HOW TO FIX
TRANSISTOR
RADIOS AND
PRINTED CIRCUITS

LEONARD LANE

$4.95
(in the U.S.)

HOW TO FIX TRANSISTOR RADIOS

& PRINTED CIRCUITS

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VOL. 2

Gernsback Library, Inc., New York 11, New York

contents

To Arlene, Stewart

and Clifford

introduction

IN the second book of this two-volume set, the emphasis is on the practical applications of the semiconductor fundamentals presented in Volume 1.

General servicing methods are stressed. For example, the special techniques required to test batteries and how to determine the circuit defects that cause seemingly short battery life are described. We will show why, although percentage-wise the tolerances of semiconductor circuits are equal to vacuum-tube parameters, small voltage changes are just as troublesome in these low-imped-ance circuits as the more apparent changes caused by defective vacuum-tube components.

Special consideration is given the unique problems of hybrid and all-transistor auto radios. Here some types of interference are treated as part of *radio* servicing although it is actually a charac-teristic fault of the internal combustion engine used to propel the radio and its listener through the most difficult conditions possible for reception of radio waves.

Circuit alignment and measurements are spotlighted. Ways of using the commonly available test equipment for in-circuit com-ponent and transistor evaluation is covered and common vacuum-tube servicing techniques adapted to the low-impedance and low-voltage characteristics of transistor circuitry.

Printed-circuit boards are evaluated, and their advantages and disadvantages analyzed from a servicing viewpoint. Some simple practical repairs are described.

This volume also covers the many types of transistors created by different manufacturing processes. Some basic circuits are used to illustrate the applications for which these specialized semi-conductors were designed.

The engine of the horseless carriage of yesteryear bears as little

resemblance to the power-plant of modern-day earthmovers as the transistor of today and the marvels it makes possible will resemble the as yet undreamed-of possibilities of future semiconductor devices.

Just as Fleming's valve generated a multi-billion dollar industry, semiconductor operated devices are sparking a new spiral of development whose future wonders we can only guess at. But one thing is certain: ever-increasing numbers of knowledgeable technicians will be needed. And don't forget that all big circuits are made up of little circuits, that the sophisticated circuitry of complex machinery utilizes the same basic theories that we are studying.

May these volumes be a stepping stone to a better and more prosperous future for everyone!

LEONARD LANE

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servicing methods—part 1

THE problems of servicing transistor radio receivers can be solved using the same test equipment you now have available. No two service technicians are ever in complete agreement as to the amount of test equipment that should be on the bench, but you should at least have an rf signal generator capable of covering the complete AM broadcast band. This generator should also have a spot frequency, generally at 455 kc, for alignment of the if stages. (Many auto radios have an if of 262.5 kc, so we cannot assume that the same if is used by all manufacturers.)

You should also have an audio generator so you can trace through stages starting with the detector diode load and proceeding to the speaker. As an alternative, you can use the audio output terminal of your rf signal generator. Unfortunately, many of the less expensive signal generators have no means for controlling the strength of the audio signal. If such is the case, you can attenuate the audio by bringing it into a potentiometer and then taking the audio output from the pot itself, as shown in Fig. 701.

You should have a multimeter, but a vtvm is certainly preferable. Since transistor receivers are characterized by very low voltages, a low-voltage scale on the vtvm is extremely important. Of course, the vtvm can also be used for measurement of resistance.

In an earlier chapter we mentioned the need for special tools for use in servicing miniaturized components so widely used in transistor receivers. Equally important is a bench lamp which can be moved into any desired position and which will permit you to focus a strong light on any part of the receiver chassis. A

desirable feature on some of these lamps is a magnifying glass'
which is hinged to the lamp and which forms a part of it. This
is ideal for examining tiny connections in close quarters.
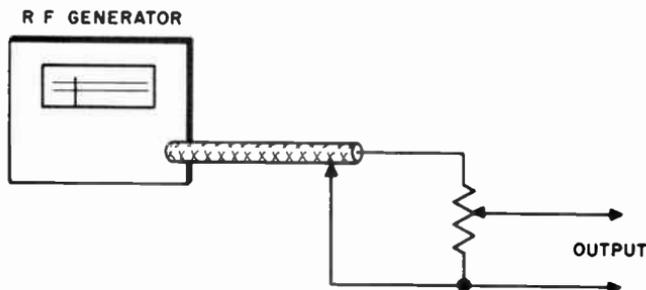
Fig. 701. *Some signal generators have an audio output con-
nection but no provision is made for controlling the audio
level. You can make a simple control unit with a 500,000-ohm
potentiometer as shown.*

Some manufacturers claim that their transistor radios are
built like a fine watch — and if we consider size as the determining
factor, they are certainly right. Don't insist on using man-size
tools for these midgets.

Dc voltage measurements

When making voltage measurements in a transistor receiver,
keep in mind that working with low voltages may require a re-
vision of your thinking. As an example, consider a vacuum-tube
receiver in which the plate voltage is supposed to be 250. If for
any reason, you get a 10% decrease in plate voltage, you will
measure 225 volts. 10% of 250 is 25, and subtracting this from
250, gives us 225 (Fig. 702).

Now let us assume a transistor receiver in which you are sup-
posed to measure a potential of 6 volts and let us further assume
that there has been a 10% decrease. But 10% of 6 is only 0.6.
Subtracting this amount from our original 6 volts, leaves us with
5.4. Note that the percentage difference in both cases is identical
and yet for the vacuum-tube receiver it would be very easy to
recognize a 25-volt difference. However, a difference of 0.6 volt
on a vtvm scale might not be so easy to detect (Fig. 703).

When working with low voltages, it is always preferable to
adjust the range switch on the vtvm so that the meter needle will
have to swing full scale or almost full scale. This will make any

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slight deviation much more recognizable. If you have any doubt about the accuracy of your vtvm on the low-voltage scale, you can easily check it by using one or more fresh penlight batteries as a calibrating voltage, as shown in Fig. 704. Four such batteries, when fresh, should give you 6 volts. With mercury type cells, four of these in series will give you a total voltage of 5.36.

Before we go into a detailed analysis of transistor receiver troubles, let us consider the symptoms that you will find in a majority of cases. The complaints, all caused by a common trouble, will consist of the following: (1) Dead receiver; (2) weak receiver; (3) receiver able to pick up strong stations only; (4) distortion; (5) receiver plays on earphones but sound is too weak for loudspeaker reception. All of these difficulties could be caused by a weak battery (in series with good batteries) or by several batteries whose terminal voltage has decreased. Just as in a vacuum-tube receiver, the first thing to suspect are the tubes so, in a transistor receiver, you should first make a check of the battery voltage (under load) before proceeding with any other servicing.

As a general rule, a transistor receiver will continue to operate even if the battery voltage takes a 30% drop. Suppose, for example, that the transistor receiver you are servicing uses three 1.5-volt cells. This gives us a total of 4.5 volts. Using our figure
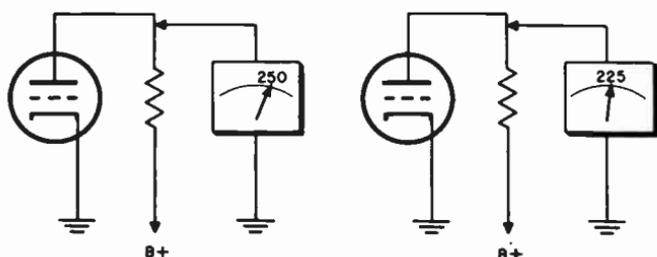
Fig. 702. If the voltage at the plate of a tube is supposed to be 250, but your meter measures only 225 volts, you have a 10% difference between the actual voltage and the voltage as specified. For most tube circuits, this small difference is of no importance.

of 30%, this means that the battery voltage had dropped to about 3.15 before any of the symptoms which we have mentioned became noticeable or annoying. Similarly if the transistor receiver uses a 9-volt supply, you will find as a general rule that the volt-

age can drop to about 6 volts before one or more of the symptoms we have mentioned begin to appear. However, if the symptoms show themselves and the battery voltage has dropped, say, only 5% to 10% of fresh battery voltage, then the trouble is not in the battery supply but elsewhere in the receiver.

In making a battery voltage check in the receiver, remember
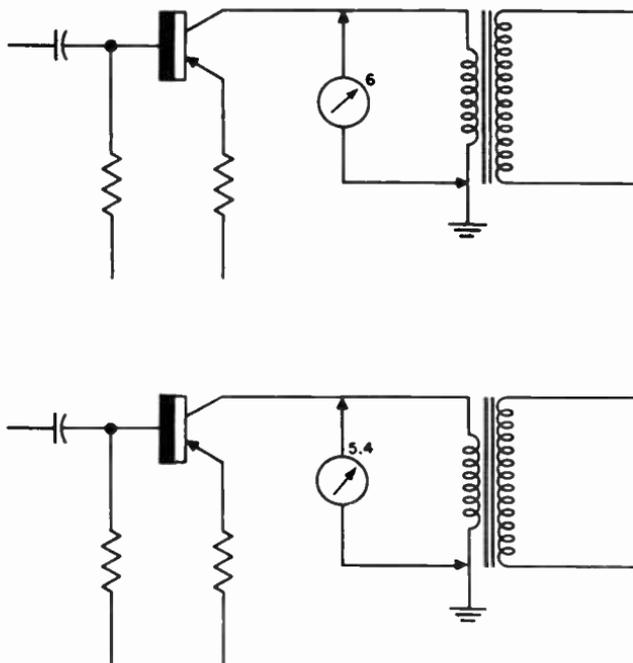
Fig. 703. *A 10% difference in collector voltage is difficult to observe.*

to turn the receiver on with the volume control set to maximum. This is a condition of heaviest load for the batteries and, if the batteries are weak or defective, the voltage will drop. If you do not wish to make a voltage check, you can always make this test by battery substitution. The voltage check is faster, however, and does not require you to have replacement batteries on hand (Fig. 705).

In practically all vacuum-tube radio and television receivers, the chassis is common ground or B-minus. Because of this it has been quite easy for service technicians to get into the habit of con-

sidering the chassis as the B-minus reference point. In a transistor receiver, however, the chassis can be B-minus or B-plus (Fig. 706). Offhand, you might think that you should be able to determine the polarity by considering whether a receiver uses p-n-p or n-p-n transistors, but this is of no help. You can determine the polarity by (1) just looking at the battery connections or (2) setting the voltmeter on a high scale (such as the 100-volt scale), connecting one lead to the chassis and momentarily touching the other lead to the battery connection. If the needle moves
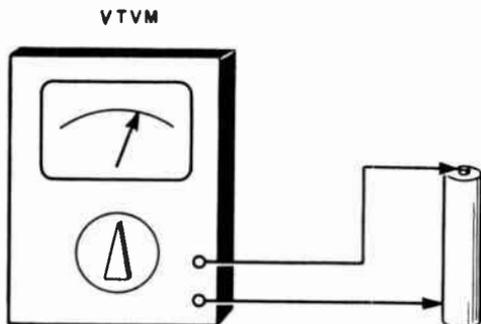
VTVM

Fig. 704. *To check the low-voltage scales of your vtvm, set the range switch to read low volts dc and then use a fresh penlight cell (or other type of dry cell) as a calibrating voltage. Low-voltage measurements in transistor receivers are very important.*

backward, transpose the connections. Some instruments have a minus—plus switch so all you will have to do is to turn this control.

The two circuits shown in Fig. 706 are almost identical yet the battery connections are different for each. However, in both cases the emitter is made positive with respect to the base. In the circuit Fig. 706-A the collector is marked zero volts, but observe that the collector is grounded through the primary of the output transformer. The collector is negative with respect to the base and the emitter. In Fig. 706-B the collector also has its return through the center tap of the output transformer primary and from that point to the negative terminal of the battery. Although in one instance the minus terminal of the battery is grounded and in the other the plus terminal, in each circuit, the collector is connected to the negative end of the battery supply. Note that p-n-p transistors are used in both circuits.

Batteries consume themselves whether they are used or not, and the batteries in transistor receivers are no exception. Your customers who operate their transistor receivers sparingly, with the idea of battery economy in mind, are fooling themselves. You
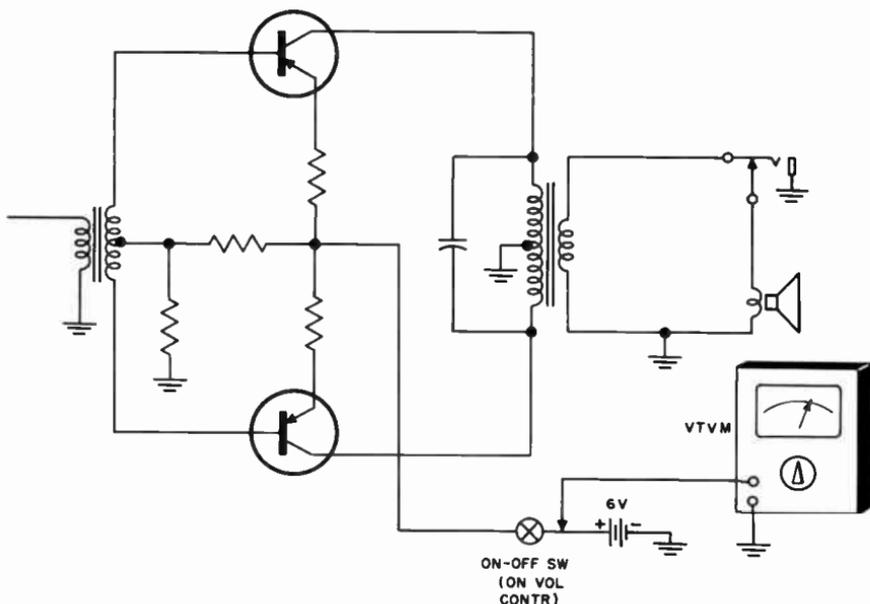

Fig. 705. *To check the condition of the battery, connect the vtvm as shown. The set must be turned on since the battery must be tested under actual load conditions. Tune in a station and then detune, noting if this has any effect on the battery.*

should educate them to the fact that it is false economy to try to conserve battery life by rationing receiver operation. At the same time, however, it is entirely possible for short battery life to be a legitimate complaint. If battery life is much less than can be reasonably expected, you can run a quick check by inserting a milliammeter in series with either the positive or negative lead of the battery supply in the receiver and measuring the total current drain as shown in Fig. 707. Check this figure against manufacturer's service notes. If the drain is excessive, a leaky condition in the receiver is indicated. If the current drain is normal, examine the battery holder and all wires coming to the batteries themselves.

