the cathode is dc, and everything from the anode (plate) right

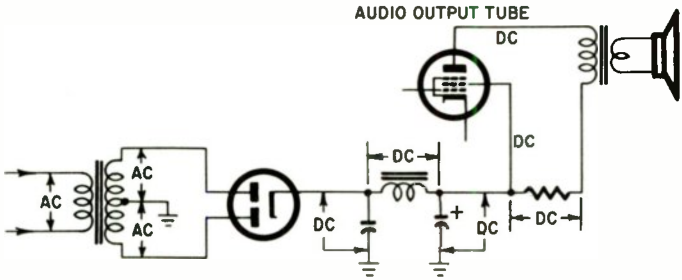



Fig. 703. *Ac and dc voltage points in a power supply. All voltages, starting at the cathode of the rectifier, are dc. All voltages, starting at the rectifier plates and going back to the power line, are ac. The voltage drops across the filter capacitors, the filter choke and the filter resistor are dc. All tube voltages (no signal input) are dc.*

back to the outlet is ac (see Fig. 703). If you keep this in mind, you won't go looking for voltages you can't find.

Make sure you know which is anode and cathode. Fig. 704 shows the symbols for a tube and a semiconductor rectifier.

How do we know whether we have B-plus or not? Start at the screen of the audio output tube. This is generally tied directly into the power supply. If you have no B-plus voltage here, follow the line right back to the cathode of the rectifier. If, at the cathode, you have no B-plus, then your trouble is from the ac line right up to the anode of the rectifier.

## Common sense

Common sense is neither so common nor so plentiful as we like to imagine. Obviously, we will have no B-plus if the filament of a rectifier tube does not light. It is true that this results in a condition of no B-plus, but a little thinking will tell us that the trouble may be something more elementary than the B-plus line.

A vom or vtvm is excellent for chasing troubles of this sort. A receiver must have voltage to operate. Start at the power line and follow the connections all the way into the receiver, up to the rectifier, past the rectifier and right up to the tube elements, if necessary. Somewhere along the line you should find an open circuit. It may be a part that is open, a connection that should be soldered but isn't. A break in a printed-circuit-board conductor sometimes will be almost impossible to see. However, if you move the probe of your test instrument along the conductor, you will find the break.

## Other troubles

Hum troubles (when caused by the power supply) are generally due to open filter capacitors. If shunting the existing capacitors with equivalent units decreases the hum, replace the filters.

Don't expect electrolytics to last forever. Their capacitance can

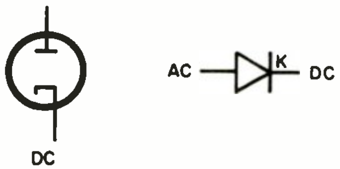



Fig. 704. *Symbols for rectifiers used in power supplies. Up to and including the anode we have ac. From the cathode and beyond it we have dc.*

change, and does change – and not for the better either. Electrolytics will lose capacitance if the receiver isn't used for some time, if they get hot, or if they get old. All electrolytics have a certain amount of leakage. As they get older, the leakage gets worse. (This is like having a hole in your pocket. You can be sure that it's going to keep right on getting bigger.) If not used for a period of time it is possible for the internal structure to break down. It is possible to revive some of these capacitors with a process called *reforming*. This is simply the slow increasing of an applied dc voltage, up to the maximum rating of the unit.

Tubes and semiconductor rectifiers get old, wear out. In a tube the amount of B-plus current depends on filament emission. Remember that the total current of the receiver – and this means the current taken by all the screens and plates in the set – must pass through the rectifier. If the cathode emission of the rectifier is down, the internal resistance of the tube is up and the lower the B-plus voltage will be.

There is a voltage drop across all rectifiers, regardless of whether they are tube, selenium or silicon. When some rectifiers get older, the voltage drop across them increases. The rectifier always gets its share of the voltage first. The other tubes in the set get what is left over.

## That's not fair!

Did you ever see kittens that were just born? They know where to get their milk and they know how to get it fast. But before the mother cat can supply any milk, she must first have been fed.

Think of the rectifier as a mother cat and you'll have an idea. In Fig. 705 you can see how all the tubes in the FM circuit are connected in parallel and are a load on the power supply. Naturally, the more tubes we have in parallel, the more current we need. All of this current must flow through the rectifier.

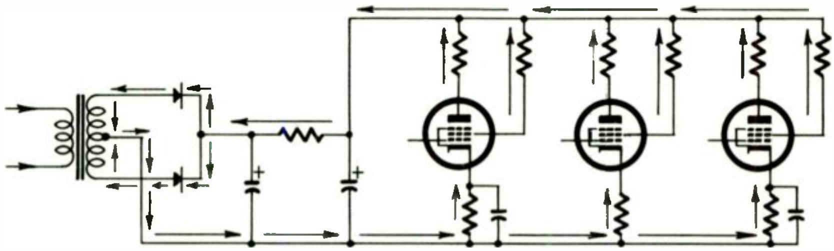


Fig. 705. *The tubes in most circuits are connected in parallel. The current that flows through the tubes must also pass through the rectifier. The more tubes, the heavier the load (that is, the greater the amount of current). As you remove tubes, less current will pass through the rectifier. The arrows show the direction of electron current flow.*

Now you can see why the rectifier is so important. If it becomes damaged in some way (low emission, gassiness), all of the tubes will suffer. The rectifier affects the entire set.

## Parallel rectifiers

Sometimes an FM set will have so many tubes that a single rectifier will not be able to pass all the current needed. A pair of rectifiers can be connected in parallel, just as shown in Fig. 706. No arithmetic is needed here. Two rectifiers will pass twice as much current as one, provided they are identical.

Can parallel rectifiers produce trouble? Naturally! Both rectifiers will not get weak at the same time any more than a pair of human twins. And, as one of the rectifiers gets weaker, a strain is put on the remaining good tube. If matters are allowed to continue, both rectifiers will be ready for the junk heap.

## Other power supply arrangements

Power supplies are like people. Some are simple. Some are complicated.

In some sets a glance at the series filament might fool us into thinking we have a transformerless type on our hands. But a second look will reveal a transformer connected to the plate of the rectifier. Sometimes the transformer is an isolation type and

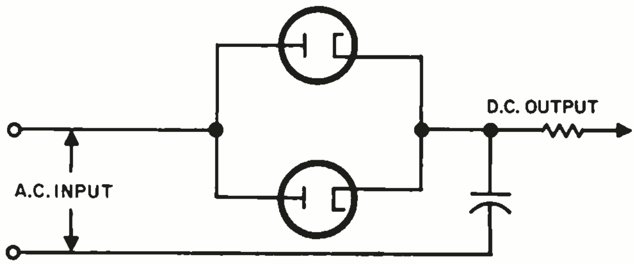



Fig. 706. *Rectifier tubes can be connected in parallel. The trouble here is that the tubes won't wear out at the same rate.*

has a 1-to-1 turns ratio. Since there is no voltage stepup, the plate of the rectifier tube gets the same voltage that it would get in an ac-dc arrangement.

Now take a look at the switching arrangement in Fig. 707. This is needed since this FM set has a record changer and phono amplifier. Which unit will receive the line voltage depends on the setting of the switch. In one position the radio will operate. In the other, the phonograph will work. And there is another position that turns all line voltage off.

Wafer switches of the type shown here (and all other switches as well) can and do have their share of troubles. If the radio doesn't play, but the phono motor works, trouble generally exists in the power supply. If nothing in the set works, then the switch, or line cord or plug or power outlet is out of order.

## Wafer-switch troubles

If a wafer switch won't turn readily, don't force it. The switch has two main parts – a movable section called the rotor, and a fixed section called the stator. Sometimes a bit of insulation or a wire gets caught and jams the rotor.

Don't poke into the wafer switch with any tools. The rotor makes sliding contact with the stator and any tool you use will only

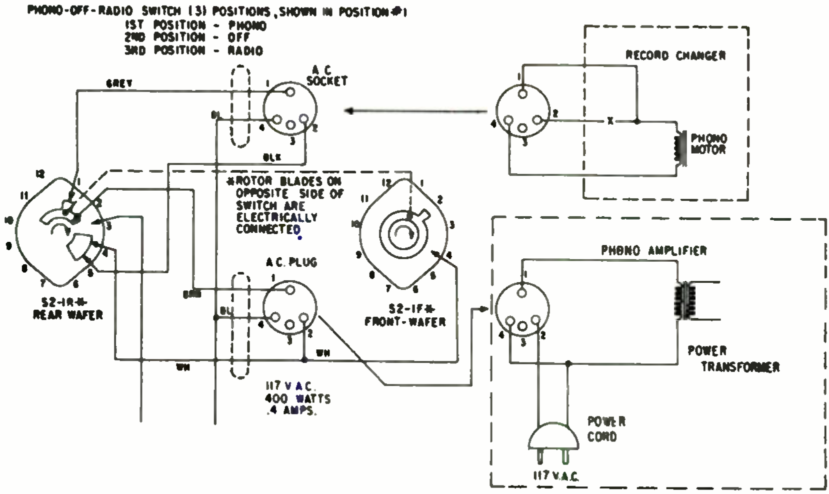



Fig. 707. *Wafer switches can be a source of trouble. In this circuit the wafer switch has three positions and serves three functions. (Shown in position 1.) First position is phono; second, off; third, radio.* (Zenith Radio Corp.)

separate the two, making conditions worse. Examine the switch carefully. If there is any interference (wire, solder) with the rotor, try to remove it.

Since the wafer is exposed, it can get dirty. Commercial cleaner lubricants are available and they do a fine job. When soldering near wafer switches, be careful. Good wafer switches are silver-plated and there is a greater natural attraction between hot solder and the wafer than between a youngster and his favorite TV Western.

Wafer-switch rotors and stators are mounted an insulating wafers of some material such as phenolic. Sometimes these wafers crack. They can also carbonize, causing a short between the lugs mounted on the wafer.

Replacing a section of a multiple wafer switch isn't difficult, but it does take patience. Before making a replacement, tag the leads so you will know where they go on the new wafer. Use a lightweight iron. Generally, these switches solder very easily and do not require strong-arm treatment.

## Transformer power supplies

You will find power transformers used much more in FM than in AM receivers. While we have covered this subject in an earlier chapter, there are a few additional points we would like to discuss.

## Power transfomer troubles

Power transformers get hot – and the longer the set has been playing, the hotter the transformer will get. Ventilation is very bad in some receivers and so, if the inside of the set seems to work more like a furnace than a radio, perhaps this is normal.

If a transformer has a shorted turn, it will get hot – fast. How, then, will we know if a transformer is hot because of a shorted turn or because it is working to supply the demands of the receiver?

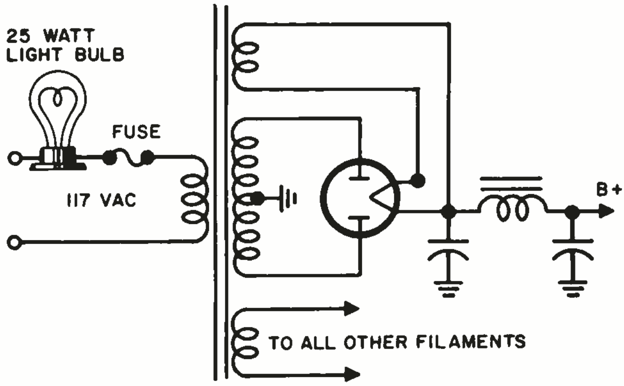



Fig. 708. *Simple test to learn if power transformer has a shorted turn.*

An easy way is to use the method shown in Fig. 708. Remove all the tubes from the chassis. Put a 25-watt bulb in series with one side of the line. If the bulb glows, start looking for a replacement for the transformer.

Naturally, if the fuse keeps popping, or if pitch starts bubbling out of the transformer, don't bother with this test. Sometimes, though, the fuse has a higher rating than it should have, or for some other reason it will not blow. And, if the transformer is generously oversized, it may be able to take a shorted turn in its stride. If you have any suspicions about this, the test in Fig. 708 is worth while.

## Audio amplifiers in FM receivers

A merry-go-round is wonderful entertainment. The trouble is the faster it goes, the sooner you get back to where you started.

Sometimes, in servicing work, you may get that same feeling. In an earlier chapter we talked about servicing audio amplifiers, supplied you with a servicing chart, and now we're back at audio amplifiers once again.

There's a very good reason for this. Not all amplifiers are alike. There are enough differences so that we can study new circuits to our advantage.

### But is it high fidelity?

There is no reason for an FM set to be high fidelity any more than an AM receiver. Many persons are quite contented with less expensive FM sets but are also just as anxious as any hi-fi enthusiast to keep their sets in good working order.

Thus, not all audio power amplifiers in FM sets are push-pull by any means. A single-ended amplifier does have definite limitations but our chief concern is to keep that amplifier in good operating condition.

One such amplifier is shown in Fig. 709. While it looks like an

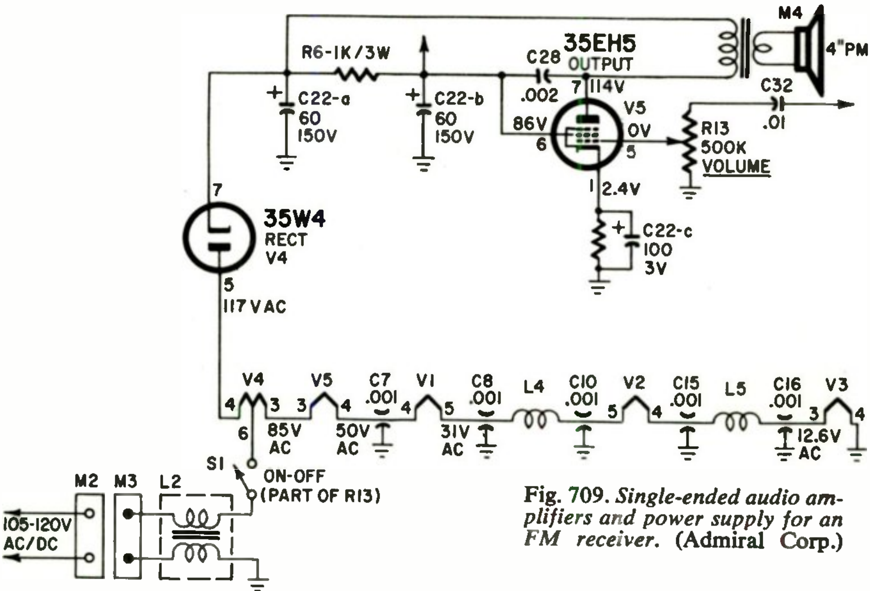



Fig. 709. *Single-ended audio amplifiers and power supply for an FM receiver.* (Admiral Corp.)

ordinary single-ended amplifier, suppose we examine it carefully to see if we can find a few differences.

In other single-ended amplifiers, the screen is usually tied right into the B-plus bus. The plate gets its voltage through the primary of the output transformer. There is a little dc voltage drop across the primary winding, and as a result the plate voltage is slightly less than the screen potential.

Examine the cathode bypass capacitor. The unit is rated at 100 $\mu$f at 3 volts. This is quite close to the cathode bias developed across the cathode resistor (2.4 volts). The cathode resistor, 68 ohms, might increase in value. Should this happen, the bias voltage will rise. When the voltage gets high enough, the cathode bypass capacitor will break down.

What does this tell us? In a circuit of this sort, do not replace the cathode bypass capacitor without first making a resistance check across the cathode resistor and a voltage test of the bias.

Now let us look at the control grid. It is marked 0 V. What does this mean? If you will look at the other elements, you will see that they also have voltages marked. All of these are dc voltages and are measured with respect to ground.

This tells us, then, that the dc voltage on the control grid, with respect to ground, is zero. Does this mean we have no bias on the tube? Remember that bias is not measured between grid and ground but between grid and cathode. If you measure from control grid to chassis, the dc voltage will be zero. If you measure from control grid to cathode, the voltage will be 2.4.

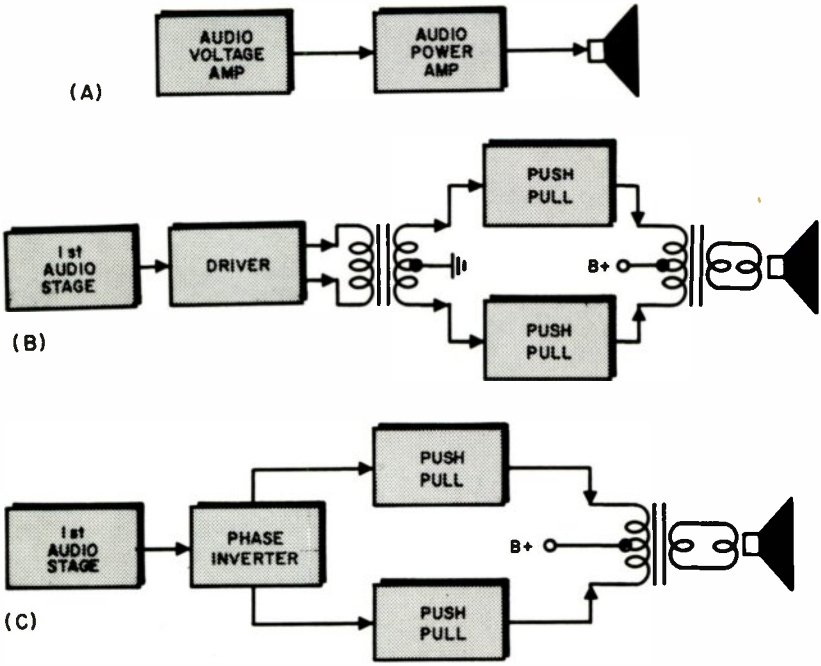



Fig. 710. *Three possible audio circuit arrangements in an FM set. In less expensive receivers the setup is very much like the majority of AM sets. This is shown in (A). In (B) and (C) we have two possible push-pull diagrams. In (B) an interstage transformer is used, while in (C) a phase inverter does the job of the interstage transformer.*

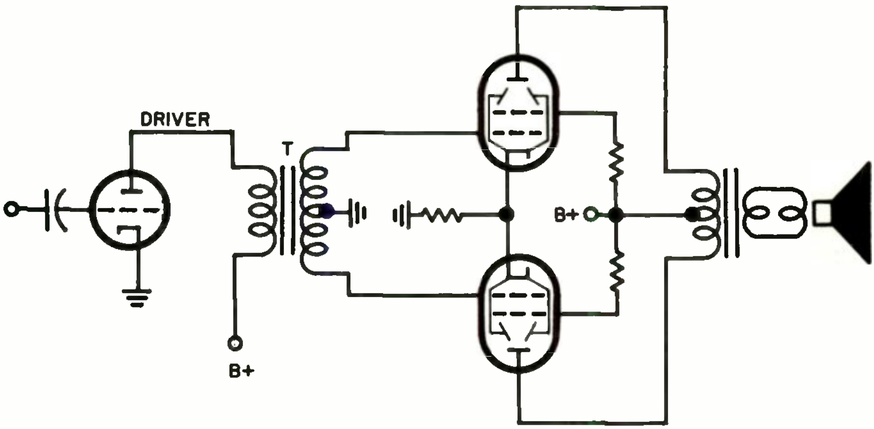



Fig. 711. *Push-pull output stage. Interstage push-pull transformer T couples the driver of the push-pull tubes. Good interstage transformers are expensive, take up room. Most sets use a tube (or a transistor) as a phase inverter to take the place of the transformer.*

Observe the location of the volume control. In AM receivers the volume control is usually placed in the input of the first audio amplifier. Here the volume control is in the control grid circuit of the power amplifier. The volume control also acts as the grid return resistor for this stage.

## Servicing the single-ended stage

To service this stage, follow all the directions and suggestions given in an earlier chapter. But is there something more we can do? There definitely is! Note the advantage of having the circuit diagram. We can look for new or unusual circuit arrangements. We can be alert for components that have values that are somewhat different. And we can use the voltages on the schematics as guideposts in servicing.

## Push-pull stages

You will find push-pull stages in the more expensive FM receivers. These push-pull stages can be either tube or transistor types. Generally the circuits are identical with those you will find in AM sets. Many sets that are combined AM-FM have push-pull output. No switchover or change is made in the audio circuitry when changing from AM to FM reception.

While the circuitry of the push-pull stage is similar for both AM and FM receivers, you may find some differences in the quality of the parts. In some FM sets the push-pull output transformer is larger and of a better design. If your customer is hi-fi conscious, it would be a good idea, when necessary, to replace the unit with an identical substitute.

For troubleshooting, use the charts and servicing information given earlier. However, you may be asked to service a receiver that has no single component which can be called defective. What you may find is a general reduction of good performance due to aging tubes and parts. Capacitors that have become even slightly leaky can change the amount of bias. Tubes get weaker, reducing gain. Speaker cones get brittle, dry, out of shape. In a case of this sort, what is needed isn't servicing so much as a general overhaul.

### The driver stage

The circuitry similarity between an FM receiver and an AM set is strongest in the audio amplifier section of the less expensive receivers. Fig. 710 shows just what we mean. Here we have the block diagram of a first audio amplifier followed by a power amplifier. This is a common arrangement in both types of sets.

In the better type of receiver, both AM and FM, the detector is followed by an audio voltage amplifier, a phase inverter (or a transformer) and push-pull power amplifier.

### The phase inverter

What is a phase inverter? Just look at the name and you have the answer. A phase inverter is a stage that inverts the phase and, since we are talking about audio circuits, it is an audio signal that is inverted.

Inverted means upside down. A clown who stands on his head is inverted. He is out of phase with everyone else.

The simplest sort of inverter is a transformer, as shown in Fig. 711. When the signal voltage at the top of the secondary is plus with respect to the center tap, the signal voltage at the bottom is minus. And when the magnetic field around the primary winding changes, so does the polarity of the voltage across the secondary.

The easiest way to understand this action is to think of a see-saw. The center tap on the transformer is like the center of the see-saw. It remains fairly fixed. When one end of the see-saw comes down, the other end goes up. They are out of phase.

We need out-of-phase signal voltages for the control grids of the push-pull output tubes. We can get these out-of-phase voltages by using either a tube or a transformer.

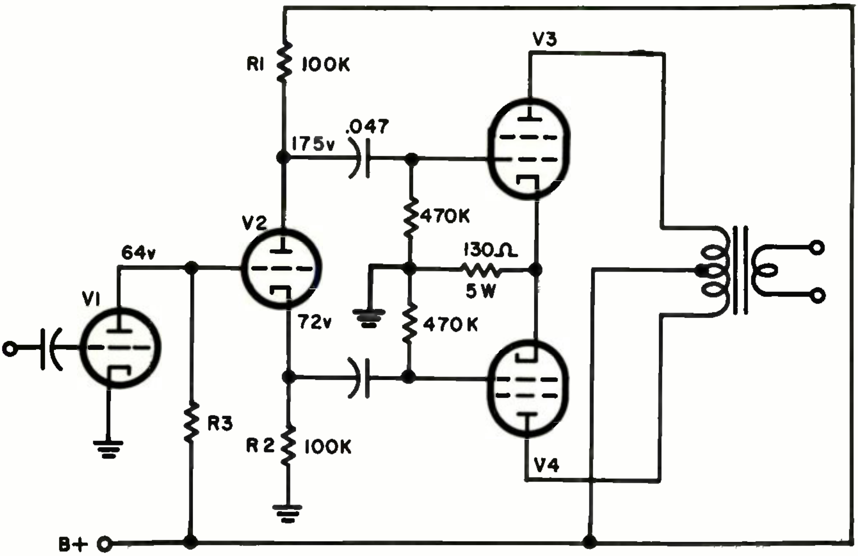



Fig. 712. *The phase splitter. Note that the cathode and plate resistors have equal values. The signal voltage is developed across both resistors and is delivered to the push-pull tubes, V3 and V4, by a pair of coupling capacitors.*

With the inverter stage we get the same servicing troubles that you will find in an ordinary audio amplifier, plus a few more. With the usual audio amplifier, we are happy if we get the correct amount of gain and if the distortion is held within tolerable limits.

When we get to phase inverters and push-pull stages, we can no longer be satisfied with the idea that the circuit is working reasonably well. Unless the phase inverter and push-pull stage give us better audio, higher fidelity audio, there is no use in having a more complicated, more expensive circuit.

There are many types of phase inverters, but the one shown in Fig. 712 is really a phase *splitter*. Like all circuits, it has its share of troubles. Note, first of all, that V1, the preceding audio amplifier, is directly coupled to the phase splitter V2. This means that the plate voltage of V1 and the voltage on the control grid of V2 are the same.

What can we expect to find when we measure the voltage from control grid to ground of V2. 64 volts! This may come as a shock, since we normally do not expect such a high voltage (and positive at that) on the control grid. However, let that be a lesson to us. We have no business measuring from control grid to ground. What were we trying to find anyway? Grid bias? Then we should have been checking between grid and cathode.

R1 is the plate load resistor and R2 the cathode resistor. Both have identical values. Now your first thought might be that identical values of voltage are at the cathode and the plate, since the same current flows through both resistors and both resistors are of the same value.

As soon as we put on our thinking cap, we can see how impossible this would be. If the plate were at the same potential as the cathode, no current would flow through the tube. With the plate at 175 volts and the cathode at 72 volts, the drop across the tube is 175 minus 72, or 103 volts. And if you were to measure the voltage between plate and cathode, this is what you would find. And, if you were to measure the voltage drops by putting your test leads across R1 and then across R2, the voltages should be exactly equal.

## What can go wrong?

In an ordinary single-ended audio amplifier, the values of the parts can change quite a bit and the circuit operation would remain passable. But what about our split-load inverter?

The bias on V2 depends on two factors. One of these is resistor R2. R2 acts as a load resistor. The signal voltage developed across R2 is transferred to the grid of V4 through the coupling capacitor. But R2 is also the cathode resistor for V2. What if R2 changes in value? What would happen would depend entirely on how much R2 did change. If its value increased, it would deliver a signal to V4—larger than that delivered by R1 to V3. This would result in distortion. With a higher voltage on the cathode, the bias is larger and would cause V2 to produce distortion. Also, we might not have enough signal developed in the tube to meet the drive requirements of V3 and V4.

Troubles in a circuit of this sort become compounded. It's almost like a dog biting his own tail.

Suppose we remove V1 from its socket. No current would flow through R3. The voltage at the control grid of V2 rises to the full value of the B-plus. This would put a strong positive voltage on the grid of V2 and probably some resistors (R1, R2) would get the bad habit of smoking.

To avoid this possibility, V1 and V2 are put into one envelope, and so, if we remove V1, we also remove V2.

How can we check a stage that seems so delicately balanced. We can do it in several ways. We can make dc voltage measurements and make certain that they are the same as the voltages indicated on the circuit diagram. Or we can feed in an audio signal to the grid of the splitter, and measure the strength of the voltage at the cathode and the plate of the splitter. It should be the same in both cases. But when using your generator, remember the B-plus on the control grid and make certain to have a blocking capacitor in series with the test lead. Your generator may or may not have such a capacitor in its output circuit.

## Checking the splitter

We can check the splitter with the help of dc/ac voltage measurements. With no signal input, measure the dc voltages across R1 and R2. These should be fairly equal. Then, set your

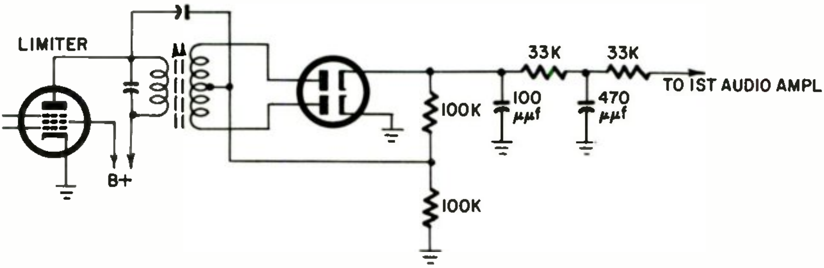



Fig. 713. *The discriminator uses a double-diode as the detector.*

vtvm to read ac volts. Use your generator and feed a steady signal into the splitter. Now, with your vtvm set to read ac volts and with the help of your ac probe, measure the signal voltages across R1 and R2. Once again, the voltages should be equal.

You may come across other types of splitters and inverters, but they should all yield to the same treatment, since they all have the same purpose—to deliver equal but out-of-phase signal voltages to the push-pull amplifier stage.

## The detector

If you were a detector and had your choice of circuit, we would strongly recommend that you select an AM set. What an easy life that detector has! All it needs to do is to take the AM signal and slice it in half.

But there is no such soft job for the detector in an FM receiver. Here the detector has work to do! It must change FM variations into an audio signal. Fortunately, we have no shortage of applicants for the position. There are at least three that are used:

1. The discriminator.
2. The ratio detector.
3. The gated-beam detector.

An FM detector is like a politician. You swear by the one you like and you swear at all others. And neither politicians nor FM detectors are perfect, no matter which you choose.

## The discriminator

The discriminator circuit was one of the first on the scene and, although it has lost popularity, you will still find it in some FM sets being made today and in many of the older sets.

One of the very nice features of a well-designed FM set is that electrical noise can be minimized or eliminated. Thus, a lightning storm or other undesired noise signal picked up by an antenna will

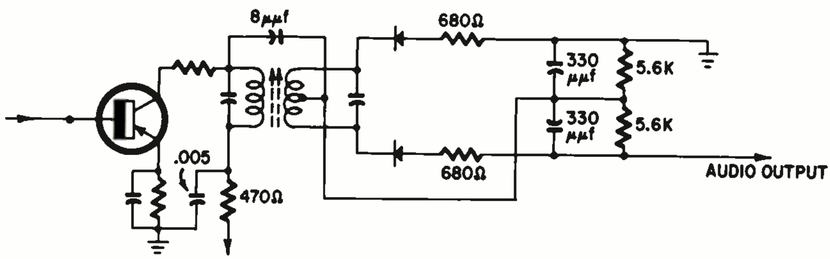



Fig. 714. *In transistor FM, receivers, a pair of crystal diodes, are used in the detector circuit.*

be amplified and heard in an AM set. Noise is AM and just adds to an existing AM signal. The FM receiver, though, responds to frequency modulation, hence the noise is eliminated . . . theoretically.

Not all FM detectors are insensitive to AM. The discriminator is one of these. For this reason the discriminator is usually preceded by one or two limiters. The limiter is designed to saturate easily and clip peaks. And is to a varying signal what a lawn mower is to a lawn that has been neglected for a few weeks. With the help of the mower, the lawn is trimmed and the blades of grass become uniform in height.

With the help of the limiter, any amplitude changes (such as those produced by electrical noise) are clipped.

If you've ever gone to a supermarket to buy olives, you will have learned that they come in three sizes—large, gigantic and colossal.

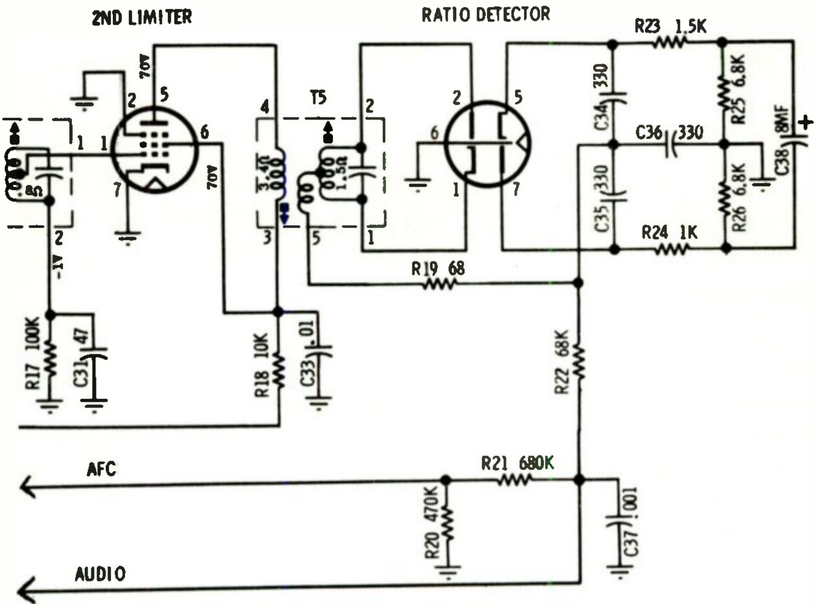



Fig. 715. *The ratio detector does not eliminate AM completely. In some receivers one or two limiters are used ahead of the ratio detector. The detector supplies audio and also automatic frequency control voltage (afc).* (Motorola Consumer Products, Inc.)

We aren't that lucky when it comes to the discriminator. We have only two of those, as shown in Fig. 713 and Fig. 714. We can't even claim that these are different since you can easily see for yourself that the circuits are very much alike. The biggest difference is that we use semiconductor diodes in one and a vacuum tube double-diode in the other.

## The ratio detector

The great ambition of every radio manufacturer is to make one tube work where three tubes would ordinarily be required. The discriminator and its assistant, the limiter, requires a minimum of two tubes. The ratio detector, shown in Fig. 715 can usually do without the limiter.

Now you would think that a change of this sort would make every one happy, and ordinarily it would, except for one very small item. The ratio detector does respond to some AM variations and so, in some sets, you will find a limiter still being placed ahead of it. In less expensive sets, though, there is no limiter circuit.

## Gated-beam detector

With the discriminator and the ratio detector, circuit designers had to "make-do" with the tubes that were available. This limited the tube and the designer. It's just as though you made a fly swatter out of a rolled-up newspaper. This is fine as a temporary relief but a complete set of screens is much better.

This sort of thinking led to the development of a completely new tube—the gated-beam detector. Designed especially for FM receivers, it is shown in its circuit in Fig. 716.

## Here comes trouble

You will note that we haven't explained how these different FM detectors work. It would help to know the theory but this isn't the place for it. We are just interested in learning what sort of trouble to expect with these detectors.

What are the problems that all detectors have? No sound or weak

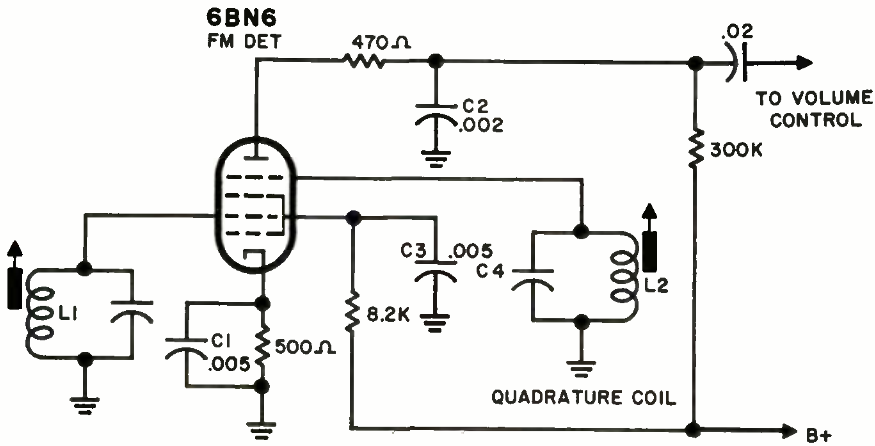



Fig. 716. *Circuit of a gated beam detector. The input is coupled through an if transformer to the preceding stage.*

sound. In most cases the difficulty is caused by the detector tube itself. The easiest check is tube substitution. If the set begins to play when you put in a tube, or the volume is much stronger, then you've found the fault.

But what if tube substitution does not help? What if you have other problems, such as distortion, a high hiss level, poor sensitivity? This is where a check list will come in handy.

| Troubles in the Detector Stage. | And What to Do About Them. |
|---|---|
| Noise. | Substitute new electrolytic (C38 in Fig. 715) across output of ratio detector.<br>Transformer primary or secondary misaligned. This applies to all detector circuits. The transformer might also be intermittent, have poorly soldered connections, missing shield or shield not secure to chassis. |
| Distortion. | Transformer detuned.<br>Detector tube defective. |
| No sound, low gain, poor AM rejection. | Replace the detector tube.<br>Check transformer alignment.<br>In the gated-beam detector (Fig. 716), check capacitors C1, C2, C3 and C4. In the same circuit, check L1 and L2 for opens. |

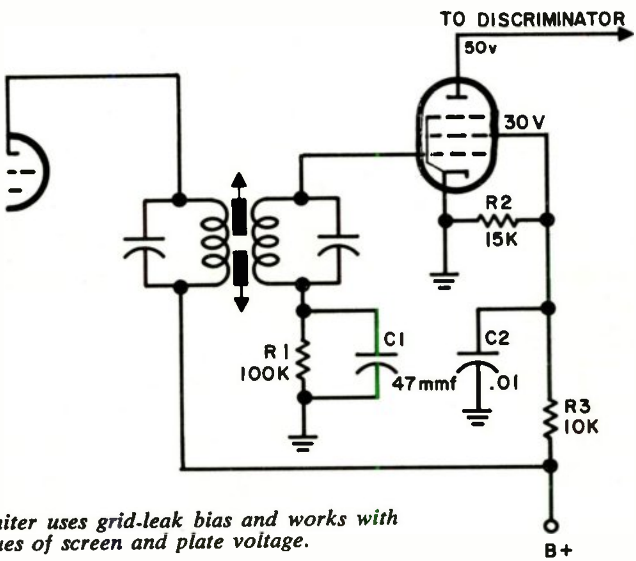



Fig. 717. *The limiter uses grid-leak bias and works with low values of screen and plate voltage.*

## Limiters

The limiter is used to remove any amplitude changes in the signal before it reaches the detector. When we say amplitude changes, we mean not only signal voltages but noise voltages as well. Thus, if an FM set is noisy, check the limiter circuit (or circuits).

The limiter (Fig. 717) works with low values of plates and screen voltages. This permits the tube to saturate easily so that the peak current remains the same for weak and strong signals. It is true that this will distort the output waveform, but this doesn't bother us since we are only interested in the frequency changes of the signal, not its amplitude changes.

To make a quick check of the limiter, set your vtvm to read low dc volts and put it across grid-leak resistor R1. Tune in a station. No voltage across R1 indicates trouble in some earlier stage, such as the if or a shorted C1 or if transformer secondary.