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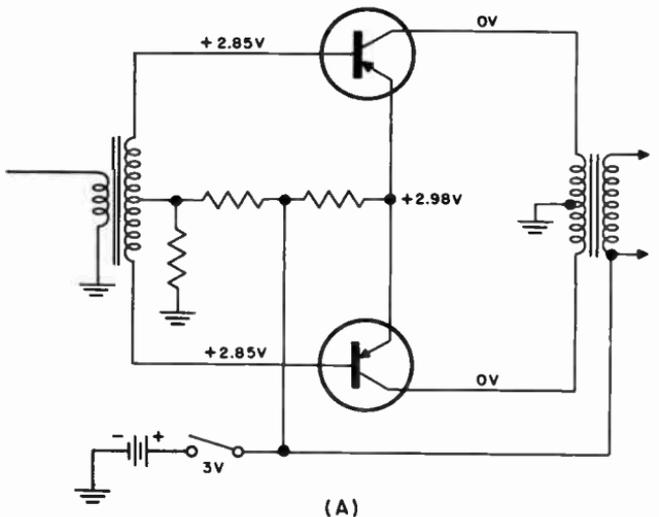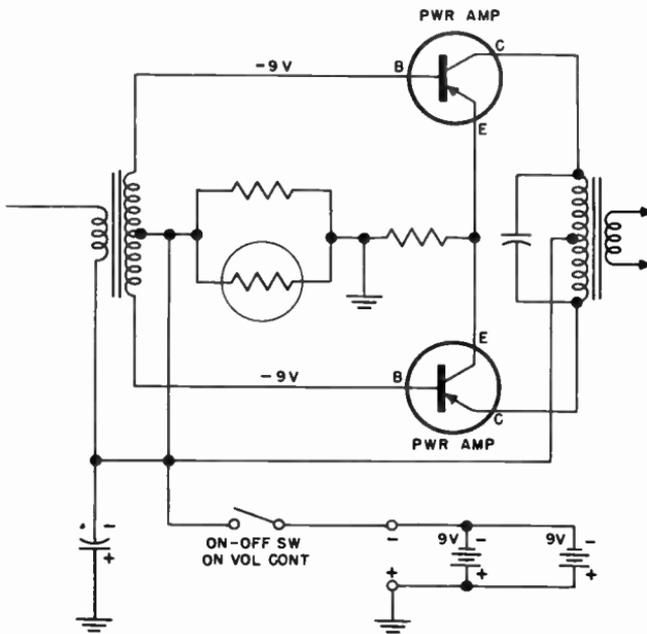
Fig. 706. *The chassis can be a plus or a minus point, depending entirely upon the circuit arrangement.*

2-13
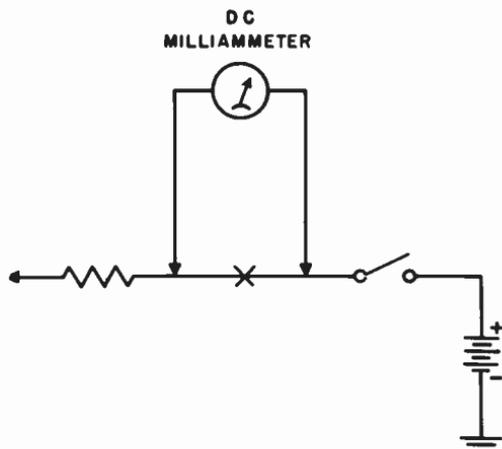
Fig. 707. To check receiver current drain, un-
solder the wire connected to the switch on the
volume control and insert a dc milliammeter as
shown. The disconnect point is shown by the
letter X in the diagram. After the meter is con-
nected, close the switch. Sometimes you can avoid
unsoldering leads by lifting the battery connec-
tor and inserting the meter between the battery
connector and the battery. This method isn't al-
ways possible since some transistor radios use
battery holders.

It is difficult to estimate amounts of current. In some receivers
the current drain will be as little as 4 or 5 ma. In other sets it will
be 15 ma or more. The current drain of auto radios is quite an-
other story and is covered in a separate chapter.

Current consumption will vary with signal. That is, it will de-
pend upon whether or not you have a station tuned in. Manu-
facturers usually specify current ratings with no signal.

It is in this instance also that your volt-ohm-milliammeter
(vom) will come in handy. Most multitesters have some provision
for measuring current and if you have such an instrument you
can put it to good use. Vacuum-tube voltmeters aren't designed
for measuring current. If you do not have a vom, a 0-1-ma dc
milliammeter provided with suitable shunts will do the job.

Short battery life

Where the customer complaint is short battery life, open the
lead to the switch on the volume control and insert a milliam-
meter. You should then proceed to take three current readings.
The first of these is with the set turned off, then with the volume
control turned on (but at its minimum setting) and finally with
the volume control at maximum and with the receiver tuned in

to a strong station. The meter needle of your milliammeter should read zero with the receiver switch in the off position.

If you get an appreciable current reading, check the switch or look for some short-circuit condition. If you get an unusually high current reading with the volume control turned down, look
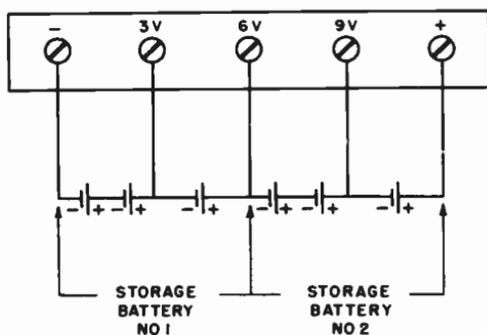

Fig. 708. *A pair of 6-volt storage batteries or a single 12-volt battery will supply all the voltage and current needed for testing transistor receivers.*

for leaky electrolytic capacitors. And, finally, if current drain is excessive with the volume control turned up, then the bias of one or more transistors, especially in the output stages, is not correct.

While we are on the subject of voltage and current measurements, keep in mind that the low-voltage supply of a transistor receiver has its advantages but also its disadvantages. In servicing a vacuum-tube receiver, a defect can sometimes be spotted very readily because the component will shown burn marks or will be hot to the touch. This rarely happens in transistor receivers, since the voltages involved are so small. At the same time, you can work with the voltages in a transistor receiver with a little more assurance since the voltages are not high enough to give you a shock. However, you will find that in circuits using heavy currents (such as in power output transistors in auto radios), you will have to exercise a certain amount of care.

Working with low voltages has other disadvantages. You will recall from earlier chapters that the proper operation of a transistor depends upon its biasing voltage. While bias voltages may be small, they must be correct. It doesn't take much of a change in bias voltage to ruin a transistor. For this reason, poking around with a screwdriver or careless use of test leads, where wires can be shorted, can easily result in a burned-out transistor.

Expected battery life

It is very difficult to give accurate figures on how long batteries should last. As a general rule, penlight cells used in a receiver might work up to 100 hours. The more expensive mercury batteries can reasonably be expected to have a battery life in excess of 400 hours. Keep in mind, however, that, when batteries are
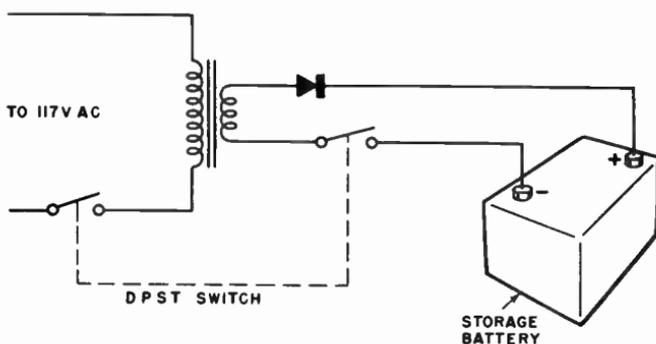

Fig. 709. *A dry rectifier type charger can be used to keep the the test storage batteries in ready operating condition. The double-pole single-throw (dpst) switch should be in the off position when the battery is in use.*

used in series (as they are in transistor receivers), the battery supply can be no better than that of the weakest cell in the group. If you find that the receiver you are servicing is restored by battery substitution, it is always safest to replace all of the batteries rather than just one.

When substituting batteries, remember that failure to observe proper polarity can result in damage to transistors. In many receivers, it will be impossible to transpose the batteries since the receiver may have some polarizing device. However, not all receivers are so equipped.

Voltage substitution

It is entirely possible in servicing a transistor receiver that you will find the cause to be defective batteries and it is also possible that you may not have a suitable replacement on hand. Under these conditions it is inadvisable to use a vacuum-tube-operated power pack or a selenium-rectifier type supply. An excellent power source would be 1½ volt cells of the type commonly associated with door buzzers.

These cells are rather large but have a long useful life. Another

substitute supply that you could use would be a storage battery. This need not be a new unit, but can be one which has seen service and is about ready to be discarded. The battery may not be able to supply the heavy current required to start a car, but might still be useful for servicing work, provided, of course, that the battery is not too far gone. Two such batteries can be used
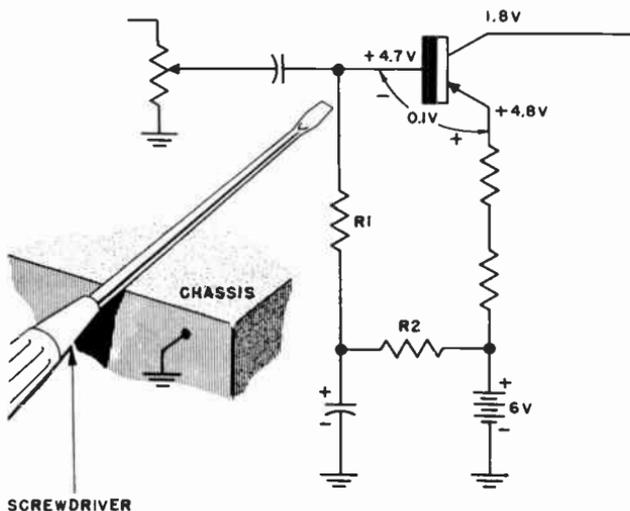

Fig. 710. *Sparking the base to the chassis removes the bias between emitter and base and can ruin the transistor.*

to supply a total up to 12 volts or a single 12-volt battery can be used (Fig. 708). You should be able to tap off at 3, 6 and 9 volts if required.

The batteries can be stored under the service bench and test leads brought up to suitable connectors in a test panel on the bench. The batteries can be kept charged by a small disk rectifier charger. These are readily available and are inexpensive. However, the charger must not remain connected when the storage battery is being used (Fig. 709).

Sparking test

A common servicing procedure in the case of vacuum-tube receivers is to "spark" either the grid or plate leads of a vacuum tube in an effort to locate a defective stage. This is a form of quick testing, but should not be done in transistor receivers. If,

for example, you accidentally short the base lead to ground, you will be removing transistor bias, and this loss of bias can result in permanent damage to the transistor.

The effect of sparking the base to the chassis is shown in Fig. 710. The voltage between the emitter and the base is very small — actually in this case, only 0.1 volt. A "disturbance" test will put the base at ground and will put R1 and R2 across the battery. The bias will no longer be the proper value for the transistor.

Battery replacements

Some receivers use individual cells, others use a battery pack. In the case of a battery pack, the cells are contained within one package and the entire battery is replaced as a unit. Exact replacements are not always required since the battery packs of one manufacturer are often interchangeable with those of another. The type of pack to be used is described in the manufacturer's service notes or you can get this information from your jobber or from radio parts catalogs. The fact that one battery pack has the same voltage as another does not always mean that it can be used. There are physical considerations as well. Not only must the voltage be correct but the battery must be able to fit into the receiver and must be held properly by the holder designed for it.

Checking transistors

In a transistor receiver, the first item to suspect is the battery or batteries. The last item to concern you should be the transistors. But, having discussed batteries and now entering our discussion of transistors, we are swinging from one extreme to the other:

You can make a rough check of the transistors using a vtvm. If the transistors are in sockets (and easily removable), they can then be checked out in the open. If, however, the transistors are soldered into place, do not remove them but check them in position. Make sure the receiver is turned off and the battery disconnected.

In an earlier chapter, you will recall, we mentioned that a transistor resembles a pair of crystal diodes placed back to back. We can take advantage of this bit of information in making a transistor check. The check consists simply of measuring the forward and reverse resistances of the transistor. Fig. 711 shows how to do this.

Set the range selector of your vacuum-tube voltmeter on the R × 10 scale. This scale is to be used for making all forward resistance measurements. In the R × 10 position, the range se-

VTVM

HIGH RESISTANCE
(A)

HIGH RESISTANCE
(B)

VTVM

LOW RESISTANCE
(C)

LOW RESISTANCE
(D)

VTVM

HIGH RESISTANCE
(E)
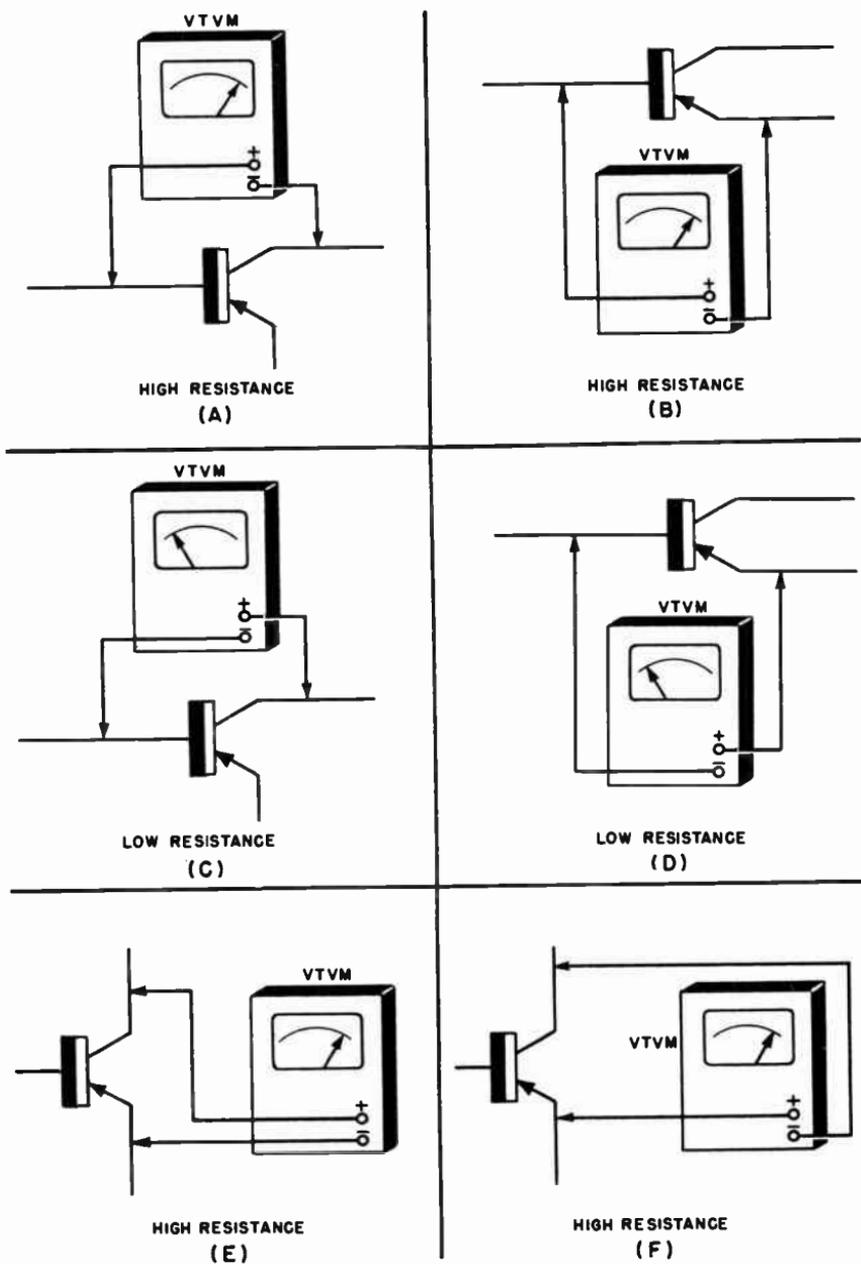
HIGH RESISTANCE
(F)

Fig. 711. *Techniques for measuring the reverse and forward resistances of a p-n-p
transistor.*

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lector on your vtvm automatically inserts a resistor between the transistor and the test instrument.

First, consider measurements of p-n-p types. Connect the positive terminal of the vtvm to the base lead. Now connect the negative lead of the vtvm to the collector lead (Fig. 711-A). You should measure high reverse resistance. The resistance should have a value of 50,000 ohms or more. With the positive lead of the vtvm still connected to the base lead, connect the negative test lead to the emitter. Once again you should measure a high reverse resistance, generally in the order of 50,000 ohms or more (Fig. 711-B).

Before checking transistors in this manner however, become acquainted with the circuit diagram of your meter. You will not obtain correct results unless the negative lead of your meter is connected to the negative side of the battery in the instrument.

Most meters used in these instruments have some identification to indicate the positive and negative terminals. Very often the plus symbol appears on one of the screws coming out of the meter itself. In some circuits this might be a help.

With your vtvm still set on the R × 10 scale, connect the negative lead of the instrument to the base terminal of the p-n-p transistor. Touch the positive lead of the instrument to the collector lead as shown in Fig. 711-C. Since you are now measuring forward resistance, your instrument should give a reading of 500 ohms or less. With the negative terminal still connected to the base lead of the transistor, touch the positive test lead to the emitter wire, as in Fig. 711-D. Once again you should measure a low resistance, 500 ohms or less.

Finally, check between base and collector, as in Figs. 711-E,-F. For these two measurements the resistance should be high.

You can measure n-p-n transistors in the manner just described except that the test leads must be transposed.

Precautions in using meters

We have stressed the use of a vtvm because it is getting to be quite common among service technicians. However, an ohmmeter can be used just as well. Normally, with an ohmmeter or a vtvm, you are supplied with a red lead and a black lead. The black lead is known as the common, ground or negative lead. The red lead is called the "hot" or plus or positive lead.

However, batteries are color blind — a condition that sometimes applies to service technicians. It does not necessarily follow

that the red lead is connected to the positive side of the cell inside the test instrument. Sometimes the red test lead has a negative voltage — that is, it is connected to the negative terminal of the cell inside the test unit. This is not a fault. It is simply the way in which the instrument is constructed.

A similar situation exists in an automobile with the chassis of the car connected to the plus terminal of the battery and not to the negative terminal of the battery, as you might readily assume. If you have any doubts as to the polarity of your test leads, you
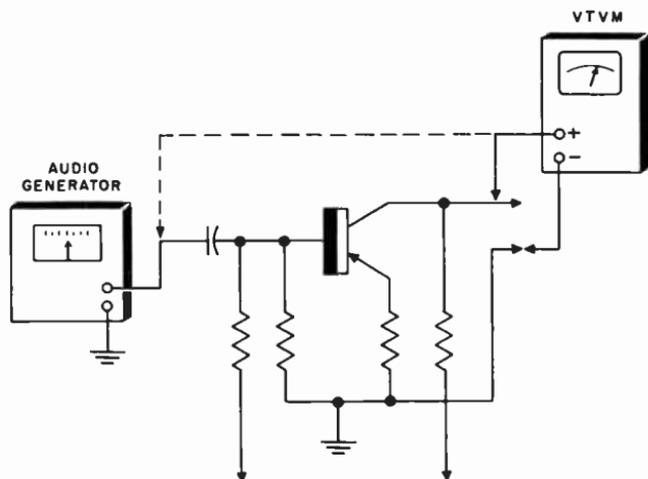
Fig. 712. *Checking the gain of a suspected transistor stage. The vtvm is alternately connected across the input and output of the audio amplifier circuit.*

can settle your suspicions quite readily. All you have to do is to connect a voltmeter across your ohmmeter test leads. Set your range selector on the highest range, and reduce or rotate the range switch until a reading is indicated. If the meter needle reads backward, transpose the test leads. You must, of course, use a voltmeter that has at least one terminal marked with its polarity. A voltmeter having a full scale range of 5 to 10 volts is satisfactory.

Not only is it important that you know the polarity of the test leads of your ohmmeter or vtvm for checking transistors, but you should remember that other components such as electrolytic capacitors are also polarized. Electrolytics are used in transistor receivers both as coupling capacitors or as emitter bypass units. In checking an electrolytic, connect the positive lead on the test instrument to the positive terminal of the capacitor.

Transistor types

Whether a receiver uses n-p-n or p-n-p transistors depends entirely on the manufacturer. You will sometimes find both n-p-n and p-n-p types used in the same set. This means you must be somewhat alert in making the forward and back resistance checks we have just described. Remember that p-n-p transistors operate with the emitter positive with respect to the base (the first letter of the abbreviation p-n-p represents positive). In the case of n-p-n transistors, the emitter is negative with respect to the base. The voltage difference between base and emitter and the transistor type are usually clearly specified on the schematic of the receiver.

Switching transistors

You can sometimes improve performance by switching transistors from one position in the receiver to another, provided that the transistors are identical types and can easily be moved from one position to the other (that is, the transistors are socket-mounted types). Performance can sometimes be improved in this way since a transistor may work better in one circuit than in another.

Further checks on transistors

The general tendency in modern transistor manufacture is to solder the transistor in place. This makes sense since a transistor is such a durable device. The method for testing transistors is exactly the same technique you would use in running a check on vacuum tubes. This is shown in Fig. 712.

For testing audio transistors, connect an audio generator to the coupling capacitor leading to the input side of the transistor. Connect a vacuum-tube voltmeter across the output side of the transistor. In checking an audio stage, for example, you could use the 400-cycle audio output of your signal generator or an audio generator itself. Since we are feeding in an ac signal and not rectifying it at all, the output will be that same ac signal, amplified, and of course must be measured with a vacuum-tube voltmeter set to read ac volts. To determine the gain of the stage, connect the vtvm across the signal generator (or input to the transistor) and then switch the hot test lead to the output side of the transistor.

Since the input will be a fraction of a volt, and the output 1 volt or less, you will have to set the range selector on your vtvm for full-scale deflection on the lowest voltage range. The gain of the stage should be approximately equal to the beta of the tran-

sistor. Thus, if the beta of the transistor is 10, the voltage measured on the output side of the transistor should be 10 times that measured on the input side.

To check all of the transistors in the receiver, you can continue to have the vtvm (or scope) connected as shown in Fig. 713 while working your way back toward the front end of the set, using your signal generator. Once you reach the rf or if side of the
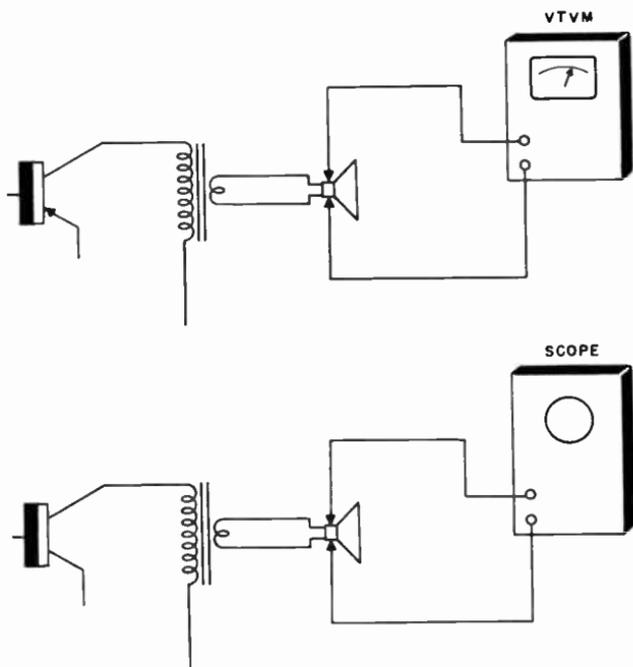

Fig. 713. *When signal-tracing through a receiver, connect a scope or vtvm across the voice coil as a signal indicator. The speaker can also be used but it is not as sensitive an indicator as these test instruments.*

crystal detector, however, you will need to switch the frequency of the signal generator. Obviously, when signal-tracing through the if stages, use a modulated if signal and, when the signal generator reaches the antenna, use a modulated rf signal.

Since we are, at the present time, merely interested in getting a general indication of operating or non-operating condition by working our way through the receiver, there will be no necessity for disabling the agc line.

In Fig. 714, we have a circuit diagram of a representative

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transistor radio. On this diagram we have marked a number of test points, starting with the letter A on the voice coil of the speaker and proceeding (using letters of the alphabet) until we reach the antenna. There is no law that says you must start at the speaker and go toward the front end. You can start at the antenna and work your way to the speaker or start at the detector and proceed to the front end or speaker if you so desire.

When using a signal-injection technique, you will find that your vtvm makes a much more sensitive indicator than the speaker. Many technicians prefer to use a speaker as an output indicator but it takes quite a change in sound level energy before it is really noticeable. A good technique is to disconnect one lead going to the voice coil of the speaker and to place a 5-ohm 2-watt resistor across the output transformer secondary leads. The leads to the vtvm can then be placed across this resistor. As you work your way from the output stage to the front end of the set, the ac voltage reading as shown by the vtvm should increase.

However, be suspicious of any stage that gives an increase in excess of what is considered normal. Sometimes signal injection produces a condition of oscillation and what you will really be measuring will be the injected signal voltage plus the voltage generated by the stage that is so triggered. Any stage that produces a decrease in gain, or any stage that does not produce sufficient gain, requires further checking.

Component replacement

Removing defective components can sometimes be a problem in small receivers, and that is exactly what many transistor receivers are. Even if the component is readily available, there is always the possibility that you might damage an adjacent part (especially a transistor) by excessive heat or pulling on component leads. If you are sure that the component to be replaced is definitely defective, cut away the part but permit the leads to remain. If the defective part is a capacitor, cut the leads as close to the body of the capacitor as possible and then use the old leads as soldering terminals for the new unit. If the part is a resistor, you can crush it with a pair of pliers (if you feel that the leads just aren't long enough).

When replacing batteries, remember that with carbon batteries, such as the penlight type, the button at the top of the battery is positive and the metal portion of the case is negative. The reverse is true of mercury cells.

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Fig. 714. *Voltages are measured from the points indicated to ground with a vtvm. Resistances are measured with the transistors out of associated circuits.*

Watching the voltage

In servicing vacuum-tube receivers, we often connect the test-equipment leads directly to the control grid. The grid return is usually to ground through a high value of resistance. In a transistor receiver, however, the input (base) is generally tied to the battery through a voltage divider connected directly across the battery itself. This voltage point is important since it establishes the working point of the transistor.

The output of your generator may be a low resistance. It can be the low-resistance winding of a transformer or a resistor. In any event, when you connect the generator leads between base and chassis, you will probably upset the bias on the transistor. To prevent this, use a blocking capacitor. A low-voltage unit rated at about 1 µf will do.

servicing methods—part II

W HEN conditions in a transistor receiver are right, the receiver will work and will work well. But when we stop to think of the job the receiver has to do, the amazing thing is, not that these sets ever become defective, but that many of them work for such long periods of time.

Troubles in the audio section

The words "audio instability" cover a number of problems that are often listed under other names. As an example of audio instability, the complaint would be that the receiver squeals, especially when the volume control is turned up. Sometimes this squealing will be intermittent — a symptom which you will promptly recognize as "motorboating."

This trouble can be produced by a variety of causes. Your first suspicion should be directed at the battery. As a battery gets older, its internal resistance increases. As the internal resistance of the battery gets larger, most of the voltage drop takes place inside the battery itself. The result is a reduction in the voltage available for the different circuits of the transistor receiver. As a consequence, the volume control must be advanced to increase the driving signal voltage to the various stages. This results in a condition of instability and the receiver tends to squeal or motorboat.

Audio instability can also be caused by poor connections. In one instance, squealing was produced by the battery itself. The battery holder was riveted into place and the rivet had become loose. The problem was solved by soldering the rivet into place.

If battery connections are made by means of snap-fasteners, examine these to make sure that the fastener hasn't "spread" and that good contact is being made. Check by removing the fastener and then trying to snap it back into place again. The action
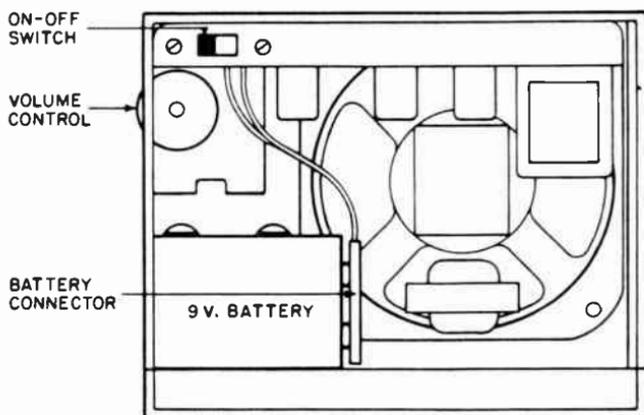
Fig. 801. *A loose battery fastener can cause audio instability.*

should be a positive one and you should hear a definite click as the snap fastener is pushed into position (Fig. 801).

Rotate the variable capacitor and observe any instability produced as you turn the tuning dial. If you do have this trouble, examine any and all screws used to fasten the tuning capacitor to its chassis.

Another cause of audio instability is leaky or otherwise defective electrolytic filters placed across the battery power supply. You will find one or more of these with capacitances ranging from 10 to 50 μf (Fig. 802). To check, turn the receiver on and produce the condition of squeal or motorboating. Take a known good capacitor and shunt it across the suspected defective electrolytic. If the squeal disappears or is reduced, replace the filter.

Sometimes, inadequate filtering is used in receivers sold for a low price. Squealing or motorboating in such sets is not due to any defect, but is simply caused by an insufficient amount of filter capacitance. In such instances, parallel the existing capacitor with a unit having an equal or greater amount of capacitance.

Motorboating or squealing can also be caused by an open collector decoupling capacitor (Fig. 803). To check if this is the

trouble, shunt the existing capacitor with a similar unit. When shunting a test capacitor across a suspected defective unit, make sure that the positive terminal of the test unit is connected to the positive terminal of the defective electrolytic in the receiver.
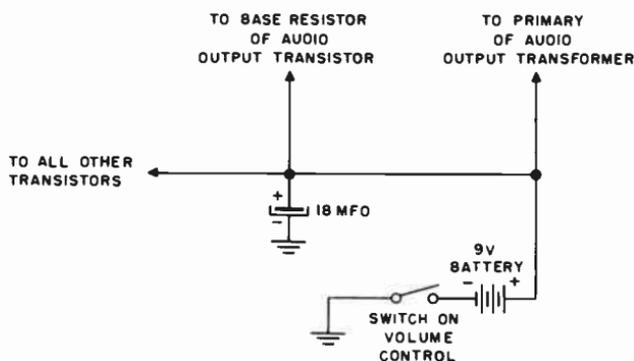
Fig. 802. *Electrolytic capacitors are often shunted across the power supply (battery).*

Similarly, the negative terminals of the two capacitors should also be connected. Do not transpose connections.

Many transistor receivers use decoupling networks from the battery power supply to the various transistor receiver stages. The decoupling network consists of one or more resistors and capacitors. If the capacitors have seriously decreased in value or have become excessively leaky, there is always the possibility of motorboating or squealing. Here again a test capacitor should be shunted across the suspected unit.

Finally, the remaining suspect in our search for the cause of motorboating or squealing could be the feedback resistor. The feedback resistor improves the stability of the set. If the resistor should become open or disconnected or if, for any reason, its resistance value is excessive, the benefits of feedback will be removed. An ohmmeter check (with one end of the resistor disconnected) will soon reveal whether the resistor meets the values specified in the manufacturer's circuit diagram (Fig. 804).

Weak audio signal

The first thing to do is to turn on the receiver and, with the volume control set in its maximum position, check the battery voltage. If the battery voltage is normal, the trouble could be due to defective electrolytics. Remember that a transistor radio re-

ceiver's electrolytics are often used as coupling capacitors and in this position can seriously affect the gain of the receiver. Check all electrolytics, whether used for coupling or bypass functions.

Run a resistance check on the audio transformers used in the
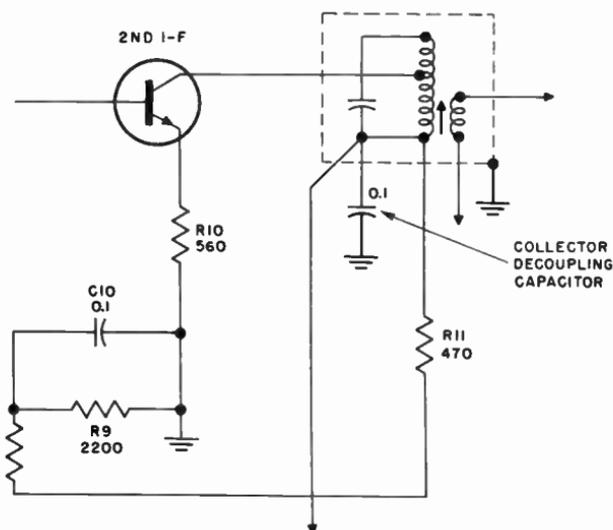
Fig. 803. *Squealing can be caused by open collector decoupling capacitor.*

receiver. This test should be supplemented by signal tracing. The reason for this is fairly easy to see. If a transformer has a shorted turn, volume will be greatly reduced. However, a shorted turn or a few shorted turns will not materially reduce the resistance of the winding. As a consequence, a resistance check is not always conclusive. However, signal tracing will reveal the defective transformer.