Once you have checked for the presence of voltage across R1, move your test leads to the detector diode load resistor, or across the volume control. Presence of audio here will tell you that the signal is passing through the limiter and the detector.

## What can go wrong with the limiter

Let's examine the circuit in Fig. 717 and see what can go wrong. C2 is a screen bypass. If it opens, the screen will no longer be at ac (if) ground potential. This means that the screen acting as a plate, will send some signal through R3 to the B-plus supply. From the supply the signal might be fed to some earlier stage to cause oscillation.

If C2 should short, R3 would be right across the B-plus supply. R3 will get hot and will burn out, sooner or later. If, in examining R3, you note that it is quite warm or hot, check C2 before replacing R3. If C2 is shorted, not only will R3 get hot, but the voltage at the screen of the limiter will disappear. Little or no signal will be passed by the tube.

If R2 should short, the effect will be the same as a short in C2.

The limiter can be the cause of distortion. When this happens, replace the tube. If this doesn't help, check the grid leak and its capacitor. Make sure the if transformer isn't detuned. Sometimes inserting a new limiter tube will detune the transformer.

## The if stages

If you were to look at the if circuit of an AM set and then at the circuit for an FM set, you would hardly notice the difference. Yet there is one, although we may not be able to see it. This difference is in the frequency of operation.

Why should we care about the frequency? As we go up in frequency, little things become more important. The stray capacitance between a pair of wires in a 455 kc if stage may cause no trouble,

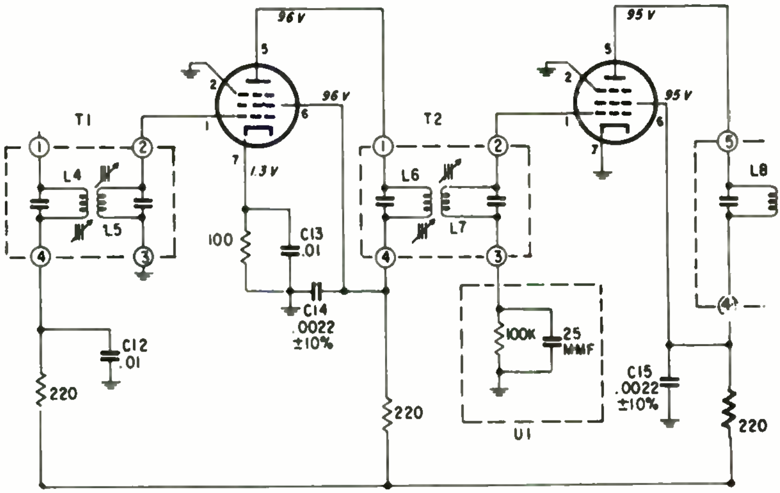



Fig. 718. *If stages in a typical FM receiver. While the second if is not truly an if amplifier it is not completely a limiter either, since the plate and screen voltages are high. Some receivers use two stages like this for limiting, with amplification. The negative portion of the signal is clipped in the first stage, phase reversed in the tube and the positive portion of the signal (now negative) is clipped in the second stage.* (Zenith Radio Corp.)

while the same pair of wires in the 10.7-mc if of an FM receiver could produce oscillation.

## First things first

The first thing we want to know is: Does the stage operate. Will it pass a signal? An easy way to find out is to put your vtvm across the limiter grid-leak resistor and tune the receiver to a strong station. A voltage at that point will tell us that the if's are working.

But what if we get no voltage there? All you need do then is to move your test leads back to the grid-leak of the second if. This is the 100,000 ohm resistor (in Fig. 718) shown connected to the secondary of if transformer T2. If you get a voltage indication here, but none at the limiter stage, then the second if stage isn't working. If you get a signal at both places, then both if stages are operating.

Parts placement and lead dress in these high-frequency if stages are critical. Substitution of components other than those specified by the manufacturer isn't advisable.

## Troubles

What sort of troubles can we expect in the if stages? We will have all of those we discussed earlier in our study of the AM receiver, plus a few more.

The voltage on the control grid of the if tubes should be negative with respect to the cathode. This could be supplied through cathode bias or a grid-leak and grid–capacitor circuit. Sometimes, though, you will find a small plus voltage on the grid instead. This positive voltage can be caused by a number of defects. The first suspect is the tube. With your vtvm connected between grid and chassis, substitute a new tube and if the positive voltage disappears the old tube was gassy.

If the positive voltage on the grid remains, disconnect the primary (B-plus) lead of the if transformer. If the positive voltage on the control grid disappears when you do this, then you have voltage leakage through the insulation of the transformer. Replace the unit.

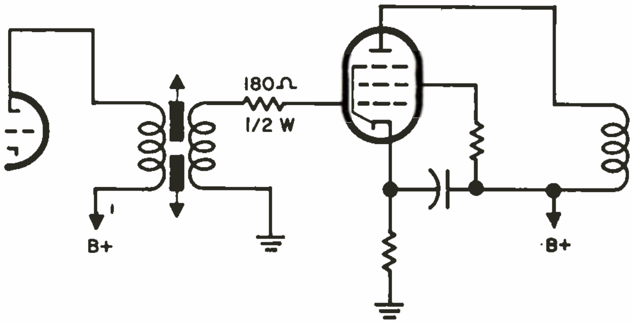



Fig. 719. *A small resistor inserted in the grid circuit of an if stage will help stop oscillation. If the if tubes are shielded, make sure the shield fits well and makes good contact with chassis, ground, or B-minus bus. Try not to disturb the wiring in high-frequency circuits. Lead dress is important.*

Although the positive voltage on the control grid may be very small, usually a fraction of 1 volt, its effects can be large. It will cause grid current. This grid current will change the response of the if transformer, making it tune more broadly. This, in turn, will make the receiver less selective, gain will go down, more noise will get through, all because of the broader frequency response of the transformer.

When you replace an if transformer, don't take for granted that because it is new, it is perfect. After you have installed the transformer, voltage check the grid.

## Squealing

The if stages are amplifiers and, like most amplifiers, will oscillate if given a chance to do so. To find the trouble, connect one end of a

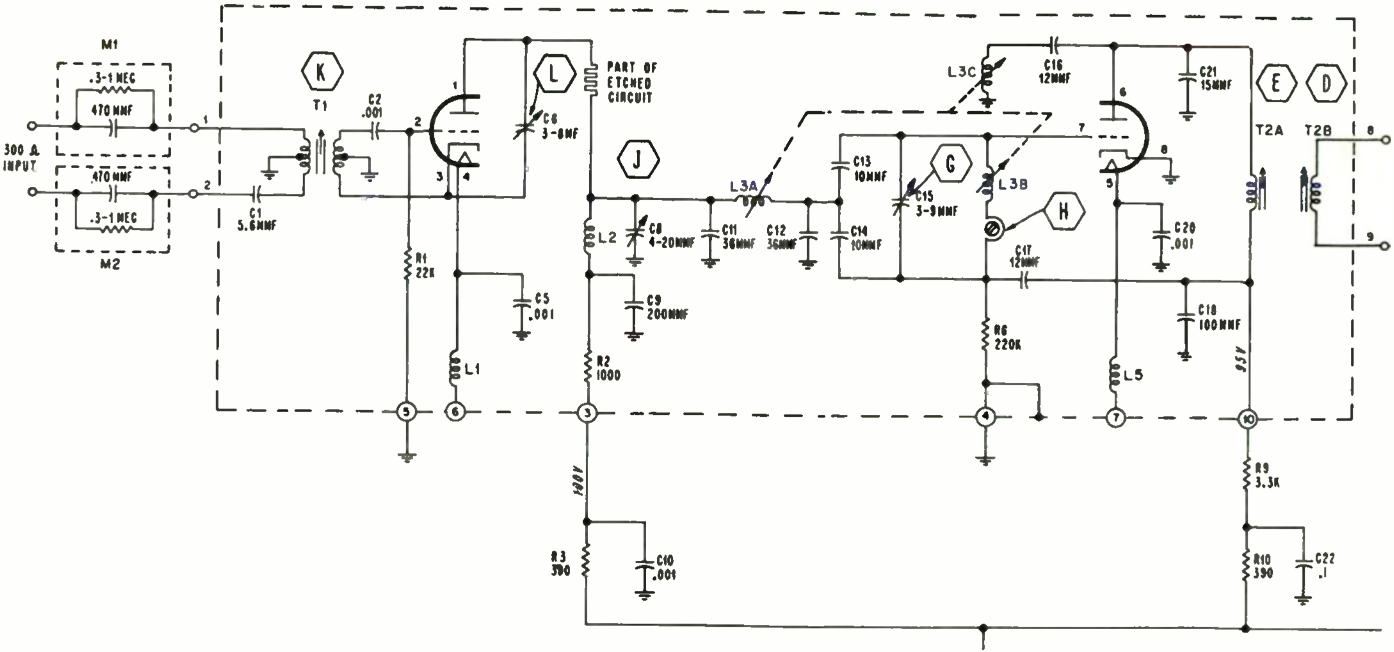



Fig. 720. *The tuner, consisting of an rf amplifier, an oscillator-mixer and the first if transformer, is completely enclosed in a shield. The rf amplifier is neutralized by variable capacitor C6.* (Admiral Corp.)

1-$\mu$f capacitor to the chassis. Now touch the other lead to each of the screen grids of the if tubes. If the oscillation stops a screen bypass capacitor may be open.

If this doesn't help, touch the lead of the capacitor to the terminal of the if transformer connected to the B-plus line. If this stops the oscillation, a decoupling filter capacitor may be open.

If the cathode resistor of the if tube has a bypass capacitor, remove it. This will add a small amount of negative feedback which may kill the oscillation. If this is helpful, but not enough, insert

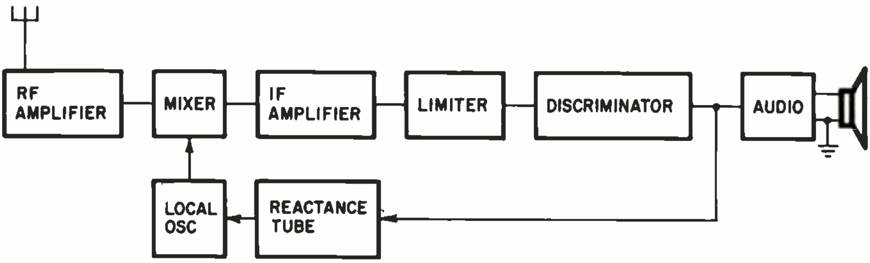



Fig. 721. *Block diagram of FM receiver using afc.*

100-ohm ½-watt resistors in series with the control grid of each if tube. To make this change, disconnect the lead of the if transformer going to the control grid of the if tube. Connect this lead to one terminal of the resistor. Now solder the other lead of the resistor to the control grid, just as shown in the schematic (Fig. 719).

Oscillation in the if will produce squealing and whistling and will make the audio very sibilant.

For all other if troubles, consult the chart given earlier.

## The front end

Some FM sets have an rf amplifier ahead of the mixer. A typical circuit is shown in Fig. 720.

It isn't advisable to attempt repair of such units. Their adjustment and alignment calls for the use of some expensive equipment. If inspection shows that the front end is defective (burned components, broken printed-circuit board, etc.), it is best to disconnect the unit and replace it with a new one. If the tuner requires a new tube, try several until you find one that won't force you to try to realign the front end.

## Automatic frequency control

Did you ever drive a car, take your eyes off the road for a mo-

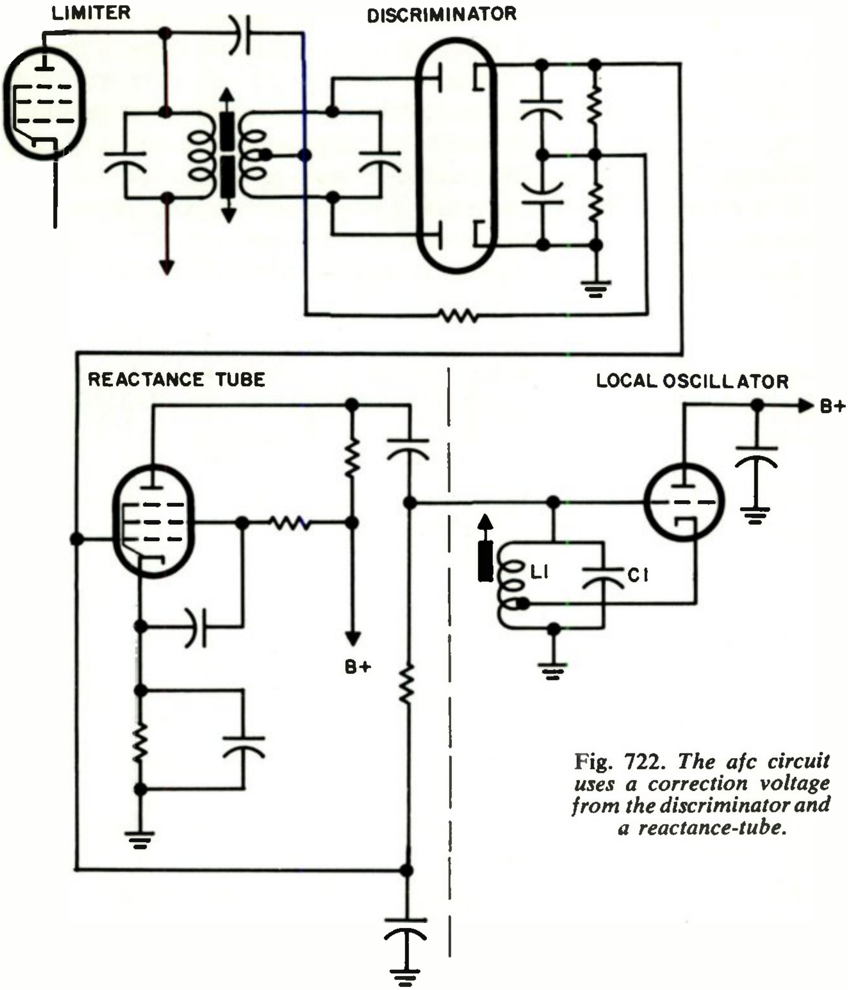



Fig. 722. *The afc circuit uses a correction voltage from the discriminator and a reactance-tube.*

ment and then suddenly note that you are almost off the highway. An FM receiver (or an FM tuner) can be like that. Its front end can drift in frequency. It won't do this right away. It will wait until you are nice and comfortable in some easy chair listening to a good program.

Drift in the front end will force you to get up and retune the set. This isn't a serious defect, but it is a nuisance and takes much of the enjoyment out of listening.

## What is afc?

Afc is an abbreviation for automatic frequency control. Afc is a "kissin' cousin" of avc. Afc, though, is more complicated. As a start, suppose we examine the block diagram of an afc system as shown in Fig. 721. The block diagram is that of an FM receiver with just a single circuit added—a reactance tube connected between the local oscillator and the output of the discriminator.

In Fig. 722 we have the circuit. What has been changed? We still have our local oscillator and our discriminator. The mixer tube isn't shown but the local oscillator is coupled to it.

The reactance tube is shunted across the tank circuit (L1–C1) of the local oscillator. It acts just like a coil whose inductance depends on the amount of current passing through the reactance tube.

As long as the local oscillator is on its correct frequency (when we tune in a particular station) the dc voltage from the discriminator will be zero. A drift in either direction by the signal at the discriminator will produce either a positive or negative voltage which, when applied through the reactance tube, will change the oscillator frequency to bring the voltage back to zero.

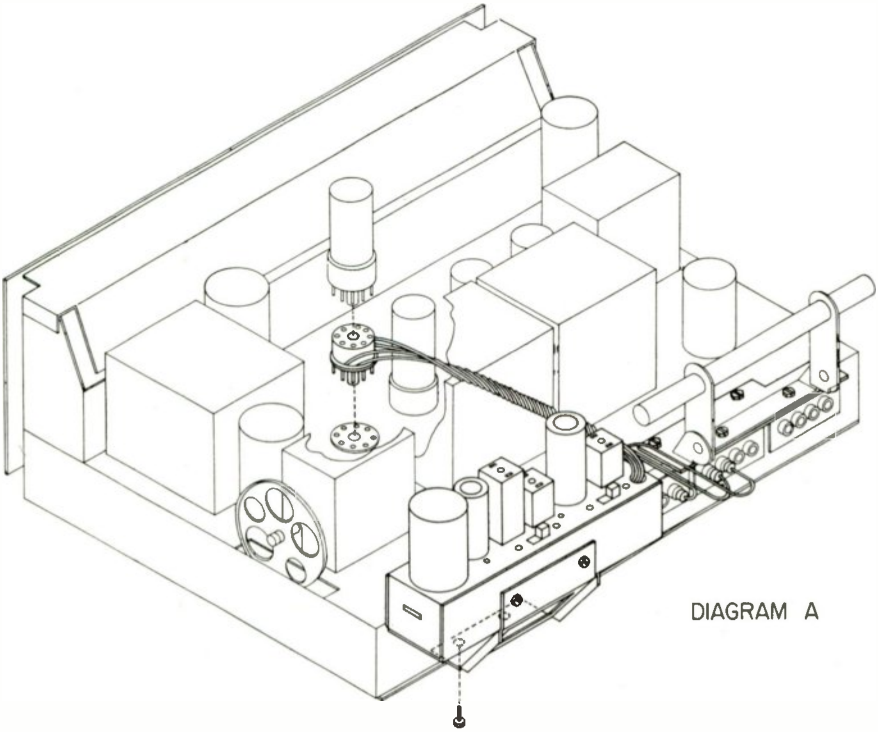



Fig. 723. *Small chassis attaches easily to the rear of FM tuner and obtains its power through adapter-plug. It is best to use multiplex stereo adapter only with receiver it was designed for.* (Harman-Kardon)

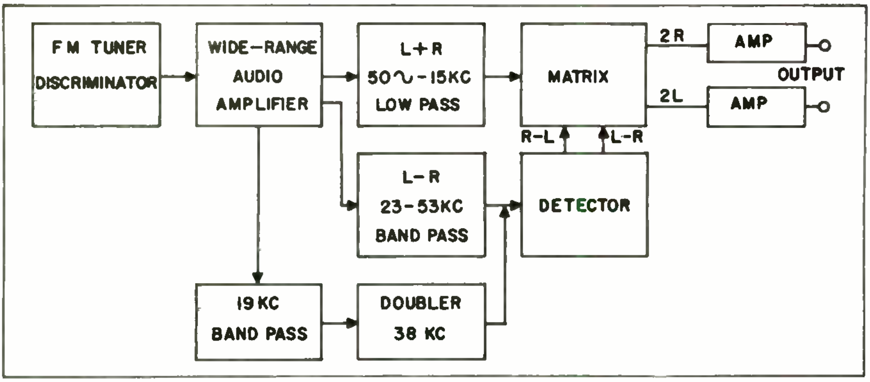



Fig. 724. *Block diagram is typical of one multiplex stereo system. Circuitry and alignment procedure can vary from one manufacturer to another. Always follow manufacturer's instructions.* (Philco Corp.)

## Multiplex stereo

Not all FM detectors have a de-emphasis network (Page 2-92) and those that do may have an output jack between the network and the detector. For multiplex stereo the high frequencies usually removed by the de-emphasis network are needed. These frequencies for multiplex stereo operation go as high as 53 kc and if other multiplex services are used may extend to as high as 100 kc.

Multiplex stereo can be obtained from a two-tube sub-chassis (Fig. 723) or from a self-contained accessory complete with balance controls and power amplifiers. We have covered the audio amplifier portions in previous chapters. The only portion of the adapter that is new to us is the few tubes that do the channel separating.

The alignment of the tuned circuits in the adapter is extremely critical. These adjustments should not be changed unless the proper, accurate test equipment is available. A slight misadjustment here will be more noticeable than in the if amplifier or detector circuits. The first thing to be affected will be stereo channel separation. As misalignment increases distortion will also increase but do not suspect the multiplex stereo stage for all distortion. Eliminate all other possibilities first—remove the stereo adapter from the circuit if necessary. Use jumper wires to feed points 2R and 2L (Fig. 724) directly from the FM detector to bypass the stereo channel splitting circuits.

Should the multiplex tuned circuits prove to be defective and the proper equipment is not available it might be better to have a *factory authorized* service organization do the repair or at least the realignment if it is necessary to replace the tuned-circuit components.

## QUESTIONS

1. What is the frequency range of the FM band?
2. Name three types of detectors used for FM. Which type requires a limiter?
3. What is a limiter? What is one of its characteristics?
4. How would you check a limiter circuit?
5. What is PIV? Name a component that would be marked in this way.
6. What is a surge resistor? Where is it used?
7. What problems can be caused by rectifiers in parallel?
8. How would you check for a shorted turn in a power transformer?
9. Describe two ways by which you could eliminate oscillation in an if stage.
10. What might be one cause of a positive voltage on the control grid of an if tube?
11. What are some of the effects produced by oscillation in an if stage?
12. Name three possible causes of distortion in an FM receiver. Assume that the output transformer and the speaker (or speakers) are in good working order.

CHAPTER 8

# AM—FM tuners

DID YOU ever watch the way a trailer truck is assembled in a depot or garage? Huge trailers stand next to each other and while they are being loaded, the "business" end of the trailer is connected. It consists of a powerful motor with the cab sitting almost on top of it. When the cab and trailer are joined, you have a wonderful combination for hauling freight.

But what has this to do with us? Simply this—many ideas in radio receivers can be compared to something that seems as different as a trailer. Thus, some receivers are made up of tuners and amplifiers. The tuner is like the cab and the amplifier is like the trailer. When we join the tuner and the amplifier, we have a wonderful combination for listening pleasure.

What is a tuner? It is half a receiver. But half a receiver is like two young children dividing a bar of candy between them. Someone is going to get the bigger half. Generally speaking, then, a tuner consists of that part of the receiver up to and including the detector, but it may also have a stage of audio amplification.

## Why should we have tuners?

At first thought, having a tuner might sound odd. Why bother with a tuner? Wouldn't it be better to have a complete receiver, ready to plug in and work? The answer here is the same as for our trailer and cab combination. What we're looking for is flexibility.

Suppose you (or your customer) own a record player, a tape recorder and possibly one or two microphones, all for home use. These are also what we would call "half" units. They just don't work by themselves. To get the benefit of the record player and microphones, we need the other half of the combination—an audio amplifier.

Now let's see what we have. In Fig. 801 we have our three units, all feeding into the audio amplifier but not at the same time, of course. Suppose we ask a question, though. Since we have an audio amplifier (usually a very good one and a fairly expensive one), why should we bother with a "whole" receiver? Why not buy just the half we need and just add it on.

## The control unit

The next time you take a train ride, keep your eyes open for the control tower. If you're taking the train out of a large station, you'll

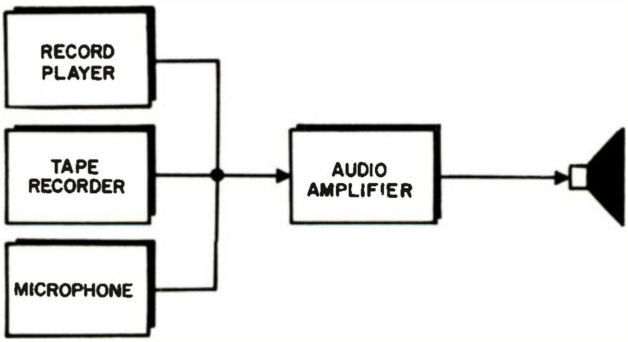



Fig. 801. *The same audio amplifier is used by a number of different signal sources.*

see the control tower almost as soon as the train leaves the yards. Without this tower, train traffic would be hopelessly mixed up.

Our control unit in Fig. 802 is a sort of electronic traffic control. Not only does it have one or more switches to select the input signal, but it may have a gain control, equalization circuits, bass and treble controls. Some have multiple outlets which are connected to the power line.

In Fig. 802 we have a number of units wired to an audio amplifier (through a control unit). Our tuner is one of these.

## Tuner systems

A number of paragraphs ago we used the word flexibility. By this we mean that we can have our choice of a number of different combinations with tuners. You will see just what we mean by examining Fig. 803. Looking at the block diagram at the top (Fig. 803-A), we have an AM tuner feeding into a control unit. To make the drawing simple we have omitted all the other devices (phonograph, mi-

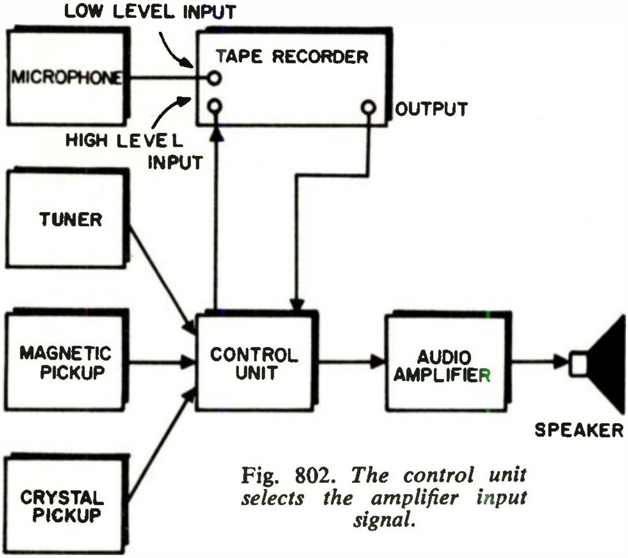



Fig. 802. *The control unit selects the amplifier input signal.*

crophones, etc.) that are also connected to the control unit. In some systems an AM tuner will be the only type that is used.

In the same way, we can have a setup using just an FM tuuner as in Fig. 803-B.

In Fig. 803-C we have two tuners connected to the control unit. One covers the AM band, the other the FM. Note that the tuners are separate items. They will each have their own chassis, power supply, cabinet and tuning dial. For a less expensive way of covering the two bands, the tuners are often combined into one as in Fig. 803-D.

## Let's look at it

What does a tuner look like? Just like a receiver. Fig. 804 shows a combined AM–FM tuner. The control at the left is a switch. It turns the unit on, selects the band (either AM or FM). There is also one little refinement that is interesting. This is an afc control. The afc circuit is connected only when the knob is turned fully clockwise.

The knob shown at the right tunes both bands.

## Tuner construction

In tuners, as in radio receivers, manufacturing methods range from the "get 'em out quick" type to those that are engineering delights. Many very fine AM–FM tuners are made and require much

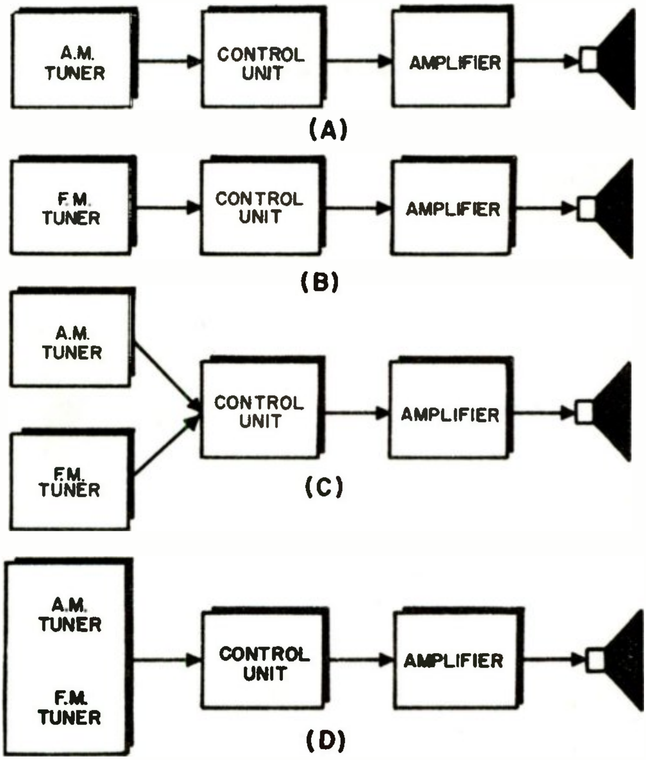



Fig. 803. *Tuners come in a number of possible arrangements.*

more careful servicing than the average radio receiver. The unit shown in Fig. 805 is completely shielded, has a total of three outputs (taken from the rear panel): AM–FM monophonic, stereo (FM and AM) and FM multiplex. The tuner has an afc circuit which keeps the receiver tuned to the center of the station channel. It also has an afc defeat position. This is a switch position for disconnecting the afc circuit.

## Tuner circuits

Why should we study tuners when a tuner is only "half a receiver"? We've studied AM and FM receiver repair, so it is perfectly fair for you to ask whether we should bother with tuners.

It is true that the circuits in tuners are basically the same as those in receivers. That word "basically" is our clue. What we are going to look for are circuit refinements. There are also some circuits that appear in FM receivers that we have postponed until this time.

## What are the differences?

We can start our work with a study of FM tuners. Your first question will probably be: "Are they all alike?" We can answer that


Fig. 804. *Combined AM-FM tuner with selection of afc.* (Altec)

with a question of our own. Why should they be? All radio receivers aren't the same and we have no reason for expecting that all tuners will be alike.

In Fig. 806 we have the block diagram of one type of tuner. The front end in this tuner uses a double-triode, one half of which is an rf amplifier while the other half is a mixer-oscillator. The unit has three if stages, a ratio detector and one stage of audio.

Another FM tuner diagram, shown in Fig. 807, uses a pentode

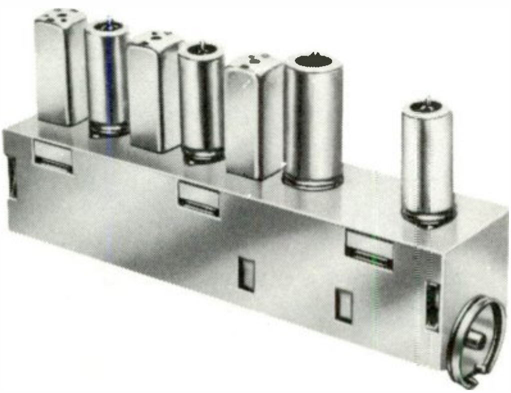


Fig. 805. *AM-FM tuner is completely shielded. It has three outputs.* (Harman-Kardon, Inc.)

rf amplifier, a double triode as a converter, two if stages, followed by a limiter and a discriminator—first audio amplifier. If you will compare the diagrams in Fig. 806 and Fig. 807 you will see that these two FM tuners are as different as they can be.

## AM–FM tuners

What is the most complicated part of an AM–FM tuner? Probably the switching arrangement. The switching circuit, though, depends on just how the tuner was designed. Some AM–FM tuners use the same tubes for many circuits. As an example, the same tubes

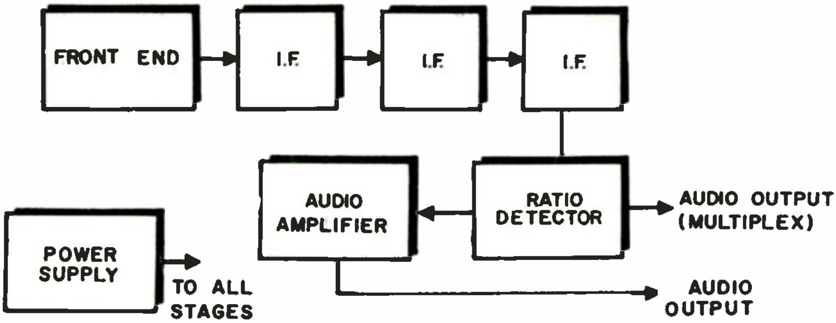



Fig. 806. *FM tuner with three if stages, ratio detector and two audio outputs.*

could be used for the if strip. In a case of this kind a switch may be needed to shift from AM to FM intermediate-frequency transformers.

In some AM–FM tuners, the two portions (AM and FM) are more independent of each other. In Fig. 808 we have the block diagram of such a tuner. Only two circuits are used in common by both tuners. These are the power supply and the detector tube.

In Fig. 809 we have the block diagram of an AM–FM tuner that uses the same tubes for both portions of the tuner. The rf amplifier is intended for FM only. When the tuner is switched to AM reception, the rf amplifier is not used, the AM signal being led directly into the converter.

In a tuner of this type the entire operation depends on switches. Because so many circuits are involved, the switching gets to be quite complicated.

## Converters

There is another type of unit, somewhat smaller in size, that you may mistake for a tuner. Known as the converter, it is simply a frequency changer. With its help a broadcast receiver can be made to operate on higher-frequency bands. Converters will be described in the last chapter.

## FM auto tuners

Servicing an AM receiver is simple in at least one sense. The entire unit is self-contained and you don't have to worry about inter-

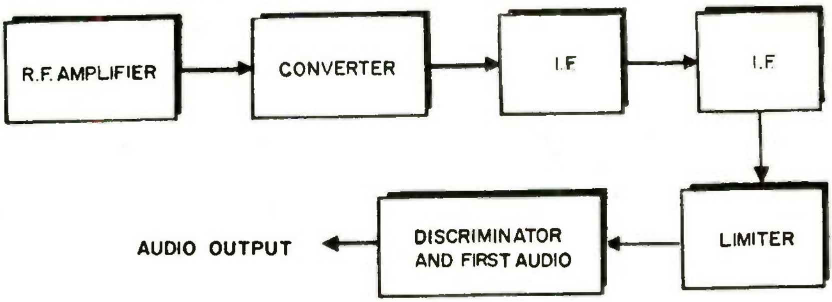



Fig. 807. *This FM tuner has two if stages and a limiter, followed by a discriminator-type detector.*

connections with any other unit. The tuner, however, whether it is AM or FM, is part of a system.

The man who likes to listen to FM in his home sometimes likes to listen to FM in his car. But now he has a choice. He can have two radios, one for AM and the other for FM, or he can have an FM

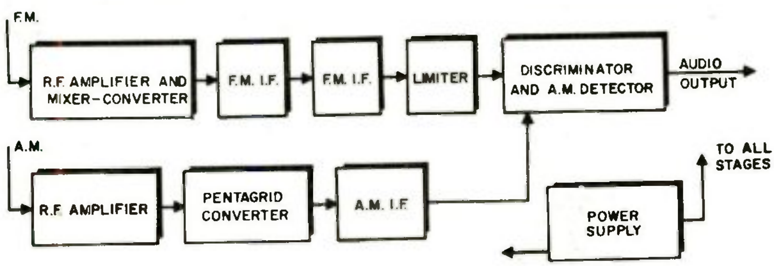



Fig. 808. *In some tuners, the FM and AM sections are separate units.*

tuner. As in any home system, the output of the FM tuner feeds into a power amplifier which drives a speaker.

In the home system a well designed audio amplifier serves as the receiving depot for a variety of input signals—AM, FM, phono, etc. The auto doesn't have this advantage. There is no separate audio

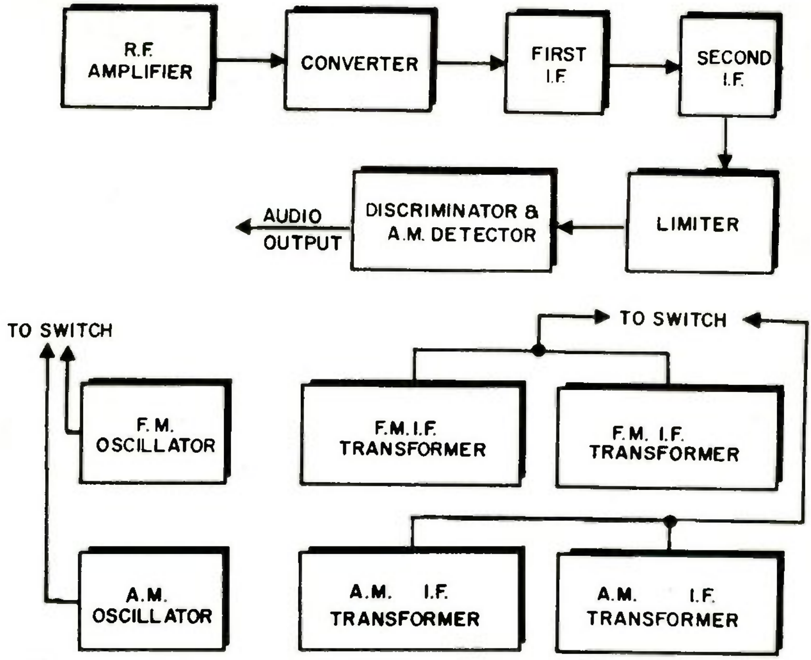



Fig. 809. *In some AM-FM tuners more circuits are used in common but the switching is more complicated.*

amplifier and so the output of the FM tuner is fed into the audio amplifier of the car's AM receiver. However, since the car does come equipped with an AM receiver, the tuner is designed for FM reception and its switching arrangement is quite simple.

## We begin at the beginning

In earlier chapters we started our servicing by working our way back from the speaker to the front end of the receiver. This time we are going to begin with the front end.

## The rf amplifier

What is so different about the rf amplifier for the tuner? Not too much except that in some sets you will find two rf amplifiers, one for the FM and the other for the AM band. In Fig. 810 we have a circuit for the rf stages in such a tuner.

Before we load ourselves with troubles, let's examine the circuit and see what we can spot at once. The amplifier for the FM section is a triode, so we certainly aren't going to get too much gain. We

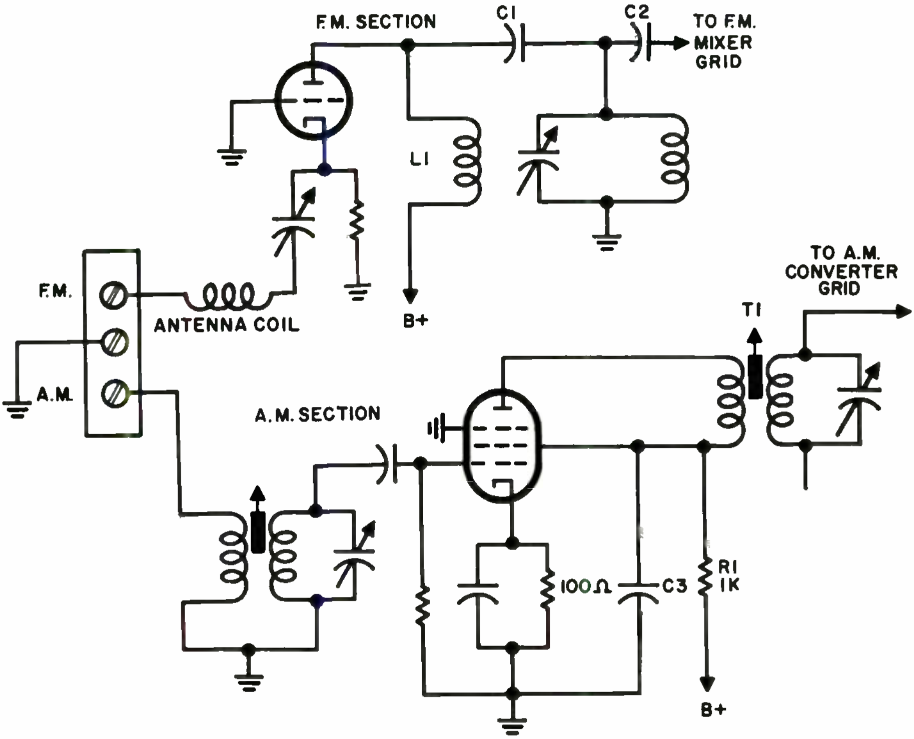



Fig. 810. *Separate rf amplifier stages are used in some tuners. The tube for the FM section is a grounded-grid amplifier.*

can also see that the tube is a grounded grid amplifier. The input is low-impedance to match the antenna circuit while the output is high-impedance, suitable for connecting into a tuned load. The big advantage of using a triode this way is that the input and output circuits are shielded from each other by the grounded control grid. Another advantage in using a triode is that a three-element tube produces less noise than another type, such as a pentode. In the AM section, though, a pentode is used.

## Trouble, trouble

What is our first question in servicing a tuner? What's wrong? This question has just two words but it does cover quite a bit of ground. In Fig. 810 our first step would be to find out which half of the tuner is causing trouble. Is it the AM section or the FM? Set the selector switch, first on one band (such as the FM) and then on the other. If the AM band works but the FM does not, then we have immediately eliminated half the unit for servicing. At the same time we know that we don't have to worry about the power supply, since it furnishes voltage for both AM and FM sections.

Let's set up a table of troubles so that we can have it handy when we work on tuners.

| Troubles in the RF Amplifier. | And What to Do About Them. |
|---|---|
| No sound when set is switched to AM or FM. | It is unlikely that both amplifier tubes are defective but it can happen. Check them. |
| | FM and AM terminals on antenna terminal board are shorted to ground. |
| | Check B-plus lines. The plate and screen circuits connect into a common line that goes to the power supply. Make sure this line reaches the power supply and that it has voltage on it. |
| AM has sound; no FM sound. | Click test FM tube. |
| | Try a new tube. |
| | Tube is a miniature and may not be properly seated in socket. Pins may be bent, not making good contact. Socket may be defective or dirty. |
| | Check plate voltage. If no plate voltage, resistance check plate coil L1 (in Fig. 810) for continuity. |
| | Check bias voltage. Cathode should be slightly positive (fraction of a volt) with respect to ground. If cathode is at zero potential, tube isn't drawing current and either the bypass capacitor is shorted, the plate coil is open, or tube emission is gone. |
| FM has sound; no AM sound. | Try a new tube. Click-test old tube. |
| | Check plate and screen voltages. If no plate voltage, check the primary of coupling transformer T1 or decoupling resistor R1. Tube will not work if cathode resistor is open. |
| | Check bias. Grid should be a fraction of a volt negative with respect to cathode. If no bias, tube isn't drawing current. |

| | |
|---|---|
| **Sound is weak; may or may not be distorted (either AM or FM).** | Defective tube. |
| | Wrong plate or screen voltages. |
| | Bias is incorrect. Cathode resistor has changed value or cathode bypass capacitor has shorted. |
| **Pinging sound in speaker.** | Tube may be microphonic. Tap gently. Pinging sound in speaker indicates microphonic tube. |

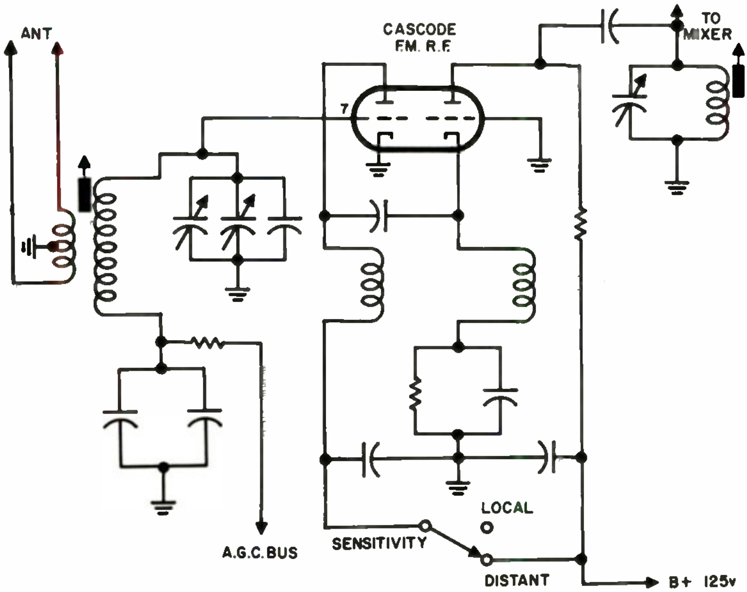



Fig. 811. *The local-distant switch controls the gain of the rf amplifier.*

| | |
|---|---|
| **Scratching sound when set is tuned.** | Caused by noisy tuning capacitor, generally in AM section; rotor plates rub against stator. Trouble may be in either section of variable capacitor. To check, disconnect leads to capacitor and shunt ohmmeter across capacitor. Turn dial from open to full mesh. Meter should show infinite resistance. If meter needle moves back and forth when dial is turned, capacitor plates are rubbing. Adjust plates of capacitor until short disappears. |
| | Trouble may also be due to dry ball bearings or rubbing action of rotor shaft. Lubricate with anti-noise lubricant, commercially available. |

## The cascode tuner

The triode in Fig. 810 for the FM section is a grounded-grid amplifier. Sometimes the tube is in series with a triode amplifier, the combination, as shown in Fig. 811, being known as a cascode tuner.

For weak signals the cascode tuner is fine but with a strong signal we may run into a nonlinear part of the tube's characteristic. One way of cutting down the gain is to operate the tube with a greater amount of bias voltage. Another method is to eliminate the first half of the double triode used as an amplifier.

In Fig. 811 the sensitivity is controlled by a local–distant switch. When the switch is in the distant position, the plate of the first triode section gets its usual ration of B-plus voltage. For strong signals, B-plus is removed from this tube. There is enough capacitance between the tube elements of the first triode section to transfer the signal to the cathode input of the grounded-grid amplifier.

If the tuner works well on local, (nearby) stations but is weak on more distant ones, check the voltage on the plate of the first triode. Absence of voltage here (while you work the sensitivity switch back and forth) means a defective switch.

## Other front ends

Whether or not a tuner will have separate front ends will depend on its design. With two front ends, one for AM and the other for FM, switching is reduced to a minimum and might be nothing more than a single-pole double-throw switch. Where there is only one front end that must do double duty for both the AM and FM bands, switching circuits become complicated.

Some tuners are constructed in combination with record changers or record players. In these systems the switching system is used to turn the tuner off but permits line voltage to be sent along to the changer motor and B-plus to the audio amplifier.

## Servicing the system

What are we trying to do when we service a tuner? Wouldn't you say that we are trying to fix two receivers at the same time—AM and FM? But is it likely that both receivers will be out of order at the same time? We cannot give a definite answer to that one since it all depends on the type of system used.

What is our first step in servicing, then? The big question is whether the trouble exists in the tuner at all? Does the audio section work? That's easy enough to determine. Follow the servicing procedures learned earlier. Turn the unit on. Switch to phono. Then touch the tip of the stylus in the phonograph pickup to see if sound comes through. Or, put a disc on the turntable. If there is no sound, your trouble isn't the tuner. Look for trouble in the amplifier, the power supply or the power line.

### The power supply

Tuners come equipped with their own power supplies. The fact that the audio section of the system is working proves nothing

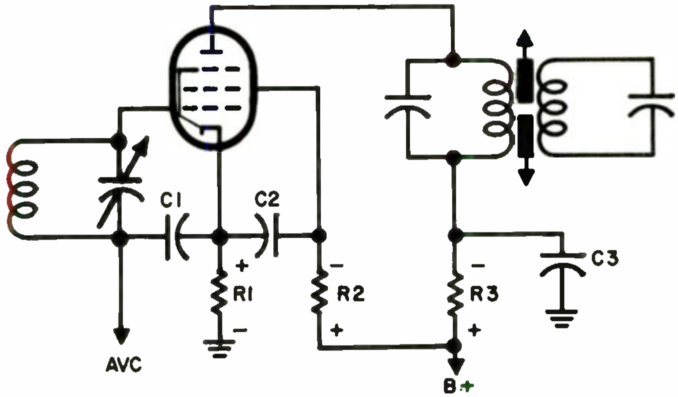



Fig. 812. *If a circuit uses resistors, voltage analysis can be used to supply considerable information about all the components.*

concerning the supply for the tuner. If both AM and FM bands are dead, the B-plus line is a good place to start checking since it is common to both tuners. The B-plus line isn't always part of the switching arrangement, so you can trace right on out to all tubes. In some sets that use separate rf amplifiers, though, B-plus voltage is often switched off the amplifier not in use.

### Antennas

On the back of the tuner you will find a terminal board with provision for external antenna connections. In some tuners you will find connecting screws for both AM and FM antennas; in others there will be provision for FM only.

Whether external antennas should be used depends on location and signal strength. Generally, no outdoor antenna is needed for

AM. For FM a good outdoor antenna is helpful in nearly all areas. If, in the tuner you are servicing, the AM section works well, while FM is poor, try checking the antenna arrangement.

## Servicing the if by voltage analysis

Ever turn on a faucet and have water come out, drop by drop, and then, after a second or two, nothing at all? You don't have to be a plumber to know you have trouble.

An amplifier tube is like a valve or faucet. The tube isn't supposed to deliver current—just control it. It can't do this unless current passes through it.

But how can we tell? In the case of the faucet we have no problem. We can see water, but a current of electricity is invisible.

If we walk into a kitchen and see a faucet we have a pretty good suspicion that water is somewhere around. And, in a radio receiver, if we can find the voltage, we can usually locate the current.

Every time current flows through a resistor we get a voltage across that resistor. Armed with this bit of information, we can learn if a current is going through a tube.

Whether we can measure voltage drops depends on whether the circuit has resistors for us to work on. We can measure the voltage at the plate of the tube, but the dc resistance of the primary winding of the if transformer could be so small that the voltage at the plate and at the B-plus bus would be practically identical.

In the case of Fig. 812 opportunity doesn't need to raise its hand to knock even once. Here we have three resistors, each ideal for the sort of test we have in mind.

We can approach voltage analysis in several ways. First set your vtvm to read low dc volts. Put the probe at the cathode and the common lead at ground. You will then be reading the voltage across R1.

There are four basic possibilities:

(a) the voltage across R1 is correct

(b) the voltage across R1 is too high

(c) the voltage across R1 is too low

(d) there is no voltage across R1

Analyze these, in turn. Suppose the voltage across R1 is correct? What does that tell us? We know immediately that the bias is right, that screen and plate voltages must be right, that the tube is passing current and that C1 and C2 aren't shorted. That's quite a few answers to get for just one measurement.

But we're not interested in circuits that work correctly. Suppose, then, that the voltage across R1 is too high. What does that tell us? This informs us at once that the tube is drawing too much current. But why?

This could happen if the tube were gassy. If the tube is made of glass, examine it around the inside near the base. Is there a small whitish deposit? If so, get a new tube. The old one has a leak in it.

Check the control grid. It should have a negative voltage on it supplied by avc action. Tune to a strong station. Generally, though, even the absence of avc voltage will not affect tube current too strongly. But there is a possibility of B-plus leaking over to the control grid through corrosion in the if transformer or through some high-resistance short to B-plus.

Now consider the case when the voltage across R1 is too low. One possibility would be weak emission in the tube itself. It takes current to produce a voltage drop and the cathode of the tube just may not be emitting.

Another possibility might be that the plate isn't attracting enough electrons. It would do this if, for some reason, plate voltage was lowered. What could cause this? The tube might have low screen voltage due to an increased value of R2 or no screen voltage if R2 were open. R3 might also have gone up in value, reducing plate voltage.

Suppose C3 became very leaky. It would force more current through R3, producing a larger voltage drop across it. But the more voltage we drop across R3, the less we have for the plate. And the less we have for the plate, the smaller the amount of current through the tube, and the smaller the voltage across R1.

Finally, what if we have no voltage across R1? The tube isn't drawing current. This could be caused by a completely dead tube, or by a heater-cathode short (or a shorted bypass capacitor as in Fig. 813).

## Other voltage checks

Now do you see what a tremendous amount of information we can get out of a simple voltage check? But there are others. We can tell if the screen is working by measuring the voltage drop across R2. Not only that, we can use this test to tell us if C2 is leaky. Connect the negative lead of your vtvm to the screen grid.

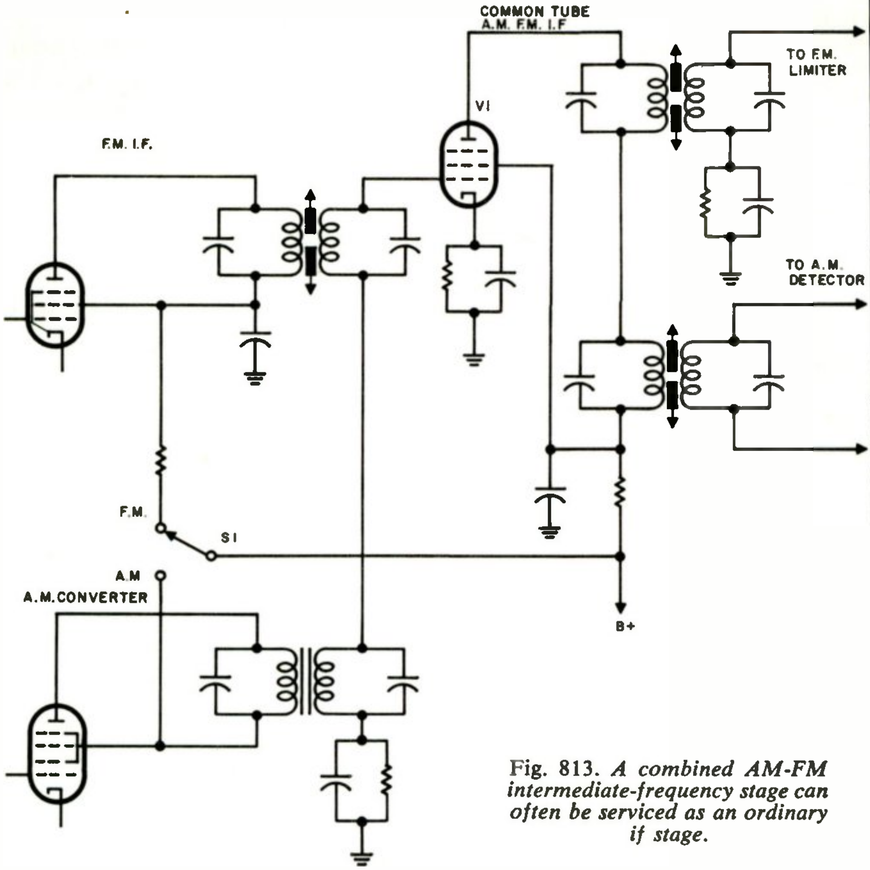



Fig. 813. *A combined AM-FM intermediate-frequency stage can often be serviced as an ordinary if stage.*

Connect the plus lead to the B-plus line. Disconnect one end of C2 (the end connected to the cathode). The voltage reading on the meter should not change. If, for example, the voltage reading across R2 should decrease, replace C2. It is too leaky.

You can also make a voltage check across R3. Connect the vtvm test leads across it, following the polarity indicated in Fig. 812. Now disconnect the ground end of C3. If, with C3 disconnected, the voltage across R3 goes down, replace C3.

While we have selected an if stage for voltage analysis, you can use the same tests on any amplifier stage that uses resistors.

## More notes on the if section

Servicing the if section depends entirely on the design of the tuner. If there are separate if stages—an if strip for the AM section and another if strip for the FM, then you can handle the tuner just as though you were working on two separate receivers. It is very unlikely that both sections would become defective at the same time.

Many tuners, though, have a common if as shown in Fig. 813. In this circuit the AM converter feeds into a circuit designed to amplify both the AM and the FM intermediate-frequency signals.

To keep the common if tube from getting hopelessly confused, we have a switch in the B-plus line. When the switch is turned to AM, the first FM intermediate-frequency stage gets no B-plus. In this way, only one if signal at a time is fed into the common tube.

The if transformer in the output of V1 consists of the primary

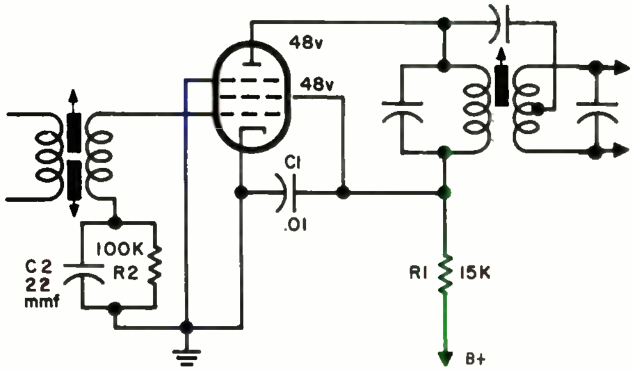



Fig. 814. *The limiter operates with low plate and screen voltages.*

windings connected in series. The if of the FM section is 10.7 megacycles and, as a result, the if transformer has very few turns.

Now consider the two if frequencies we have. One is 455 kc and the other is 10.7 mc. Quite a difference. For 10.7 mc, the AM winding of the if transformer is simply a reactance in series with the transformer. For 455 kc, the FM winding is just a small reactance.

Suppose, though, that we had the switch set to receive FM. Couldn't some of this get through to the AM detector? Possibly. But following each detector we would have another switch, ganged to S1 in Fig. 813. This second switch would make sure that only one detector's output is used at a time.

## Troubles in the if

How do we check a circuit such as the one shown in Fig. 813?

In this case we can make the switch, S1, help us determine which section, AM or FM, is out of order.

To analyze troubles in V1, treat it as though it were an ordinary if stage. You can inject a signal for AM output, or you can run a voltage analysis.

Switch S1 is in the B-plus line. If you cannot get voltage on the AM converter tube (no matter what position the switch is in) run a resistance check (test for open and short) on the switch.

Quite often the only trouble is oxidization of the switch contacts. Treating it with a lubricant cleaner will put it into operation again. Be suspicious of the switch if the set is intermittent or if you can make the set play by jiggling the switch or exerting some pressure on it.

## The limiter

A better name for the limiter is AM clipper. The circuit, as shown in Fig. 814, works with very low values of plate and screen voltages and has its cathode tied to ground. As a result, the tube saturates easily.

Not all sets have limiters. You will usually find them with receivers using a discriminator type detector, although they are sometimes also used with a ratio detector. Most sets with limiters have just one, but you may come across a tuner having two. The idea here is that one limiter will remove AM variations from the top of the waveform, while the other will take care of the bottom of the wave.

| Troubles in the Limiter Circuit. | And What To Do About Them. |
|---|---|
| Receiver noisy. | Try a new limiter tube. We depend on cathode emission to get a saturated current. |
| | Check screen bypass capacitor C1 (in Fig. 814). |
| | Screen and plate dropping resistor R1 may have decreased in value, putting too high a voltage on plate and screen. |
| | Limiter transformer detuned. |
| Very weak signal. | Defective limiter tube. |
| | Open dropping resistor R1. (Some signal may get through even though tube will have no B-plus.) |
| | Shorted or very leaky C1. |
| | Open grid-leak resistor R2. |

| | |
|---|---|
| **Distortion.** | Defective limiter tube. |
| | Grid-leak network (C2 and R2) changed in value. |
| | Limiter may be oscillating. |
| | New tube may sometimes cause distortion. Limiter transformer may need realignment when new tube is used. |

Whenever we use a circuit, such as a limiter, we pay a price. In the case of avc, the price we pay is in reduced gain, since the stronger the signal, the more the gain of the controlled tubes is cut down.

We have a similar idea in a limiter circuit. Signals of a certain strength will produce saturation (maximum current flow) through the limiter tube. Having a stronger signal will do us no good, since

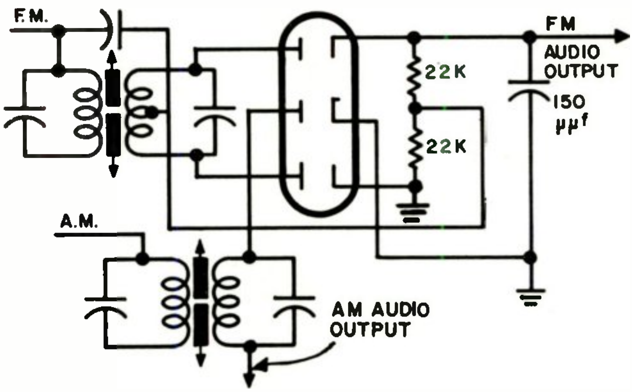



Fig. 815. *This tube is a combined AM and FM detector. The FM section is a discriminator. The AM is the usual diode type detector.*

the output will be constant for all signals over and above those producing maximum limiter current. We can solve this problem by raising the voltages on the plate and the screen of the limiter tube, but then we would need a stronger signal input to reach saturation again.

In the same way, by having lower plate and screen voltages, we can get limiting action for weak signals, but at the sacrifice of signal strength for stronger signals.

## Quick check

If you want to know (quickly) if the limiter is working, set your vtvm to the *minus* 10-volt dc scale. Connect the probe of the instrument to the top part of grid-leak resistor R2 and the common lead to ground. Tuned between stations, the voltage reading should be zero. Now set the dial to a strong station. You should get a reading of 3 to 40 volts, depending on the signal strength and the gain of the stages ahead of the limiter. If you get no voltage reading at any time, either the limiter isn't working or some stage ahead of the limiter is defective.

## The double detector

By the time we reach the detector, all signals can be funneled into one tube. This tube, as shown in Fig. 815, is a combined discriminator (for FM detection) and single diode (for AM detection). The unusual feature of Fig. 815 isn't the circuit—it's the tube.

## Double-detector troubles

Since this is a meeting point for both AM and FM signals, both bands may be affected at the same time. If signals are weak or missing on both AM and FM bands, substitute a new tube.

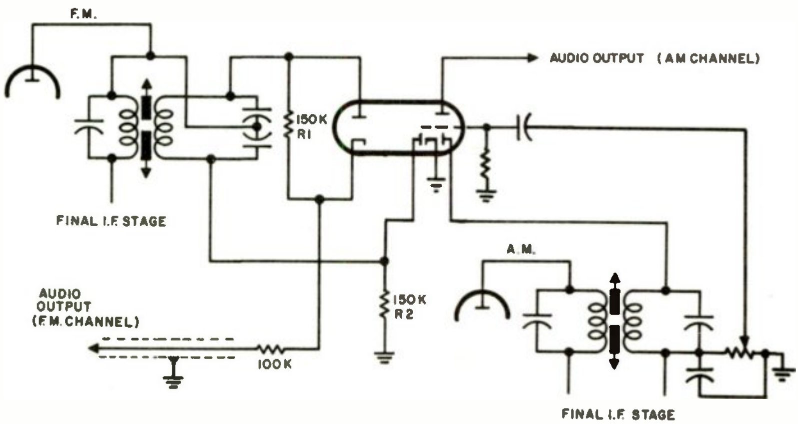



Fig. 816. *This circuit is similar to that of Fig. 815. The FM detector is a discriminator. The AM section uses a diode detector but this is followed by a stage of audio amplification. The audio output of the FM discriminator does not have this feature.*

You can run into odd troubles at this point. We can't expect equal signal strength out of both bands. In a fringe FM area, a low emission in the detector tube could result in very weak audio when the set is switched for FM. However, AM signal strength could be strong enough so that weakness in the detector tube might not be recognized. You can't expect both channels to drop strength in equal amounts.

If you get distortion when tuned to FM but not AM, check the 22,000-ohm diode load resistors. They should be equal in value for FM. The two resistors are not used for AM.

## Double detector and audio

In Fig. 816 we see how the idea of using a double detector is carried just one more step. Basically, the idea is exactly the same as that shown in Fig. 815 but now the tube is also used as the first audio amplifier for the AM section.

Because of the tube arrangement you may not spot the FM diode

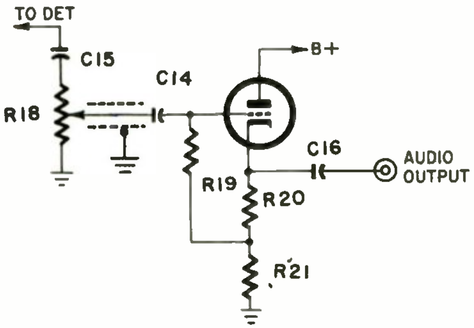



Fig. 817. *In some tuners, a cathode follower is the audio output stage. The signal at the output of the follower is less than at the input.*

load immediately. Look for a pair of equal value resistors. In Fig. 816 these are R1 and R2. Note in this case they are 150,000 ohms, a much higher value than the 22,000 in Fig. 815. They must still be fairly equal in value. Check with an ohmmeter. If either resistor is off value by more than 10%, you have an unbalanced condition that will upset the sound.

## Other detectors

Not all tuners use a double detector tube. In some, the FM detector will be either a ratio detector or a discriminator. The detector for AM will often be a semiconductor. With this arrangement you can work on the circuits separately, following the procedures given in an earlier chapter for servicing such detectors.

Having separate detectors will simplify repairs since the detectors are independent of each other. If FM sound is weak, distorted or missing, the ratio detector could be responsible, but you would not need to concern yourself with the AM detector. It's like having two horses pulling a wagon. It wouldn't take you very long to find out which horse needed to be rushed to the vet.

### Output circuits

In some tuners the output of the detector is the end of the line. This isn't always the case, since you will sometimes find a single stage of audio amplification. This could be an ordinary resistance-coupled triode amplifier or a triode working as a cathode follower. In some tuners, a dual triode is used–one half for FM sound, the other half for AM.

### The cathode follower

Ever watch a baby in a high chair at feeding time? A lot of food is pushed into a very reluctant mouth and almost as much comes spilling out. Some amplifiers are like that, and the cathode follower is one of them. No matter how much signal we stuff in, we always get out less.

In the cathode follower the signal input is between control grid and cathode while the output is taken off the cathode resistor. The use of the cathode follower is a loss of gain but it's a fine way of connecting a high-impedance circuit to a low-impedance load. We could have used a transformer for this purpose but it would take a well designed and expensive unit. The cathode follower costs less and does the job very nicely.

One circuit is shown in Fig. 817. In this case our servicing has been made a bit easier since it appears in a tuner for FM only.

### Cathode-follower troubles

The cathode follower of Fig. 817 is an audio tube. This means that we can test it just as we would any audio amplifier circuit, keeping in mind that we won't have any audio appearing at the plate of the tube. The plate is connected directly to the B-plus line and since this is always bypassed with high value capacitors, we have the plate at zero or ground signal potential.

You can check the circuit by click-testing it or by using any of the methods described earlier. Or, you can connect a scope across the input and the output, in turn. The cathode resistor, now acting as the load resistor, isn't bypassed any more than we would bypass a plate load.

No signal out of the cathode follower could be caused by a defective tube, an open in either of the coupling capacitors C14, C15 or C16, an open R19 (the grid-return resistor), or lack of B-plus on the plate.

Note the two resistors used in the cathode circuit, R20 and R21. Resistor R20 supplies self bias for the tube but R20 and R21 in series represent the output load. To determine the correct amount of bias, measure the voltage drop across R20 alone.

Not all cathode followers use two series resistors in this manner. In some followers just one resistor is used, this single resistor acting to supply self-bias and at the same time working as the load.

## Volume control

There's one thing we can say about tuners and that is you won't ever get bored with them. It's doubtful if any two tuners are exactly identical. The chances for being "different" are very good and it

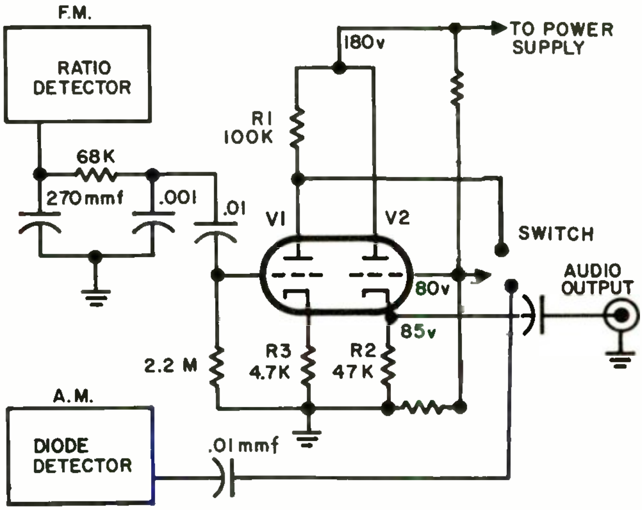



Fig. 818. *A double-triode is sometimes used for the audio output section of a tuner.*

does seem as though each manufacturer is trying his best to make them that way. You will find volume controls in some tuners, but don't reach for the knob instinctively. It may not be there. Some tuners have volume controls, others do not.

The circuit in Fig. 817 does have such a control. Note that the wire to the control from the cathode follower grid is shielded as shown by the dashed line, marked as being connected to ground.

The shielded cable used for this purpose can be very tricky. It is separated from the wire by an insulating plastic material which melts very nicely in the presence of heat, such as that supplied by a soldering iron. Since the shield is grounded, it shorts the signal to ground if, through some accident, the shield touches the center wire. This trouble usually happens at either end of the shielded wire, where it attaches to coupling capacitor C14 or to volume control R18. An ohmmeter check will tell you whether the wire has shorted to its braided shield.

If you need to replace the shielded wire, don't be tempted into using ordinary wire. The purpose of the shield is to keep hum and noise pickup out of the audio system. And when you do put in shielded wire, make sure that it is grounded. Ground does not mean laying the shield in against the chassis. Ground means a good ground. Wrap one turn of bare No. 22 tinned copper wire around one end of the shield. Solder as though you were working with a transistor—neatly and as quickly as possible. Solder the other end of the wire to a nearby ground point on the chassis.

Don't take for granted that your workmanship is perfect. Resistance check the wire to make sure you haven't grounded the "hot" lead. And don't make the wire any longer than you need.

## Double-triode output

Fig. 818 shows another way of getting the audio out, in this case from an FM–AM tuner. The FM section has its own demodulator, a ratio detector circuit, while the AM side uses a diode (crystal) detector.

If you've ever eaten in a boarding house, you probably have noticed that the best seats at the table are those nearest the kitchen. This is the unloading point. Fig. 818 reminds us of that situation.

The FM side of the tuner is favored in this case. Its signal gets fed into V1, the first half of the double triode. V1 amplifies the signal and then sends it along to V2.

V2 has no favorites. It works as the cathode follower for both the FM and AM detectors, but the FM signal does get the advantage of being amplified by V1.

## Servicing the amplifier-cathode follower

The circuit shown in Fig. 818 is only a partial schematic so we mustn't let it push us into any false conclusions. Our tube, V1-V2,

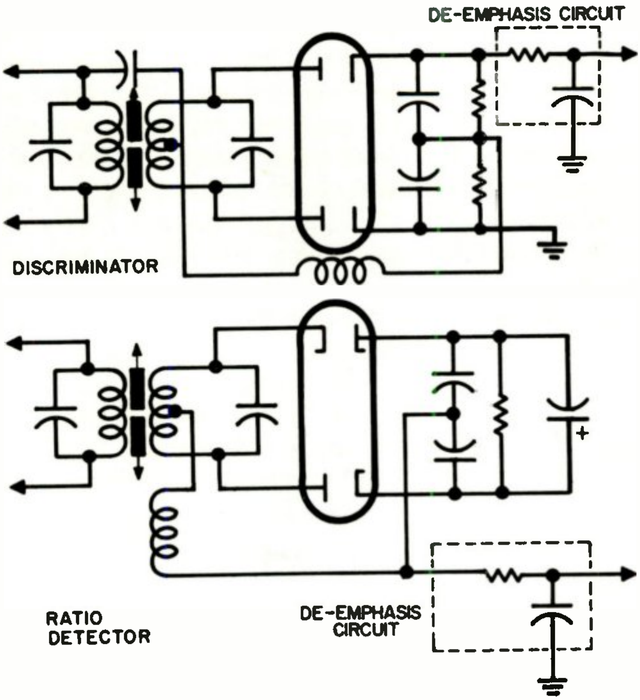



Fig. 819. *The de-emphasis circuit can cause frequency distortion if its values change.*

receives the audio from either the ratio detector or the AM detector, but not from both at the same time.

As a quick check on V1–V2, touch the grid of V1 with a screwdriver. A loud hum or squawk will tell you that the tube is working. If the sound is weak, try a new tube.

V1 is directly coupled into V2. This means that the plate voltage on V1 will also appear on the control grid of V2. However, the cathode of V2 has 85 volts on it, so the bias of V2 is 5 volts. If you get distortion, check the bias voltage. If the bias isn't what it should be, resistance check R1 and R2. R1 is the plate load for V1. If, for any reason, the plate voltage on V1 should rise, so will the plus voltage on the control grid of V2. This will reduce the bias. For example, if cathode resistor R3 for V1 should open, the voltage on the plate of V1 would rise to 180 volts. This would put a higher positive voltage on the grid of V2 and the grid would disappear faster than hot dogs at a picnic.

## Emphasis and de-emphasis

At the FM broadcast station there is a boost given to the high audio frequencies. This boost is produced by a pre-emphasis network. At the receiver we must lower the treble end of the audio by the same amount that the radio station has boosted it. This is done by a de-emphasis network made up of one or more resistors and capacitors.

The time constant of the de-emphasis circuit must be 75 microseconds. To get the time constant of the R-C network, we multiply the value of resistance by the amount of capacitance. Since we can

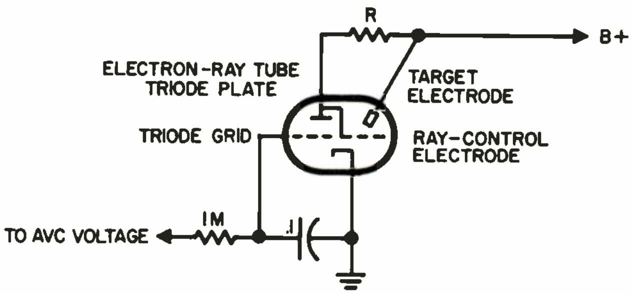



Fig. 820. *Indicator-tube circuit. Indicator tubes are often used with FM receivers or tuners.*

have any number of combinations which will give us 75 μsec, you will find many values used. De-emphasis circuits in FM receivers and in FM tuners are part of the detector circuit.

In Fig. 819 we have two such circuits, one for a discriminator detector and the other for a ratio detector. Actually, the type of detector circuit makes no difference. The product of R and C must still equal 75 μsec.

## Trouble in the de-emphasis circuit

The de-emphasis circuit has so few components that we generally have no trouble with it. However, the innocent-looking de-emphasis circuit could make us reach for an aspirin. If the values of the de-emphasis components should shift, so will the de-emphasis curve. The result is frequency distortion. This could send you off on a wild-goose chase for some more likely or frequent cause of distortion.

## Tuning indicators

How do we tune in an AM receiver? Just turn the dial until we get maximum sound and minimum distortion. With lower-cost receivers, though, we can't expect sound of too good quality. A good

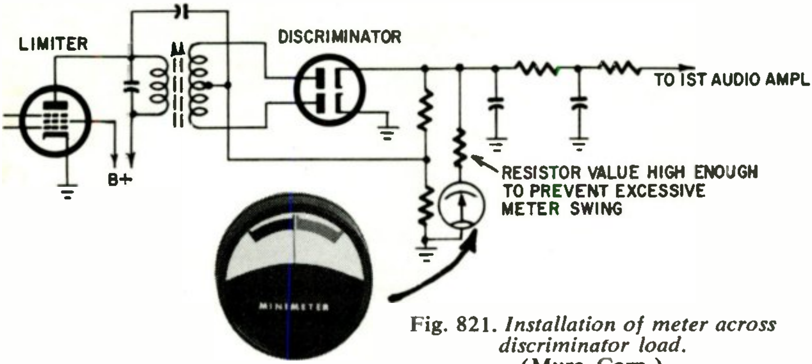



Fig. 821. *Installation of meter across discriminator load.* (Mura Corp.)

receiver or tuner is an expensive, well engineered device and the people who use them are inclined to be more fussy about the sound quality. For that reason you will often find tuning indicators included.

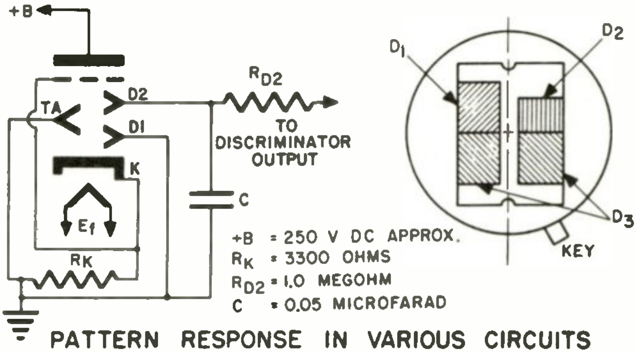
Fig. 820 shows a simple indicator circuit. The tube has a target area that glows when hit by electrons. The control grid of the triode section is tied into the avc line. When the avc voltage is less negative, as it would be for a weak signal, more current flows through the triode section, producing a greater voltage drop across resistor R. This puts a smaller voltage on the ray-control electrode, resulting in a shadow on the fluorescent area. When a strong signal is received, avc voltage is higher, less current passes through the triode section and as a result the voltage on the ray-control electrode goes up. More of the fluorescent area glows.