Cases have been reported where a weak output signal was due to rubbing of the voice coil in the loudspeaker. Push the speaker cone gently with your fingers. The cone should move back and forth easily and with no rubbing sounds. A good check is to use a substitute test speaker. This condition is often accompanied by distortion.

No output signal

Make sure that the battery leads have not become disconnected. Turn on the receiver and, with the volume control in its maxi-
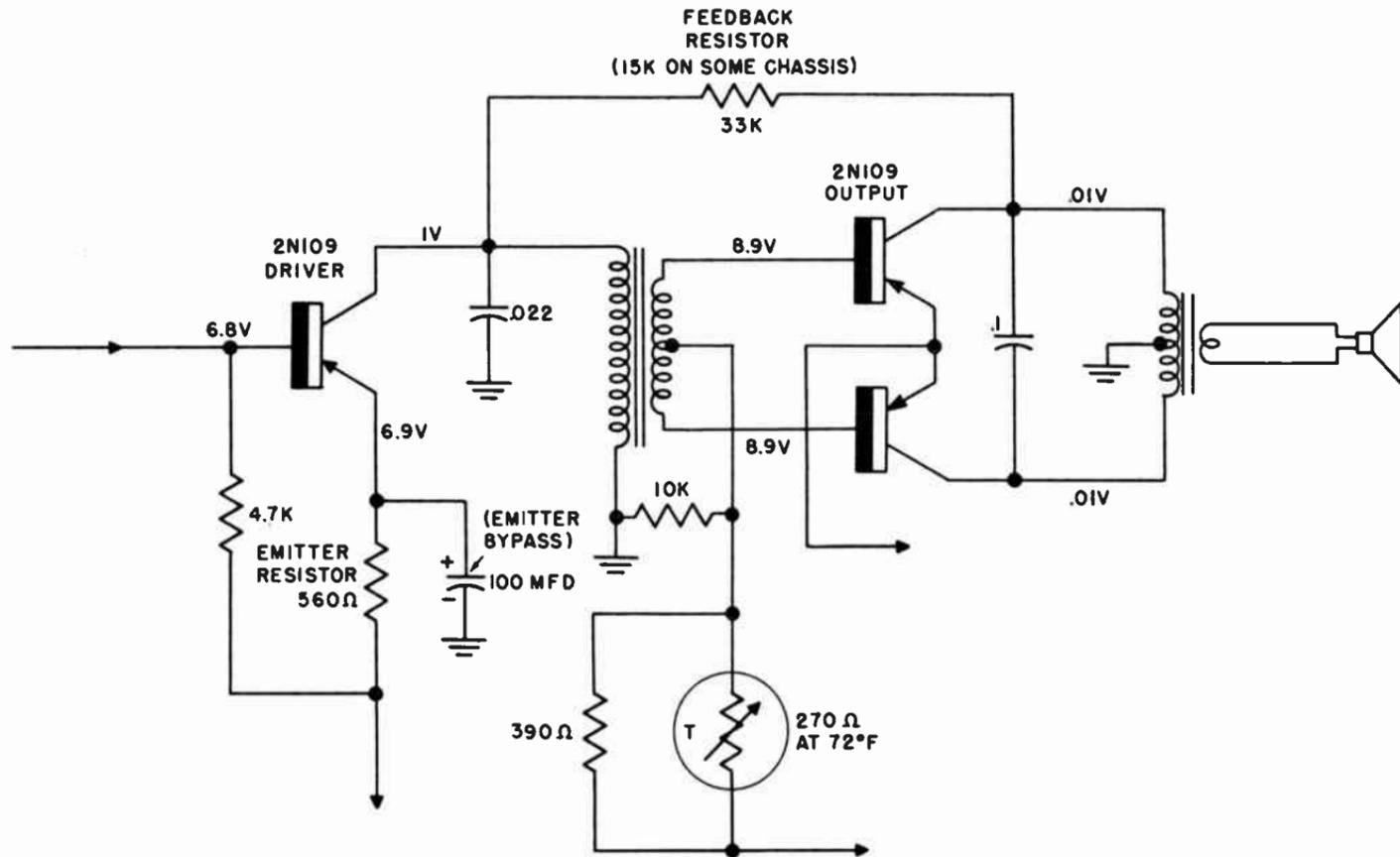
Fig. 804. *An open or changed-value feedback resistor can cause squealing. Check the value of resistor against the receiver schematic.*
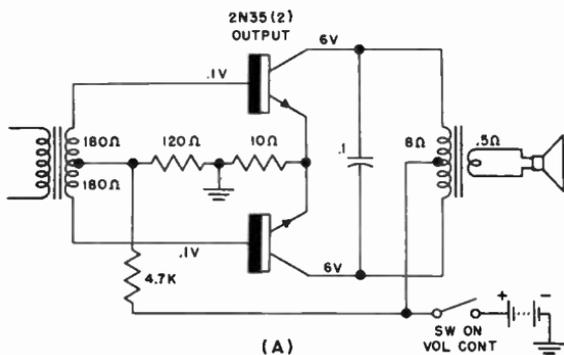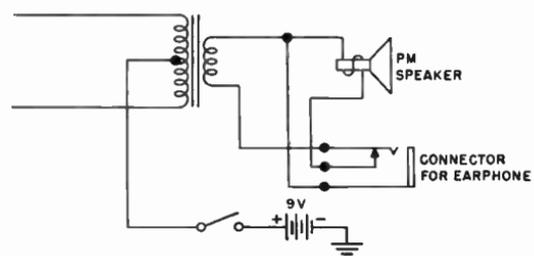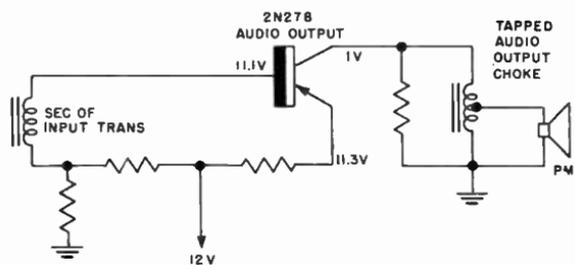
Fig. 805. *Some transistors have loudspeaker output only. Others have one or more jacks for earphones. Impedance coupling is used in Fig. 805-C. The choke is tapped down to match the impedance of the voice coil. In some radios, the phone jack is placed at the output of the driver stage instead of the push-pull stage.*

mum position, make a check of battery voltage. If the battery voltage is normal, connect the audio generator across the diode load resistor and use signal-tracing techniques to find the defective component.

If the batteries are in good condition, a complete loss of signal

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could be caused by an open voice-coil winding in the speaker, an open output transformer (either the primary or the secondary winding could be defective), or there is an open component in any circuit between output of the detector and the output stage.

Sometimes the trouble is due to the on-off switch mounted on the volume control. This should make a definite click as it is rotated from the off to the on position. Short the switch terminals with a screwdriver and note if the receiver comes on. If it does, then the switch is defective.

Some receivers use a jack so that earphones can be used in place of the speaker. In some sets, inserting the earphone jack automatically disconnects the speaker, putting a load resistor across the voice coil in place of the speaker. In other sets, no load resistor is used. If the earphone jack is defective, it is possible that that speaker is not reconnected into the circuit when the earphone jack is removed (Fig. 805).

Complete lack of audio could be caused by a leaky or shorted component placing an excessive drain on the battery. Connect a milliammeter in series with either battery lead. Turn on the receiver and note the current reading. If the current reading is greatly in excess of normal receiver requirements, then you have a leaky or shorted component.

Distortion

In transistor receivers as in vacuum-tube sets, distortion often arises in audio amplifier stages. A common cause is incorrect bias, although other components such as bypass capacitors can also produce distortion.

Since distortion (in the audio section) can come from a defect anywhere from the output of the detector diode to the speaker, one of the easiest techniques for localizing the difficulty is to signal-trace the entire amplifier system. Before you do so, however, become familiar with the sound of your own generator. Connect a speaker or earphones to your audio generator (or audio output terminal of your signal generator) and listen to the tone at low volume. Use any frequency between 400 and 1,000 cycles.

Now connect the audio generator directly across the voice coil leads. It isn't necessary to turn the receiver on. Listen to the tone. If there is any roughness, examine the speaker for a sticking or rubbing voice coil, rips or tears in the cone. Sometimes one side of the voice coil is grounded. Make sure the connection isn't open since it may be part of a feedback network.

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If the sound is good, connect the generator leads across the primary of the output transformer. (The receiver is still turned off.) Distortion can be caused by corrosion in the transformer or by shorted turns. If the transformer is a push-pull type, test each half (from tap to outer lead) separately. Since the tone-control capacitor is connected to the output collector, unsolder one end (end connected to the battery or chassis) and note if the disortion disappears. If it does, then the capacitor is defective. If the tone control has a switch, try putting the switch into its different positions. If distortion occurs at one postion only, then the capacitor connected to that position is defective. If the receiver sounds shrill or tinny, the tone capacitor may be open.

If the check across the primary of the output transformer does not reveal the trouble, connect the audio generator to the base input of the last stage (here we are assuming single-ended output). Make the connection through an audio coupling capacitor inserted in series between the generator lead and the base of the transistor. Turn on the receiver and listen to the tone. The signal should come through much louder than in the previous tests (assuming that you have not touched the gain control of the generator).

If it does not, then examine the base resistor, emitter resistor and emitter bypass capacitor, if any. Remove the transistor from its socket and resistance-check all components in the base and emitter circuits. If you cannot remove the transistor conveniently, check emitter and collector current by making a voltage check across the emitter resistor using a vtvm set to read low volts dc. Measure the base-to-emitter voltage to make sure the bias for the transistor is good.

If the transistor is a push-pull stage, make the check by connecting the generator across the primary of the input transformer.

By now you undoubtedly have the idea of how we proceed. If the audio output stage tests do not reveal the trouble, move your generator lead back to the base input of the audio driver or to the hot end of the volume control.

Distortion often stems from the audio stages. If, however, distortion appears only when the signals are strong, then look for trouble in the agc network, starting at the detector or separate agc rectifier if one is used.

In push-pull stages, distortion can be produced if transistors do not match or if one transistor has become defective. Substitution of a matched pair will quickly reveal if this is the cause of the

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trouble. Push-pull transistors are often sold as matched pairs and should be replaced as such.

When replacing transistors, be very careful to keep from shorting any one of the transistor leads to the chassis. This is especially the case for power output transistors. For example, it is entirely possible to short the bias resistor. The resulting large increase in collector current will probably ruin the transistor immediately.
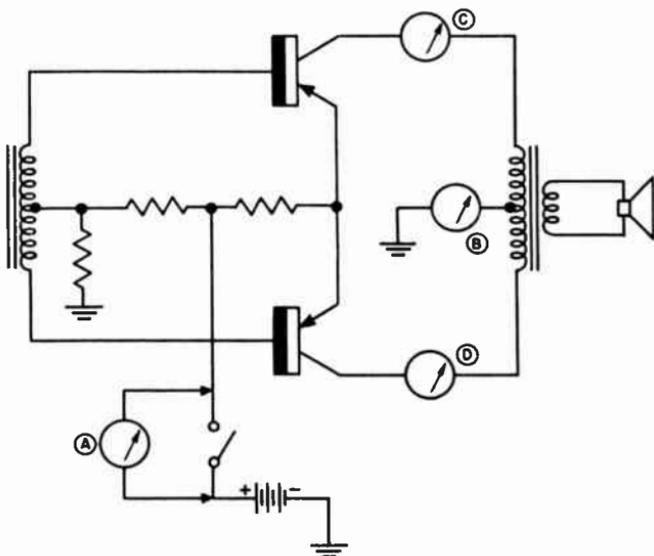
Fig. 806. *Methods for making current checks. With the meter shunted across the on-off switch, you will read total current (A). At B, you will read collector current of both output transistors. When making the test at A, keep the switch open. Note: The test shown at A does not permit adjustment of the volume control.*

Most push-pull output stages of transistor receivers are operated in class B. In this circuit arrangement, the current required by the transistor increases considerably as signal voltage is applied to the output stage. In a typical receiver, the current required by the push-pull output transistors in the absence of driving signal is less than 10 ma. For maximum audio output, the current demand grows to 35 ma. This gives us a clue for checking push-pull stages without the necessity of removing the transistors. Set a milliammeter in series with the lead going to the center tap of the output transformer. Adjust the tuning dial so that it is between stations, that is, so that no signals are received. Note the

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current reading. Now tune in the signal and turn the volume to maximum.

The current reading as indicated by the milliammeter should be about three times that obtained with the first check. If you get but a slight increase, or if the increase in current reading does not agree with the amount of current specified in the manufacturer's literature, then one of the transistors can be presumed to be defective. To find which is the defective transistor (assuming that you do not wish to replace both), put the milliammeter in series with the collector lead, that is, the lead between the collector of the output transistor and the primary of the output transformer (Fig. 806). In this way you will be able to measure the individual transistor current. By running a test on both transistors in this manner, you will be able to determine how closely the two transistors are matched.

The troubles we have described are those which will most commonly appear in the driver and power output stages of a transistor receiver. Remember, many of the troubles which you will encounter in vacuum-tube sets will not crop up in transistor receivers. For example, breakdowns due to unusually high voltage or burned-out resistors and similar troubles will not be part of the routine in servicing such sets. However, from what we have described thus far, you can easily see that servicing transistor receivers is no more difficult (and in many cases is easier) than servicing vacuum-tube sets. Fig. 807 shows how an audio generator (or the audio output of your signal generator) can be used to check single-ended and push-pull output stages. And now that we have covered the back end of the receiver, let's move forward to the detector stage.

The detector

There is a quick and easy way to determine if the detector is providing any difficulties. Connect your signal generator to the output (collector) of the last if stage preceding the detector (Fig. 808). Set the signal generator to the intermediate frequency of the receiver. The modulation of the generator should be turned on. If the detector and the audio stages are working correctly, you should hear the audio tone in the speaker. If no signal is heard, transfer the test lead of the generator to the diode load resistor. Change the cable connection on the signal generator so that it is connected to the audio output terminal. The frequency dial of the signal generator can be left in any position desired
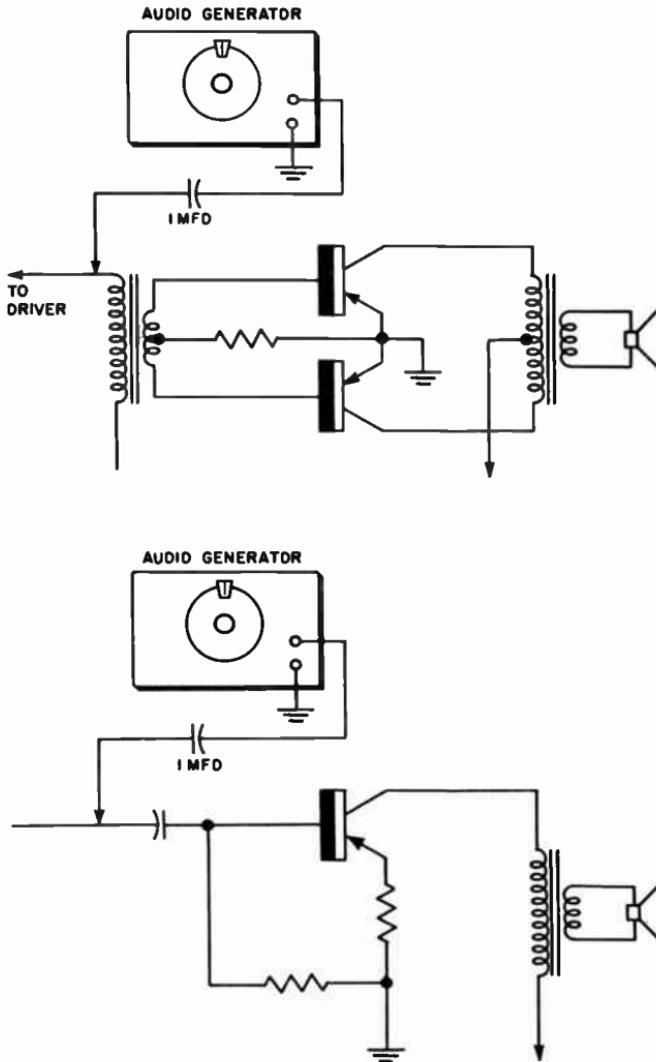
Fig. 807. *Methods for checking single-ended and push-pull audio output stages.*

since (for most rf signal generators) the audio test frequency has a fixed value. If you now hear a signal coming out of the speaker but you did not hear a signal when the generator was connected to the collector of the last if stage, you have a positive indication that the detector circuit is at fault.