The receiver dial is adjusted until maximum glow area appears on the front of the indicator tube.

There are a number of types of indicators. Some are double indicators, others are single. They all work on the same general principle.

This is fine for AM reception where we tune for a maximum signal. FM is a different story. Tuning is for the center frequency at the discriminator or other FM detector. The simplest method, and often considered the best, is to connect a sensitive zero-center meter across the discriminator load with a series resistor as in Fig.

821. But meters were large and expensive for many years. A dual tuning-eye tube was developed to use in this circuit to give




PATTERN RESPONSE IN VARIOUS CIRCUITS

| CONTROL VOLTAGE SOURCE | OFF CHANNEL (-) | ON CHAN. OFF TUNE (-) | ON TUNE | ON CHAN. OFF TUNE (+) | OFF CHANNEL (+) |
|---|---|---|---|---|---|
| DISCRIMINATOR |  |  |  |  |  |

Fig. 822. *Basic circuit of dual tuning indicator tube. Electron beam is spread by positive voltage and compressed by negative voltage applied to D2.* (Sylvania Electric Products Inc.)

discriminator tuning indication. The basic circuit in Fig. 822 supplies this indication by the change in the box pattern displayed.

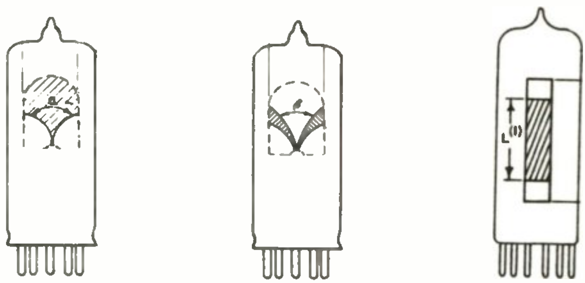



Fig. 823. *New indicator patterns are more appealing than the "cat's eye". Tube can be mounted directly on chassis, eliminating cables, extra connections and mounting hardware.* (Amperex Electronic Corp.)

The cost of meters has been reduced and their design made more attractive so they are now sometimes included as part of the eye-catching front panel of hi-fi tuners. In AM–FM stereo tuners,


Tuning indicator (electron ray) tubes are manufactured in a variety of sizes to make cabinet and panel design more flexible. One subminiature type moves along with the slide-rule-dial pointer. (Mura Corp.)

separate meters are often installed permanently across their respective detectors. There are no switches, no tubes, no resistors or capacitors, which partially offsets the extra cost of the meters.

Some cabinet designers and consumers consider meters too technical- or industrial-looking to be included in an entertainment device. So to please the consumer the tuning-eye was made smaller and patterns (Fig. 823) made more decorative and pleasing to the lady of the house.

## QUESTIONS

1. What is the function of the afc circuit?

2. Name the two sections of the cascode amplifier. What are their functions?

3. Why are tuning indicators important to FM receiver circuits?

4. What stage usually precedes a discriminator? What does it do? How can you test it?

5. Where is the de-emphasis circuit used? What is its purpose? What trouble can it produce?

6. What are the major characteristics of a limiter stage?

7. What is a double detector?

8. Why is the cathode resistor of a cathode follower unbypassed?

9. What is the advantage in using a grounded-grid amplifier stage?

10. Describe the function of a converter in the front-end of a receiver.

# CHAPTER 9 communications receivers

A COMMUNICATIONS receiver is to an ordinary radio set what a souped-up, streamlined, supercharged racer is to an automobile. Communications receivers are special. Designed to work with small-signal inputs, their sensitivity and selectivity are remarkable. Communications receivers are the royalty of radio.

## How good is good?

This type of radio—the communications set—ranges from inexpensive types to those costing several thousand dollars. They are built with precision and skill. They contain circuits not found in ordinary radio sets. All of them cover quite a number of frequency bands, some ranging from 500 kc to 34 mc. Other sets cover the region below 535 kc, while others are designed to operate in the uhf, vhf and the microwave spectrums.

Some receivers are SSB (single-sideband), operate on both AM and CW (code reception). You will find dual conversion sets with a crystal-controlled oscillator, special filters, electrical bandspread, and a beat-frequency oscillator (bfo). Most of these receivers come equipped with an automatic noise limiter circuit.

Right now we are looking for the new features, new circuits. We've learned how to service if stages, but what shall we do if the if is different from those we learned about? What shall we do if the rf or the detector circuits aren't the kind that are familiar to us?

Examine these circuits, find out how different they really are. To be able to fix them, we must understand them.

## Frequency range

Because the range of frequencies to be covered is so enormous, communications receivers switch coils in and out to cover various bands. In a typical set the bands might be something like this:

| | |
|---|---|
| Band A | 500 kc to 1.8 mc |
| Band B | 1.6 mc to 4.9 mc |
| Band C | 4.8 mc to 13 mc |
| Band D | 12 mc to 34 mc |

Band switching has its disadvantages. A band switch is a mechanical device. It can wear out, get dirty, get jammed. But when you pick a rose, you learn to watch out for thorns. If you get no recep-

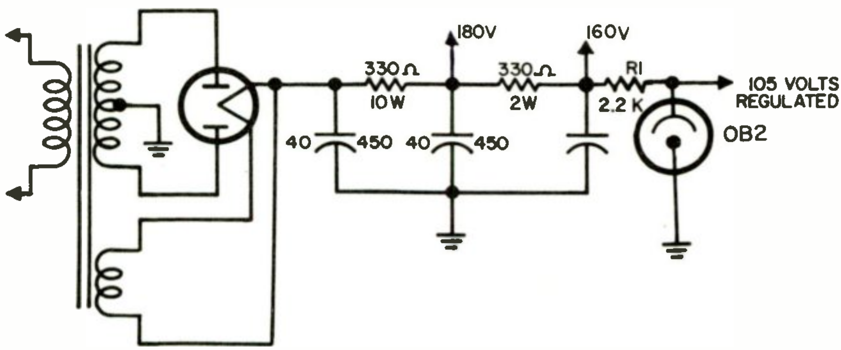



Fig. 901. *A gas tube is used as the voltage stabilizer in this power supply.*

tion on one band but the set works fine on all the others, you know enough not to go chasing around through the audio amplifier. Here the trouble could be in the switch or in the coils associated with that particular band. We know we're not plagued by tube trouble since the tubes work for all bands.

## So what's new?

A communications receiver is a superheterodyne. Basically, it is a first cousin to the lowly ac–dc receiver although most proud owners of communications sets won't even mention their pride and joy in the same breath with an ac–dc set. But the relationship does exist.

Because of the similarity it won't be necessary for us to go through the communications receiver, stage by stage, but we will spend our time on:

(a) Completely new circuits.

(b) Circuits to which we have been introduced before but which have been designed to work in a different way.

## Voltage stabilization

What happens when a current flows through a tube? Theoretically, at least, the current should remain steady until a signal comes along to disturb it. But unwanted plate voltage changes can also affect the current, not as much as the control grid, but enough to be annoying or disturbing. To avoid this we make the plate voltage regulation as good as we can.

For amplifier tubes in communications receivers, the regulation of the typical full-wave power supply is adequate. For oscillator

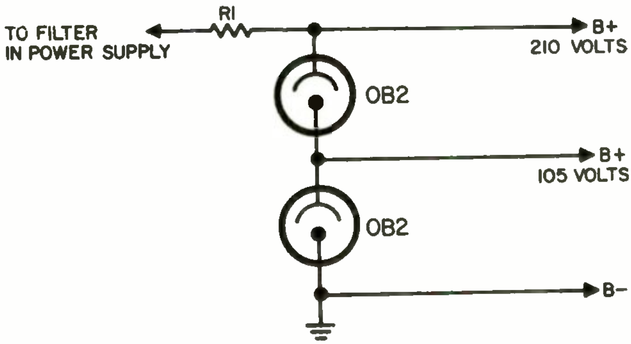



Fig. 902. *Regulator tubes can be connected in series to act as a voltage divider. A regulated voltage can also be obtained at the point where the two tubes are connected.*

circuits, though, somewhat better regulation is needed to remove one of the possible causes of oscillator drift.

An easy way of doing this is to use a gas tube in the power supply, as shown in Fig. 901. When the supply is turned on, the voltage appearing across the regulator tube is higher than 105. This drops to 105 when the gas tube "fires" or "ionizes". The tube then glows with a red or purple color (depending on the type of gas used in the tube). If the voltage at the plate of the regulator should try to rise, more current will flow through the tube, and a greater drop will appear across R1. Should the current through the tube decrease, the drop across R1 will decrease and the voltage at the plate of the regulator will rise.

How do we know if the regulator is working? If it is glowing, it is very likely hard at work. Connect your vom or vtvm to the plate of the tube, with the meter set to read 300 volts dc, full scale. The meter pointer should be absolutely steady. Now tune in a station, preferably one that will give a strong swing on the S-meter (if the receiver has one) or that will produce a loud signal. (You may have to set the band switch to the broadcast band to do this.) Once again, the pointer should remain steady at 105 volts. If it fluctuates, check the value of R1 and the B-plus voltage on the unregulated side of R1. If the resistance and voltage values are correct, try a new regulator tube.

The current through the gas tube depends on the type that is used, but on the average ranges from about 5 to 40 ma. The voltage at the plate of the regulator (when the supply is first turned

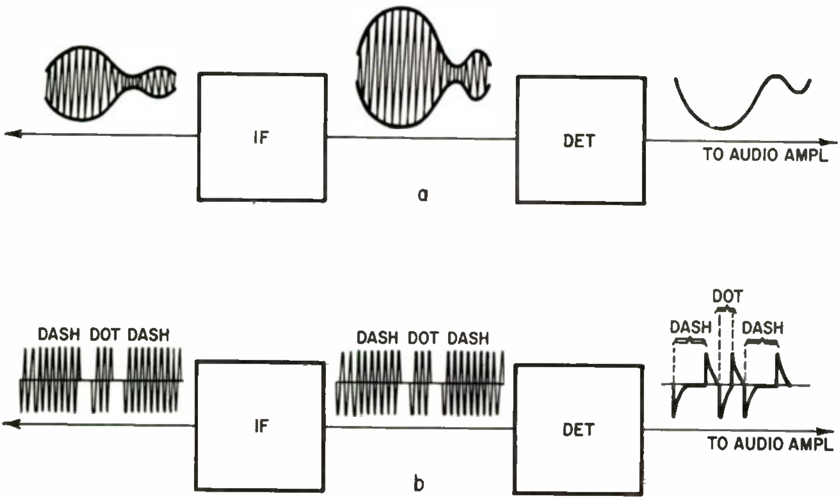



Fig. 903. *Audio modulation on the rf/ca if signal (a) easily passes into audio amplifier. Code transmission (b) has no audio and only start and stop edges of the code characters are passed on to the audio amplifier.*

on) must be higher than the value of regulated voltage, otherwise the tube will not "fire". To check this, connect your test instrument to the plate of the regulator tube. Set the meter to read 300 volts dc, full scale. In the circuit of Fig. 901, the meter pointer should swing up beyond the 105-volt point, and then, as the regulator fires, should drop back to 105.

Two regulator tubes can be put in series, as shown in Fig. 902 to get twice the regulated voltage. Since the tubes act as a voltage divider, a tap can be put at the point where the two tubes are connected.

Gas tubes are available which can regulate at as low as 75 volts. Others are manufactured which regulate 90, 105 and 150 volts. Make sure you use a correct replacement when you substitute new tubes. Regulator tubes in series need not be identical.

## AM vs CW

Suppose we have an AM broadcasting station with everything going full blast, with one exception. No one is talking or singing into the microphone.

What does this tell us? Our first (and natural) reaction would be to say that nothing is being broadcast. But is that really true? We know that the carrier isn't being modulated, but what about the carrier itself? Why should it stop working just because the microphone isn't employed? So the station carrier goes on its happy way until it reaches the antenna of your receiver. Does it stop there? Why should it? And so it goes into the receiver, is changed into an if by a converter and then reaches the detector. Is this a stopping point? Again, why should it be? The carrier is rectified and then passes into the audio amplifier.

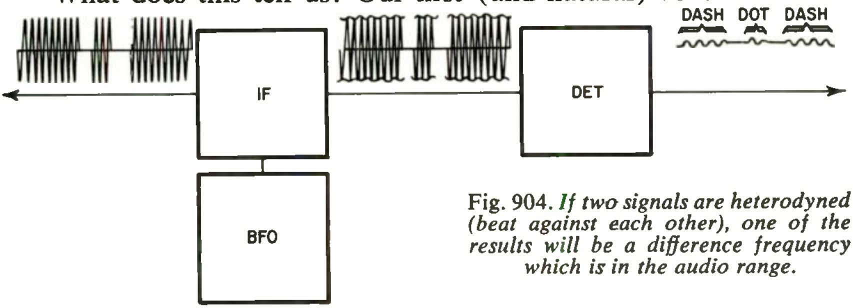



Fig. 904. *If two signals are heterodyned (beat against each other), one of the results will be a difference frequency which is in the audio range.*

What is this rectified carrier? If the original carrier came from a broadcast station we know that it was transmitted within a certain frequency range. But our converter changes every station to a single, intermediate frequency. It is this intermediate frequency which is sliced in half by our detector. Suppose this frequency is 455 kc. (Remember–there is no modulation on it.) What can our audio amplifier do with that? And if some of this 455 kc could get through the audio amplifier, what could the speaker do with such a high frequency? And, finally, even if the speaker could possibly respond, our ears couldn't. At best, our hearing only goes up to about 20 kc.

Under what circumstances will we hear a signal? Only if the carrier is modulated—that is, if we change it in some way so that we can hear it (Fig. 903-A). Modulation is something that is usually done at the broadcast station, but we can modulate the carrier in the receiver.

We can make the carrier convey information by chopping it into longer and smaller pieces at the transmitter, but at the receiver we will need the cooperation of a special circuit known as a beat-frequency oscillator.

## The bfo

Did you ever walk into a dark room after having been out in bright sunshine? For a minute or two you see absolutely nothing, and then, as your eyes begin to adapt, you manage to begin to see.

We can "adapt" our ears to the carrier with the help of a little electronic trick, shown in Fig. 904. In the receiver we have a

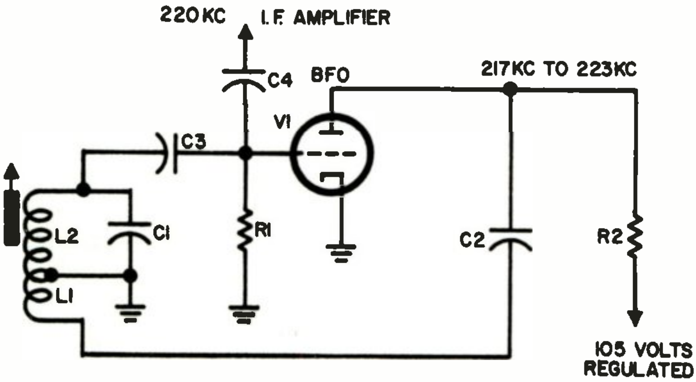



Fig. 905. *This bfo is a Hartley oscillator.*

circuit known as a bfo. This is an abbreviation for beat-frequency oscillator, a good name, because it tells us just what the circuit is supposed to do. The bfo generates a frequency which beats with the intermediate frequency signal in the receiver.

If the if is 455 kc, we could set our bfo at 456 kc (or 454 kc) and mix or "beat" the two frequencies. The output consists of a number of frequencies, but the one we are interested in is called the difference since it is equal to one frequency minus the other.

Let's see what a typical bfo looks like. The one in Fig. 905 is a Hartley oscillator. Feedback is through capacitor C2 to coil L1. L1 is part of the feedback circuit. C3 and R1 are the grid leak and grid capacitor and furnish bias for the tube. Note that the

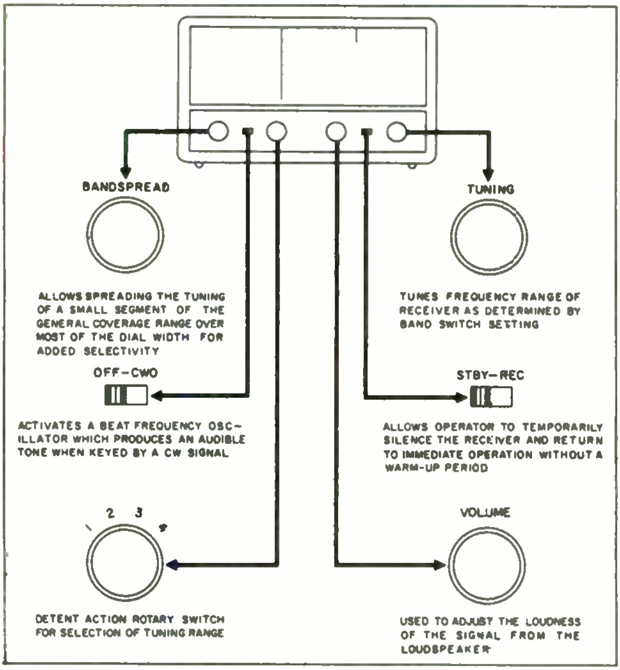



Fig. 906. *Communications sets have a large number of controls.* (National Radio Co. Inc.)

plate of the bfo is connected to a regulated source similar to that in Fig. 901.

When the receiver is turned on, the bfo will oscillate at a frequency set by the values of C1 and L2. Either C1 or L2 is adjustable so that the frequency of the bfo can be changed over small limits.

What are these limits? In the case of Fig. 905, our bfo will work in the range of 217 to 223 kc. If we set the bfo to 217 kc (its lower limit), the output from the if amplifier will be the difference between these two frequencies, or 3 kc (220 − 217 = 3).

Now suppose we set the bfo to its upper limit. What do we have then? Once again we will have a 3 kc output from the if (223 − 220 = 3).

This tells us that the maximum frequency of the audio tone we will hear will be 3 kc. We could set the bfo to hear any lower-frequency tone (such as 2 or 1 kc). When the bfo is at exactly the same frequency of the if (or very close to it) we will hear nothing.

## Bfo troubles

We use the bfo only when our receiver is set to pick up CW. What is CW? This is an abbreviation for continuous-wave or code signals. This sort of signal consists of a carrier only, with no modulation. We need the bfo since, without it, it would be impossible to hear anything.

A switch on the front of the receiver is used to turn the bfo on and off. As a quick check, turn the receiver band-selector switch to the broadcast band and tune in a station. This signal will be modulated—that is, we will be able to hear speech or music. Now turn on the bfo by means of the bfo switch. You should hear a whistle. If you do not, turn the bfo frequency control slightly. If the set does not have a variable control, turn the tuning dial slightly. If you still do not hear a whistle, turn the tuning-range switch and pick up a code station. Try to select a strong station. You won't hear sound but, if two CW stations are close to each other in frequency, you may be able to heterodyne between them to get sound.

Suppose, though, your set works fine with speech or music but you are unable to hear code signals. Examine the power supply. Is the regulator tube conducting, as shown by a glow? Set your vtvm on the 300-volt dc scale and measure at the plate of the bfo. If you get no voltage here, move the test prod over to the plate of the gas tube regulator. Voltage here indicates R2 (Fig. 905) is open.

If you do get voltage at the plate of the bfo but it is much lower than the amount shown on the schematic, you have an indication that the tube (V1) isn't oscillating. When V1 oscillates (as it is supposed to do), it produces a negative bias (with the help of C3 and R1) which acts to keep tube current low. When the tube does not oscillate, a much larger current flows through the tube. This current passes through R2, producing a large drop across it, hence much less voltage remains for the plate of V1.

As another check to determine if V1 is oscillating, connect your vtvm between control grid and cathode (actually across R1). Set the instrument to read negative dc volts on its 10-volt scale. You should read several volts negative on the control grid. If not, the tube is not oscillating.

Failure to oscillate could be caused by lack of B-plus voltage, an open or excessively leaky feedback capacitor C2, a defective tube or a defective grid leak (R1) or grid capacitor (C3). Sometimes the slug inside coils L1 and L2 shorts the terminals. Broken, loose or corroded connections can also put the bfo out of operation.

If the bfo is working but you get no beat action, shunt C4 with a small capacitor. Any capacitor having a value of .0001 (10 $\mu\mu$f) $\mu$f or less will do. If this restores operation, C4 is open.

## Controls

There is one thing you can say about almost any communications receiver and that is it usually has enough dials and knobs to keep any dial-twiddler happy. This doesn't mean they aren't needed. They most definitely are. But you should examine each knob and know just what each one is supposed to do.

Fig. 906 shows the controls on one type of communications receiver. There are six controls, some of which are fairly obvious, while others may require a few words of explanation.

## Bandspread

Even with low-cost ac–dc receivers, there is no difficulty in

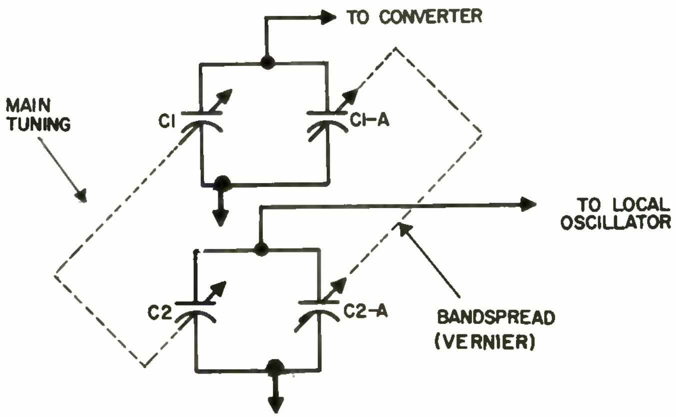



Fig. 907. *Communications receiver tuning and bandspread capacitors operate independently of each other.*

separating stations on the AM broadcast band. Receiver selectivity is good enough so that we can pick out each station easily.

On the broadcast band, though, each station is assigned a particular channel and a particular time for operation, and a limit on the maximum transmitter power that can be used. Other services on other channels must share frequencies and, as a result, two stations may be transmitting simultaneously on frequencies close to each other. This is especially true of code transmissions.

If two stations are very close to each other, we can use several methods of tuning them in. One would be to use a vernier dial so that rotation of the control would result in a very small motion of the tuning capacitor. A set of gears inside the vernier could take care of this for us.

Still another method is to shunt the main tuning capacitor with a variable unit having a much smaller capacitance. Thus, in Fig. 907, we see that the main tuning capacitors (C1 and C2) are shunted by variable capacitors (C1-A and C2-A). The main tuning capacitors are used to get as close to the desired station as possible. The band-spread units are then rotated until the station is tuned in. The tuning capacitors are ganged and are controlled by the main tuning knob. This knob also operates a dial indicating the approximate frequency of the station selected. The band-spread control operates the bandspread capacitors and its dial but does not change the main tuning dial setting as the vernier system does.

### Tuning troubles

Because communications receivers cover quite a number of bands, often four or more, it is easy to decide if trouble exists in the front end. If all bands work except one, then the trouble is up at the front end.

Tuning capacitors bring their share of troubles. Look for plates that short or connections that are loose. Sometimes tuning-capacitor plates will touch only when the plates are fully meshed or close to it. The result is that the receiver will work well on stations from the middle- to the high-frequency end of a band but will be dead for stations at the low-frequency end.

If you get a scratching sound or if the set sounds noisy when you turn the main tuning control, look for mechanical defects. An ohmmeter check across the capacitor won't help since it is shunted by low-resistance coils. However, the stator is usually connected to the band switch by a single wire so it should be fairly easy to lift this temporarily. Disconnect at the capacitor end, rather than at the switch end.

### Receiver analysis

Some communications receivers are fairly complex; others are much less so. Fig. 908 shows a type that covers broadcast and short-wave bands. This receiver covers four bands, selected by wafer switch sections. Note that the band-spread and tuning capacitors have the arrangement shown in Fig. 907.

This circuit has no separate bfo tube. Instead, the first if ampli-

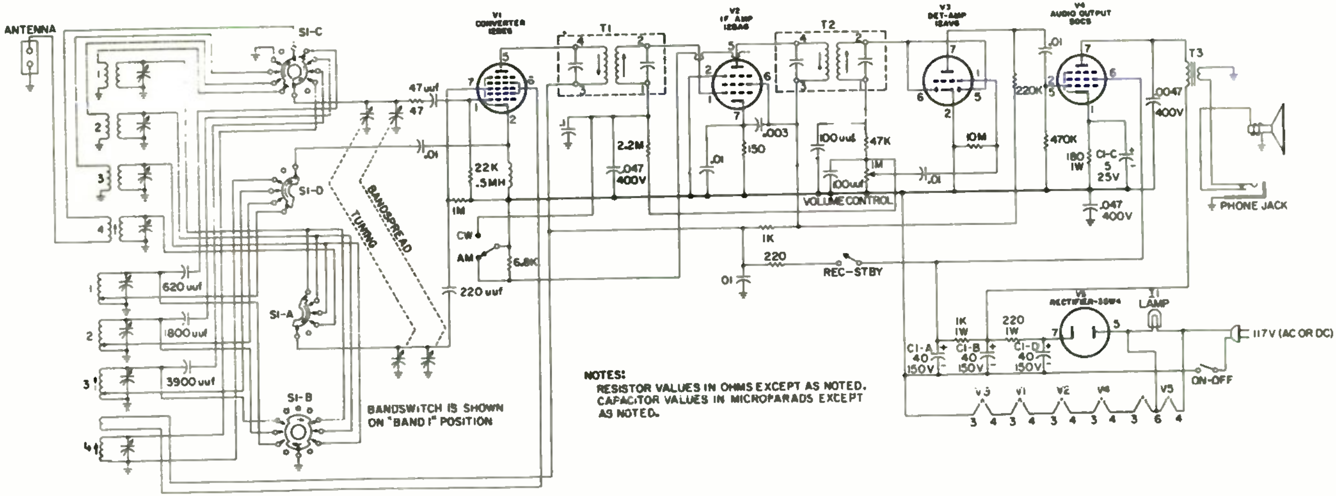



Fig. 908. *Simple type of communications receiver. Rotary wafer switches are used to select any one of four different bands. The set has bandspread tuning. Regeneration is used in the first if for CW signals.* (National Radio Co., Inc.)

fier tube is made to regenerate. When the single-pole double-throw switch is put in the CW position, we get feedback from the plate of the first if amplifier to its control grid. When the switch is put in the AM position, the feedback wire is grounded to the B-minus line.

A little earlier we mentioned the number of controls on a communications receiver. You can get some idea of the various knobs

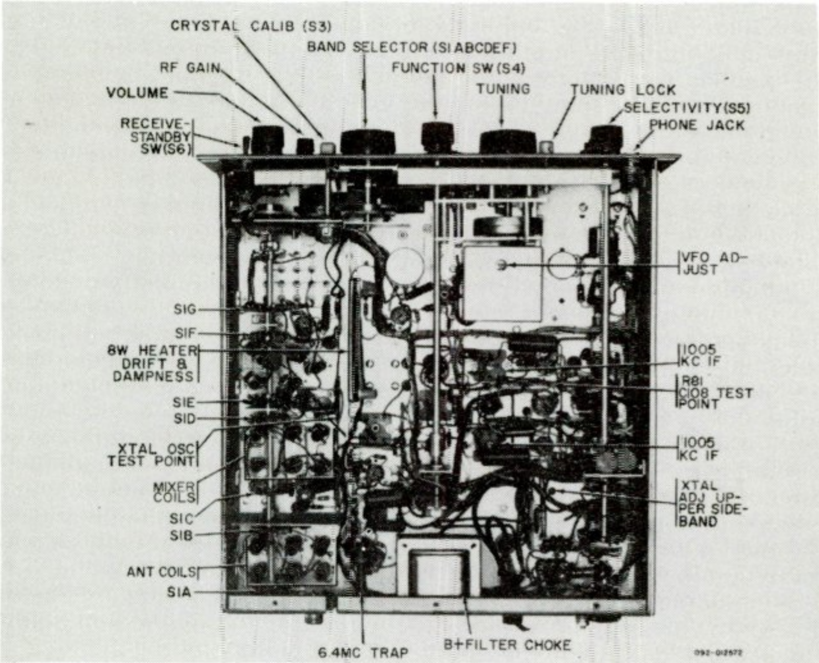



Fig. 909. *Communications receivers have many more controls and adjustments than the ordinary receiver used on the AM broadcast band. These must be made correctly if the receiver is to work as well as it should.* (The Hallicrafter Co.)

and switches by examining Figs. 909 and 910. Fig. 911 shows a communications receiver at work in a ham station.

## Receiver construction

Some of the older communications receivers use point-to-point wiring, but the trend is toward the printed-circuit board. In some sets you will find a single board, but in the bigger receivers you may find two boards mounted on a metal chassis with cutouts provided for the boards. Small printed-circuit assemblies are mounted either on the main printed-circuit board or on a metal chassis. Fig. 912 shows the underchassis view of a communications receiver using several printed-circuit boards.

## Calibrating the receiver

For some communications purposes, it is essential that the operator of the receiver know the frequency of a particular station.

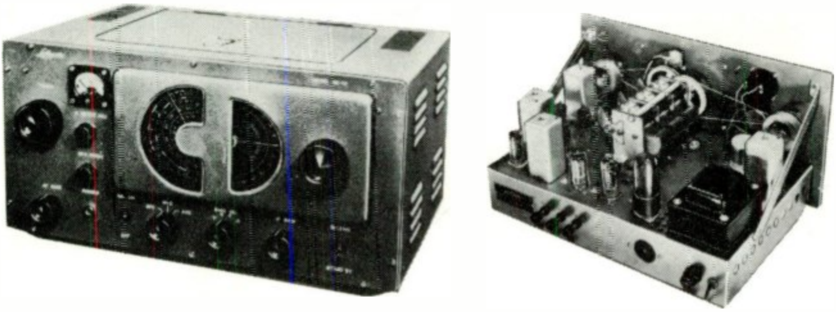


Fig. 910. *With 9 tubes and 10 controls this communications receiver chassis is not crowded. Speaker is in separate cabinet.* (Lafayette Radio Electronics Corp.)

One way of doing this is to tune in on stations whose frequency is known. US Bureau of Standards station, WWV, broadcasts on these frequencies:

2.5 mc
5 mc
10 mc
15 mc
20 mc
25 mc

Another station, WWVH, in Hawaii, operates on 5, 10 and 15 mc. Their broadcasts are characterized by standard tone frequencies and a time interval tick. Other information, such as ionospheric conditions, are inserted at scheduled intervals.

To calibrate the dial, it is necessary to pick up WWV on each of its frequencies since accuracy on one band in the receiver doesn't necessarily mean accuracy on another.

Some receivers come equipped with a means for plugging in a crystal calibrator. This consists of a 100-kc crystal oscillator. Power for the tube is taken from the receiver's power supply. The circuit for a calibrator is shown in Fig. 913. When the calibrator


Fig. 911. *Communications receiver being used in a ham station.*
(Allied Radio Corp.)

is turned on, it supplies beat notes every 100 kc. If calibration is very far off, the rf coils of the particular band being checked need realignment.

If the receiver you are checking does not have provision for crystal calibration, use an external calibrator. The trouble with a calibrator is that getting beats every 100 kc can be very confusing. You can use a 1-mc crystal calibrator instead, and once you have spotted points 1 mc apart on the dial, you can fill in by using a 100-kc calibrator.

For a short-wave listener, extreme accuracy won't be necessary. With the help of the calibrator you can make up a chart showing dial numbers vs frequency.

## Troubleshooting the calibrator

The calibrator in the circuit of Fig. 913 has a small trimmer, C1. This will vary the frequency of the crystal enough to enable a zero-beat on WWV. If you get no zero beat, check the voltage at the plate of the oscillator. If it is much below the value specified by the manufacturer, the tube is not oscillating. Check bias and screen voltages. The trouble could be a defective tube.

## Image rejection

In the usual superhet, a local oscillator signal beats against the incoming signal from the radio station to produce an if signal—

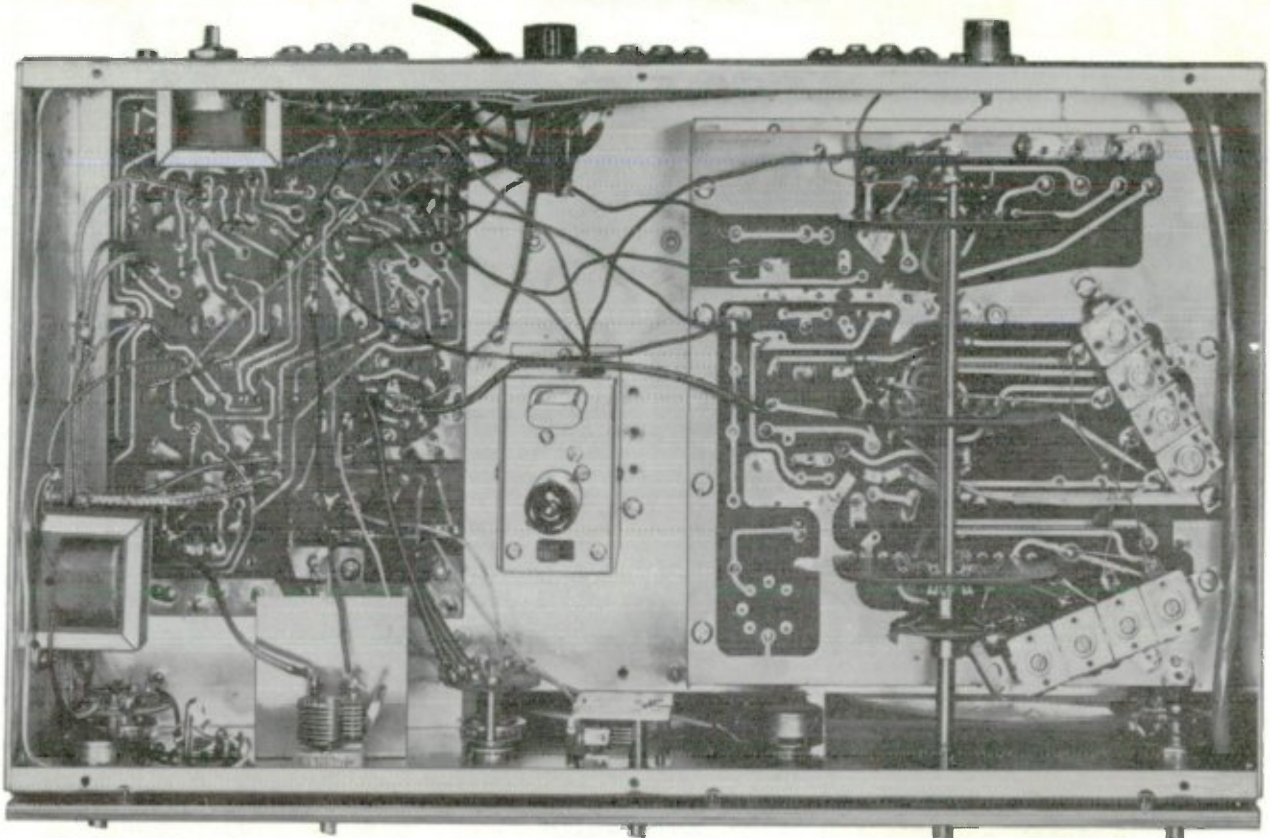


Fig. 912. *Communications receivers are often constructed with one or more printed-circuit boards.* (Allied Radio Corp.)

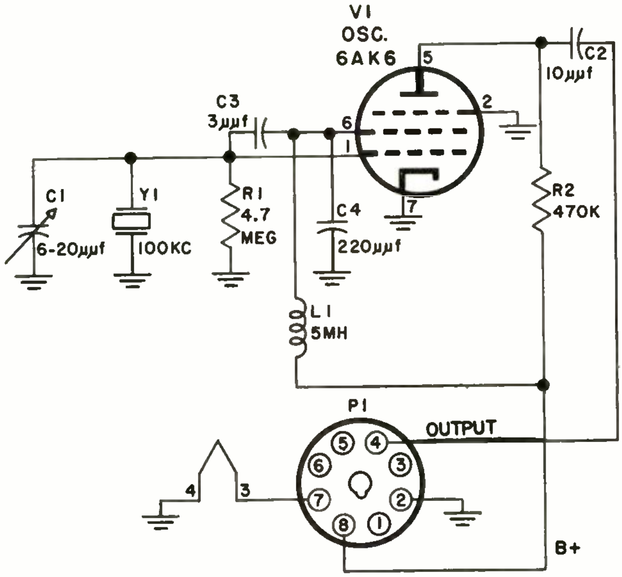



Fig. 913. *Crystal calibrator helps make the receiver a precision frequency instrument. (National Radio Co., Inc.)*

the intermediate frequency. Just as an example, suppose our incoming signal is 545 kc and our local oscillator at this time is at 1000 kc. Our intermediate frequency would be:

$$1000 - 545 = 455 \text{ kc}$$

Suppose, though, that at this time another radio station is transmitting on a frequency of 1455 kc and that it is sufficiently strong to force its way into our receiver, even though our dial isn't set for this frequency. What will our local oscillator do with this signal?

$$1455 - 1000 = 455 \text{ kc}$$

This is the sort of output our if stage likes, and so we now have two signals running through the if. They will both be amplified, detected and heard in the phones or speaker. It is true that the second signal, the one at 1455 kc, will be weaker, but it can be loud enough to be annoying. This second signal is known as an image.

The greater the number of tuned rf stages we have, the better is our chance for image rejection. Images on the broadcast band don't bother us too much, since, if they do occur, we just tune to a different station. But in a communications receiver we do not have a choice. The station we are listening to is the one that has a message for us.

### Double conversion

Adding more tuned rf stages is one method for cutting down on images. Another is by using double conversion, as shown in the block diagram of Fig. 914.

The station signal is brought into the mixer, beats with the

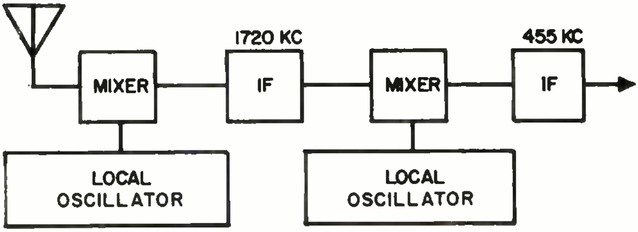



Fig. 914. *Block diagram of a section of a double superheterodyne reeciver.*

local oscillator to produce an if of 1720 kc. This if is then brought into another mixer where it is beat once again with an oscillator voltage, this time resulting in an if of 455 kc.