Many of the symptoms we have discussed in the preceding

paragraphs with respect to the audio amplifier stage or stages also appear in the detector circuit. Thus, defects in the detector can cause a weak signal, complete absence of output signal, distortion, etc. The detector circuit is quite simple and consists of the detector unit, the volume control and a coupling capacitor, usually connected to the base of the first amplifier transistor. The agc network is generally made part of the detector circuit.

To determine if the volume control and the coupling capacitor
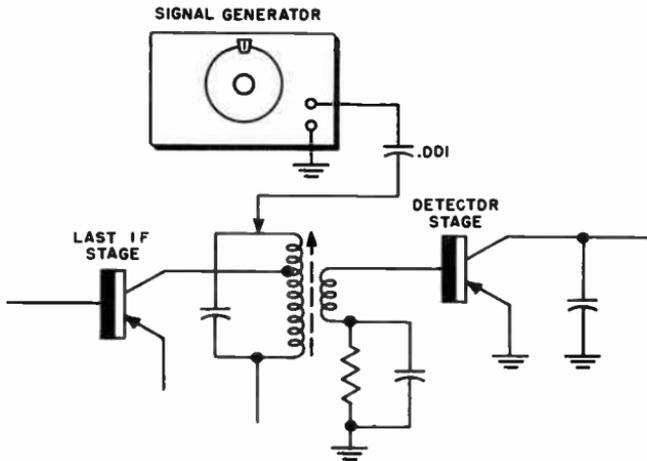
Fig. 808. *Method for checking the transistor detector stage.*

are functioning properly, connect an audio signal across the output terminals of the volume control. With the receiver turned on, vary the volume control and note if you can control the strength of the output signal. If you do get a strong output tone and you can vary this with the volume control, then the trouble lies in the detector itself or in the secondary of the last if transformer. If, however, you get no signal or a very weak signal, under these test conditions, move the generator test lead until it is across the input of the first audio amplifier. A test signal which appears at the speaker when the generator is so connected indicates that either the volume control or the coupling capacitor following it is defective. An ohmmeter check of the volume control will soon reveal whether it is in good working order. Make this test by connecting one lead of the ohmmeter to either outer terminal of the potentiometer and the other ohmmeter lead

to the center terminal of the potentiometer. Vary the potentiometer and note whether you can make the ohmmeter needle move smoothly back and forth. In most receivers, the volume control will have a total value ranging between 1,000 and 10,000 ohms, and you should set the range switch on your ohmmeter accordingly. If the potentiometer checks satisfactorily, try shunting the coupling capacitor between the volume control and the base input of the first audio amplifier tube with another capacitor. The coupling capacitor is generally an electrolytic, having a value in the region of 1 to 10 μf. Here is a spot where you must watch polarity and not make any assumptions. Sometimes the negative lead of the coupling capacitor is connected to the base of the first audio amplifier and sometimes the positive terminal of the electrolytic coupling capacitor is so connected. Disconnect one
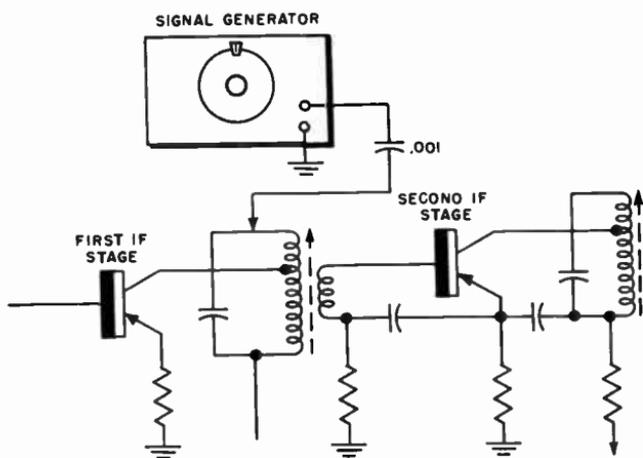
Fig. 809. *Method for checking the if stages.*

lead of the suspected capacitor and then use your test capacitor to see if the sound will come through.

Distortion in the detector circuit

Distortion, whether on strong or on weak signals, could be caused by a defective rf bypass capacitor. The purpose of this capacitor, as you know, is to keep rf out of the following audio stage and to prevent its being overloaded. Of course, if the coupling capacitor between detector and first audio stage is shorted, you will also get distortion. Distortion can also be pro-

duced if one or more of the filter capacitors in the agc network connected to the detector have become defective. In some instances, distortion is caused by a misadjusted slug in the secondary side of the last intermediate-frequency transformer. This is considered part of the detector circuit.

The if amplifier stages

The number of intermediate-frequency amplifier stages depends entirely upon the type of receiver you are servicing. However, no matter what number of stages the receiver has, you can check through for trouble by signal tracing, working your way back from the detector to the output of the converter (Fig. 809). As you proceed in this fashion, the signal at the output should become stronger because the output of the signal generator is being multiplied by each transistor stage.

To determine quickly whether all the if stages are functioning, connect your signal generator at the output side (generally the collector) of the converter transistor. The setup for the signal generator should be exactly the same as that used for checking the detector stage. That is, the signal generator should be set to the intermediate frequency of the receiver with modulation turned on. If, with the signal generator connected to the collector output of the converter stage, you get no signal out of the speaker, move forward toward the detector, stage by stage, until the signal reappears. If, for example, you get audio output when at the collector of one of the if stages but no audio signal when you move back toward the input of that same transistor, you have quite obviously located the defective stage.

The troubles which you will encounter in intermediate-frequency amplifier circuits are much the same as those in the audio section. That is to say, many of the symptoms produced by defects in the audio stages are similar to those produced by the if stages. Now, the question may very well arise as to how you will know which section of the receiver is causing the trouble. For example, a weak signal could be caused by trouble anywhere in the if, in the detector or in the audio circuit. Once again, signal tracing will show which part of the receiver requires your attention.

Weak signals in the if

Weak signals are quite often caused by misalignment in one of the if circuits. The if transformers in transistor receivers are quite selective and it doesn't take much turning of the slug to produce either distortion or loss of signal. We are not going to
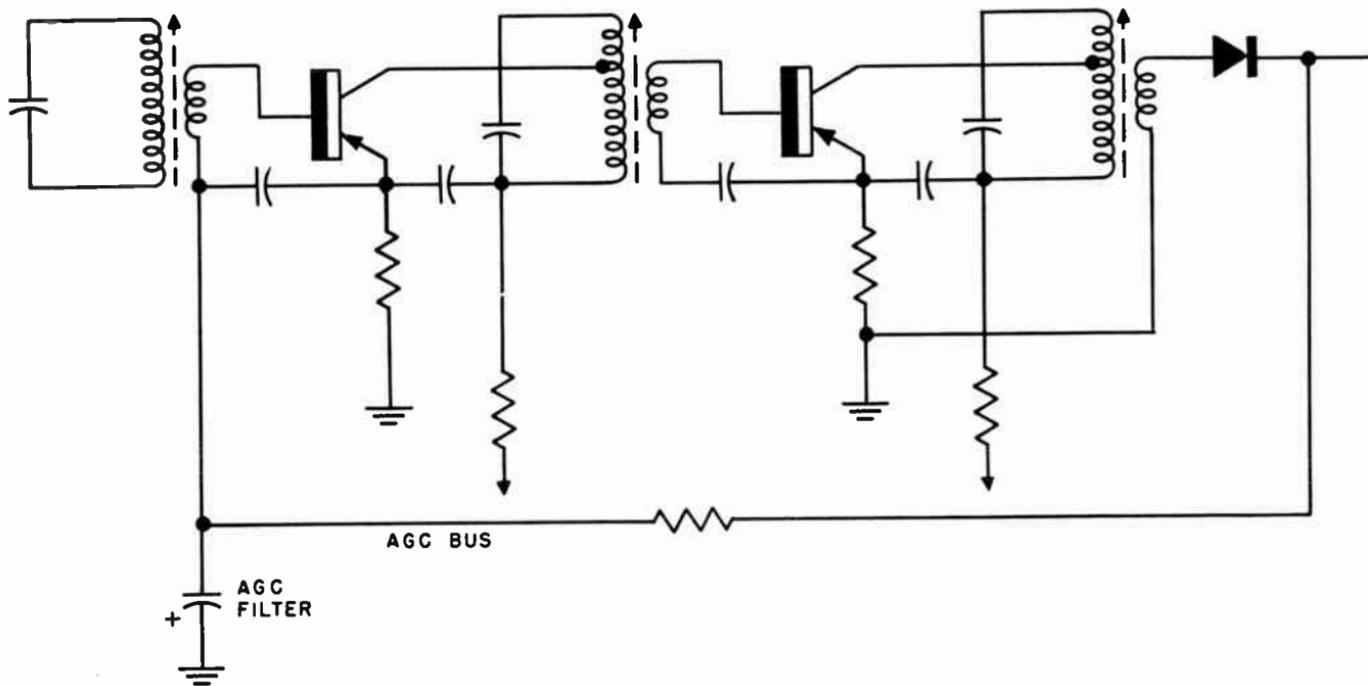
Fig. 810. *Defective resistors and capacitors in the agc bus can result in oscillation.*

discuss realignment at this particular time since complete align-
ment instructions for a typical receiver are given in chapter 10,
beginning on page 2-77.

In the case of weak signals, you should always check battery
voltage with the receiver volume control turned full on. If you
have previously checked this and have also determined that none
of the audio or detector stages is defective, and have definitely
located the cause of the weakness in the if section, then it would
be helpful to check the if bias voltages.

Bias voltages in a transistor receiver are not easy to check. As
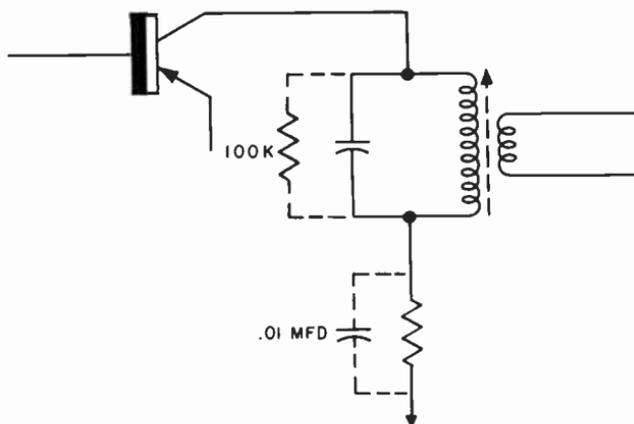
Fig. 811. A 100,000-ohm resistor shunted across the primary
of the if transformer and an additional decoupling capacitor
(.01 μf) will help kill oscillation.

we have mentioned previously, your vtvm must be capable of
measuring small voltages, and you must learn to look at the
meter needle somewhat more carefully. Although the normal bias
voltage for a transistor may be a small fraction of 1 volt, this
small fraction is extremely important. A decrease in bias voltage,
for example, of only .05 volt (5/100 of 1 volt) is enough to cause
a serious decrease in receiver gain.

Open bypass capacitors in the if section can also reduce gain.
With the receiver turned on, shunt each bypass capacitor with
a similar unit and note any possible increase in gain.

Oscillation in the if

An intermediate-frequency amplifier stage means just that. The
transistor is supposed to amplify the signal fed to it and not pro-

duce any signals of its own. When a transistor stage oscillates, it
becomes a generator and from then on supplies its own signal.
This signal will sound like a squeal and may very well ride in on
top of the signal to which the receiver is tuned. Some receivers
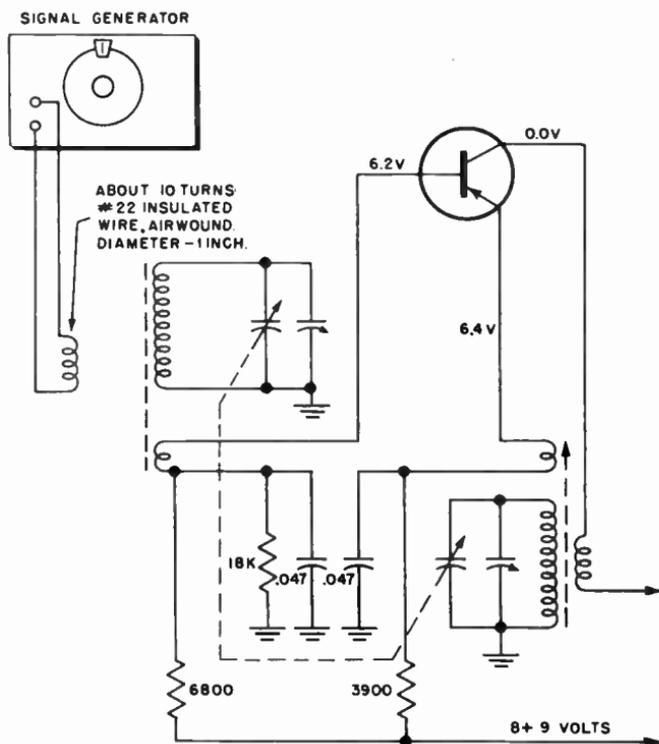
Fig. 812. *Method of checking the converter stage.*

use neutralizing capacitors or neutralizing resistors. Check these
to make sure that they are in good condition. A more likely
cause is trouble in the agc line. Check all resistors and capacitors
in the agc network (Fig. 810).

If the neutralizing resistor or capacitors check good, don't try
experimenting with them since this will be time-consuming and
may not produce results. Instead, shunt a 100,000-ohm resistor
across the primary of each if transformer (one transformer at a
time) until you have managed to kill the oscillation. A decoup-
ling capacitor should also be added. This should be done even if
the receiver has an existing decoupling unit (Fig. 811).

Oscillation is sometimes caused by substituting an equivalent type of transistor instead of an exact replacement. Use the transistor type specified by the manufacturer. Transistor substitution can also lead to distortion since the biasing may be different.

Converter stage

The converter stage can also supply its own share of problems. As a quick check, set the dial of the signal generator to the low-
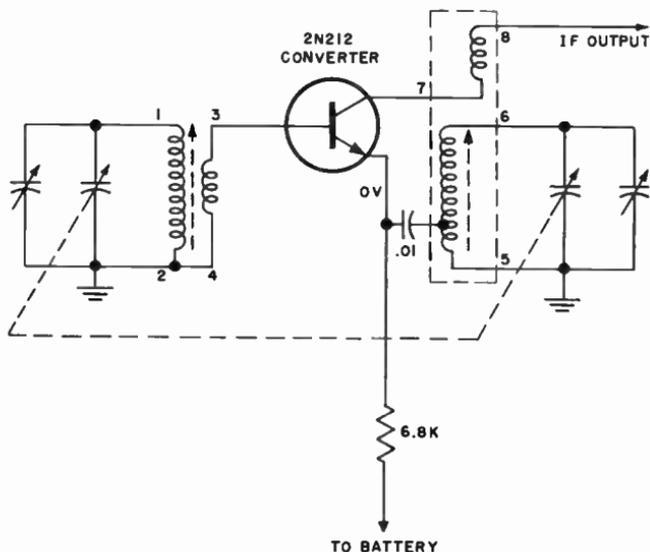
Fig. 813. *To check the mixer and oscillator coils with an ohmmeter, test across the numbered points.*

frequency end, somewhere in the region of 600 kc (Fig. 812). Tune the receiver to the same frequency. With the modulation of the generator turned on, the output should be heard in the speaker. To get a complete check across the broadcast band, run a similar test at 1000 kc and also at 1500. If you get no signal output or if the signal is extremely weak, connect the signal generator lead to the output of the converter and change the frequency setting of the signal generator to the intermediate frequency of the receiver. If at this time the signal comes through loud and clear, then trouble in the converter is definitely indicated.