The if's used are selected by the manufacturer and vary from one receiver to the next. The choice of if's will even be different in various models of receivers made by the same manufacturer. In Fig. 914 the two if's are 1720 kc and 455 kc. In another receiver they could be 2215 kc and 230 kc. The first if could be any frequency from 1000 to 10,000 kc. You will find double if's, though, only in the more expensive communications receiver.

The higher the first if, the greater the separation between the wanted frequency and the annoying image frequency. The greater this separation the weaker the image signal voltage will be when it passes through circuits that are not tuned for it.

### Checking the if's

In an earlier chapter we learned how to check the if stages of AM broadcast receivers. The same troubles that exist in those sets can appear in communications sets. There is a difference, though. The average AM receiver, especially the ac–dc type, is made to sell for a fairly low price and as a rule the components are seldom top quality. In the more expensive communications sets you will find a much better grade of parts.

What does this mean to us? Use the best components when making replacements. Even in communications receivers, parts can and do go bad, change value, dry out or weaken with age.

Most ac–dc sets are fairly alike in their general circuit design. Communications sets are more individualistic. Don't try to work on them without a circuit diagram. If a set is a double superheterodyne, you will need to know the two if's.

Although we show two local oscillators in Fig. 914, we do not want you to think that these are alike in every respect. The

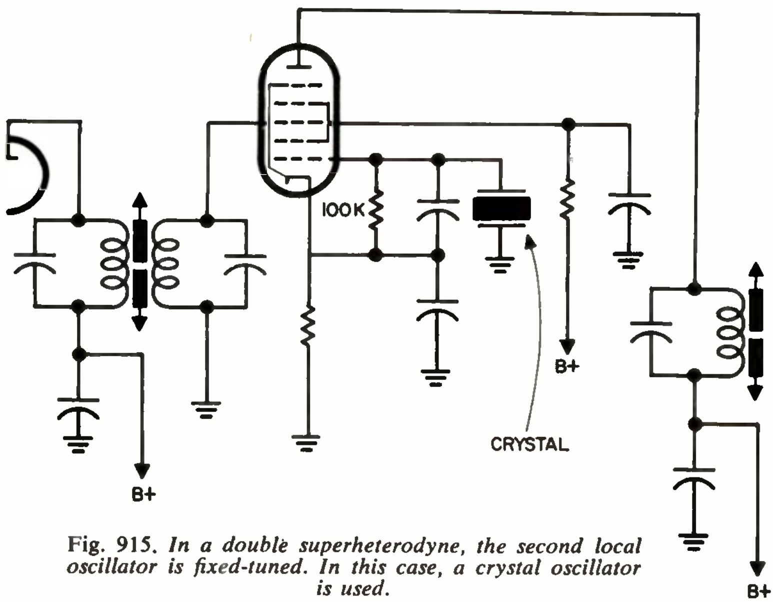



Fig. 915. *In a double superheterodyne, the second local oscillator is fixed-tuned. In this case, a crystal oscillator is used.*

first local oscillator is continuously tuned. This is necessary since we are going to pick up quite a variety of signals of all frequencies. The local oscillator must be tuned since its frequency must always be higher than that of the incoming signal. In the case of Fig. 914, the first local oscillator will always be tuned to a frequency 1720 kc above any incoming signal.

But what about the second local oscillator? It must beat with a frequency of 1720 kc. This frequency is the same regardless of the station being received. As a result, the second local oscillator can be fixed tuned and is often crystal controlled. In the case of

Fig. 914, the second local oscillator will be 2175 kc. This frequency, beating with the if of 1720 kc, will give us our if of 455 kc:

$$2175 - 1720 = 455 \text{ kc}$$

In Fig. 915 we have a pentagrid converter. This tube receives the if signal. One part of the tube, though, works as a crystal oscillator. With two signals going into the tube, one of the output frequencies will be the new if.

## Antenna trimmer or compensator

"Once upon a time" is a good way to start any story and the story of radio is no exception. Once upon a time all radios used

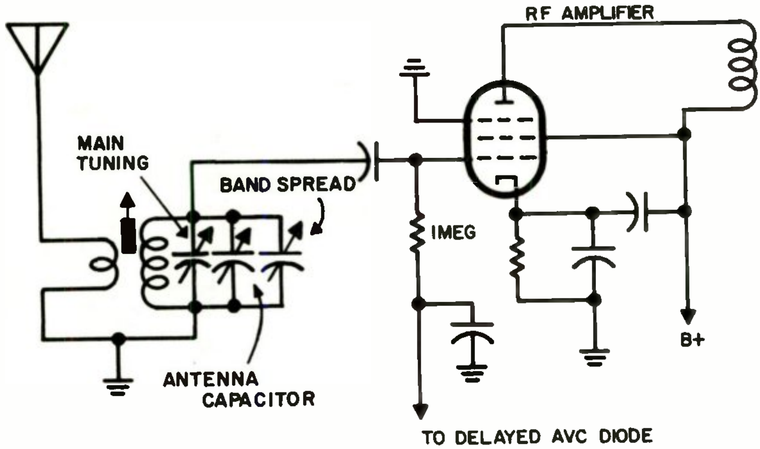



Fig. 916. *Antenna capacitor actually tunes rf amplifier. If antenna or lead-in is too long, excessive capacitance coupled to tuned circuit will detune it. With too short an antenna, the capacitance will be too little. The loading capacitor is used to increase or decrease the capacitance across the coil to compensate for the variation.*

outside antennas. As tubes were made to give more and more gain and the transmitters more powerful, the antenna got smaller and smaller, and, in the case of AM broadcast receivers, crawled right into the set.

For communications sets, though, we need a good outside antenna. An antenna is a broadly tuned circuit which can be "tuned" by changing its length. But a communications receiver covers such a very wide band of frequencies that it is impossible to have one antenna suitable for every wavelength.

We can change the "electrical" length of antenna in a number of ways. We can put a coil in series with it, as is often done in the case of auto radios. Another technique is to put a variable capacitor in series with the antenna or to connect a variable capacitor between one end of the antenna and ground. A variable capacitor used in this way is called an antenna trimmer—a good name since it does "trim" the antenna.

Fig. 916 and 917 show two antenna-trimmer circuits. The trimmer is mounted on the front panel of the receiver. Adjustment is simple. Tune in a station and then turn the trimmer knob until the signal is maximum. But you can do more than that. With the help of the trimmer an offending station can often be pushed into the background to minimize or eliminate the interference.

Very little can go wrong with this control. To see if it works,

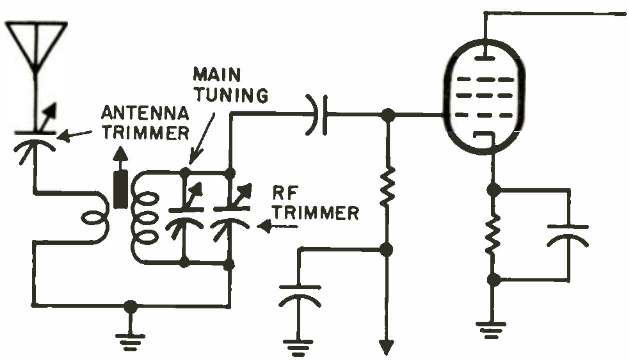



Fig. 917. *Antenna trimmer is also helpful in separating stations.*

tune in a station and then rotate the trimmer. It should have some noticeable effect. If it doesn't, check to make sure that someone hasn't disconnected it for some reason. The trimmer lead could be removed and the set still operate.

In Fig. 916, if the trimmer is shorted, signals will be killed on all bands. In Fig. 917, a shorted trimmer won't be noticed, except if you try to use the trimmer to improve the signal.

The circuit in Fig. 916 is used to compensate for the loading of the antenna capacitance on the rf tuned circuit. It also adjusts for slight variations in the tracking of the rf amplifier, mixer and oscillator tuned circuits.

The trimmer in Fig. 917 is more effective on the high frequency bands. Its effect becomes less and less noticeable as you approach the AM broadcast band.

## Noise limiters

You might think that the life of a radio signal is an easy one. But the radio signal, like almost everything else, has competition. All sorts of noise voltages conspire to drown out the signal.

Noise can come from outside the receiver and also from inside. All sorts of devices have delusions of greatness and try to act as

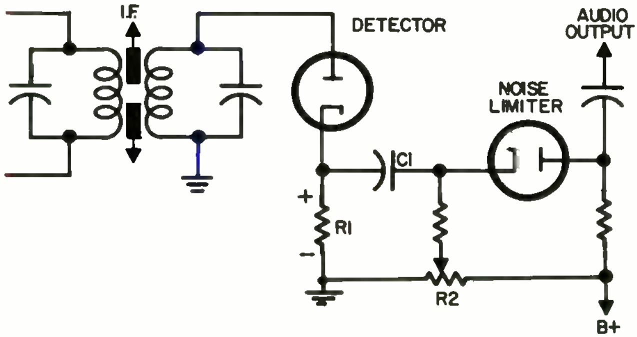



Fig. 918. *This noise-limiting circuit has to be adjusted for noise conditions. It is called a manual noise limiter (mnl).*

transmitters (and some of them do it very successfully). Motors with carbon brushes and other arcing contacts generate electrical noise. The well known offenders are neon and fluorescent lights, automobiles and electrical appliances such as vacuum cleaners, mixers, refrigerators, washing machines and elevators.

Inside the receiver, noise is produced as the current flows through components and past tube elements. Tubes, especially multi-element types such as pentodes and pentagrids are noisy. So, too, are gas tubes. Current flowing through resistors results in noise, although there are resistors especially designed to minimize this effect.

Poor connections, intermittent connections, corroded connections—all produce noise. A poor ground connection or an antenna and lead-in that flop around in the breeze produce noise. A washer can result in noise if, instead of making biting contact with a metal chassis, it makes poor or intermittent contact. Worn controls produce noise.

Finally, to add to this long (but by no means complete) list, Nature adds her own noise to our growing collection. Static, lightning, atmospheric conditions—all add up to more noise.

We admit the situation looks very bad, and sometimes it is, but before we hang a "for sale" sign on our communications receiver, let's see what can be done about the problem.

There are many types of noise-limiting circuits, one of which is shown in Fig. 918. The detector rectifies the signal, and the audio current flows through R1. The signal is resistance-coupled to the noise-limiter diode.

Note that the top end of R1 is positive and it is this varying positive voltage that is applied to the cathode of the noise limiter. Ordinarily a positive cathode would cut off the diode, but a B-plus voltage is applied to the plate. As long as this voltage is higher than the signal put on the cathode, the noise limiter will conduct and the signal will be transferred to the next stage.

Suppose, though, a noise pulse rides right in with the signal, which, in its own nasty little way, it will do. If the noise pulse is big enough, it will make the cathode of the noise limiter more positive than its plate and the tube will cut off.

You will probably argue that this will kill the sound too, and you will be right. But, unlike man-made modulated signals, noise pulses usually come in short, separated bursts. The time that the diode is cut off is extremely short, not enough to give you the impression of missing audio.

## Mnl vs anl

Some noise limiters have a potentiometer so that the point at which the noise limiter comes into action is under the control of the operator. There could be a variable resistor in the plate of the limiter so that its B-plus voltage could be adjusted. In the circuit of Fig. 918, the mnl (manual noise limiter) control is potentiometer, R2. Its setting puts a greater or lesser amount of dc on the cathode of the noise limiter.

Anl (automatic noise limiter) refers to a noise-limiting circuit that does not require the attention of the operator. Some sets have a switching arrangement so that the operator is given his choice of anl or mnl.

## Rf gain control

Did you ever eat a buffet dinner where you had to select different kinds and amounts of food to make up your meal? If the buffet is well organized, you may spend more time choosing your food than eating it.

A communications set has a similar sort of problem. It has a tremendous assortment of signals to pick from. You mightn't think that so bad, but the signals at the antenna range from those that are so weak that even a blood transfusion wouldn't help, while other signals are so strong that they would blast like dynamite if given half a chance.

Now that's exactly the point. Do we want to give signals a chance to do this? What about our automatic volume control? Isn't that supposed to protect us against very strong signals?

When a very strong signal comes in, our avc voltage is high. This avc adds to the existing bias we have put on the controlled

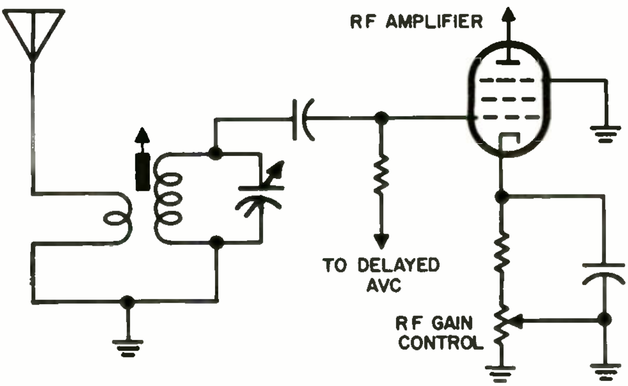



Fig. 919. *Rf gain-control circuit.*

tubes. A strong signal will make the total bias very high, driving the if tubes right into the curved part of their characteristics and causing lots of distortion. In other words, avc isn't a cure-all. It has its limitations.

There is a simple and easy way of getting around this problem, as shown in Fig. 919. All we do is put a potentiometer in series with the cathode of the rf amplifier tube. The control, now known as an rf gain control, supplies part of the bias for the tube. When the arm of the control is at the ground end, we get maximum bias.

What about avc for this tube? The tube still gets its avc voltage, but since the rf gain control has reduced the gain of the tube, the avc voltage will be much less than it would have been otherwise.

## Checking the gain control

You can check the gain control in two easy ways. The easiest is to tune in a strong signal, vary the gain control and note the effect out of the speaker or on the S-meter. Another method is to set your vtvm to read low volts dc and connect it directly across the rf gain control. Vary the arm of the control and note the effect on the bias. There should be a definite change. Still another technique is to connect the vtvm between control grid and cathode and note the effect the gain control has on the overall bias.

### Audio gain

On most communications receivers you will find a control marked afg (audio frequency gain). This is a volume control and you will find it where volume controls are usually connected . . . somewhere between the detector and the first audio. Volume-control troubles are no different from those in ordinary broadcast receivers. And, as in the case of broadcast receivers, the on-off switch is mounted on the volume control unit.

### Phone operation

Communications receivers always have provision for earphone operation. Some sets have jacks for two phones; others just one. Fig. 920 shows a typical audio output arrangement.

The resistor appearing across the secondary of the output transformer makes certain that there will always be a load on the transformer. When the phones are plugged in, the speaker is automatically disconnected.

The speaker is a PM unit and, in many sets, is a separate item.

### S-meters

People who use communications receivers are like sports car or boating fans. They take their fun seriously. They like to know everything that happens, everything that is going on in their particular hobby.

What does go on? A signal comes into the receiver. How big is the signal compared to others that have been received? The meter that tells us this is called a signal-strength meter or an S-meter.

Our next step is to decide just what sort of meter we should use and where in the receiver we should connect it. What about a dc meter hanging right off the avc bus? The dc voltage in the avc line is proportional to the strength of the signal. The stronger the signal, the more avc voltage we get.

But is it practical? What if our receiver has delayed avc? Or what if the signal being received is so weak that it does not have the strength to give us enough avc voltage to more the meter pointer?

What do we need then? We need to put our meter in such a place that it will respond to small variations. We need a circuit such that we can take advantage of the sensitivity of the meter.

Fig. 921 shows just one of many possible S-meter circuits. The S-meter is connected between the cathodes of a pair of if tubes. One of the if tubes is avc-controlled—the other is not. When the set is turned on, current will flow through each of the cathode resistors. The S-meter adjustment control is rotated until the S-meter reads zero. At this time there will be zero voltage between the two connecting points to the cathode resistors.

Now suppose we tune in a signal. The avc-controlled tube will

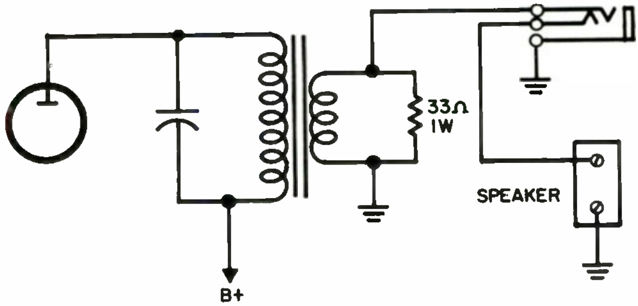



Fig. 920. *A load always appears across the secondary of the audio transformer. The resistor is needed since, with high-impedance phones, loading of the transformer will be inadequate.*

receive an avc voltage. The bias of the tube will be increased. What happens? The current through the tube is decreased and, as a result, the voltage drop across the cathode resistor becomes lower.

But what about the other if tube, V2? It is not affected by the avc voltage and as a result its bias doesn't change. We now have our S-meter connected between two voltage points, one of which is at a higher voltage than the other. We know the result. Current will flow through the S-meter.

How much current? Wouldn't you say that it depends on the signal? The greater the signal, the greater the avc voltage. This is exactly what we want, though, an indicating device that reads in proportion to the signal strength.

### S-meter troubles

What can go wrong with the S-meter? Sometimes, accidentally, the meter will "pin"—that is, the pointer will slam over to one end upon strong signal reception and will be bent or jammed. Generally, this isn't a fault of the meter but of the circuit using the meter. The S-meter circuit isn't designed to prevent this from happening.

You may note that the S-meter pointer will move when you clean its glass or plastic covering with a cloth. This is normal and does not affect the meter. An S-meter is usually a fairly sturdy 5-ma movement. If it doesn't respond when you adjust the S-meter potentiometer, check it and any other series resistors. If you suspect

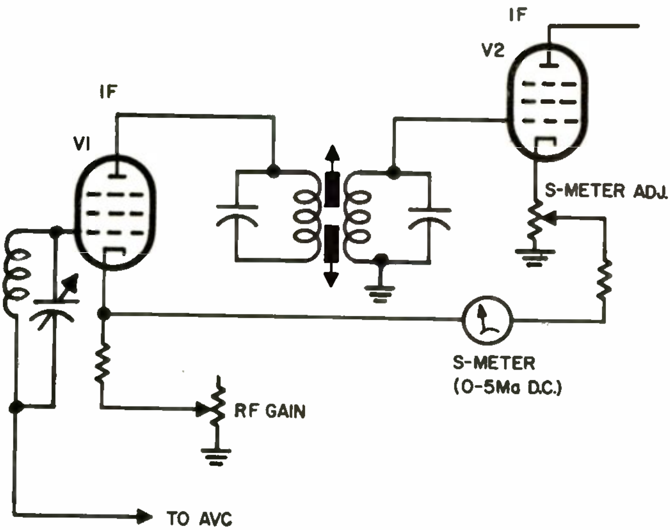



Fig. 921. *S-meter circuit. The S-meter must first be adjusted to zero by means of the S-meter potentiometer.*

the meter, disconnect its two leads and substitute the test leads of your vom, set to read low current. If your tester meter indicates when substituted for the S-meter there is no doubt that the S-meter has seen its best days.

## Single side band reception

Did you ever have to chop or saw wood for a fire? If you did, we are sure you had the feeling that the fire had an enormous appetite and that you put in a lot of energy for very little heat in return.

When a carrier (at the broadcast station) is modulated, the carrier grabs the bulk of the power. Two-thirds of the power goes into the carrier, while the sidebands, like poor relatives, get what is left over.

Actually, when we modulate the transmitter, we only need the carrier at that moment. We can't transmit audio by itself. An audio signal wouldn't radiate very far. As a sideband, though, the audio signal has some of the characteristics of the carrier—one of them being its ability to travel through space with the greatest of ease.

So we do need the carrier, not for traveling purposes, but so we can modify our audio signal. Once we modulate, we can suppress the carrier.

This leaves us with two sidebands. This is a luxury. At the receiver we are going to throw away one of the sidebands, since the same audio information is contained in both of them. And so, at the transmitter, filters are used for suppressing one of the sidebands. A balanced modulator is used to get rid of the carrier.

What we are concerned with, though, is reception. The method used varies from one receiver to the next. The average avc receiver doesn't function with single sideband reception, so unless the receiver's instructions say so, turn the avc control off.

Your first step is to tune the signal in as carefully as possible, for maximum output as indicated by the speaker. Turn the bfo on. Adjust the bfo control back and forth very slowly until you hit a spot where the speech will come through clearly instead of sounding all mixed up. If you cannot get the sound so you can understand it, go back to the tuning dial and adjust it slightly on either side. If this improves matters, return to the bfo control for further adjustment.

Tuning of an SSB signal isn't quite like tuning in an ordinary signal. It requires a little experience and a lot of patience, especially if you aren't used to it.

Two other controls will need some attention. If the set has an anl control, turn this to the off position. Keep the rf gain control turned down.

One of the important factors in SSB reception is that the bfo (beat-frequency oscillator) should not shift frequency once SSB signals are coming through. You may have gradual slurring or distortion. If readjustment of the bfo brings the speech back in again, then the oscillator may be drifting.

In many sets the plate of the bfo gets its B-plus voltage from the plate of a gas voltage regulator tube. If the set has a regulator in the power supply, and you are troubled with drift or are unable to get good SSB reception, try a new bfo tube.

## QUESTIONS

1. What is a bfo? How is it used in a receiver? How could you determine if it works?
2. Describe a method for calibrating a communications receiver.
3. What is an image signal? What causes it?
4. What is double conversion? Why is it needed? How does it work?
5. What are the advantages of an antenna trimmer?
6. Draw the circuit for a manual noise limiter and explain its operation.
7. A communications receiver has an rf gain control. How can you check this control for proper functioning?
8. What is an S-meter? Why is it used?
9. Describe a method for tuning an SSB signal.
10. What might be the cause of drifting in a bfo circuit?
11. What do the following abbreviations represent—CW; mnl; anl; AM?
12. What circuit or circuits should you check if a communications receiver works on all bands but one?

CHAPTER 10

# marine receivers

HAVE YOU ever been lost? Really lost? It probably put you in the same position as the little boy who wandered away by himself. When he was questioned about it, he put it quite simply: "My Mommy is lost." He was quite right. He knew where he was. But he couldn't vouch for his mother.

We don't make a habit of getting lost for a very good reason. We have too many landmarks. Wherever you live, you have set up certain references. The name of your street, the light on the corner, the size and shape of certain buildings, a well known tree or fence—all of these, and many more, are used as landmarks.

But what happens when you get away from these familiar objects? If you travel by car, you use a road map and you keep a watchful eye for road signs.

If you own a boat, and if you stay in sight of shore, you can also use landmarks as a guide. However, most boat owners don't like the idea of being tied to shore any more than a lively "young 'un" wants to be tied to his mother's apron strings. Getting away from shore, though, can be dangerous, since, if you are completely surrounded by water, you may suddenly realize how much alike all water looks. Water makes a very poor reference.

## A new job for radio

There are many ways of knowing where you are, but some of these methods are more or less crude. You might guess your position by looking at the sun, by using a compass or by estimating through a knowledge of the speed of your boat. It's much better to be sure!

A good technique would be to use your radio receiver, but before

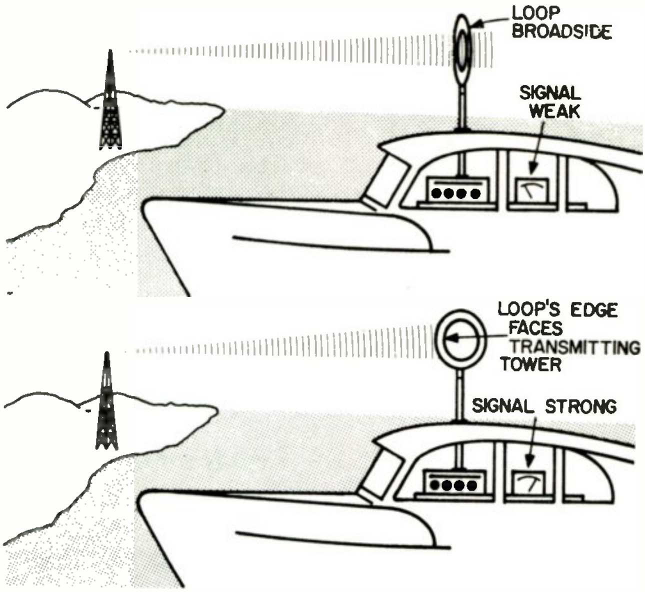



Fig. 1001. *The signal sounds loudest when the edge of the loop antenna faces the transmitting tower of the radio station.*

we do that, let's consider the loop antenna shown in Fig. 1001. When the loop is broadside to a station, the signal is very weak (or it may disappear completely). When one edge of the loop faces a station, the signal is strongest.

## The marine receiver

Our purpose in talking about the loop antenna is simply to show one of the reasons for having a radio receiver on board. Frankly, a receiver is far more important on a boat than it ever could be in a car or home, since human life depends on it. Not only are marine receivers used for direction finding, but also for weather reports and as part of a two-way communications system with other boats and with shore stations.

What is a marine receiver? Probably any radio you take on board can be classified as such, for even a transistor portable can be used to get weather reports. But a true marine receiver is one that is designed especially to cover certain frequencies.

## Marine frequencies

A special band of frequencies has been set aside for boat use, but


Fig. 1002. *Two-band transistor portable covers the standard AM broadcast band and the radio-beacon band.* (Zenith Radio Corp.)

this does not mean that other bands cannot be used. The AM broadcast band can be used for direction finding and also to take advantage of weather newscasts. In addition, boat operators can use the low-frequency band. This range, covering 150 to 500 kc (near the bottom end of the AM broadcast band), is known as the radio-beacon band. Some transistor portable receivers are known as two-band sets. They cover the broadcast band and also operate over the beacon band.

Fig. 1002 shows a two-band all-transistor portable radio being used as a self-powered standby navigation instrument. Instead of a loop antenna, the receiver has two ferrite, plate type antennas which supply the sharp null characteristic of an adf (automatic direction finder) loop. The receiver comes equipped with a switch which enables the operator to disable the avc.

## How many bands?

Once a receiver is taken on board, it becomes a marine receiver. Some are more so than others. Fig. 1003 shows a lightweight port-

Fig. 1003. *Transistor portable covers nine bands and is useful for marine navigation* (Zenith Radio Corp.)

able that covers no less than nine bands, including the standard broadcast, government lf (low-frequency), aviation band, international short-wave and beacon bands. The receiver is tropicalized—that is, its components have been sprayed with a liquid which resists fungus, molds and corrosion found in highly humid and tropical climates. The case is made completely of metal to avoid pickup other than that supplied by the antenna. This adds to its value as a direction-finding unit since signal pickup is confined to the direction-finding circuits.

## The beacon band

What sort of stations operate on this band? On this band you will pick up signals transmitted by lighthouses, lightships, Coast Guard stations, ships, airports, etc. Some of these transmit CW (continuous-wave or code) signals while others broadcast speech.

Since there are so many other bands and single-spot frequencies available, you may wonder why we should bother with the fairly low-frequency beacon band. The answer lies in dependability. The

AM broadcast band is satisfactory for daytime reception, but at night, at a distance beyond 15 miles, reception may not be steady or consistent.

## The marine band

The marine band is another group of frequencies suitable for navigation. It covers the range from 1,600 to 5,000 kc.

Thus, many receivers made for boat operation cover the three bands we have described: beacon, standard AM broadcast, and marine. This is especially the case in sets that are designed to work as rdf's (radio direction finders).

## Receiver circuitry

Marine receivers belong to the general family of superheterodynes. Just because a receiver is used on a boat doesn't make it anything special. There are some differences but, if you can service a home receiver, you should be able to do the same with a marine set.

One of the most important differences is right up at the front of the set. You will usually find at least one stage of rf amplification and sometimes you will find two such stages. Rf stages add to a receiver's sensitivity and its selectivity, but there is much more to it than just that. What we are looking for is dependability. It's like carrying a spare tire in the trunk of your car. It is possible you

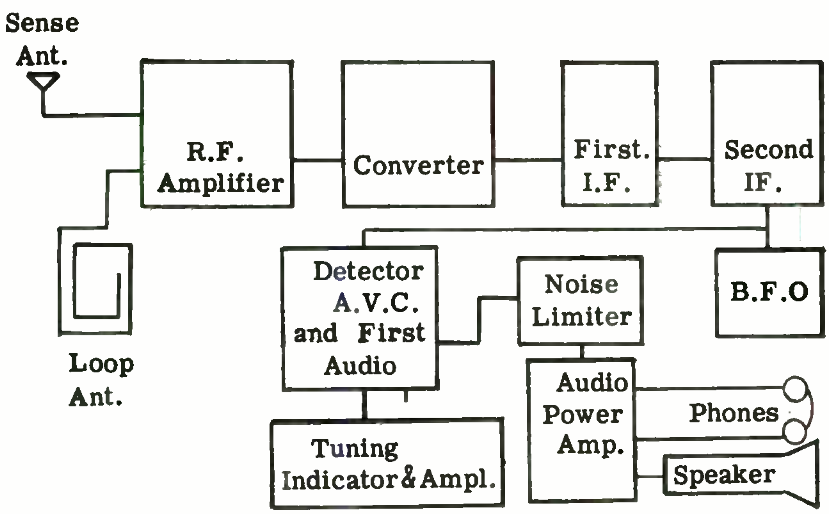



Fig. 1004. *Block diagram of a marine radio receiver.*

won't need to use it but it's a mighty comforting thought to know you have it along—just in case. With a marine receiver we don't want to hope to be able to pick up a particular station—we want to be sure. Also, stations that broadcast on the beacon and marine radio bands don't use the high transmitting power of standard AM radio stations, so we must make up for the difference at the receiver.

Fig. 1004 shows the block diagram of a marine radio receiver. We were about to say "a typical marine receiver" but is there really any such thing? You might have a typical ac–dc set, but marine

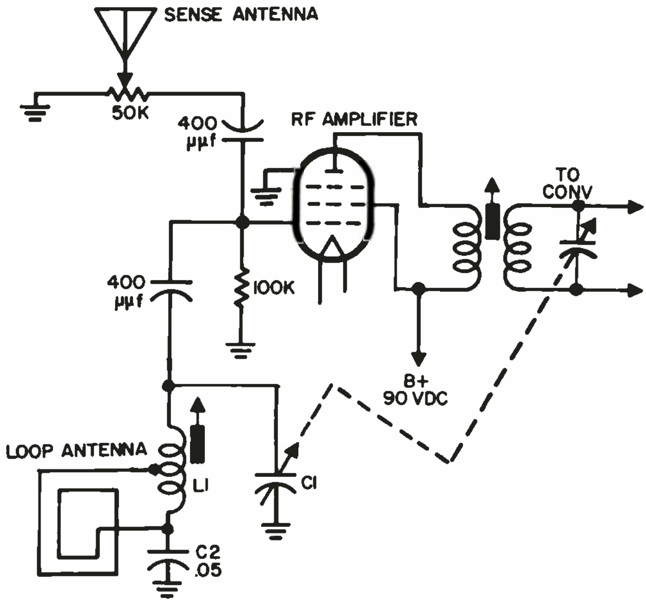



Fig. 1005. *Front end of a marine radio receiver. Two antennas are used for direction finding.*

radio sets depend a great deal on how much the customer is willing to spend. Some marine receivers are wonderful communications equipment in every sense of the word.

Now what about Fig. 1004? What is different about it? Stripped of its accessory circuits, we can see that it is an ordinary superheterodyne. It does have some interesting features. It has two antennas, one marked LOOP and the other marked SENSE. It has a beat-frequency oscillator (bfo) so that we can make code signals audible. It has a noise limiter and a tuning indicator. The tuning indicator has its own amplifier also.

## The rf amplifier stage

A marine receiver rf amplifier stage is shown in Fig. 1005. Once we get over the shock of seeing two antenna inputs, we will realize that this is a fairly usual stage.

Antenna transformer L1 is tuned by C1. At first glance it might seem as though C1 couldn't do this, since L1 isn't connected to ground. However, the value of C2 is much greater than that of

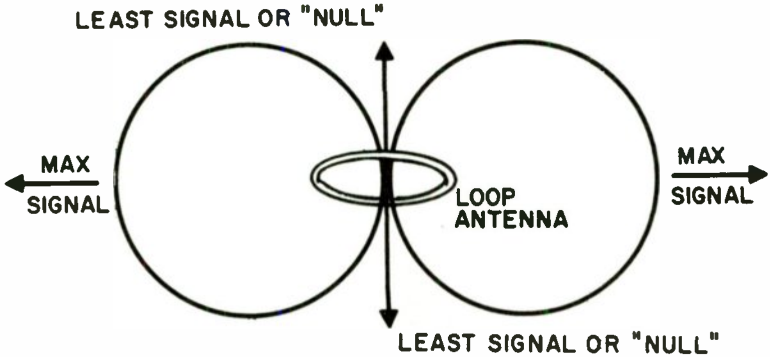



Fig. 1006. *Maximum and minimum signal positions of a loop antenna.*

tuning capacitor C1 so, as far as signals are concerned, C1 is shunted right across L1. The two antennas (sense and loop) are both coupled into the control grid of the rf amplifier. The amount of pickup by the sense antenna is governed by a 50,000-ohm potentiometer. The knob for this potentiometer will appear on the front panel of the receiver and will be marked SENSE.

## Back to the loop

We started this chapter by talking about a loop antenna and now we are back to it again. The old-timers probably remember the loop antennas used on early sets and how often they had to adjust the loop to improve reception. And how often have you walked along with a portable receiver and found you had to turn it to keep from losing the station?

Fig. 1006 shows just what is going on. When the edge of the loop faces the transmitter antenna, we get maximum signal. Turn the loop just 90° and the signal drops to a whisper or disappears.

This is something like a pie for four hungry youngsters. We had better divide that pie into four equal sections. The same applies to a loop antenna. We can turn that loop through a complete circle or 360°. At two points on that circle we will get practically no signal or complete absence of signal. These are known as the "null" points. At two points on the circle we will get maximum signal.

### We tune for minimum

What do we do when we tune a radio? Almost without thinking we adjust the dial until the signal comes in loudest. Now that is just what we don't want to do here. We adjust our loop antenna for a null, rather than for a maximum. There's a good reason for this. When we are direction finding, we're not so much interested in what


Fig. 1007. *This portable radio direction finder receives signals from long-range Consolan stations and standard broadcast bands as well as regular marine beacons. Sense antenna, right rear, differentiates between correct bearings and reciprocal bearings. Six standard flashlight batteries power the receiver. A dual purpose meter indicates battery strength and provides visual null reading for accurate bearings.* (Raytheon Co.)

the announcer has to say, as where we are. When we adjust a loop antenna for a null, we can do so quite sharply and accurately. It's much more difficult to tune for maximum signal since you can turn the loop antenna quite a few degrees on either side of the maximum point and not notice the difference.

### Two nulls for the price of one

Suppose we turn our loop antenna (Fig. 1007) until we get a null point. We could turn the loop through half a circle (180°) and get another null. Where is the station then? Is it in front of us or behind us? It's like being on a straight road. We may know that the road goes north and south but, unless we have a road sign or some other indication, it would be just as easy for us to go in either direction.

### Figure eight

You will see that the two circles in Fig. 1006 resemble the number 8. This figure-8 pattern tells us something about the behavior of a loop. Each half of it is the same. All that this means is that the

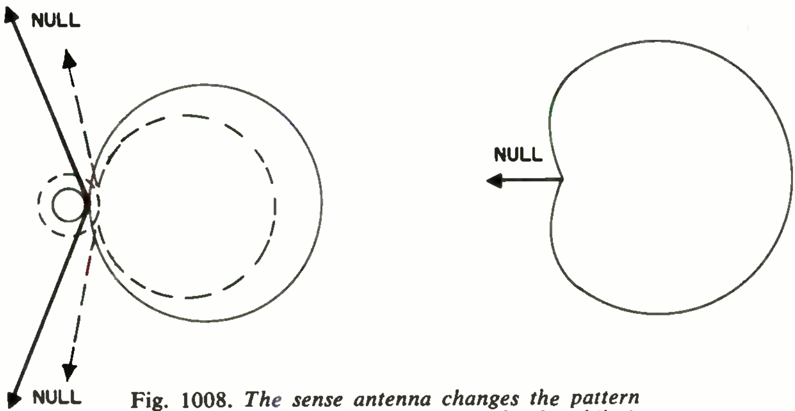



Fig. 1008. *The sense antenna changes the pattern of the loop from a figure-8 to a cardioid. While it would seem that extreme care of sense antenna adjustment would be needed to get a sharp null for direction finding when used with a loop, this is not so. The loop figure-8 pattern is used for getting the null and determining the two possible directions. The sense antenna is used only to pick the correct direction of the two and is not used for accurate direction-finding.*

loop can pick up a signal equally well in two positions. This is why the loop antenna by itself won't tell us whether the station is in front of or behind us. But suppose we make the loop antenna pick up better in one direction than the other, what then?

### The sense antenna

Let s see how we can do this. Suppose we have a vertical rod antenna. The rod antenna has its own pickup characteristics and these are such that they will change the shape of our figure 8. This is shown in the drawings in Fig. 1008. To understand what is happening, suppose we go back to Fig. 1005 for a moment. In series with the sense antenna we have a 50,000-ohm potentiometer. This potentiometer controls the amount of signal pickup (by the sense antenna) that we couple to the control grid. By adjusting this potentiometer we can control the shape of the figure-8 pickup by the loop. As we turn the potentiometer, one half of the figure-8 pattern begins to disappear. At the same time, the null point changes its position in the loop. If we get a correct ratio of sense-antenna pickup to loop pickup, the figure-8 pattern changes to a cardioid shape. A cardioid pattern is heart-shaped.

Now what do we have? The illustration shows that we have signal pickup in one direction only.