Front-end troubles

In speaking of the front end of a transistor receiver we refer to the converter or, where they are used, a mixer and local oscillator.

Since most transistor receivers do not use an rf amplifier, troubles in this section will be discussed when we reach Chapter 9. Auto radios do use an rf amplifier.

There are a variety of front-end troubles ranging all the way from complete inoperation to poor reception. In discussing these symptoms, please remember that a single trouble can cause a number of symptoms. For example, a defective transistor used as a converter can cause poor sensitivity or it can make the receiver completely dead. It all depends on what we mean by the word defective. If the transistor is burned out, it is defective. If one of the leads has broken off completely, it is defective. If its gain is much lower than it should be, it is defective. And yet some of these defects permit the transistor to operate (after a fashion) while in other cases the transistor might just as well be out of the circuit.

The word defective covers a tremendous amount of territory. However, the situation isn't as hopeless as it might seem. It is much better to know that a bad transistor can cause a number of different troubles than to imagine that each trouble has one and only one specific cause. Knowing the various troubles that components can produce enables you to narrow your search for the culprit.

Receiver doesn't work

If the receiver doesn't operate and you have localized the trouble to the front end, then you can be fairly certain that either an open or short is the cause. Check the coils in the front end for continuity. Make sure that you do not have a break in the antenna or oscillator coils. Remember, antenna and oscillator coils have primaries and secondaries, so check both (Fig. 813).

If you decide to make a resistance check, you will have to remember that you aren't dealing with a vacuum-tube set. A vacuum tube with no voltage on it, is just a lot of empty space surrounded by a bit of glass or metal. A transistor is quite different, resembling a group of resistances stuck into the circuit. As a result, every time you make a resistance check, some part of the transistor will manage to get into the act, giving you completely misleading readings. If the transistor has a socket, take the transistor out. If the transistor is soldered into place, it is advisable not to tamper with it.

If you can make a resistance check and the resistance check shows that the coils are good, then it is possible that the oscillator

isn't working. There are a number of tests that you can perform, depending upon the equipment you have at your disposal. In Fig. 813, we have a typical converter stage using a Hartley circuit as the local oscillator. Set the dial of the receiver to about the center of the scale. Connect your scope "hot" lead to the emitter
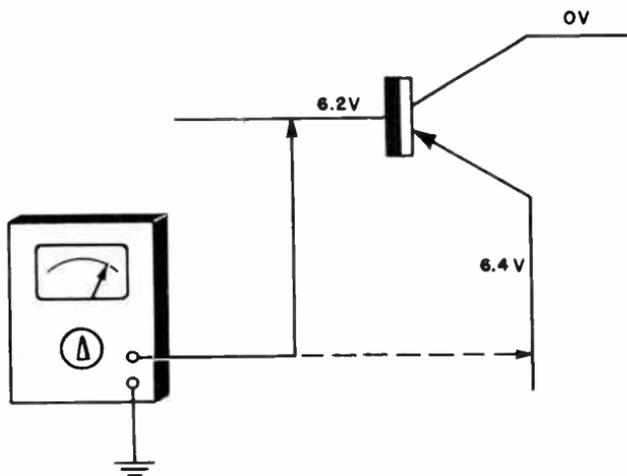
Fig. 814. *To measure bias use a vacuum-tube voltmeter. Set it to read dc volts but use the lowest possible range so that the meter needle will read as far over to the right as possible. The difference between the two meter readings is the bias voltage.*

of the transistor and see if you can pick up the rf voltage being impressed on the emitter by the local oscillator. If you have an rf type of vacuum-tube voltmeter, you can actually measure the rf voltage at this point. Use an isolation probe with your vtvm. The technique which you use for determining oscillator operation in a TV or AM set (by measuring the voltage developed across the grid return resistor of the oscillator) cannot be used in transistor receivers.

If you do not have the test equipment we have just described, but do have a signal generator, you can still run a test on the local oscillator in the receiver. Connect a loop to the test cable of the generator as shown in Fig. 812. The dimensions of the loop are not critical. It can consist of about 10 turns of insulated wire (No. 22 wire). Couple this coil loosely to the oscillator coil in the receiver. Set the dial of the receiver to a point at which a station is normally tuned in. Now set the signal generator to a frequency

equal to the sum of the station frequency and the if. For example, suppose you have set the dial to 1000 kc and the if is 455 kc. The sum of these two frequencies is $1000 + 455 = 1455$ kc. This is the frequency at which you should set your generator.

The output of the generator should be the rf signal, but with no modulation. If the local oscillator in the receiver is not working (and you have the receiver correctly tuned), you should now hear the station. Rotate the dial of the signal generator back and forth over a narrow range if you do not hear anything.

The next step would be to check the voltage at the base and emitter of the converter transistor to make sure that proper voltages are reaching the transistor. (Another method of checking the local oscillator is described on page 2-62 in Chapter 9.)

If you must replace the mixer transistor, try to use an identical type. An equivalent transistor may work, but sometimes such a substitute unit will work only over part of the broadcast band.

Tweets and birdies

You must first make sure that this condition is originating in the receiver and is not confused with interference picked up from
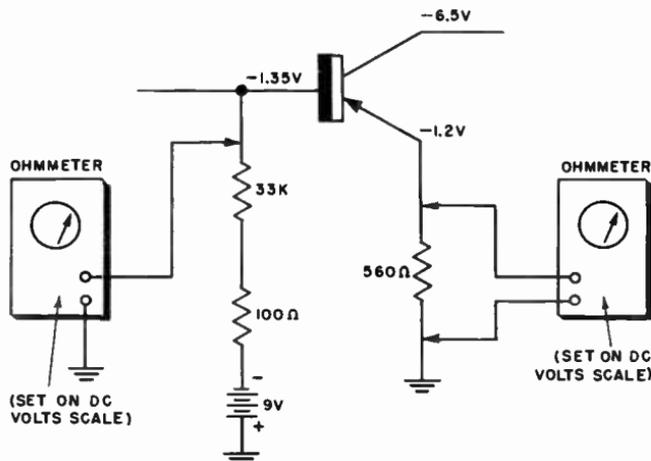
Fig. 815. *An ohmmeter (used to measure voltage) will load the circuit, giving an incorrect reading. Use a vtvm.*

outside sources. If you are checking the receiver on a bench equipped with fluorescent fixtures, turn the receiver on but shut off the light switch. Notice if there is any improvement in

receiver operation. If there definitely is, then the cause is outside the receiver.

Tweets or chirps in the sound can be caused if the oscillator voltage of the receiver is too high. This condition can be relieved by using a converter transistor that is not as good as the one you have in the set. In other words, what we are trying to do here is to reduce the strength of oscillation. Of course, if the local oscillator isn't working, no signals will be heard.

Quick check

We have previously discussed the use of a milliammeter in series with the B-plus to measure receiver current under different
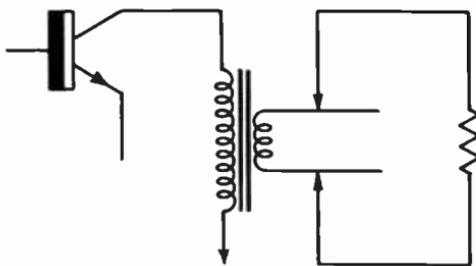
Fig. 816. *Put a dummy load across the secondary of the audio output transformer if you want to make tests with the speaker disconnected.*

operating conditions. Inserting the milliammeter isn't too difficult since all it means is lifting (or disconnecting) one battery lead (either one). If you wish, you can connect the milliammeter leads directly across the switch on the volume control. This will give you the amount of current taken by the receiver under a condition of minimum volume. However, the switch must be kept in the off position since closing the switch would short the milliammeter. No damage would be done to the meter, but it simply would not read. (See Fig. 806 once again.)

As a quick check on receiver operation, connect the milliammeter in series with the battery and measure the total receiver current with no signal coming in. Make a note of the current reading and then turn the volume control to maximum with a strong station tuned in. The current should increase to a little more than three times the no-signal value. For example, if the current without a signal is 8 ma, the current with maximum

signal will be about 24 ma or more. This technique was described earlier. We are repeating it here for its value as a quick check.

Insufficient gain

This trouble can be caused by an open bypass. Shunt suspected units with a known good capacitor. Weak signals on all stations can be due to a misaligned if. In aligning if's, remember that some stages may have a double peaked response. That is, while you may have a theoretical flat-top bandpass, it isn't so in reality. Generally, one peak will be higher than the other. To get more gain and selectivity, align for the higher peak. To do this, you will have to use a sensitive output indicator and not rely upon the signal output from the speaker.

Also, instead of connecting your vtvm across the voice coil of the speaker, put it across the volume control instead. Use the two outer terminals of the volume control. Rotate the slug of the if transformer and watch the meter needle. If it swings up, then down and then up again, you have a double-peaked if response. Then just align for the higher of the two peaks.

If the if transformer seems to tune very broadly, its Q is too low. This can be caused by a shorted turn in the if transformer. Also check for open if bypasses connected to the transformer.

Sometimes gain is reduced when a new transistor is used to replace an existing unit. Don't assume that the two transistors are identical. Replacing a transistor may mean that you will have to realign the if. If you transpose transistors, you may also have to realign.

Finally, if you still don't have enough gain, take a look at the diode detector. If, for any reason, it has been turned around, the agc voltage will be incorrect.

Measuring bias

The bias is the voltage existing between base and emitter. However, as we know, the bias is very small — usually a fraction of 1 volt. In a typical case, the bias might be 0.2 volt. This is very difficult to read on a meter.

An easier technique for measuring bias is illustrated in Fig. 814. Measure the voltage between base and battery using the correct reference point and then make a voltage measurement between emitter and battery. The difference between the two voltage readings will be the bias. The advantage of this technique is that it moves the meter needle further up on the scale where it can be read more easily. However, the difference in the two volt-
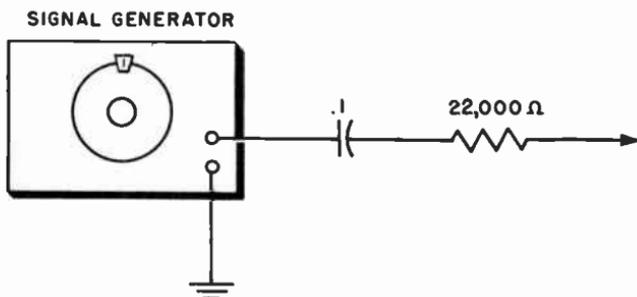
Fig. 817. *Use a blocking capacitor in series with the hot lead of the generator. A 22,000-ohm ½-watt resistor will provide isolation when checking in rf or if stages. The resistor isn't needed for audio circuit testing.*

age readings will be slight, so you will have to make the test with care.

Test instruments

For servicing transistor radios, both the volt-ohm-milliammeter and a vacuum-tube voltmeter are needed. It is true that both the volt-ohm-milliammeter (vom) and the vacuum-tube voltmeter (vtvm) can measure voltage, but you need the vom for measuring current. (A few vtvm's also measure current.) ·

However, since the vom also has voltage scales, it might seem offhand that we could dispense with the vtvm and work with just one instrument. The whole point hinges around the sensitivity of the test units. A vom may have a sensitivity as low as 1,000 ohms per volt. But what are the voltage ranges we will encounter in a transistor receiver? Seldom will we get above 9 volts, with many receivers working at voltages lower than this! Now suppose we would wish to measure the voltage at the base of a transistor and that this was indicated on the manufacturer's circuit diagram as —1.35 volts. We would set our vom on its lowest dc range. But at 1,000 ohms per volt, the meter represents a resistance of only 1,350 ohms. However, in making a voltage measurement, what we are really doing is putting the meter in shunt with the circuit being checked. In Fig. 815 we see that doing this has the effect of reducing the 33,100-ohm base resistor to an equivalent of 1,280 ohms.

If you use a vom having a sensitivity of 20,000 ohms per volt, this would be 100,000 ohms on the 10-volt scale (full-scale deflec-

tion). Making the test indicated in Fig. 815 reduces the base resistor to an equivalent of 14,900 ohms. The situation is a little better (but not good enough) since the more sensitive vom does not load the circuit as much. A vtvm would be best since it is
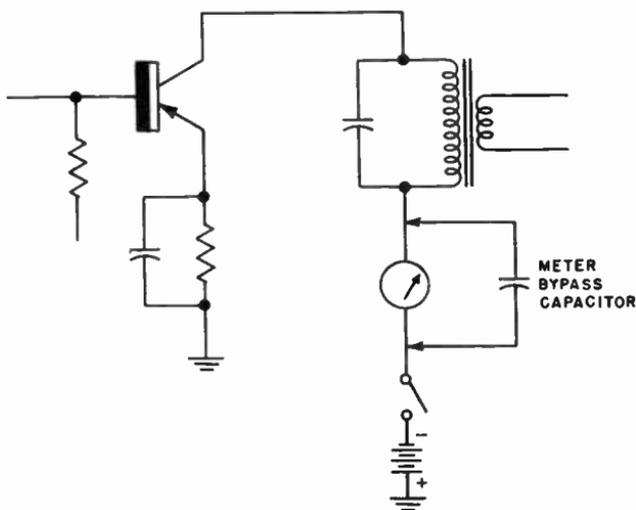
Fig. 818. *Use a meter bypass capacitor when making current measurements.*

rated in megohms and has practically no effect on the circuit being tested.

If you do use a 1,000-ohms-per-volt meter, the bias readings you measure will have no significance. They will not be correct since the very act of connecting the instrument will change the bias.

Some testing suggestions

Never operate a transistor without a load. If you must remove a speaker, do not assume that keeping the test instrument leads connected across the secondary of the output transformer is sufficient. Keep a 5-ohm 2-watt resistor handy for connecting across the leads to the secondary of the transformer (Fig. 816).

Always use a blocking capacitor in series with the hot lead of your signal generator. Some technicians put a 22,000-ohm resistor (Fig. 817) in series with a 0.1-µf capacitor to isolate the signal generator from the circuit being tested. The resistor is not needed for audio circuits.

2-51

When using a milliammeter to make a current measurement, it is always good practice to bypass the meter for if or rf. Use a .01-μf capacitor for these frequencies. Use a 10-μf capacitor when measuring current in audio circuits (Fig. 818). While this technique is a desirable one, it isn't always observed.

Transistor receivers can be click-tested but you must be careful not to short the input bias of the transistor. You can hum-check by holding the metal shank of a screwdriver and then touching the metal end of the screwdriver to the base lead.

When checking collector-to-emitter voltage, connect a vtvm between collector and emitter. Watch polarity, depending on the type of transistor used. The voltage should be not less than 50% of the battery voltage, and most probably in the order of 80%.

auto radios

As you might expect, transistors lend themselves very well to use in an automobile radio. They can operate with considerably lower power drain from the automobile battery; the transistor auto radio takes up much less room and, finally, the vibrator power supply is completely eliminated. Obviously, since the vibrator power supply is a source of noise and trouble, its removal is very worth while.

Fortunately, most of the servicing procedures and troubles we have analyzed earlier are also applicable to the transistor automobile receiver. We still need to study the transistor automobile radio though, since it has a few problems of its own.