### Front-end troubles

In an earlier chapter we examined the troubles that could afflict an rf amplifier. The fact that an rf amplifier is used inside a marine

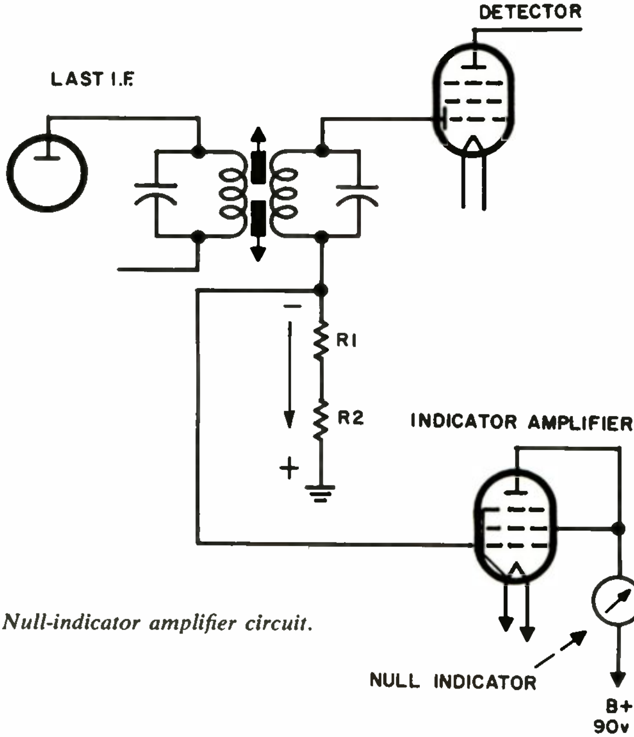



Fig. 1009. *Null-indicator amplifier circuit.*

receiver doesn't mean that it will not have the same troubles. It also has a few of its own. The loop of the marine receiver is a mechanical device. Sometimes the loop is a separate unit while in others the loop is part of the case. The loop must be turned to get the null. The loop may have slip rings and brushes to permit it to turn and yet allow electrical connection to the receiver. The rings must be kept absolutely clean. This can be done with any commercial cleaner lubricant.

The housing for the loop is made of metal but it is not a complete, unbroken enclosure. The shield for the loop is made of copper or aluminum. Somewhere along the housing you will find a bit of

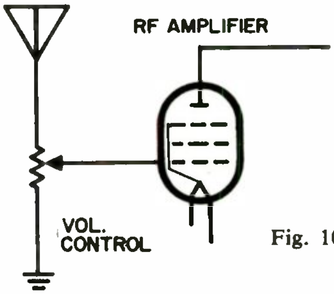



Fig. 1010. *Volume control in the rf input.*

insulating material. Make sure that this insulator is clean and free of dust. Some ambitious boat owners like to put paint on everything. If they get paint on this insulator, the loop will not work well or may not work at all.

## Checking the direction finder

The direction-finder part of the marine receiver may be inaccurate for a number of reasons. The sense potentiometer may not be set correctly or it may be defective. To check on the direction finder or to verify its accuracy, tune in on a radio tower you can see, at the same time operating the rdf. Take bearings with the boat headed in various directions.

## Null-indicator circuit

How can we tell when we have managed to reach the null point? We could listen to the receiver with a pair of phones or a speaker. But, unless we are operating a sailboat, there are going to be plenty of distracting noises. Generally, we pay very little attention to noise, provided it isn't above a certain level. But you can suddenly notice the slapping of water against the side of a boat if you're trying hard to pick the null—and this is true even if you're using earphones. Don't blame the instrument. That's the way our hearing is made.

To get around this difficulty, marine receivers come equipped with electronic null indicators. One type is shown in Fig. 1009.

To understand how this circuit works, suppose we are tuned to a strong signal and that the signal has been amplified by the if and presented to the detector. The diode will rectify the signal and a current will flow through the two series diode load resistors, R1 and R2.

What about the polarity of the voltage appearing across these resistors? That's easy enough to determine. Just looking at the arrow tells us that the top end is minus and the bottom end is positive. But the top end is connected to the control grid of our indicator amplifier tube. If we make the control grid negative enough (a strong signal will do it), very little current will flow through the indicator amplifier tube.

It's time we took a good look at the indicator amplifier tube. It's a pentode, connected as a triode. Measuring the combined screen

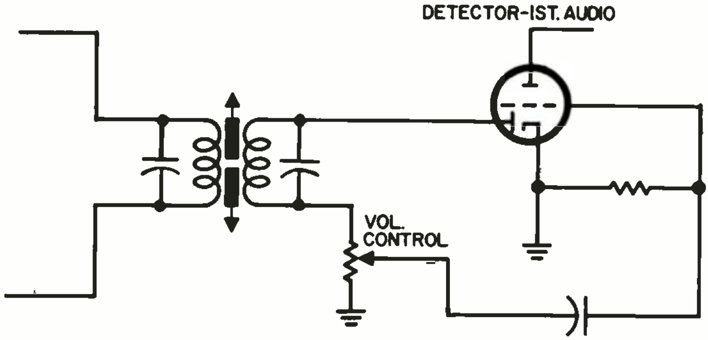



Fig. 1011. *Volume control works as the diode load.*

and plate currents is a dc milliammeter. At the present moment it is reading a very small amount because we have a signal at the detector's diode plate.

Now let's rotate our loop antenna toward the null point. As we do so, less and less signal reaches the diode plate. This means that less current will flow through R1 and R2. As a result, we put a smaller negative voltage on the control grid of the indicator amplifier tube. When this happens, more current passes through the tube and the pointer of our null-indicator meter starts to move toward the right. How to tune for a null? Keep an eye on the null-indicator meter and turn the loop until the meter pointer is as far to the right as possible.

By watching the null-indicator meter you can also tell if you have adjusted the sense-antenna potentiometer correctly. If it is set right, you will get only one forward movement of the meter pointer for a complete rotation of the loop antenna. Otherwise, for each rotation of the loop you will get two readings.

## Null-indicator troubles

The null indicator is a simple circuit and easy to service. If you get no indication on the meter, try a new indicator amplifier tube. If that doesn't help, listen for the signal on the phones or speaker. If the signal comes through satisfactorily, then you know that the fault is in the indicator amplifier circuit.

Set your vtvm to read low volts dc. Tune the receiver to a loud

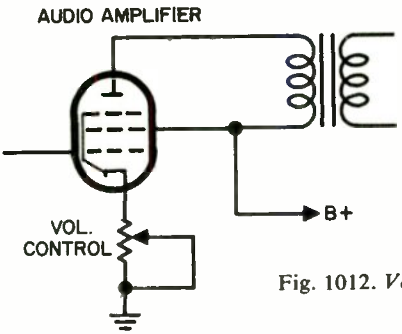



Fig. 1012. *Volume control in the cathode circuit.*

signal and see if you get a voltage drop across R1 and R2. If you get no voltage, check R1 and R2 for continuity. If you do get a voltage drop, substitute a meter for the null indicator. You can use your vom for this by setting it to read low milliamperes, dc.

## Volume-control circuits

There is a big advantage in learning how a circuit works but there is a big disadvantage too. If we get accustomed to seeing a particular circuit, we get so that we can't imagine it appearing in any other way. Take a volume-control circuit. Most often we find it as part of the detector–first audio tube. But just because it is used that way regularly does not mean we cannot have our volume control elsewhere.

In Fig. 1010 the control is a variable resistor between the antenna and ground. The tube can be the rf amplifier or possibly the converter. Fig. 1011 shows the most common arrangement with the volume control acting as the diode load for the detector. In Fig. 1012 the volume control is the variable cathode-bias resistor for an audio amplifier tube. Another way of controlling the gain is by the method shown in Fig. 1013. Here the screen grid of one of the if amplifier tubes is connected to a voltage divider shunted across the B-supply.

## Volume-control circuit troubles

Let's examine Fig. 1013 a little further. The plate gets almost the full 90 volts. The screen grid cannot reach 90 volts since there will be a voltage drop across the 100,000-ohm resistor.

What sort of troubles can this circuit give us? Unlike the volume control that is more familiar to us (Fig. 1011) the volume control of Fig. 1013 is a bleeder connected across the B-battery supply. This means that we will have a current flowing through the volume control—a current supplied by the battery. This current will be very

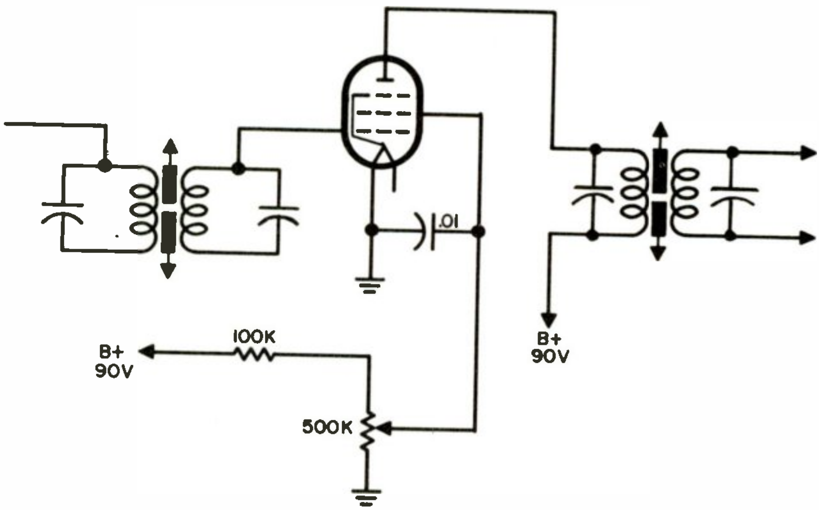



Fig. 1013. *Volume control in the screen circuit of an if tube.*

small—less than 1 ma. But it is enough to give us a voltage drop across each resistor, the 100K and the 500K.

Note particularly how the volume control is wired. In some volume-control circuits the center terminal and the ground terminal are wired together (Fig. 1012). We don't want this in the circuit of Fig. 1013 since we would then be grounding the screen for any position of the arm of the potentiometer.

To check the volume-control potentiometer, either turn the set off and make a resistance check, or, with the set turned on, measure the voltage drop across the outside terminals of the volume control. You should read 5/6 of 90 volts or 75 volts (since the volume control is 5/6 of the total resistance between 90 volts and ground).

If you get no voltage across the pot, make sure the battery is connected. Also measure the 100,000-ohm resistor for continuity. If the .01-$\mu$f screen bypass is leaky, the voltage drop across the 100,000-ohm resistor will be above normal and it will be difficult to control volume. The sound may be weak, depending on the exact condition of the capacitor.

### Automatic noise limiter

What could be more peaceful than a smooth-running boat on a river or sea that is absolutely calm? Lucky for us our ears can pick

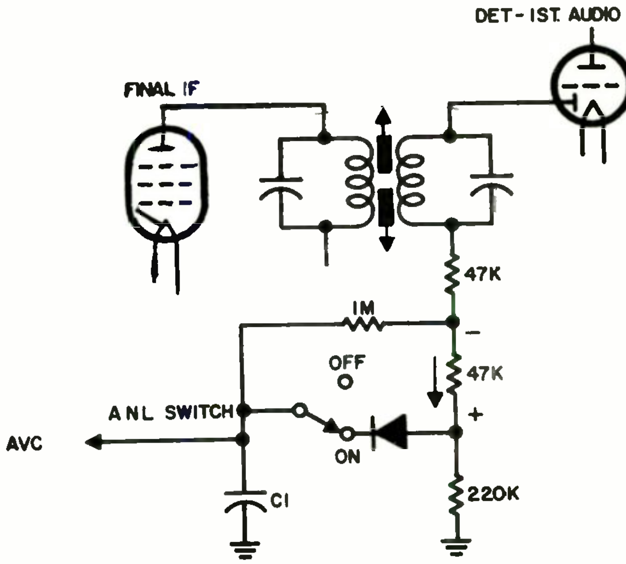



Fig. 1014. *Anl (automatic noise limiter) circuit.*

up only a limited range of sound. If our hearing were different, we might hear the electrical noise put out by the engine, the electrical noise radiated by motors on board, the static of a distant storm, the electrical noise produced when two metal parts of the boat rub against each other. We might also hear the electrical noise being radiated by our transmitter and being picked up and re-radiated by any bit of metal on the boat. All in all, the world is quite a noisy place and it is just as well that we have been provided with ears that can't hear everything!

Our receiver isn't that lucky! To the receiver, an electrical noise

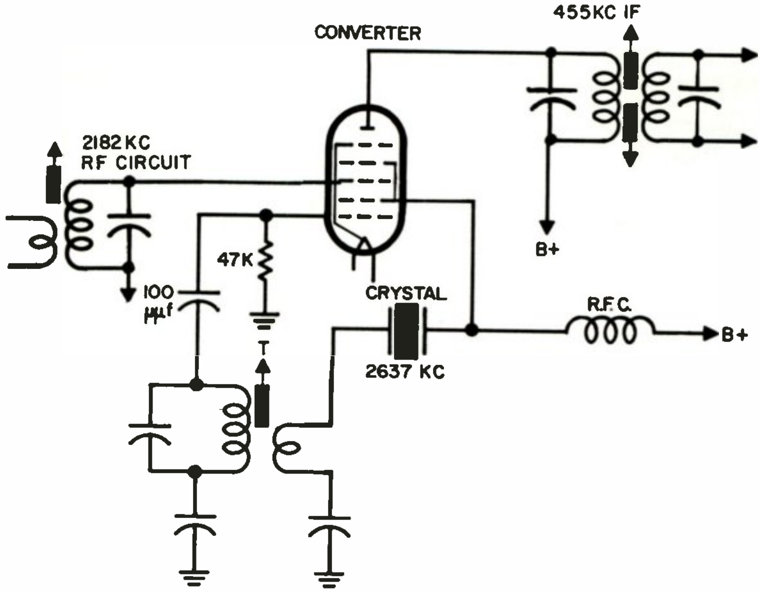



Fig. 1015. *Crystal control of the local-oscillator circuit.*

is a signal and, since the set is designed to amplify signals, that is exactly what it is going to try to do. You might think that the tuned circuits we have in the receiver would have enough sense to pass radio signals and block noise signals. They do the best they can, but some noise signals are so much stronger than radio signals they just bully their way through.

There are a number of ways of reducing electrical noise. One of these is using a noise limiter circuit, as shown in Fig. 1014. Here we have a crystal diode shunted across one of the decoupling resistors (1 megohm) of the avc network. When the anl (automatic noise limiter) switch is in the off position, the 1-meg filter is directly in the avc network. What happens when we put the anl switch in the on position?

Note the direction of the arrow through the 47,000-ohm resistor. The top end of the resistor is negative and it is this negative voltage that is applied to the grids of the controlled tubes through the 1-megohm resistor. Capacitor C1 is a filter in the avc line. The speed with which this capacitor gets charged depends on its capacitance and the amount of resistance in the avc line.

For normal signals the crystal diode does not get enough voltage to make it conduct. When a noise burst comes through, though, the diode conducts, effectively shorting the 1-megohm resistor, allowing a higher negative bias to be placed on the grids of the controlled tubes. Capacitor C1 also gets a chance to charge much more rapidly. C1, though, is connected to the grids of the tubes receiving the avc voltage and lowers the gain of these tubes for the duration of the noise pulse.

To check the anl circuit, try to pick up some noise deliberately. Note the difference as you work the anl switch back and forth.

## Spot frequency operation

The international distress frequency is 2182 kc. The US Coast Guard has several hundred radio stations maintaining a constant watch on this frequency. Some marine receivers come equipped with tuned circuits permitting spot reception of this particular frequency.

Fig. 1015 shows how this is done. The band-switching arrangement has been omitted so that you can see the details of the circuit. The other bands would be the beacon band, broadcast band, etc.

The local oscillator, when switched to the international distress frequency, consists of a local-oscillator transformer and a crystal. Note that the crystal is made for 2637 kc. Since the distress fre-

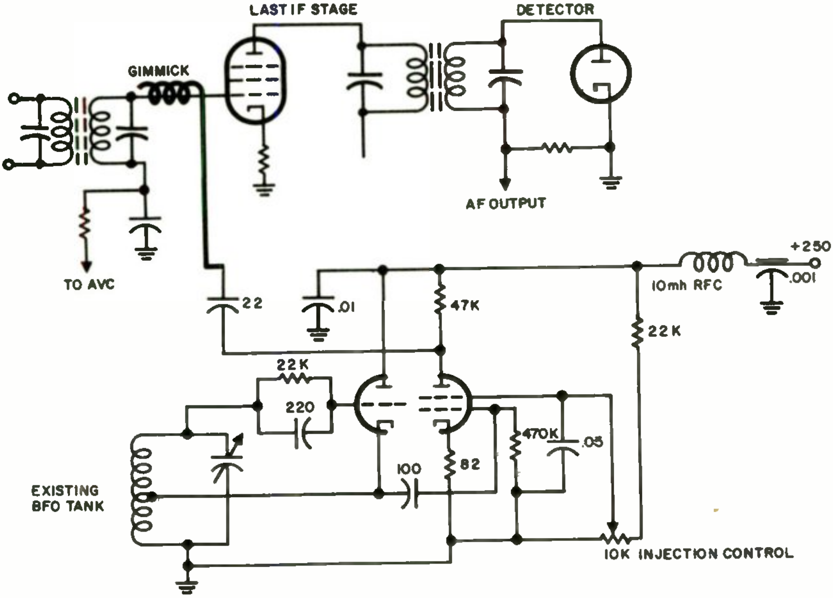



Fig. 1016. *Beat-frequency oscillator circuit.*

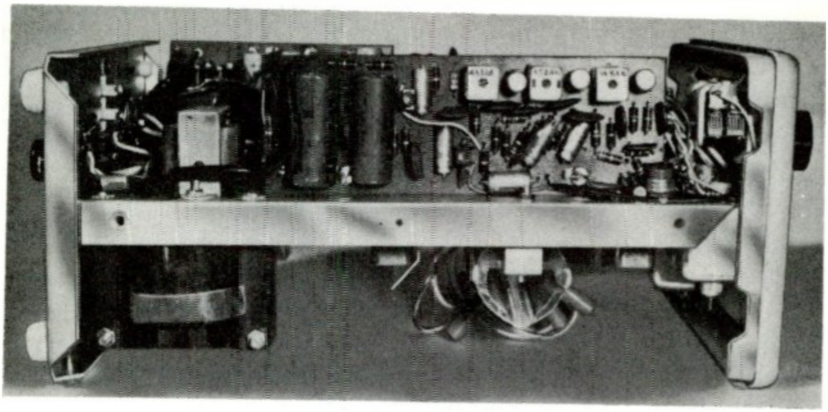


Fig. 1017. *Side view of transistorized receiver.*
(Bendix Radio Corp.)

quency is 2182 kc, the difference between these two frequencies is 455 kc (our intermediate frequency):

$$2637 - 2182 = 455 \text{ kc}$$

For all the other bands, the local-oscillator transformer is tuned by a variable capacitor. However, the distress frequency is not a band but is a single, fixed frequency. For this reason the local oscillator transformer can be fixed-tuned.

Now the big question is—why the crystal? Couldn't we just tune local-oscillator transformer T to 2637 kc? Wouldn't it work? The answer to that one is, yes, it would work. But could we always be sure that the transformer wouldn't get detuned? This could happen if the slugs rotated slightly or if the shunting capacitors changed their values. With a crystal in the circuit, however, the local-oscillator frequency remains fixed.

The purpose of the radio-frequency choke (rfc) is to keep the rf (2637 kc) out of the B-supply. At the same time we want a low-resistance B-plus connection to the anode grid of the converter.

## Beat-frequency oscillator

You were first introduced to the bfo (beat-frequency oscillator) when we covered communications receivers. You'll find it turning up in practically all marine receivers since code transmission is so frequently used.

Why code? Why bother with dots and dashes when phone (speech) transmission is so much easier to understand? There are a number of good reasons why code is still used and why it will probably continue to be used.

The amount of power required for a code transmitter is much less than for one using speech. Code transmitters are simpler, cost less to build, can be much more compact. Furthermore, code transmission will often come through during very poor receiving conditions when speech would be garbled and impossible to understand.

Since a code transmitter has no modulator, it is up to the receiver to change code into a signal that can be heard. An easy way of doing this is to wrap an insulated wire around the plate lead of one of the if tubes. The other end of this wire is wrapped around the control grid lead of the same tube. There is no direct electrical connection between the wires and the plate and the grid. There is, though, a small amount of capacitance. A wire of this sort is known as a gimmick.

The ends of the gimmick are connected to a switch. When the switch is closed, a small amount of feedback exists between the

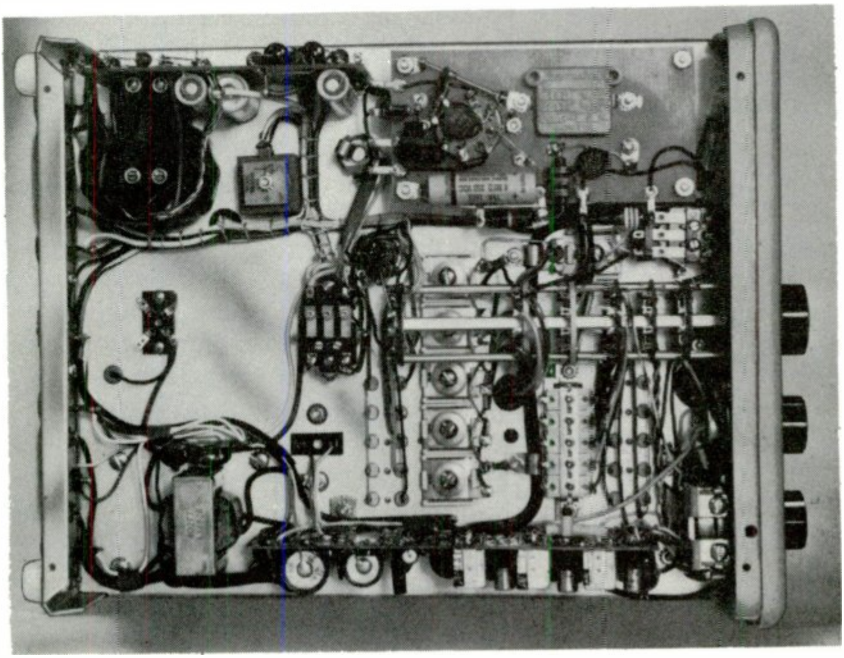


Fig. 1018. *Underside view of a transistorized receiver.* (Bendix Radio Corp.)

plate and the control grid, enough to make the if tube oscillate. Heterodyning (beating) action now takes place between the if signal and the signal produced by the oscillating if tube. The result is the difference between the two signals—an audio frequency.

There is very little that can go wrong with such a circuit. If you get no bfo action when the switch is closed, try another tube. If this does not help, connect a small capacitor (5 to 20 $\mu\mu$f) between the plate and control grid to see if you can start oscillation. If you can, it is possible that the bfo switch is defective and is not connecting the two ends of the gimmick.

Some marine receivers use a separate circuit, such as the one shown in Fig. 1016, to supply bfo action. Here the bfo oscillator is a Hartley. Note, though, that the oscillator is followed by an amplifier. The amplifier, acting as a buffer, isolates the oscillator from the if stage. This arrangement helps minimize drift in the bfo. Even a small amount of drift would be very annoying and would cause the CW tone in the phones to vary in pitch.

In Fig. 1016 a 22-$\mu\mu$f capacitor is shown in the lead connecting the gimmick to the plate of the bfo amplifier tube. This capacitor isn't really needed since the gimmick will work without it, but it does prevent damage in the event the gimmick accidentally shorts to ground.

## Transistorized receivers

If we were allowed to use just one word to describe marine receivers, that word would be variety. They come in all sizes, shapes and designs. Some cover just two bands, others cover as many as nine. Some have separate direction finding loops; others have the loops as part of the receiver itself.

There are other differences. You will find receivers using tubes only (powered by a B-battery pack and a storage battery). Some will be hybrid sets consisting of tubes and transistors, and, of course, you will also find all-transistor receivers.

Fig. 1017 shows a side view of a transistorized receiver while a bottom view is shown in Fig. 1018. Note the band-switching arrangement in Fig. 1018.

Finally, to add to our list of marine receiver types, we have the transceiver, a combination radio receiver and transmitter.

## Other receivers

At one time a radio receiver had just one reason for being. The buyer of the receiver hoped to get some free entertainment. Then the use of radio receivers for communications and entertainment was a neck-and-neck race for a long time.

Today, though, radio receivers have gone way beyond their simple beginnings. Wherever you go, you are very likely to find a radio receiver at work. It could be in the pocket of a salesman getting orders by radio. It could be in a tractor out in the field. It could be in a lift truck in a factory. In our next chapter we are going to learn about some of the very special (and unusual) uses for radio receivers.

## QUESTIONS

1. What is a sense antenna? How is it used?
2. What are the advantages of having one or more stages of rf amplification?
3. What is the marine band? What range does it cover?
4. What is tropicalization? Why is it used?
5. What is the beacon band? What range does it cover?
6. Why are two antenna inputs needed in a direction finder?
7. What is a null point? Why is it used in direction finding?
8. What is a null indicator meter? How does a null in-indicator amplifier circuit work?
9. Describe at least three volume-control circuits. Explain a technique for checking each one of them.
10. What is spot frequency operation? Why is it used? What sort of circuit is used to obtain it?
11. What is a gimmick? Why is it used?
12. Why are marine receivers designed to cover more than one band?

CHAPTER 11

# mobile radio

SUPPOSE SOMEONE were to ask you, "What is radio?" Sounds like an easy question, doesn't it? But is it as easy as it looks? What is radio? Is it just the little ac–dc set you have in your home? Is it just the little transistor portable you carry around with you? In short, can radio do more than provide us with entertainment?

Here are just a few of the places where you will find radio receivers: in trucks, tractors, police cars, ambulances, taxicabs, locomotives, in the pockets of physicians and salesmen, on fork-lift trucks, in repair service trucks, planes and missiles. What is the purpose of having radio receivers in such unlikely places? We can sum it up in just one word–communications.

When the engineer of a locomotive wants to get in touch with the men in the caboose, he does it by two-way radio. When a central office wants to talk to a salesman making his daily rounds, it notifies him by radio. A busy physician leaves his office but a little receiver in his pocket makes sure that he is always available for an emergency. A fork-lift truck operating in a remote corner of a big factory gets its pickup instructions by radio.

## Is it good business?

The average home radio set owner wants to get the best radio repairs at the lowest possible cost. Since many radio receivers are bought for a low price to begin with, the amount that can be charged for servicing has a ceiling put on it immediately. Very often this works to the service technician's disadvantage since he is then unable to get a fair return for his labor.

But what about the much higher priced receivers used for communications? Companies using such receivers will expect to pay a reasonable charge, not only for repair, but for preventive maintenance. Here is a field in which a technician can build a steady, dependable business.

## Mobile systems

A mobile radio setup is something like a telephone system. You have two people who want to talk to each other, or, at least, you have one person who wants to talk and another who must listen. One telephone could be considered the transmitter and the other the receiver.

Just about the most elementary mobile system you could have is shown in Fig. 1101. Here we have a transmitter located at some fixed point. We can call this transmitter the base station. We also

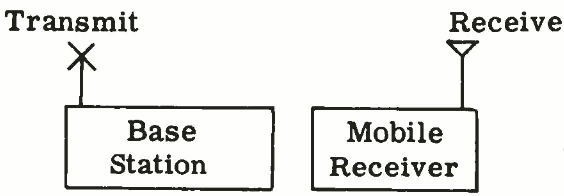



Fig. 1101. *Simple mobile communications system consists of a base station (transmitter) and a mobile receiver.*

have a receiver, but because this receiver can be moved (and is moved) from place to place, we call it a mobile receiver. Sometimes the receiver is in motion when it is being used—for example, a receiver in a taxi. Or, the receiver might be expected to pick up signals at certain times and certain locations. In either instance we call the radio a mobile receiver.

Mobile systems generally use quite a large number of radio receivers. Fig. 1102 shows a base station controlling three receivers but it is quite common for the base station to be in touch with 40, 50 or more receivers at one time.

The system shown in Figs. 1101 and 1102 is limited. The persons operating the mobile receivers can get instructions or orders, but they have no way of replying to the base station, other than using a telephone . . . and this might be inconvenient or impossible. For this reason, some mobile units are not only equipped with receivers but with transmitters as well. This, as shown in Fig. 1103, is really two-way radio.

There are other arrangements. In some cases there is no base station, but all the units can receive and transmit.

## Frequencies

Depending on how it is to be used, mobile receivers work over a wide range of frequencies, all high. Typical ranges are 25 to 50, 152 to 162 and 460 to 470 mc and the Citizens radio bands of 27 and 450 to 460 mc. Others bands are available but are reserved for government use, aircraft work, etc.

## Receiver operation

What is so different about a base station, say, compared to an ordinary broadcast station? A base station is not only equipped to transmit, but it is just as important for it to be able to receive.

At the base station we can have a complete transmitter (power supply, antenna, etc.), plus a complete receiver, with its own power supply and antenna, just as shown in Fig. 1104. The signal may be transmitted on one channel and the reply received on another, or all on one channel.

This system has certain disadvantages. Two separate power supplies are needed and also two separate antennas.

What other method could be used? We can borrow an idea from truck manufacturers. Did you ever see a truck with interchangeable bodies? Or a piece of furniture that worked as a couch during the

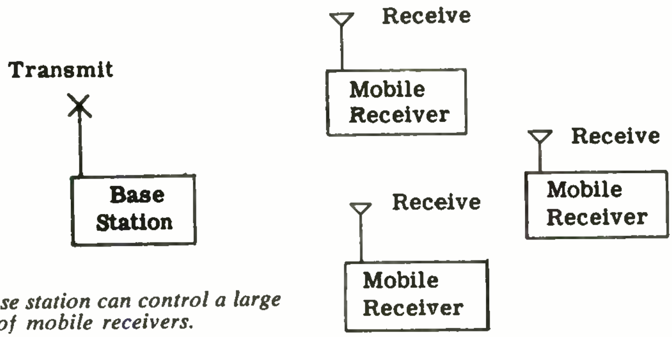



Fig. 1102. *The base station can control a large number of mobile receivers.*

day and as a bed at night? The idea isn't new. Only the approach is different.

Now let's look at Fig. 1105 to see how we get the arrangement we want. Here we have a transmitter and a receiver. Note the relay and the switch. The push switch is sometimes called a push-to-talk switch.

At the present moment the switch is open. This means that no current flows through the relay and as a result the armatures (there are two on this relay) touch their upper contacts. (The little inset drawing supplies some basic relay circuit details just in case you aren't familiar with the terms.)

What happens when the push-to-talk switch is open? The antenna is connected to the receiver and disconnected from the transmitter.

Look at the bottom armature. Right now it connects the receiver to the power supply.

When we want to reply, we press the push-to-talk switch. This permits current to flow from the battery through the relay coil. The relay coil becomes an electromagnet and attracts the metal armature. The bottom armature moves down. So does the top armature since it is linked to the bottom one.

What has happened? The antenna is connected to the transmitter (and at the same time becomes disconnected from the receiver.)

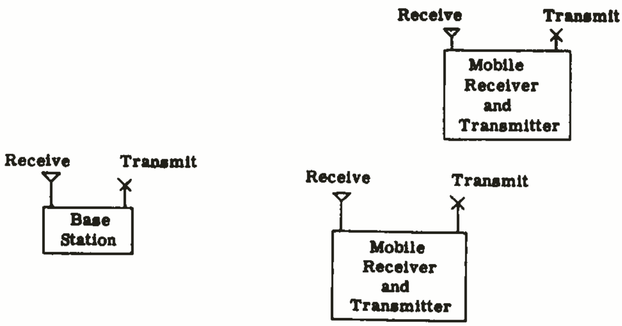



Fig. 1103. *In this system, all units, base and mobile, can receive and transmit.*

The power supply becomes connected to the transmitter and disconnected from the receiver.

## Receivers for mobile use

What we have told you about so far is background information to give you some idea of what is meant by mobile radio.

What sort of receivers can we expect to service? As you might very logically expect, the receivers are superheterodynes. The word superheterodyne, as we learned in the chapter on communications receivers, covers quite a lot of territory.

We have a good idea of how a superheterodyne works. What we are interested in right now is not basic superheterodyne theory but rather in the circuit changes that have been made for this application.

## AM or FM

Most (but not all) the receivers used in the vhf (very-high-frequency) and uhf (ultra-high-frequency) bands are FM. You will find some specially assigned mobile bands operating with AM.

Receivers for mobile work are fairly large. There's a double reason for this. The sets must work on high frequencies so extra circuits are needed to bring the if down to a reasonable value. Also, since the important factors are dependability and sensitivity, more rf and if circuits are used. Thus, some sets have from 10 to 20 tubes.

## Double conversion

We have come across the double-conversion superheterodyne in our studies of communications receivers. What about mobile receivers? Fig. 1106 shows a block diagram of a typical unit. And what is (or should be) our first question? What's different about it?

Start right in at the front end. Our antenna is connected to an rf amplifier through coaxial cable. Here, working with high frequencies, ordinary wire just won't do.

There is at least one item about coaxial cable we should know and that is its impedance. The signal picked up by the antenna isn't the strongest in the world and, if we want it to have a chance to survive its slide down the cable to the antenna transformer, we

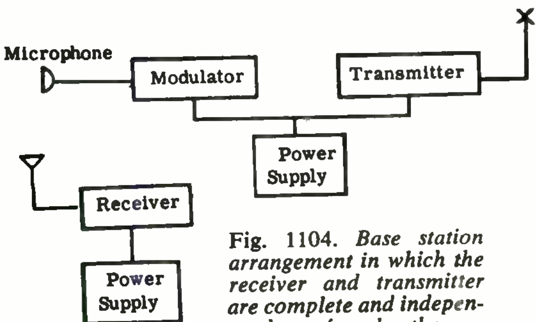



Fig. 1104. *Base station arrangement in which the receiver and transmitter are complete and independent of each other.*

must be sure to use the right type of cable. Its impedance should match that of the antenna and antenna transformer.

## What can go wrong?

Coaxial cable is made of a conductor (a wire) surrounded by some insulating material. Around the insulation is a flexible metal sheath known as shield braid. The center conductor or wire is the "hot" lead while the shield braid is the "ground" connection. The shield braid is, in turn, usually covered with an insulating substance such as synthetic rubber.

It's difficult to expect that anything could go wrong with some-

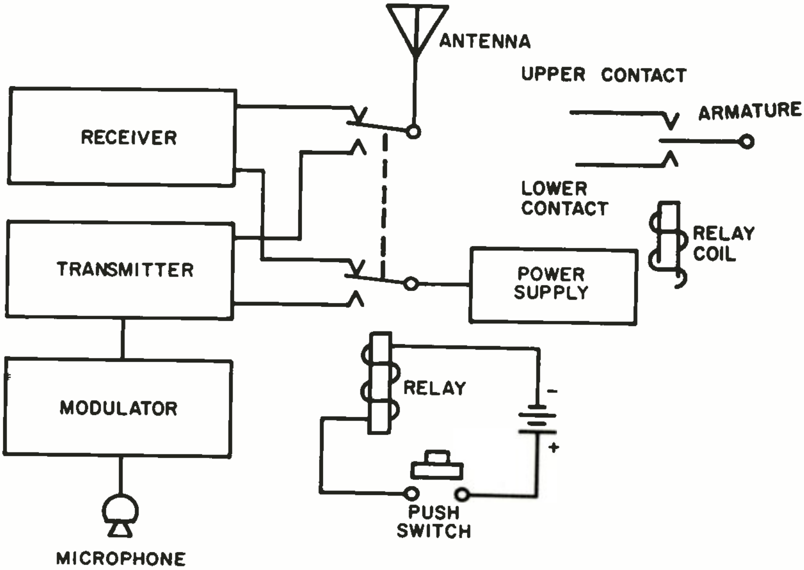



Fig. 1105. *Base-station arrangement in which a single power supply and a single antenna are used for receiver and transmitter.*

thing as well made as coaxial cable, but the passage of time has no pity on people or the materials that people make. If the cable has been flexed severely, the center conductor can break. The shield braid itself is made of individual wires and sometimes these pull away and short to the "hot" lead. If this is a permanent short, the transmitter won't "load" and the receiver won't pick up. If the short is an intermittent one, both receiver and transmitter will behave erratically. Sometimes the units will work and sometimes they won't.

## The front end

Still working with Fig. 1106, let's move down the transmission line (the coaxial cable) to the front end. Here we will find either one or two stages of radio-frequency amplification. Wiring, parts layout and components are critical since we are working with high frequencies. Mobile receivers use high-quality components, generously overrated and selected for maximum stability and minimum noise. No bargain basement parts are used.

From the rf amplifier the signal moves into the mixer. At this point we notice a few differences. The mixer receives a signal from an unusual sort of local oscillator.

Is it hard to recognize the local oscillator? That isn't too surprising since the local oscillator is crystal controlled. Its output is fed into a frequency multiplier. The mixer gets its local oscillator voltage from the frequency multiplier.

Suppose we examine the local oscillator circuit just a bit closer. Why do we need a crystal oscillator? And what is the purpose of a frequency multiplier? For example, our receiver is to pick up signals at 155 mc. Our set is hard at work in the band covering 152 to 162 mc.

What about our intermediate frequency? It can be any value that the manufacturer chooses, so let us settle for 20 mc, a nice round number. What is our problem then? We must change 155 megacycles to 20.

We could do this very easily by building a local oscillator to work at 175 or 135 mc. Thus:

$$175 - 155 = 20 \text{ mc}$$
$$155 - 135 = 20 \text{ mc}$$

If we selected 175 mc, we would be working "above" the incoming signal. If we decided to use 135 mc, we would be working "below" the incoming signal.

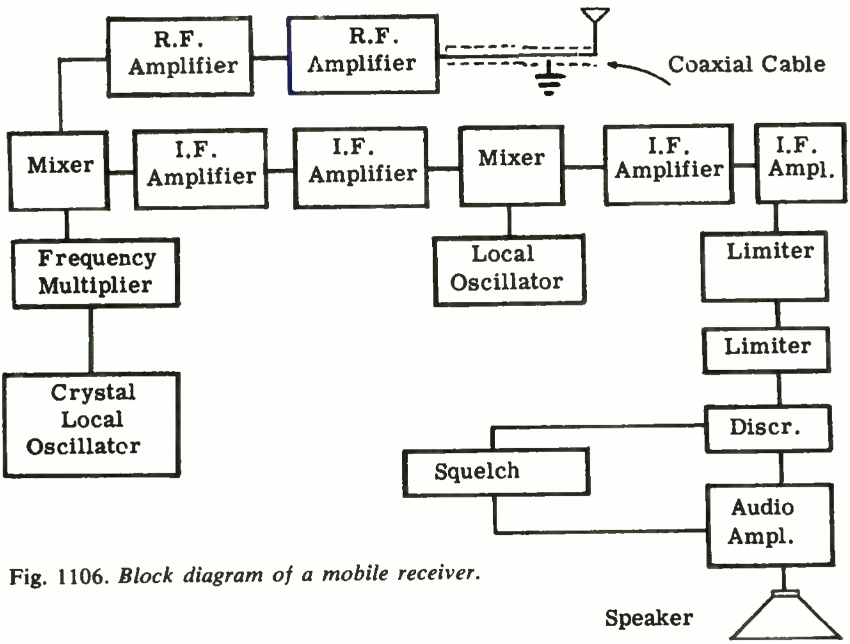



Fig. 1106. *Block diagram of a mobile receiver.*

### What's wrong with that?

Here we have a good question. What's wrong with that? Tubes and parts are available which can be assembled into an oscillator that could work very nicely at either 135 or 175 mc. That's no problem.

The big problem is stability. As an example, what if we had a local oscillator and it worked at 1 mc. This is 1,000,000 cycles. Let us also say that our oscillator had just one bad habit—drifting. It would drift in and out of frequency by just one-half of 1%. Have we got a problem—or not?

To answer that question, let's change our percentage into other numbers. One-half of 1% is .005. When we multiply this by 1,000,000 cycles we get:

$$.005 \times 1{,}000{,}000 = 5{,}000 \text{ cycles}$$

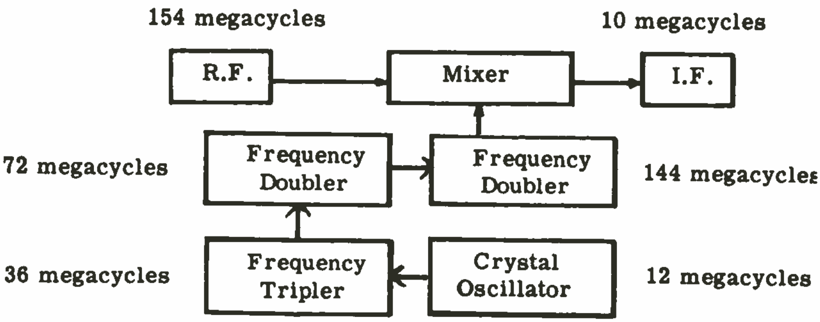



Fig. 1107. *The local oscillator has a crystal and a number of frequency multipliers.*

We might imagine that this is a large amount of drift, so suppose we apply the same sort of thinking to our local oscillator in the mobile receiver:

$$.005 \times 135{,}000{,}000 = 675{,}000 \text{ cycles}$$

Some difference! Just to give you an idea of how much of a drift this really is, think of the broadcast band. For the sake of round numbers, start at 500 kc and then add 675 kc (675,000 cycles to it). You will end up at 1175 kc, not far from the upper end of the broadcast band. In other words, a drift of just one-half of 1% is enough to shift the local oscillator in our mobile set a distance almost equal to half the length of the broadcast band.

Note that to make our arithmetic easier, we did not say a drift of plus or minus .005. If we had done that, then our drift would be twice the value we have given it. All in all, not a good situation.

### How do we get around this problem?

There are two ways of getting over a fence (other than opening a gate). You can prop a ladder against it and climb over, or you can dig a tunnel and crawl under. In the case of the local oscillator, we can make a fast trip downstairs (in terms of frequency, that is).

In Fig. 1107 we have taken the mixer circuit of Fig. 1106 and have expanded it a bit so that we can see what is happening.

### Be fruitful and multiply

To make our arithmetic a little bit easier, let us imagine that our receiver is tuned to 154 mc and we want an if of 10 mc. We can start (as shown in Fig. 1107) with a crystal-controlled oscillator operating at 12 mc. The output of our oscillator is led into a frequency tripler. Since this circuit will multiply our local oscillator by 3, our tripler output is 36 mc. We then feed this frequency into

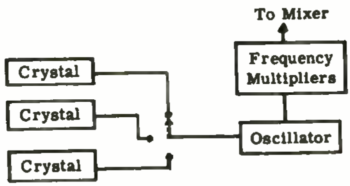



Fig. 1108. *Some mobile receivers have a switching arrangement so that any one of a number of crystals can be used. In other receivers the crystals are plug-in types.*

a doubler. This multiplies the frequency by 2, giving us 72 mc. By using another doubler circuit, we manage to get our local oscillator up to 144 mc.

Our mixer circuit is going to receive two signals. One of these will be the rf at 154 mc and the other will be the very much multiplied local oscillator signal of 144 mc. What is the result? Just this:

$$154 - 144 = 10 \text{ mc}$$

This 10 mc is our intermediate frequency.

### You can't do that

It's probably a good thing we can't hear you, because if we were together we would probably be listening to some anguished shrieks, "You can't do that. A crystal oscillator is a fixed frequency. This means you can receive only a single, fixed frequency."

This is sad, but true. If you will think back to an ac–dc set on the broadcast band, you will remember that the local oscillator is tuned by a variable capacitor. This means that, every time we change the variable capacitor (when we tune the receiver), we change the frequency of the local oscillator as well.

The situation isn't quite so bad as it seems. The way in which we get around it is shown in Fig. 1108. Here we have a number of crystals connected to a switch. Now you might think that the local oscillator, adjusted to work on a particular frequency, might not like the idea of having crystals on three different frequencies. But these frequencies are very close to each other, so the oscillator circuit does quite well.

## Is that good?

Does having the three crystals close to each other in frequency mean that we can tune only to a limited range? First, keep in mind that our crystal frequency is going to be multiplied (in this case) by 12 times (tripler-doubler-doubler) and so, while each crystal might be close in frequency, the final local oscillator frequencies will be well separated.

Note what this has done to us. We've paid a price for stability. With the arrangement shown in Fig. 1108, our receiver will pick up three spot frequencies in the 152- to 162-mc band. This might be enough for a particular operation using a mobile receiver. If not, more crystals can be used for the oscillator. In some sets, the crystals are plug-in types while in others a switching arrangement is used.

## Back to work

In our detailed inspection of the front end we've wandered away a bit from Fig. 1106, so let's get back to it.

Following the first mixer we have from 2 to 5 if stages. The output of the if is then fed into another mixer which also receives a voltage from a second local oscillator. This local oscillator is fixed-tuned to some frequency slightly higher than the if. The output of the second mixer is still another if. For this second if strip we could use frequencies from 450 to 460 kc. However, any frequency can be selected by the manufacturer. A typical if would be 1500 kc.

The output of the if is fed through one or more limiter circuits, then into a discriminator type of detector and finally into the audio section. Note the use of a squelch circuit.

Thus, we have covered the signal arrangement of a mobile receiver. Now let's see what we can learn about some of the circuits.

## Squelch circuits

Under most conditions of mobile operation, the receiver must be left on for long periods of time or else the receiver must come on at regular intervals. Typical examples might be in police cars, taxicabs or trucks where the operator of the vehicle must get messages at unexpected times. To be able to do this, the receiver must be kept on.

However, Fig. 1106 has probably given you the correct impression that mobile receivers have a tremendous amount of gain. As a result, noise voltages and weak signals have more fun with a mobile receiver than a mob of ants at a Sunday School picnic. To

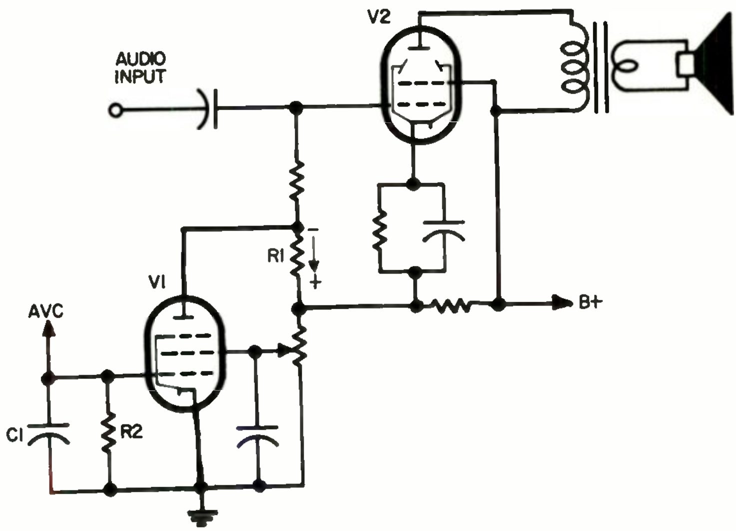



Fig. 1109. *Squelch circuit is used to mute the audio output in the absence of a strong signal.*

keep the operators of mobile receivers from investing their earnings in ear plugs, squelch circuits are used. A squelch circuit will cut off or will lower the gain of part of the receiver when there isn't enough signal present to listen to.

There are many types of squelch circuits and, to make the situation more confusing, they hide behind aliases. They are known as quieting circuits, silencing circuits, quiet automatic volume control (qavc), muting systems, and codan (carrier-operated device, anti-noise). But like a half-dozen young boys going out on a date, they all have the same thing in mind.

Fig. 1109 shows one type of squelch circuit. V1 is the squelch tube while V2 is the audio output power amplifier.

To see how the squelch tube has its hands around the throat of V2, consider the avc input to V1. When there is no signal input to the receiver or when there is a very weak signal, little or no avc

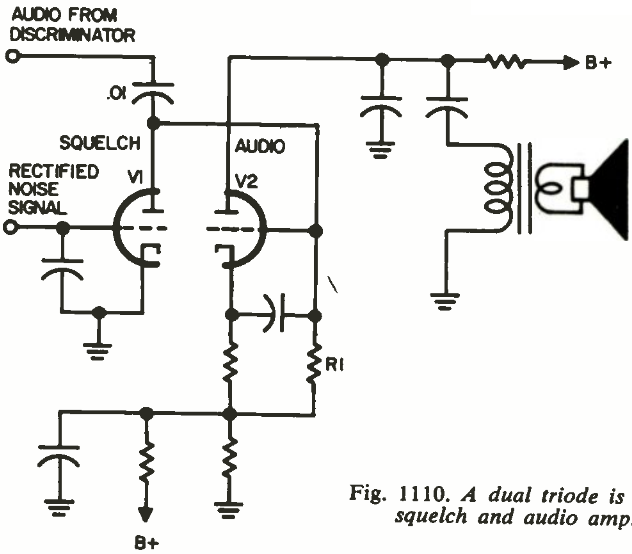



Fig. 1110. *A dual triode is used as a squelch and audio amplifier.*

voltage is produced. As a result, V1 runs hog wild since there is nothing to restrain its plate current. It has no bias on it and so the plate current of V1 manages to reach the top of its limit.

What will this current do? It will flow through R1 toward the B-plus end of the line. But when it passes through R1 we get a voltage drop across it, with the polarity shown in the circuit.

What is R1? We know it's the plate load resistor for V1. But what else? It has also managed to install itself very neatly between the control grid and cathode of V2. In this position it behaves as a bias resistor.

The voltage drop across R1 is fairly large and because of the polarity, V2 receives a hefty negative voltage on its control grid. The current through V2 becomes very discouraged and practically stops flowing. It's like having a policeman, a stop sign and a red light at a corner—all at the same time. V2, though, is the audio output tube, and, with no current passing through it, the only sound you will be able to hear in the room will be the heavy breathing of the base-station operator.

Now what happens when a strong signal arrives? V1 gets hit by a high avc voltage and, just to make sure that V1 doesn't go on and off like a movie neon light, we have R2 and C1 in the grid circuit. C1 charges to a steady dc voltage and manages to keep the control grid of V1 fairly constant.

Since the avc voltage is negative, the current through V1 decreases and so does the voltage drop across R1. This reduces the bias on V2 and current flows through V2 very nicely once again and once again sound fills the room.

## Another squelch circuit

The circuit in Fig. 1110 looks quite different from that in Fig. 1109 but, basically, both work in a similar way. During the time no signal is being received, some noise voltage is developed at the output of the discriminator. This noise voltage is rectified and is

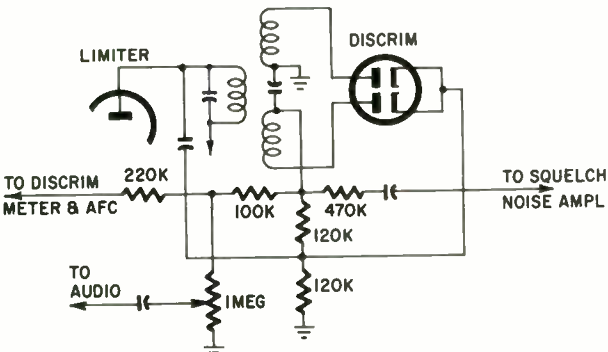



Fig. 1111. *Phase detector used in a mobile receiver. There are four types of FM detectors that can be used: the discriminator, the ratio, gated-beam and phase detectors.*

fed to the squelch tube, V1, as a dc control voltage. The polarity of this voltage is such that V1 conducts heavily. This current flows through plate load resistor R1. But R1 is also connected as a bias resistor between the control grid and cathode of V2. The polarity of the IR drop across R1 cuts off V2 and no signal is heard from the speaker.

When a signal comes in V2 is allowed to conduct and amplify the audio signal it gets from the discriminator.

## Phase detector

For the most part, mobile receivers use a typical discriminator type detector. Unlike the ratio or the gated-beam detectors, this type does not remove amplitude modulation or AM noise spikes from the if signal.

Discriminators use one or more limiters to clip the AM that may be with the signal. Sometimes a phase detector, such as the one shown in Fig. 1111, is used. This circuit resembles the discriminator very closely.

The phase detector has two outputs. One is the audio signal, which can be fed into an audio amplifier stage (through the volume control). The squelch noise is supplied to a rectifier diode. The output of the rectifier diode is then sent (as a dc control voltage) to the control grid of the squelch tube.

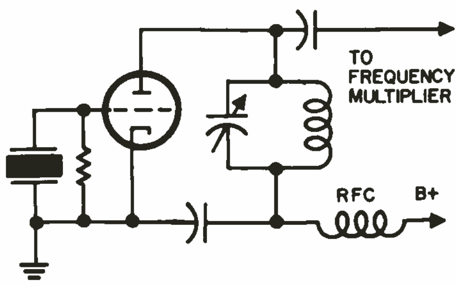



Fig. 1112. *In this circuit the frequency is controlled by a quartz crystal. The tuned circuit must be able to resonate at the frequency of the crystal.*

## Crystal controlled oscillators

A crystal is just a bit of quartz that has been carefully ground to a certain size and shape. It is then placed between a pair of metal plates and the entire unit is enclosed. A pair of external pins connect to the metal plates. These pins are used for mounting the crystal into a socket.

The size of the crystal determines its operating frequency, but for the most part it is controlled by its thickness. The thinner a crystal, the higher its operating frequency. There is a practical limit to this since if you keep grinding the crystal thinner and thinner you finally end up with no material left to grind.

There is also another practical limitation. A crystal undergoes mechanical stress. The thinner the crystal the easier it is to pop it out of the realm of good working units.

Fig. 1112 shows a simple circuit using a crystal. The output of the crystal controlled stage can be capacitively coupled to the frequency multiplier (as shown) or it can be transformer coupled.

Another method of coupling is shown in Fig. 1113. Here we have a gimmick coupling the output of the crystal oscillator into the mixer. Where the receiver does not use frequency multipliers, the coupling can be made right to the grid of the mixer, just as in Fig. 1113.

The gimmick is shown as a coil. Actually, it works because of capacitive coupling, not inductive. In some cases there is no direct

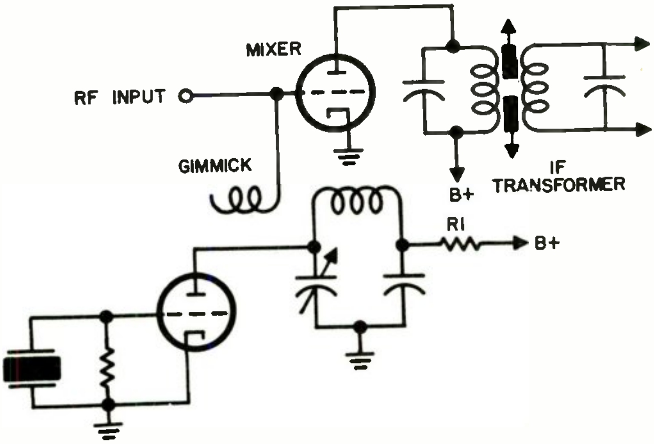



**Fig. 1113.** *In this circuit a gimmick is used to couple the output of the crystal oscillator to the mixer.*

connection at all. A few turns of well insulated wire are wrapped around the plate end of the oscillator coil. The other end of the wire is then brought over to the grid of the mixer (or the multiplier) and wrapped around the grid lead, or soldered to it. (Also see Fig. 1016 on Page 2-141.)

Fig. 1112 shows the use of a radio-frequency choke (rfc) to keep rf out of the B-plus line. Sometimes, as shown in Fig. 1113, a resistor (R1) is used. The choke is more effective and produces less of a voltage drop. The resistor is cheaper and easier to mount.

## Checking the crystal oscillator

A bias voltage will develop on the grid of the oscillator tube if the circuit is working properly. Connect your vtvm between control grid and ground and check the amount of negative voltage on the grid. It will range between −3 to −10 volts, depending on the circuit. If you get no voltage reading, the circuit may be detuned or you may have the wrong crystal in position.

Another check method is to put a dc milliammeter in series with the crystal and measure the amount of crystal current.

## Oscillator, multiplier and mixer

If you get a chance to look at the complete schematic of a well built, mobile receiver you might find it confusing – just at first glance. It isn't as bad, though, as some TV schematics. The best thing to do is to locate some familiar circuit and work your way out of the jungle from there. For example, you might look at the crystal oscillator, multiplier and mixer circuit, as shown in Fig. 1114. First, note oscillator coil L1. The notation, F1, alongside means that the coil is tuned to the fundamental frequency of the crystal. The coil has no tuning capacitor, its point of operation being adjusted by a slug.

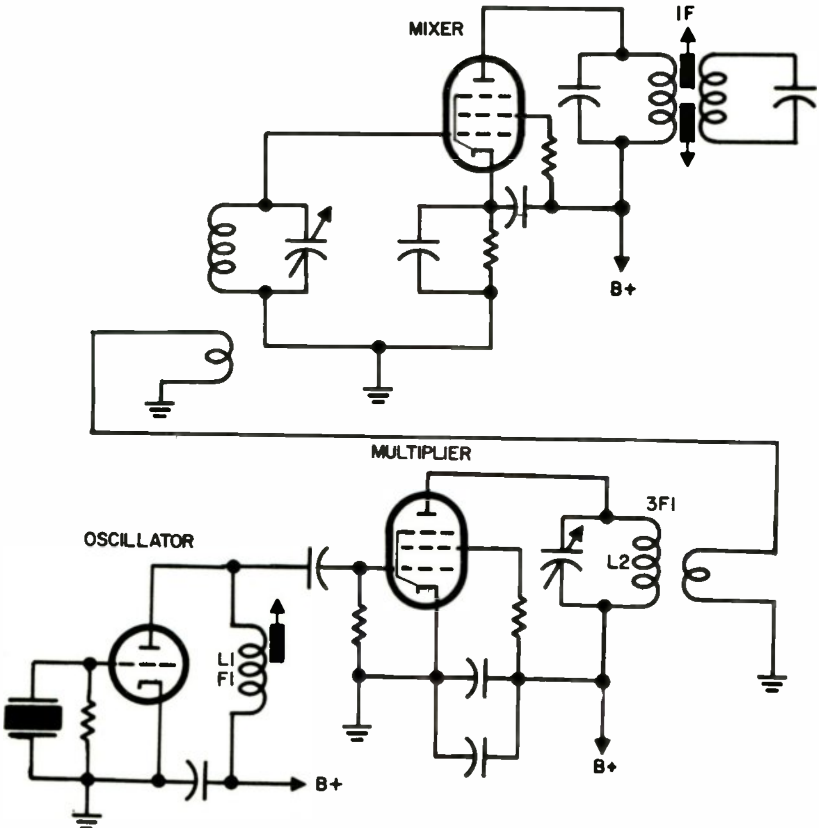



Fig. 1114. *Local oscillator, multiplier and mixer circuits. Only one multiplier is shown. Some receivers use several frequency multipliers.*

The output of the crystal oscillator is capacitively coupled into a frequency multiplier. The multiplier has no cathode bias and so we have a fairly strong current through the tube. The current is enough to put the tube into the curved part of its characteristic—or, to talk just a little more plainly, we deliberately encourage the tube to distort. Now you might think that this puts us in the same position as the bank manager, who opens the vaults, doors and windows—and then goes home.

We want the tube to distort, since the output will then contain

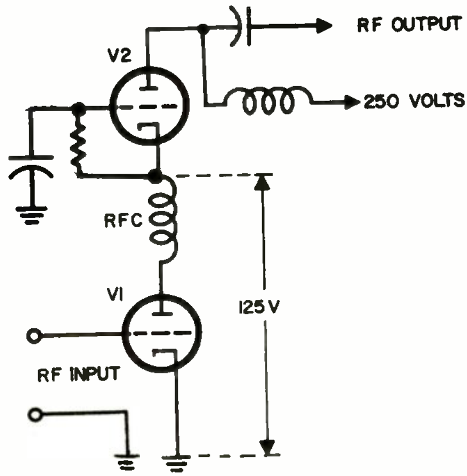



Fig. 1115. *Cascode rf amplifier circuit. The two tubes are connected in series.*

not only the fundamental but also harmonics. Having harmonics is like going to a big party. You pick what you want. In the case of Fig. 1114 we went the third harmonic. How do we know this? The tank coil is marked 3F1. This means that it is tuned to three times the fundamental frequency, F1. In some circuit diagrams you will see the actual frequency marked alongside the crystal and also the multiplier tank coils. Armed with this bit of information (supplied by the manufacturer) you will be able to decide whether you are working with a straight rf amplifier, a doubler or a tripler circuit.

To save space, the oscillator and multiplier tubes live under the same roof—that is, the tube can be a triode-pentode.

## Cascode radio-frequency amplifier

Radio can be more full of surprises than a monkey out of its cage. You would expect pentodes to be used up in the front end of a mobile receiver . . . and for a few good reasons at that. They do not need to be neutralized (that is, we don't expect them to oscillate) and they supply a large amount of gain.

However, you will often find triodes since they produce much less noise than pentodes. What price do we pay? Triodes must be neutralized and their gain is much lower than pentodes.

Fig. 1115 shows two triodes in what we described earlier as a cascode circuit. Basically, it consists of a triode followed by a grounded-grid amplifier. Taken together, the two tubes supply at least as much gain as a single pentode and less noise. In the cascode of Fig. 1115, B plus is connected to the plate of V2 and indirectly the plate of V1. Note that the two tubes act as a voltage divider.

Since V1 is a straight rf amplifier, it needs to be neutralized. (See Fig. 1116.) This is done by means of a feedback coil L1. Capacitor C1 is included to keep B plus off the control grid. V2 does not need neutralization since the grounding of the control grid supplies a shield between the input and output circuits.

You may have trouble seeing V1 and V2 as a series setup. If (going back to Fig. 1115) we assume equal voltage drops across the two tubes, then the cathode of V2 will be at about 125 volts when the B-plus supply is 250 volts. Since the cathode of V2 is so much higher in voltage than its filament, we get an occasional breakdown.

Offhand you might think that the circuit of Fig. 1116 gets around this problem, but it doesn't. For the circuit of Fig. 1116 to work the B plus for V2 must be higher than that for V1. The cathode of V2 and the plate of V1 are almost at the same potential.

### What's next?

Since we are now coming down the home stretch, you've probably realized just what our approach has been. Radio receivers used today are superheterodynes. If we start with this as our generalized heading, our next step would be to classify receivers as AM or FM. But where do we go from here?

Before we answer that one, suppose we ask a question. What is the difference between a low-cost ac–dc set and a communications receiver? Both are superhets and both can be AM. The same basic circuits are used in both.

The big difference is in the number of circuits and in special circuits. A low-cost home receiver might have just one if. A communications receiver could have three or four. A communications receiver could have special circuits such as noise limiters, delayed avc, tuning indicators, etc.

Thus, if you can repair a low-cost superhet, you should be able to (theoretically) repair any other superhet, provided you become acquainted with any new circuits involved.

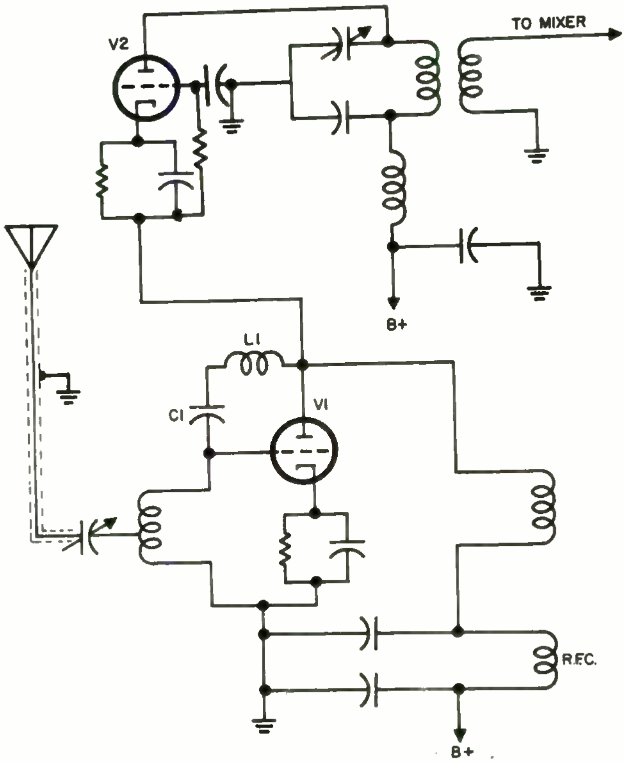



Fig. 1116. *The cascode circuit is a voltage divider.*

Does this mean that servicing is a hopeless case? Hardly! All you have to do is to consider the basic circuits of communications receivers, mobile receivers, marine receivers, etc., as just being specialized versions of the ac–dc set. All of the knowledge that you have about servicing can always be put to use.

Not all receivers come under our general heading of superhet AM or FM. We are going to cover these mavericks in the next chapter just so that your store of information about radio repair will be complete.

## QUESTIONS

1. What are some of the operating frequencies used by mobile receivers?
2. What is a base station?
3. What is double conversion? Why is it used?
4. What is a frequency multiplier? Where is it used in a mobile receiver? Why is it used?
5. Why is the local oscillator crystal-controlled in some mobile receivers? How is the local oscillator frequency changed when crystal control is used?
6. Why is local oscillator frequency drift a serious problem in mobile sets?
7. A crystal-controlled local oscillator works at a fundamental frequency of 15 megacycles. It is followed by a doubler and two triplers. What frequency is fed into the mixer?
8. Why are squelch circuits used? Describe the operation of a squelch circuit.
9. What do qavc, a muting system and codan have in common?
10. Name four types of detector circuits used in receivers.
11. Why is distortion desirable in a multiplier circuit?
12. What is a cascode rf amplifier? How does it work?

# CHAPTER 12 miscellaneous receivers

HOW MANY WAYS do you think there are of preparing an egg? Fried, boiled, sunny side up, omelette, poached? You could probably name at least half a dozen more. But would that be the end of the list? Not by any means. We must take into account those special cooks who can do things with eggs that we never thought of.

What has this to do with radio receivers? Well, if you can remember that one egg is pretty much like any other egg, and what can be done to one can be done to all of them, can you imagine what can be done with a whole collection of components?

## Is it difficult?

When you take your first look at some odd receivers (odd because they may be new to you) you might be tempted to throw up your hands and say, "That's all, brother! I've had it." But how different are they? Just a radio, and usually a superheterodyne at that. And when you come right down to it, a superhet is just a mixer, a couple of if's, a detector and some audio. But (as with the egg) you can add circuits, change circuits, make parts do things you never expected.

The strange thing about all this is that you know how to service these sets. The tough part isn't the repair so much as being told just what is new or different. It's something like the difference between talking to an old friend and someone you have just met. It does take a little time for the strangeness to wear off.

## Can we cover them all?

In this chapter we are going to tell you about different radio receivers, converters, preselectors, regenerative sets, etc. It would be impossible to cover them all, since, even as you read this, somewhere manufacturers are busy as little beavers making up new and unusual sets.

## FM–AM portable

Do you remember all the different "crazes" we've had? For a while we had flag-pole sitters, marathon dancers, goldfish swallowers, mah jong players. After a while the novelty wears off and people get back to normal. However, once in a while some of these wild shenanigans turn out to be not so wild after all, and gradually make a comeback.

Take FM for example. In like a lion and out like a lamb. At one time, if you didn't have an FM receiver you were the next


Fig. 1201. *Outside view of the 12-transistor AM-FM portable.* (Sony)

thing to being a social outcast. But then FM lost its popularity and FM sets became just another ornament. When it was "rediscovered" people began to realize that FM could supply some very good music that sounded sweeter and better than AM broadcasting.

If there is anything you can say for Americans as a group, you can say they always go "whole hog." If they like something, they really like it. And so, when FM made its comeback, it did so with a great big rush. We now have FM not only in the home, but in automobiles, and as portables. Take a look at Fig. 1201, a picture of a 12-transistor AM-FM portable receiver. Fig. 1202 is

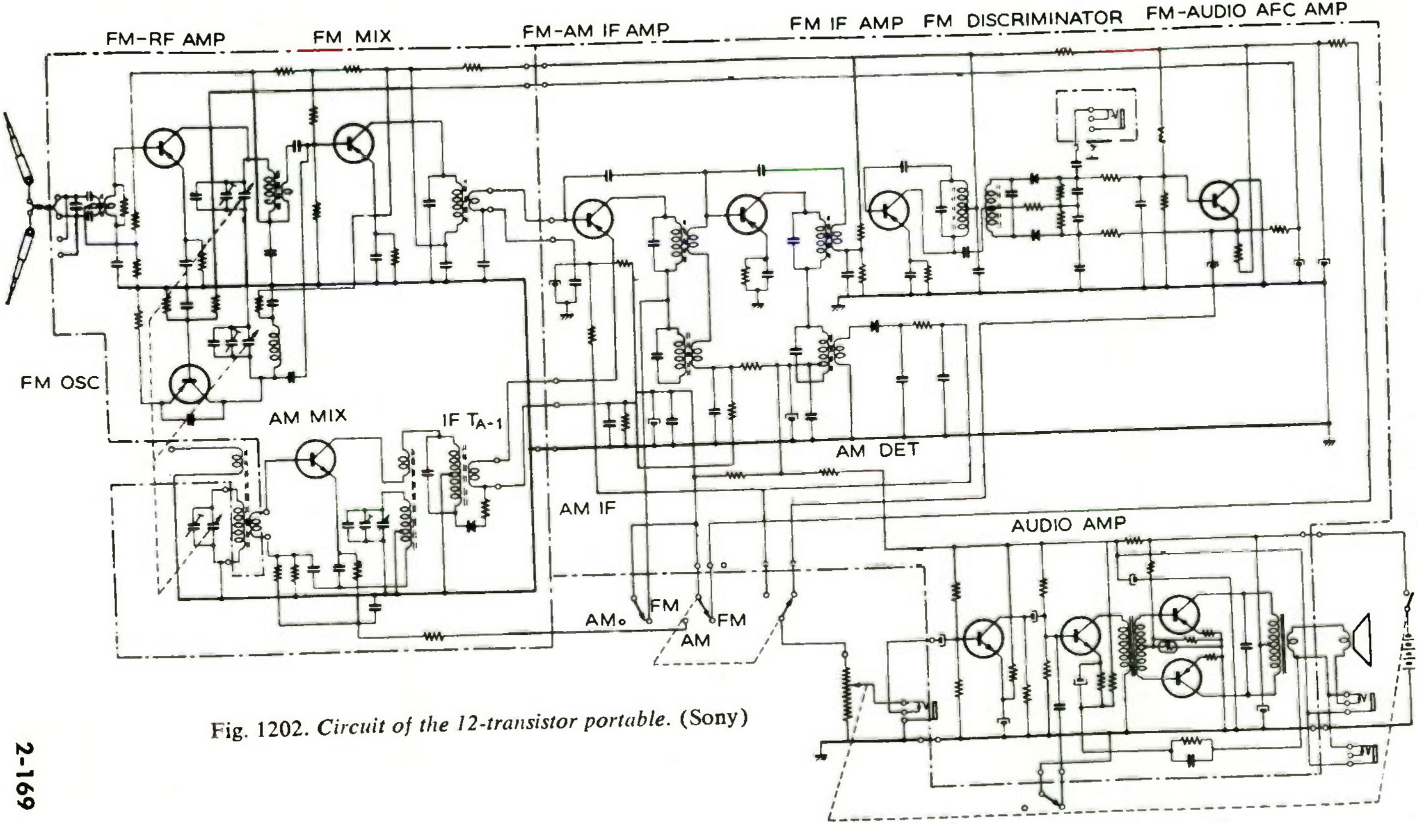



Fig. 1202. *Circuit of the 12-transistor portable.* (Sony)

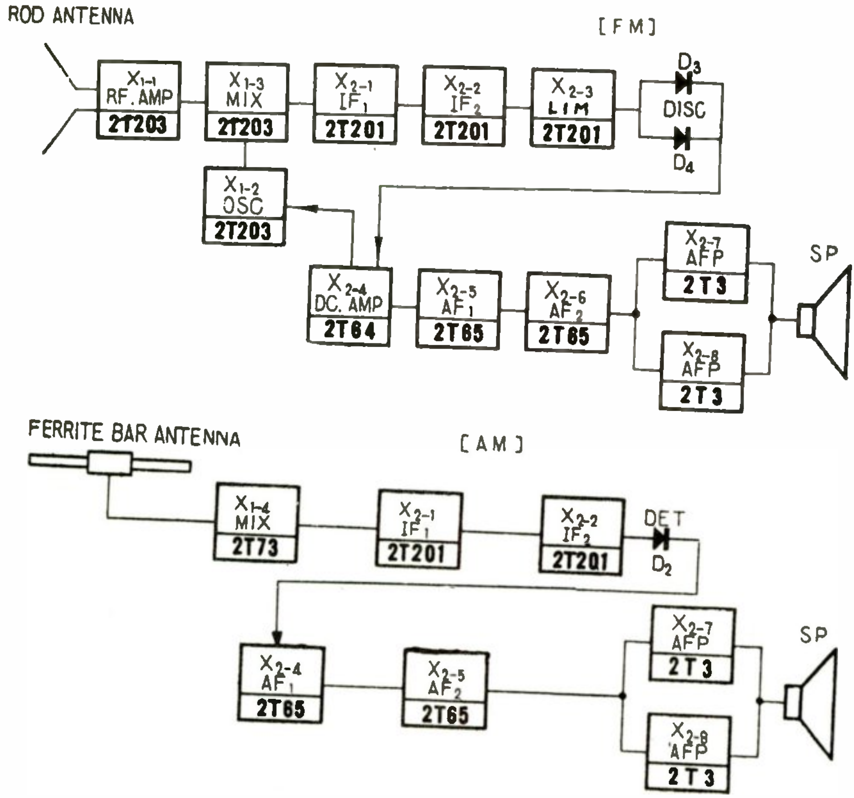



Fig. 1203. *This block diagram of the AM-FM transistor portable shows that more stages are used for FM broadcast reception (top) then are required for AM broadcast listening.* (Sony)

the circuit diagram. This portable, incidentally, can also be used as an AM–FM tuner.

A first look at Fig. 1202 might convince you that the circuit is complicated, but take a second look. As in most receivers that pick up more than one band, some of the components do double duty—that is, they work for both bands.

Let's take the FM section. It has a telescoping dipole antenna (mounted on the handle of the receiver). The signal passes through through an rf amplifier stage into a triode transistor mixer. The mixer receives the local oscillator voltage from another transistor.

Following the mixer we have three transistor if stages. The FM detector is a discriminator circuit with audio output taken off through a jack for a pair of earphones. There are several stages of audio amplification and then push-pull output.