A few differences

The transistor automobile radio is a superheterodyne and so are the various portable and home receivers. This means that the fundamental circuitry of all of these sets is the same and yet the receiver designed to work in the home certainly has better operating conditions than one that is forced to compete with an automobile engine. The auto engine not only moves the vehicle, but it also does a very good job of acting as a miniature transmitter. The program it sends out, however, is nothing for us to get happy about. It not only consists of noise but of noise that is somewhat difficult to eliminate at times.

Because the auto radio is placed within a shield (the body of the auto) it must have an external antenna. Since it isn't possible

to have an antenna of any great length, a loading coil is some-
times used in series with it, as shown in Fig. 901. The loading
coil produces an effect equivalent to the use of a longer antenna.

Practically all auto radios have an rf amplifier stage. This stage
usually does not appear in low-cost home radio receivers. But
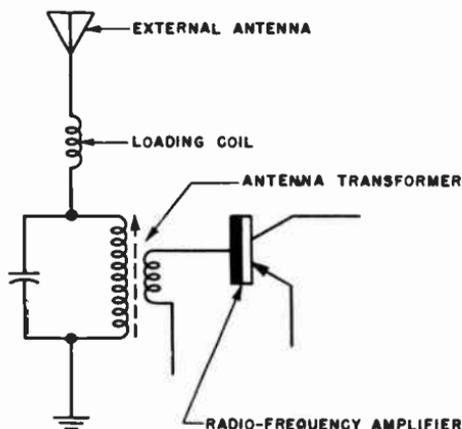
Fig. 901. *The loading coil is placed in ser-
ies with the antenna. The loading coil oc-
cupies a small space but makes the anten-
na effectively longer.*

it is invariably used if the receiver is designed to work in an auto.

Not all auto radios have transistors throughout. Some, known
as hybrid auto receivers, make use of both vacuum tubes and
transistors. When vacuum tubes are used, you will find that they
may be the types which will operate with 12 volts or less on
the plate and screen.

In place of the vibrator power supply, some auto radios make
use of what is known as a dc-to-dc converter. Finally, there are
auto radios that come equipped with search tuners. A search
tuner is simply an automatic tuning circuit, permitting the oper-
ator of the car to keep both hands on the wheel, letting the re-
ceiver select and tune in the signal.

In Fig. 902 we have block diagrams showing the essential differ-
ence between home and portable receivers and receivers used in
autos.

Fig. 903 is a schematic of a representative auto radio using
transistors throughout, while Fig. 904 is the schematic of a hybrid
auto radio.

(A)

(B)
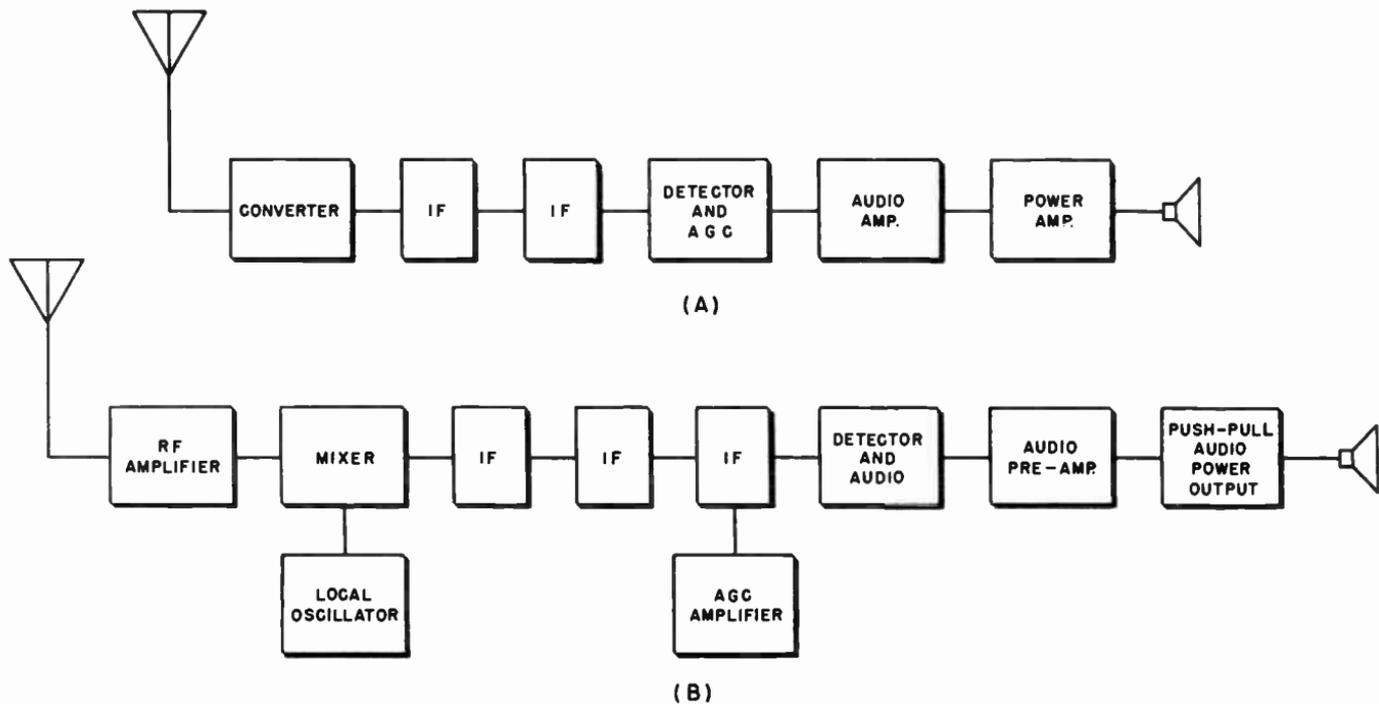
Fig. 902. *The portable or home radio (A) is not as elaborate as the auto radio (B).*
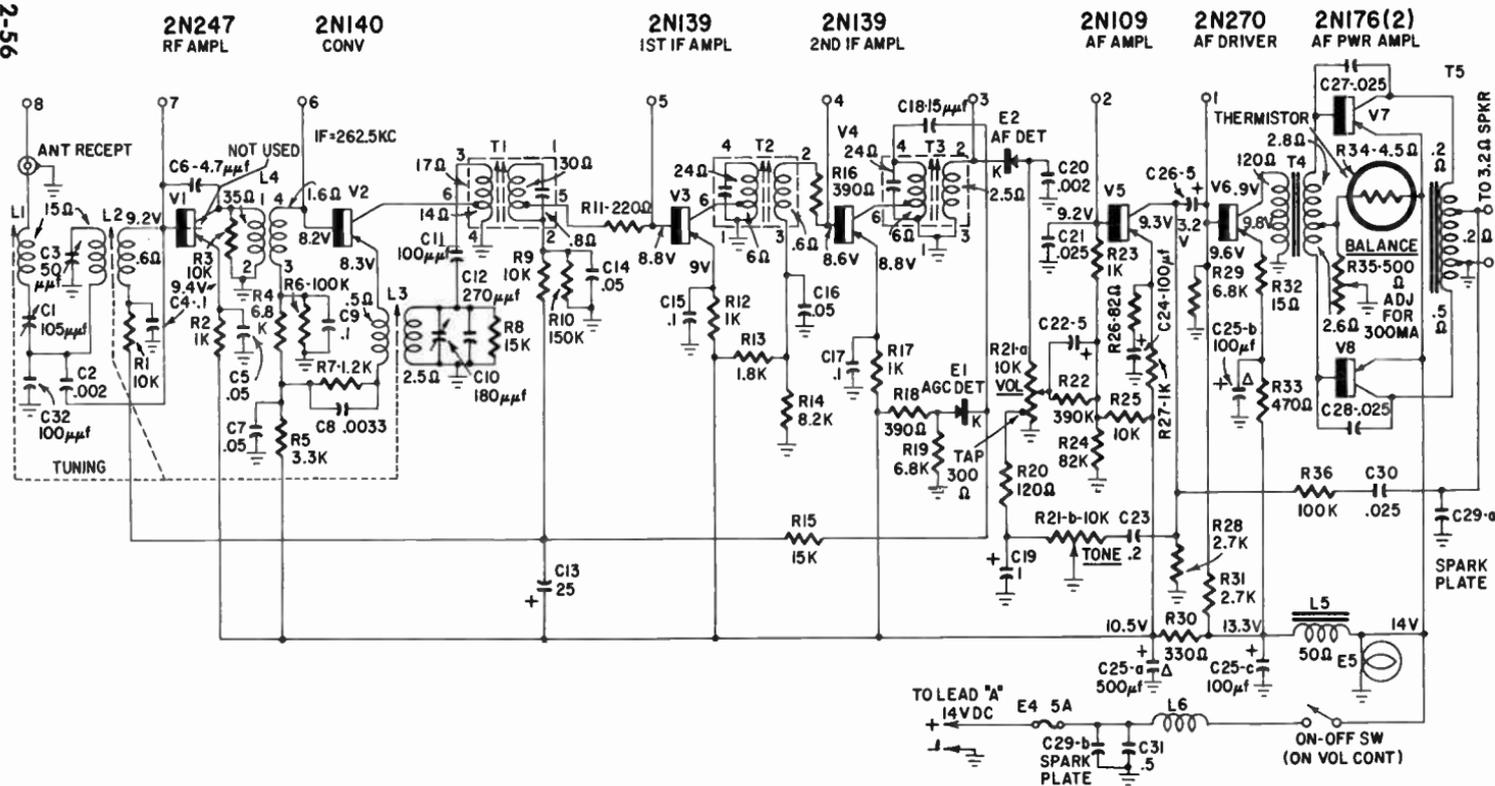
Fig. 903. *Auto radio using transistors only.*

Power consumption

Auto radios using transistors but no tubes do not put a heavy drain on the car battery. A typical transistor audio radio will draw a total of about 2 amperes compared to about 8 to 10 amperes for a tube type auto radio.

The front end

For best operation, it is important to get the maximum amount of signal into the first stage of the transistor auto receiver, the rf amplifier. Fig. 905 shows a typical front end.

This receiver is permeability-tuned. The rf amplifier, the mixer and the local oscillator are all tuned simultaneously. All of the iron-core slugs are moved in and out of their respective coils by a suitable mechanism. The emitter of the rf amplifier is connected into the agc bus through a resistor. The loading coil generally has a value of less than 20 µh, while the trimmer capacitor across the primary of the rf transformer generally has a range of 3 to 30 µµf.

The setting of the trimmer is simple. This is usually a screwdriver adjustment and can be made without removing the receiver from its cabinet.

A hole in the chassis is provided to allow the use of a small screwdriver. Set the dial of the receiver to approximately 1400 kc, tune in a very weak station and then adjust the trimmer until the volume is maximum. If you should happen to tune in a strong station, it will seem to you that the trimmer tunes broadly. This is a deception. The agc will operate to keep the signal strength constant. If, however, you select a weak station, the agc voltage will be such that the receiver will be working with maximum sensitivity and, as a result, you will be able to make a very fine adjustment with the trimmer capacitor. This trimmer compensates for the variations in capacitance of antennas (and their lead-ins) of different models and manufacturers.

The rf amplifier stage has tuned input and also tuned output. The stage, however, isn't transformer-coupled to the mixer in the circuit of Fig. 905. In this case, an R-C network is used to transfer the signal from the collector output of the rf amplifier. Sometimes, however, transformer coupling is used as shown in the drawing of Fig. 906. The agc bus in this instance is fed into the base of the rf amplifier. The output transformer in the collector circuit is tapped down to provide a better impedance match between the transformer and the collector.

2-57
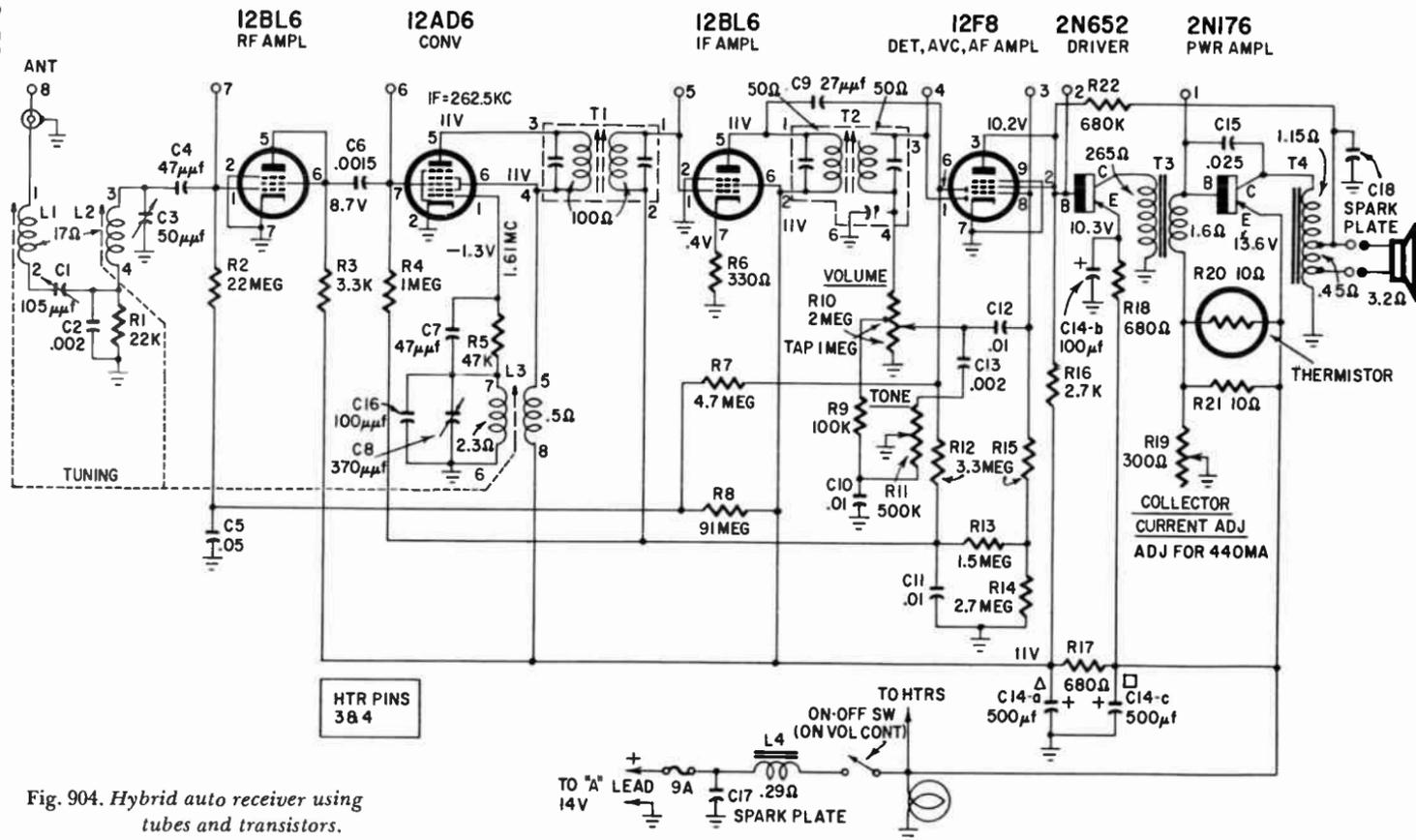
Fig. 904. Hybrid auto receiver using tubes and transistors.