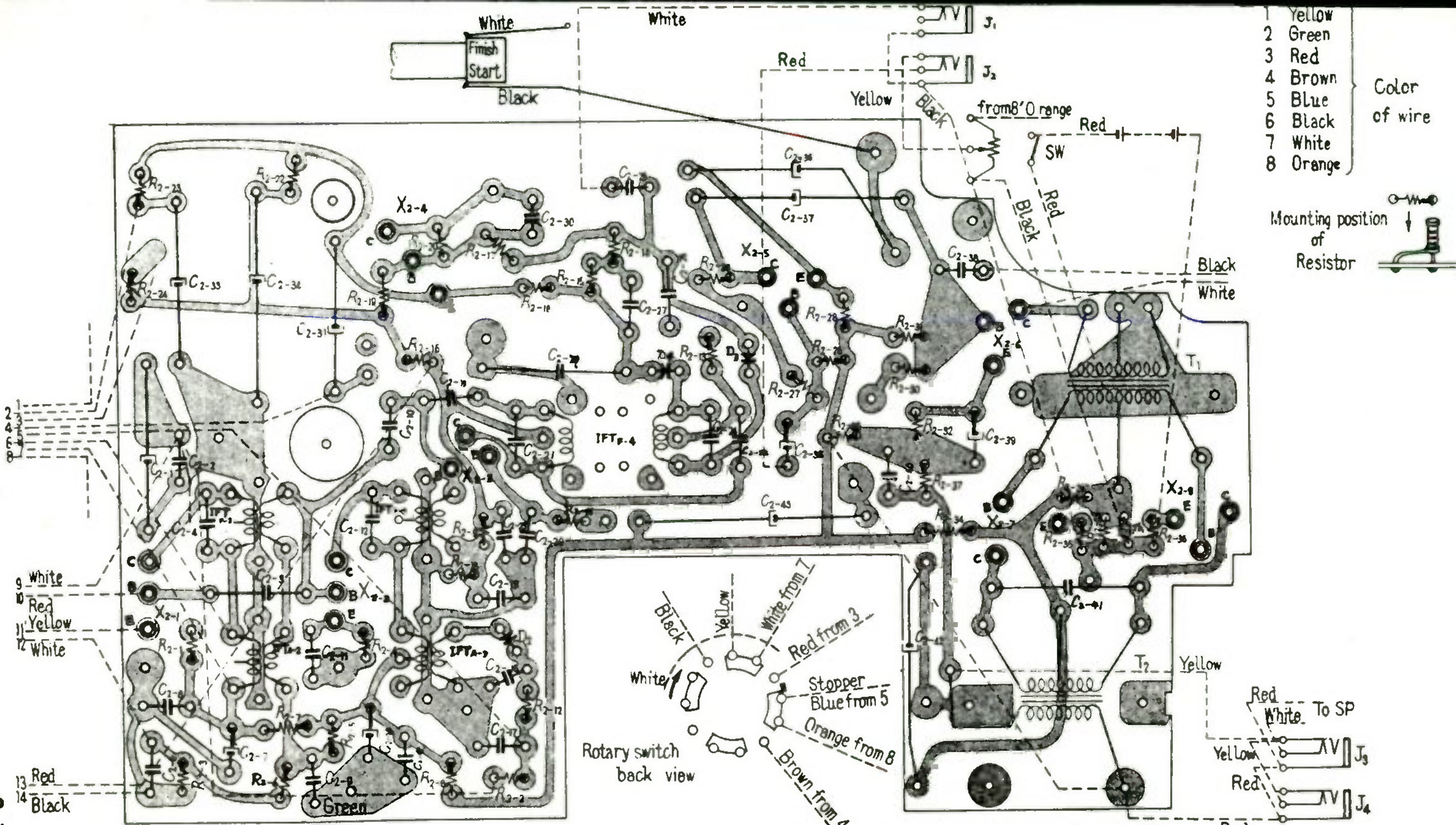



Fig. 1204. *The if and af sections of the 12-transistor receiver are mounted on a printed-circuit board.* (Sony)

The AM section is a little less elaborate. The signal is brought into an AM mixer. The same transistors that are used for the FM intermediate-frequency stages are also used for the AM intermediate frequency. The AM detector is a crystal diode. The audio output of the AM detector is fed to the same audio amplifier as the FM.

You can get a better idea of the circuit by following the block diagram shown in Fig. 1203.

On AM the receiver covers 535 to 1605 kc. For FM, the range is 86.5 to 108 mc. The if for the AM section is 455 kc. while it is 10.7 mc. for FM. For AM, the antenna is a built-in ferrite bar provided with a jack for an external antenna. For FM, a built-in balanced rod antenna is used. There are also terminals for using a balanced type external antenna (such as a dipole) having 75 to 400 ohms impedance. The entire set is powered by four size C flashlight batteries (total–6 volts).

## Circuit details

Like most of the transistor sets we covered earlier, the circuit of Fig. 1202 uses almost all p-n-p transistors. Be careful, though. The AM mixer and some of the audio amplifiers are n-p-n's. While both types are used, the positive terminal of the battery is grounded.

There are two printed-circuit boards. One is for the if and af section (Fig. 1204), while the other is for the rf section (Fig. 1205). A large part of the copper foil material on these boards is at ground potential.

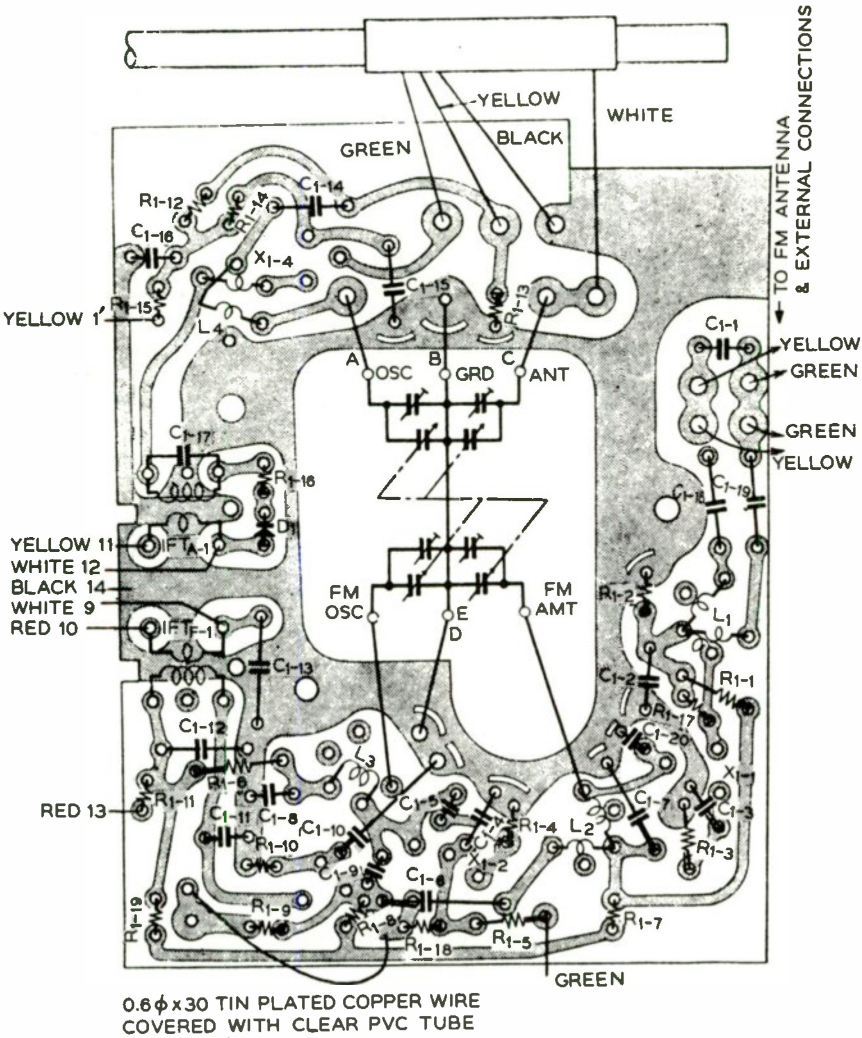
## AM–FM switching

Most of the circuits are used for both AM and FM. Those that are not are switched on or off, depending on whether AM or FM is wanted. When the set is switched to FM, here are the changes that are made:

1. The converter circuit is switched to FM.
2. A limiter circuit is added to the if stage.
3. Afc current is fed to local oscillator X1-2 through dc amplifier X2-4. (Fig. 1203.)

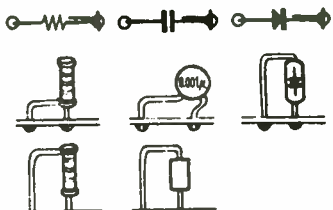
## The if stage

The if stage works as a grounded emitter circuit for FM and as a grounded-base circuit for AM. The purpose of the change is to prevent unstable operation due to excessive gain at 455 kc.




TOP HEIGHT OF COMPONENT FROM CIRCUIT BOARD SURFACE

SYMBOL FOR COMPONENT POLARITY



| | |
|---|---|
| $X_{1-1,2,3}$ | MUST BE LESS THAN 17MM |
| $C_{1-2,4,6}$, $C_{1-7,8,10}$, $C_{1-18,19}$ | MUST BE LESS THAN 11MM |
| $C_{1-5,9}$ | MUST BE LESS THAN 5MM |

Fig. 1205. *Schematics that come with imported receivers include more information than we are used to seeing. Here component polarity is indicated. In compact units component size and height are important.* (Sony)

## Afc operation

For portable FM radio, we need an afc circuit to minimize detuning due to "body effect" or variation of the local oscillator frequency because of the transistor's temperature characteristics.

Here is how the automatic frequency control circuit works: Let us say that the local oscillator shifts in frequency. A dc voltage is developed at the output of the FM discriminator. This voltage is applied to the base of X2-4, which works as a grounded collector dc amplifier. The output voltage, taken from the emitter of transistor X2-4 is sent along to the base of transistor X1-2, the local oscillator. On the way, the correction voltage is filtered by a resistor and capacitor.

The dc correction voltage changes the collector current of the local oscillator, at the same time changing the frequency of resonance of the oscillator tuned circuit. But what is this change? It

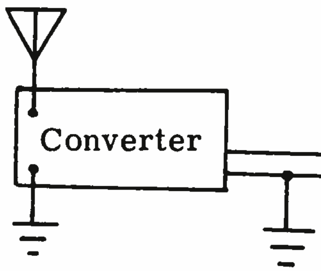



Fig. 1206. *The converter and the receiver, working together, form a double-conversion superheterodyne.*

is in the direction of correct local oscillator frequency. When this happens, the dc correction voltage disappears and will remain at zero as long as the local oscillator is on frequency.

A little earlier we mentioned "body effect." Sometimes known as "hand capacitance," it is simply the ability of the body to change the frequency of an oscillating circuit. To test it for yourself, bring your hand close to (but not touching) a tuned coil in the front end of a receiver and note how you can tune the set in and out just by moving your hand.

Because the action of afc is important and because you will run across afc in many well built FM receivers, let's review it on a step-by-step basis:

1. Local oscillator shifts.
2. The if frequency deviates from the center frequency.

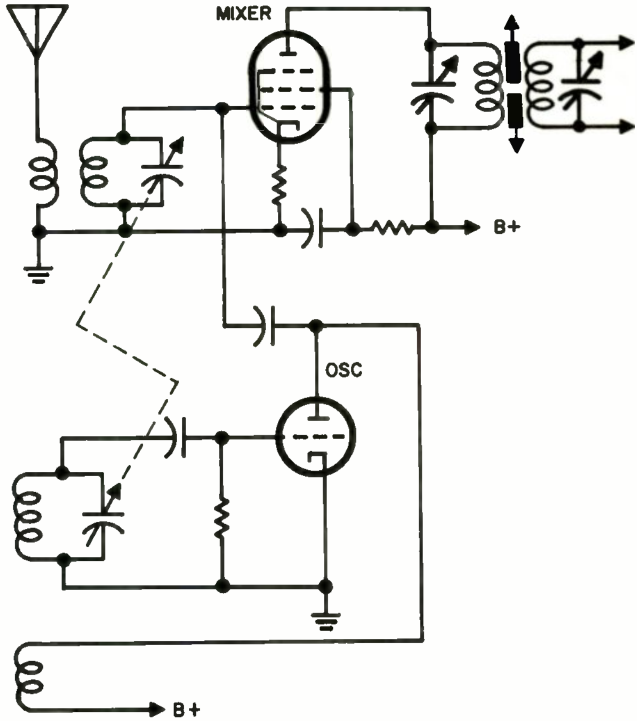



Fig. 1207. *Converter circuit. Some converters use an rf amplifier while others have crystal-controlled oscillators.*

3. A dc voltage appears across the discriminator output.
4. The dc voltage is amplified.
5. The dc voltage is fed back to the base of the local oscillator.
6. The dc voltage sent to the local oscillator changes its base bias.
7. This changes the collector current of the local oscillator.
8. The change of collector current modifies the frequency of the tuned circuit connected to the collector.
9. This change brings the local oscillator back to its original frequency.
10. As the local oscillator moves back to its original frequency, the if deviation becomes less and less, and the dc voltage across the discriminator reduces until it disappears.

## Converters

We studied FM and AM tuners in Chapter 8. At that time we learned that a tuner was half a radio and that it included all circuits up to and including the detector. Sometimes it also has a single stage of audio.

A converter is different. Its purpose is to enable receivers to tune to bands other than those for which they were originally designed. Let us say that you have a home receiver and that you use it just for the broadcast band. With the help of a converter you could pick up radio amateur signals, beacon signals, police calls, aeronautical signals, short wave, etc.

The arrangement is quite simple, as shown in the block diagram of Fig. 1206. All we do is pick up the signal and change it so that our receiver can use it. The converter consists of a mixer and a local oscillator. These two units change the signal to some frequency in the broadcast band. Our receiver is tuned to this one frequency and remains tuned to it.

Does this action sound familiar? It should! What we are doing, if you haven't already guessed, is making a double conversion superhet out of our receiver with the help of the converter.

## Converter circuit

When we look at the converter circuit (Fig. 1207), we see that we are in for a bit of a surprise. That's all it really is. A converter.

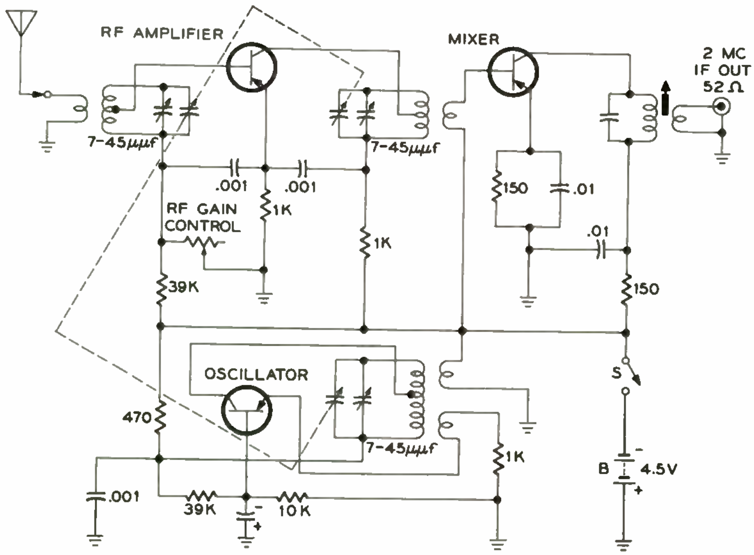



Fig. 1208. *Converter can be used to adapt communications receiver for broadcast-band reception.*

It's just like the front end of a receiver. The frequencies picked up by the converter depend entirely on the tuning circuits. The output of the converter is some frequency in the broadcast band.

The output of the converter goes into an if transformer. The secondary of the if transformer is connected across the antenna and ground terminals of the receiver. In the receiver, the mixer and local oscillator form the "second mixer circuit."

The converter of Fig. 1207 has been simplified. Usually you

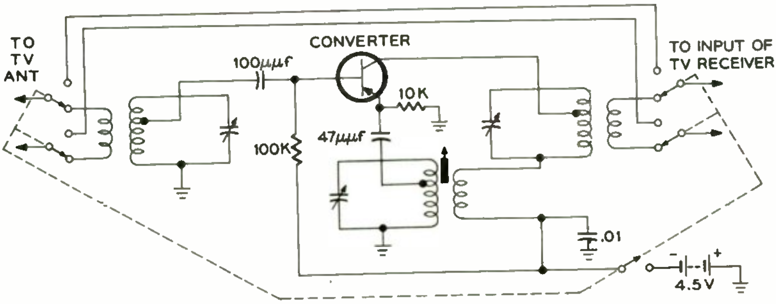



Fig. 1209. *Converter for picking up signals in the FM broadcast band. The output is connected to the input of a split sound TV receiver.*

will find some switching arrangement so that the converter can cover a number of different bands.

## Other converters

Some communications and short-wave receivers do not cover the broadcast band. Thus, a communications receiver might have a switching arrangement for tuning from 400 to 500 kc and its next band might be from 1,600 to 3,000 kc. In this way it would skip the broadcast band entirely.

A converter, such as the one shown in Fig. 1208, can be used to adapt the communications receiver for broadcast-band operation. Its output frequency (actually an if) is 2 mc. The communications receiver is tuned to this frequency and remains tuned to it as long as the converter is being used. A switch can disconnect the converter when the communications receiver is to be used for bands other than AM broadcast.

The unit in Fig. 1208 uses three transistors. One is an rf amplifier, while the others are for the mixer and the local oscillator. Note the use of an rf gain control in the emitter circuit of the rf amplifier. This helps keep the gain down and minimizes the possibility of overloading the front end of the communications receiver.

You may be wondering why we don't run an agc lead from the receiver out to the converter, instead of using an rf gain control. There are several reasons for this. The first is that it is more convenient to have the minimum number of connections between the converter and the receiver. In Fig. 1208, the converter is self-powered—that is, it has its own battery.

There is another and more important reason. We don't know whether the communications receiver is a transistor or a tube type. And even if the communications set is a transistor type, its agc voltage may be of the wrong polarity for the type of transistors used in the converter.

The converter circuits we have covered are just a few of the many available types. Some use a single tube, while others have

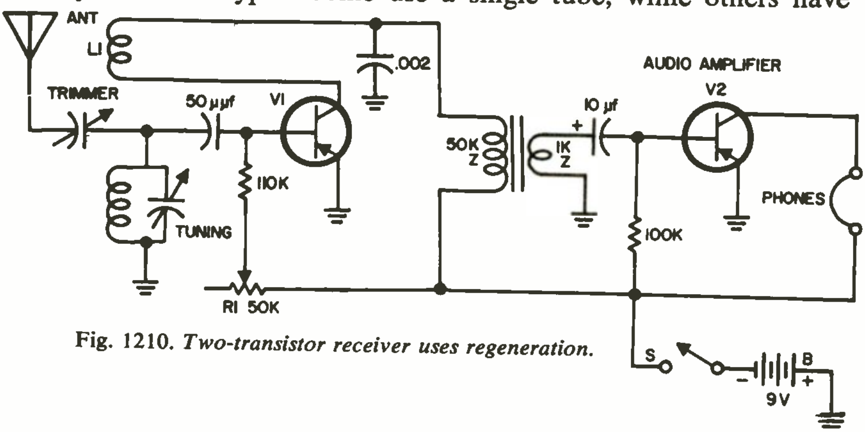



Fig. 1210. *Two-transistor receiver uses regeneration.*

three or four. Some cover a single band (such as the broadcast band) while other converters have elaborate switching systems to tune many different bands. Some have transistors. Others have tubes. Deluxe converters have an rf amplifier stage and may have one or two if stages before the output. But no matter how simple or complicated they may be, all they can be, basically, is a mixer circuit.

## FM converters

As you know, the FM band (88 to 108 mc) is sandwiched between the lower and the higher TV channels. The sound part of a TV set is FM and so a converter can be used to pick up FM broadcast signals. A converter of this type is shown in Fig. 1209.

Note the switching arrangement in Fig. 1209. The television set can remain permanently attached to the converter. With the help of a switch, the television set can be connected directly to the antenna for TV reception. This same switch turns the converter battery supply off.

## Regenerative receivers

Did you ever get stuck with a "dead" car battery? One way of getting into motion is to get a push but, if you're on the downgrade of a hill, so much the better.

In a radio receiver we can get some extra gain out of the set by taking part of the output and feeding it (in phase) back to the

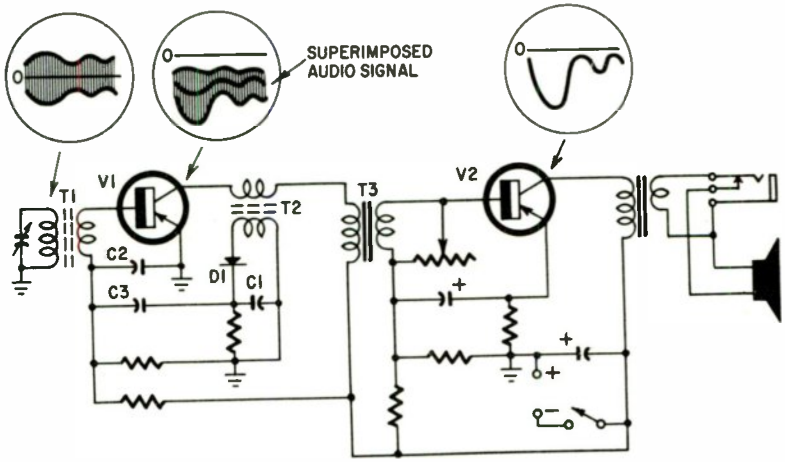



Fig. 1211. *Reflex receiver gets maximum effort out of transistors.*

input. As with our dead car on the hill, we take advantage of the "extra push" we can get from the output signal.

Fig. 1210 shows a two-transistor receiver using regeneration. The output signal is taken from the collector of V1 and fed back (through L1) to the base input. Since the fed-back signal is in phase with (in step with) the incoming signal, the signal is strengthened. The amount of feedback is controlled by R1. If feedback is permitted to become too strong, the first transistor V1, will oscillate.

You might think that no one would be interested in a two-transistor receiver, yet many of these low-priced "vest-pocket" types are being manufactured. They are usually about the same size as a pack of cigarettes. They can seldom receive more than a few stations.

V1, in Fig. 1210, is quite an important transistor. It acts as an rf amplifier and is also the detector. The output of the receiver is seldom strong enough to operate a speaker, although it will do so if the local station is strong enough and close enough.

The circuit of Fig. 1210 can be used to pick up CW signals. (This assumes, of course, that the tuning circuit covers bands on which CW is transmitted. Most of these two-transistor radios, though, are intended for the broadcast band.) With proper adjustment of R1, code signals will come through quite clearly. No extra bfo circuit is needed.

Fig. 1212. *Front-view of a Citizens-band transceiver. Minimum number of controls gives this unit a clean look, makes it easy to operate.* (Allied Radio Corp.)

## Troubles with regenerative receivers

It may be hard to believe (as the little boy said when he saw a giraffe for the first time), but there it is. You might think that nothing could go wrong with a two-transistor radio but they have their troubles just the same.

What can happen? The set may fail to regenerate. Most often the trouble is a weak battery, but it could also happen if the leads to coil L1 were transposed, if we had an open in R1 or in the primary of the audio transformer. You can "hear" if the set regenerates. Plug in the phones and advance R1. At some point you should hear a soft rushing noise. If you do, there is regeneration.

Test the audio section just as you would any audio amplifier. Follow the instructions given earlier on servicing audio stages.

## Two-transistor reflex receiver

For economy, one transistor can be made to do the work of two. In the circuit of Fig. 1211, the first transistor, V1, amplifies the signal at the broadcast frequency and feeds it to a transformer-coupled diode detector, D1. From here, the signal voltage, now an audio frequency, is supplied to the ground end of the rf input tuned-circuit coupling winding. This is in series with the base of the first transistor.

Although this is a feedback circuit, neither regeneration (and possible oscillation) nor degeneration exists since the feedback would have to be at the broadcast frequency to have effect. Most or all of the rf is removed by C1 and C2.

The coupling winding in the base circuit of V1 has several effects. It acts as an rf choke as well as an inductively coupled trap, tuned to the broadcast frequency. Thus, there is little or no voltage able to support oscillation.

The audio signal voltage at the base of V1 is amplified again and coupled to the audio output stage through T3. The output stage needs no explanation since it is little different from that found in many other pocket portables.

For troubleshooting, an audio signal can be injected at the junction of D1, C1, C3. If audio is heard at this point but a station cannot be tuned in, it might indicate that the tuning circuit, T2 or D1 is defective.

Little or no servicing information is available for these receivers. Special parts such as T2, the volume control and the tuning capacitor, might be difficult or impossible to replace. V1 could probably be substituted by any appropriate transistor capable of 1.5-mc operation. D1 can be any diode small enough to fit, provided proper polarity is maintained.

For the most part these receivers are available for less than $10 and it is usually not worth while to repair them except for personal satisfaction.

## Transceivers

Radio receivers and transmitters have so much in common that it isn't surprising to find them (sometimes) united in the bonds of holy matrimony. When this happens, what can we call the combination? Receiver? It's more than that! Transmitter? Still not good enough. The unit is really a transmitter-receiver—so we take the first part of transmitter and the last part of receiver, combine them, and come up with transceiver.

Fig. 1212 shows the front view of a transceiver. The tuning range is from 26.965 to 27.255 mc, covering all 23 channels of class-D Citizens-band.

This compact receiver can be put on top of a desk or fitted into a car or boat. The set has a single transmit–receive switch and a built-in ac power supply.

The more expensive models have better receivers. This usually is a high-sensitivity, double-conversion superheterodyne which can be tuned manually to cover all 23 channels. The receiver has a built-in noise limiter to reduce automobile ignition and other noises, and a squelch circuit to keep the receiver quiet until a signal is received. (In this book we are concerned with receivers. A license is required to repair any portion of the transmitter that will affect either its operating frequency or its power output. This license is acquired by examination. No examination is needed for the operator's license.)

Before we start talking about circuit details, look at the inside of the transceiver shown in Fig. 1213. Note the printed-circuit board mounted on a cutout in the metal chassis. In this trans-

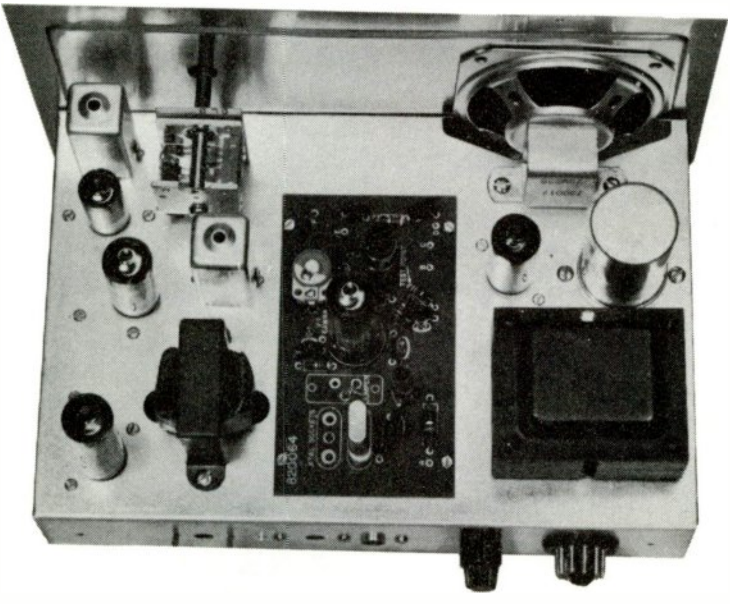


Fig. 1213. *Inside view of Citizens-band transceiver. The printed-circuit board is mounted on a chassis cutout.* (Allied Radio Corp.)

ceiver, both printed-circuit and point-to-point wiring are used. The printed-circuit board is held in place by four screws.

To learn more about transceivers, start by looking at Fig. 1214. Here we have the complete circuit diagram. The circuit shows that we have both a transmitter and a receiver. With the help of the transceiver we can talk to another unit or receive a signal from another transceiver. This function is selected by switch S1.

When the switch is put in the transmit position, the antenna is connected to the output of the transmitter, the microphone is connected to the audio amplifier while the speaker is disconnected from the circuit.

When S1 is put in the receive position, the antenna is connected to the receiver input and is tuned by L3 and C19. At the same time, the speaker is connected to the output of the audio amplifier and the microphone is disconnected from the circuit.

The receiver uses a superregenerative circuit. The first stage, V2, is an rf amplifier. Since superregenerative receivers can radiate, the rf amplifier helps isolate the superregenerative stage from the antenna to prevent radiation.

## What is superregeneration?

The superregenerative circuit oscillates in two different ways. There is positive feedback from output to input—that is, from the plate to the grid circuit. This is regeneration and strengthens the 27-mc signal.

The more positive feedback we have, the more output we can get from the tube using the feedback. Like all good things, though, there is a limit. Use too much feedback and the tube starts to produce a sickening howl. To prevent this, we use an interruption voltage which turns the tube on and off very rapidly, preventing a buildup to a howling point.

The interruption voltage is called a quench voltage. The quench voltage usually has a frequency in the ultrasonic range – that is, somewhere above 30 kc.

## Why the howling?

Regenerative receivers use a grid leak and a grid capacitor to supply bias to the regenerative detector tube grid. As we begin to use more and more feedback, the grid capacitor begins to discharge through the grid leak more and more slowly. Regeneration doesn't give the grid capacitor a chance to discharge and charge

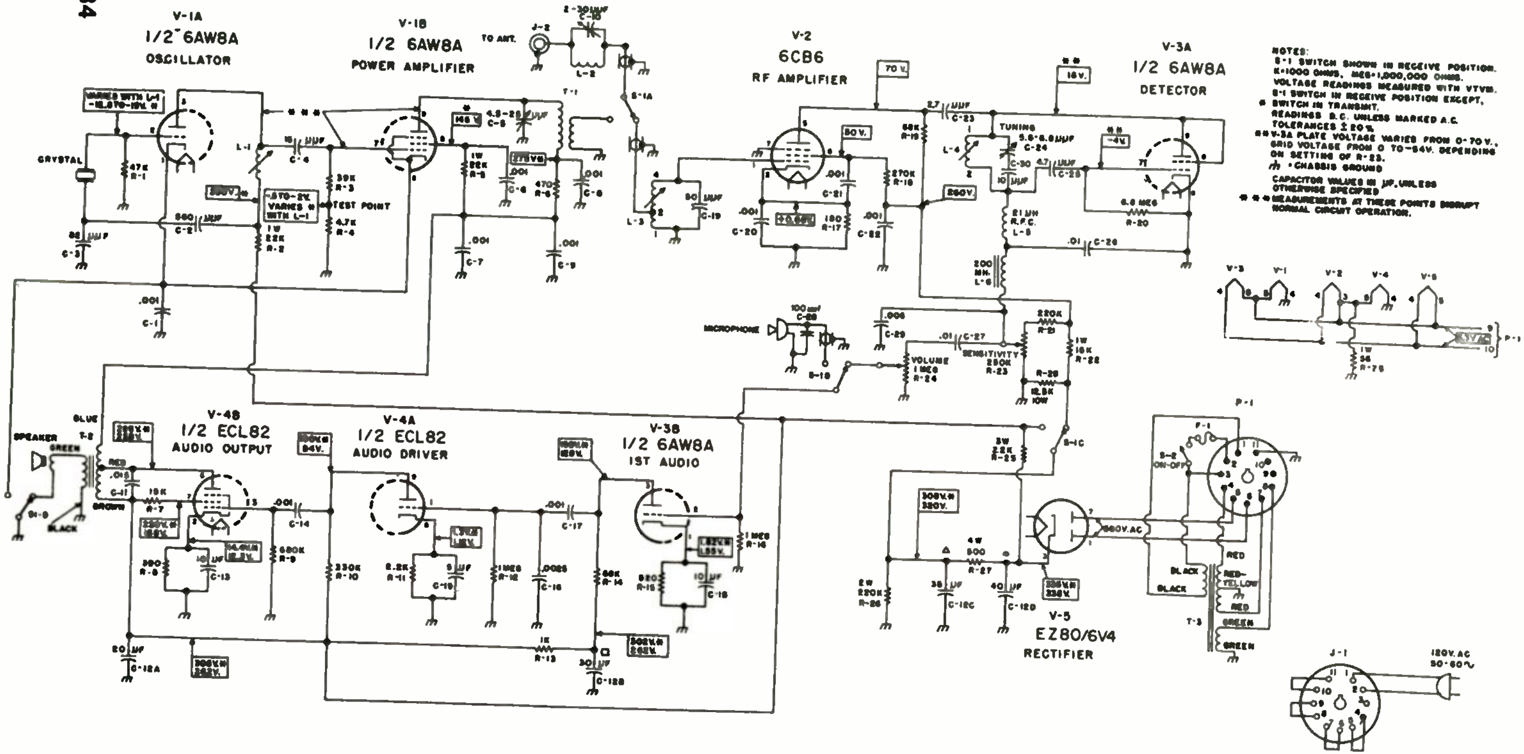



Fig. 1214. *Complete circuit of the transceiver.* (Allied Radio Corp.)

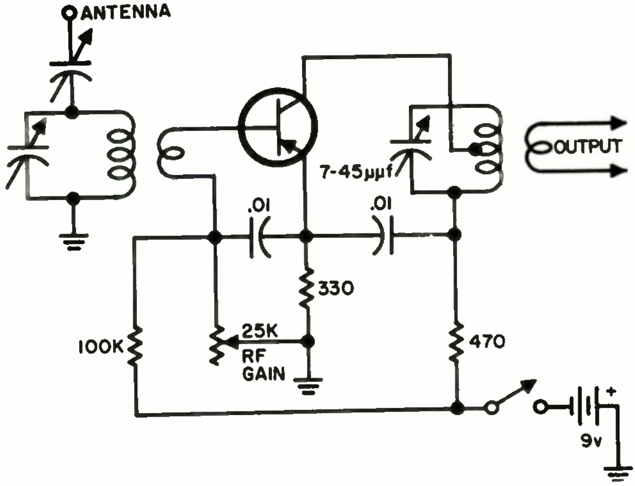



Fig. 1215. *Preselector circuit is a tuned radio-frequency amplifier.*

again at a very rapid rate. The effect is just as though we were turning the regenerative detector on and off at an audio rate. When we use a quench circuit, though, the grid capacitor (C25 in Fig. 1214) is forced to charge and discharge much faster – so rapidly that it proceeds at a ultrasonic rate. In Fig. 1214 the grid leak is R20.

## Detection

Detector V3A is operated as a triode. When the signal is negative, the detector tube is cut off. Current flows through the detector tube when the signal becomes positive. Since the signal is neatly sliced in half, we get detection. The rectified signal appears in the grid–cathode circuit. Radio-frequency choke (rfc) L5 holds back the rf component of the detected signal, but has much less opposition for audio. Any rf that does get through is bypassed to ground by C26, a .01-$\mu$f capacitor. The audio signal is developed across the volume control and from there moves into the grid of the first audio amplifier tube.

## Preselectors

Not all sets have as much rf gain as they should have.

For sets that need just a little more rf boost you can do one of two things (or both). A better outside antenna is a help. Often, though, this isn't possible. Another solution is to use a preselector. What is a preselector? It is just a tuned stage of radio-frequency amplification, as shown in Fig. 1215.

The preselector is usually a compact little unit and is self-powered. Some have a ferrite-loop antenna with a terminal for

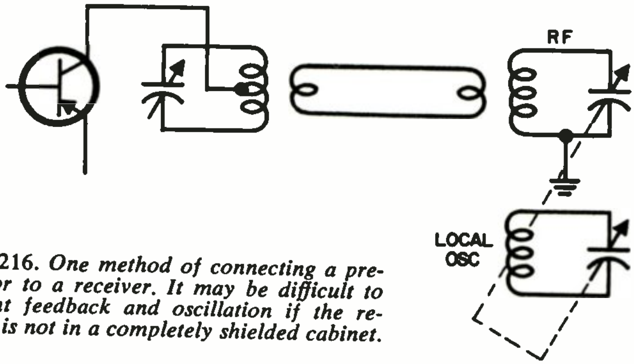



Fig. 1216. *One method of connecting a preselector to a receiver. It may be difficult to prevent feedback and oscillation if the receiver is not in a completely shielded cabinet.*

making connection to an outside antenna. Since the preselector uses a transistor, no warmup time is needed.

It does have one big disadvantage. It needs to be tuned every time the receiver itself is tuned. It all depends on the particular unit. Some have fairly broad tuning and so you will get some gain regardless of the position of the tuning capacitor. Other preselectors are selective, so they require more precise tuning.

The preselector in Fig. 1215 has an rf gain control. Generally, once this has been set, it requires no further attention. As the battery gets a little weaker, the gain control will need to be turned up a little more.

## Connecting the preselector

If the radio receiver has an antenna-ground terminal board, just connect the secondary leads of the preselector output transformer to them. Most sets do not have such a terminal board, however, so you will need to make some changes.

One way of making the connection is shown in Fig. 1216. Another way is to connect the output of the preselector to a pair of capacitors. The exact value isn't critical. One capacitor should connect to the stator of the rf tuning capacitor or to the top of the rf coil—which ever connection is easier. The other lead should be attached to the ground bus.

## Boosters

When used with a television receiver, the preselector is often called a *booster*. This design is usually different in that a sharply tuned circuit is not used. The tuned circuit may be so broad in response that it is called a bandpass filter.

In some locations, it is necessary to increase the signal to an FM tuner. In many instances, it is quite practical to utilize a TV booster, since the 88- to 108-mc frequency spectrum is higher than channel 6 and lower than channel 7. If this is done, make sure the booster will cover the FM broadcast frequencies. Some boosters are broadly tuned for channels 2 to 6, and for channels 7 to 13. Selection is made by a switch which gives choice of LO or HI band operation. Here, bandpass filters are used. Some boosters may have traps or band-rejection filters to reduce the amplification of FM or communications frequencies that might interfere with the TV picture quality. Such a booster would not give any advantage to an FM or communications receiver.

## The end of the road

For quite a while radio receiver repair has been pushed into the background by its more glamorous relative—television. Television, though (as people are beginning to learn), requires full attention. Either you watch it or you don't. And if you don't, you might just as well turn it off.

With radio, though, you can do a dozen different things. You can listen to news, weather reports, get background music and still not be taken away from whatever else you might want to do.

Radio receivers are now moving in a number of directions—all at once. Radio sets are becoming smaller, so they can be carried in pockets right along with keys, billfolds, papers and other items. In the home, radio sets are being housed in large, fine pieces of furniture. In autos, boats, trains—wherever you have a vehicle that moves—you will find a radio.

Radio is being used for more than just entertainment. Its value as an aid in communications is growing more and more.

Receiver servicing is also growing. We hope you will let this section of your repair business grow with it.

## QUESTIONS

1. What is the purpose of afc in portable FM receivers?
2. What is meant by correction voltage? Body effect?
3. What is the purpose of a converter attached as a separate unit to a receiver?
4. Why is regeneration used in some receivers?
5. How do you know when regeneration is working? If regeneration is inoperative, what would you do to repair the receiver?
6. From a servicing viewpoint, what are some of the disadvantages of reflex receivers?
7. What is a transceiver?
8. What is superregeneration? Why are rf amplifiers often used with superregenerative receivers?
9. What is a quench voltage? Why is it used? What is a typical operating frequency?
10. Describe method of connecting a preselector to a receiver.
11. What are boosters? How do they differ from preselectors? Can boosters always be used with radio receivers?
12. Describe the operation of afc in a transistor portable.

# INDEX

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## V



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