The local oscillator

The local oscillator stage (Fig. 907) oscillates because of energy fed back from the output (collector) to the input (base). The
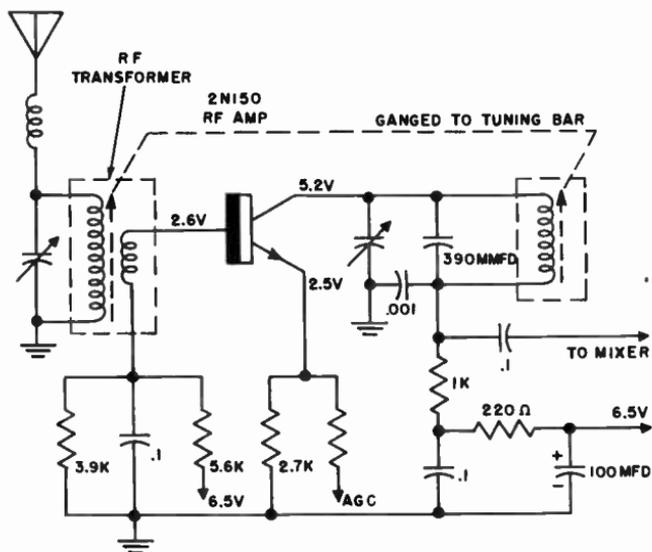
Fig. 905. *Typical auto radio rf amplifier stage.*

oscillator voltage is injected into the mixer circuit by capacitive coupling (C1). The output coil of the oscillator is shunted by two series capacitors, C2 and C3. These two capacitors form an impedance-dividing network, permitting impedance matching between the oscillator and the mixer. C1 is connected to the emitter of the mixer. The emitter is a low-impedance point, hence the lead going to the oscillator must also be attached to a low-impedance point. Using C2 and C3 as shown permits such a connection. An alternative technique would be to omit the capacitors and to tap down on the coil of the local-oscillator collector circuit.

The resistor in the emitter circuit of the local oscillator has a stabilizing effect on the collector current. The bias developed across the emitter resistor helps prevent collector-current runaway.

In auto radios the local oscillator usually operates at a frequency of 262.5 kc above that of the incoming rf signal. Note also that
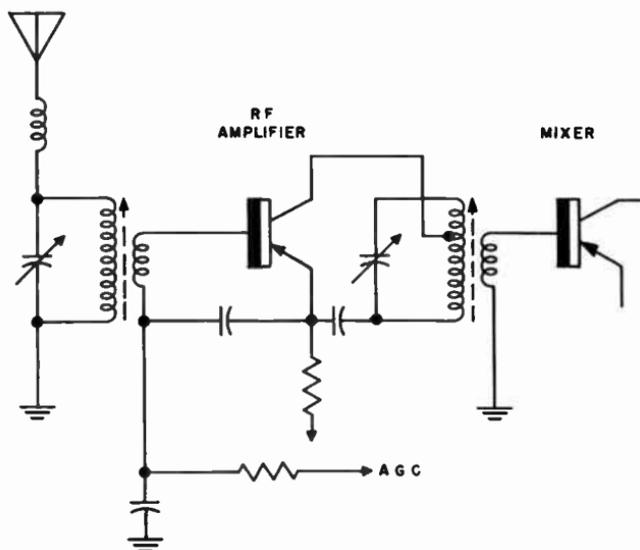
Fig. 906. *Rf amplifier stage transformer-coupled to the mixer circuit.*
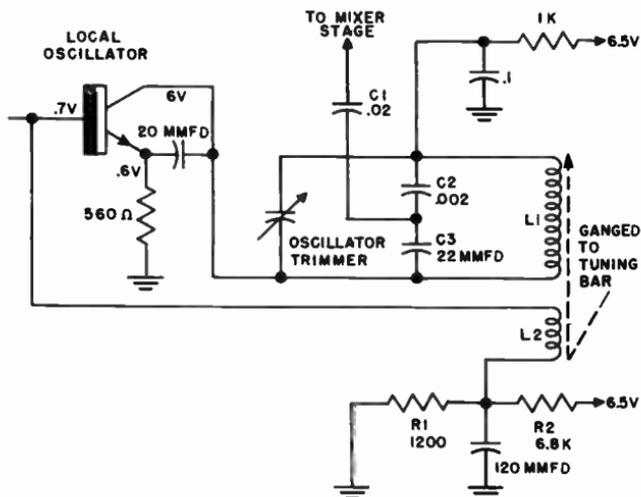
Fig. 907. *Local-oscillator stage.*

resistors R1 and R2 are connected in series and that the base is connected to the junction of these resistors through feedback coil L2. R1 and R2 are connected across the battery and act as a voltage divider to provide the proper forward biasing voltage
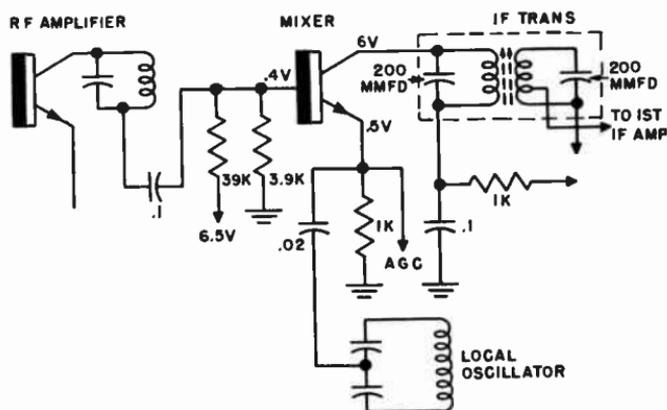
Fig. 908. *The triode mixer receives a number of dc and signal voltages.*

for the base. L2 is used only for feedback. The frequency of the oscillator is determined by the inductance of L1, the position of the tuning slug and the values of capacitors C2 and C3.

The mixer stage

The mixer is quite a busy circuit. It receives rf and local-oscillator voltages; it gets its own dc voltages from the power supply, and (in some sets) receives an agc voltage. A mixer circuit is shown in Fig. 908.

The function of the mixer is to heterodyne (or mix) the rf and local-oscillator signals. The output of the mixer contains four main frequencies, one of which is selected by the tuned circuitry of the following stage.

In Fig. 908, the rf signal is injected into the base of the mixer while the local-oscillator voltage is fed into the emitter. The transistor used in this circuit is an n-p-n type. The voltage on the emitter is higher than that on the base. Part of this voltage on the emitter is due to the voltage furnished by the local oscillator. If, for any reason, the local oscillator should stop working, the voltage on the emitter will decrease. If, in making voltage checks, you should find that the emitter voltage is less than that of the

base, you can be fairly certain that the local oscillator has stopped working — especially if you get no signal output from the receiver.

A mixer circuit is often referred to as a first detector. Mixing takes place because the mixer transistor is made to act in a non-linear manner. The mixer stage operates as a class-B unit, or very close to it.

As in the case of the local oscillator, the resistor in the emitter circuit produces a bias which opposes undue increases in collector current.

The if stages

As a general rule, you will find that auto radios have at least one more if stage than a portable or home transistor receiver, and certainly more than a vacuum-tube set. Auto radios use more if stages to supply additional gain and selectivity. Transistors do not have as much gain as the pentodes used in vacuum-tube if's, hence more circuits are needed.

A representative if stage is shown in Fig. 909. Because the base is a low-impedance point, it is connected to a tap on the secondary of the first if transformer. Compare this method of impedance matching with the capacitance impedance divider described in connection with the local oscillator. Another technique for impedance matching is shown in the construction of the second if transformer. The primary has more turns to match the impedance of the collector. The secondary has fewer turns to match the impedance of the base input of the following if stage.

R1 is part of the agc filter. R2 and C1 form a decoupling unit inserted between the collector of the first if stage and the battery.

The detector

As you can see in going through this chapter, circuits used in auto radios are quite similar to those we have examined previously in connection with portable and home receivers. The detector is no exception. The only difference is that in auto radios there is a tendency to use a transistor as the detector (instead of a diode), to take advantage of the gain supplied by the transistor. This isn't a fixed rule, however, and you may very well find auto radios with diode detectors and portable sets using transistors for this purpose.

A typical detector circuit using a transistor is shown in Fig. 910. This circuit has a few unique features that were not discussed when we studied detectors previously. For example, the

last if transformer has three windings instead of the usual two. The primary couples the if signal into the secondary, connected to the detector. At the same time, the primary winding is also coupled to a coil which is connected to a separate agc rectifier.
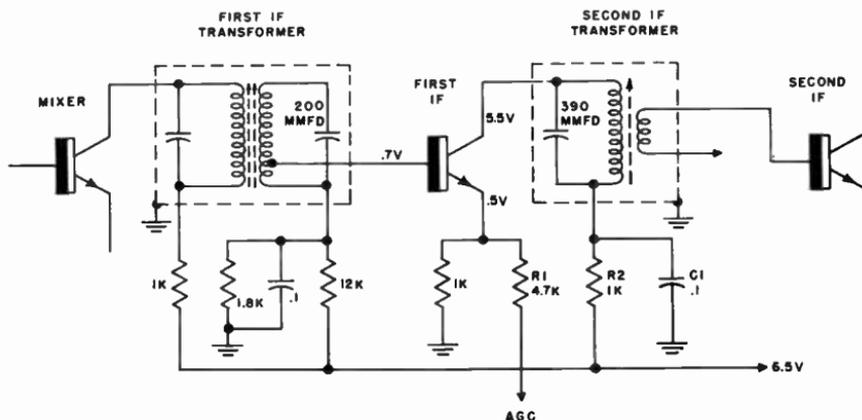
Fig. 909. *Typical if stage in an auto receiver.*

If you will examine Fig. 910 somewhat more closely, you will see that there is no bias voltage connected to the base (that is, between the base and the emitter). You will recall that the purpose of biasing a transistor was to put its operating point on the proper portion of the characteristic curve. The bias that is usually put on the base is forward bias — that is, the transistor is so biased that collector current flows. If we do not place this bias voltage on the base, collector current will be almost zero.

In other words, by not biasing the transistor we have reduced collector current to cutoff or almost to cutoff. But, as you know, this is class-B operation, which is exactly what we want in the case of a detector.

The base of the detector is connected to the secondary of the if transformer. When the incoming signal has the proper polarity, the detector transistor will conduct. Since the incoming signal is positive half of the time and negative during the other half, one half of the signal will have no effect. In the circuit shown in Fig. 910, only the positive portion of the if signal voltage will have any effect. For this reason, the transistor will act as a recti-

2-63
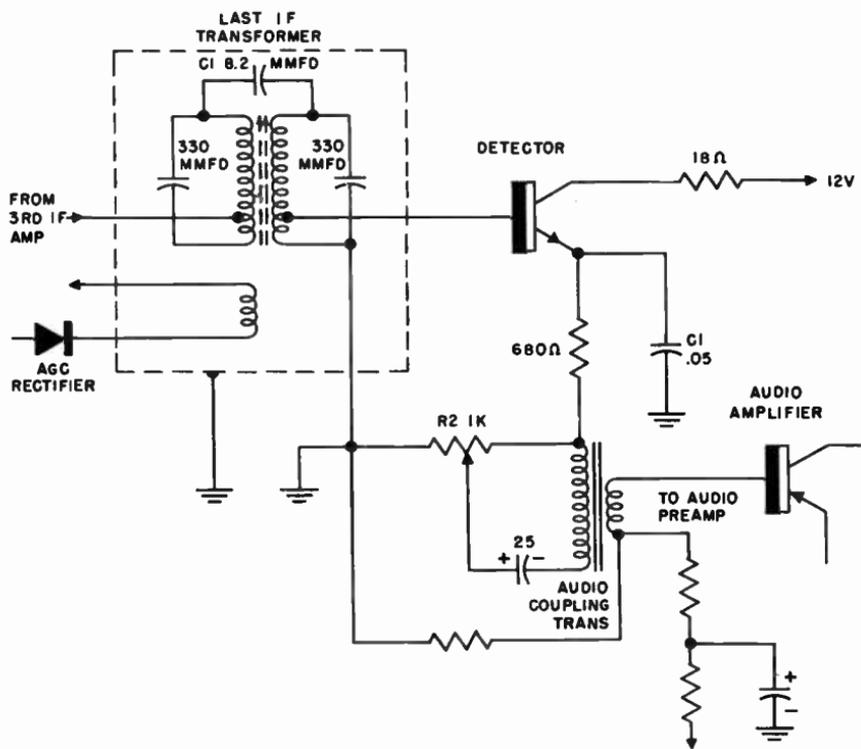
Fig. 910. *Transistor detector. Note the use of a separate agc rectifier.*

fier (or detector). Only the rectified portion of the if signal will appear in the output of the transistor detector.

The output of the detector is in the base-emitter circuit. Capacitor CI acts as a bypass for it. The volume control, R2, is a 1,000-ohm potentiometer. The signal is coupled from the volume control through an electrolytic capacitor to the primary of the audio transformer. Sometimes the transformer is omitted, the detector being coupled to the audio amplifier through an R-C arrangement.

In Fig. 910 and earlier drawings, you will see that the if transformer is surrounded by a dashed line. This represents a shield can. (All components inside the dashed lines are inside the shield can.) The small capacitor, C1, connected between the primary and the secondary of the if transformer improves the bandpass of the unit. Most if transformers do not have this capacitor. When making a transformer replacement, make sure that the trans-

former has this capacitor if it was included in the original unit, as indicated on the schematic for the receiver.

Sometimes, as shown in Fig. 911, a crystal diode is put in series with the base input of the transistor detector. This unit is usually
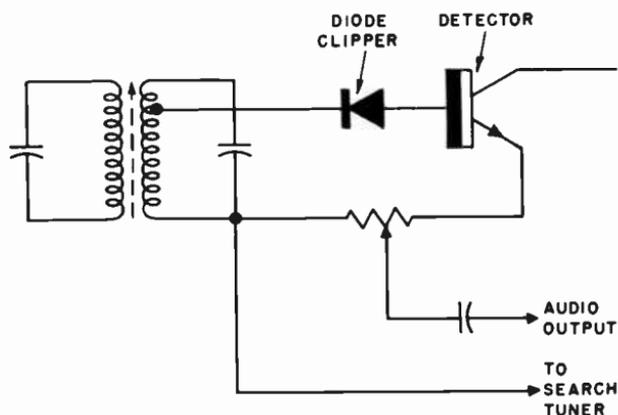
Fig. 911. *A diode is sometimes placed in series with the base of the detector transistor.*

included in auto receivers using search tuners (described later in this chapter). The diode acts as a clipper, helps prevent mistuning and supplies a certain amount of isolation.

Automatic gain control (agc)

You will find a variety of agc circuits used in auto radios. Some of these are quite simple, as shown in Fig. 912, and simply consist of one or more resistors and capacitors fed back from the collector output of the transistor detector. In this arrangement, the agc setup is almost the same as the type you will find in most vacuum-tube ac-dc radio sets.

A somewhat more complex arrangement is shown in Fig. 913. The if signal is coupled into the detector, as usual, through the secondary of the if transformer. However, there is another coil, coupled to the primary of the if transformer, and it is this coil which feeds the signal voltage to a crystal diode which acts as the agc rectifier. The rectified agc voltage is then fed into a transistor working as an agc amplifier.

The agc amplifier operates very much like a transistor detector

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circuit. Note that neither the base nor the emitter of this amplifier is connected to any source of dc voltage. This means that the transistor has no forward bias and so the collector current is extremely small. However, when the if transformer couples some
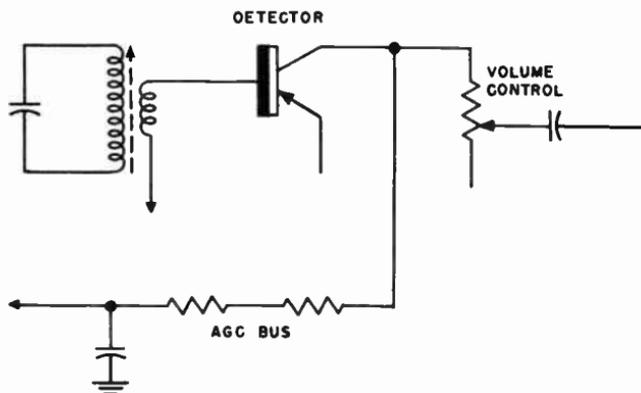
Fig. 912. *Simple agc system used in some auto radios.*
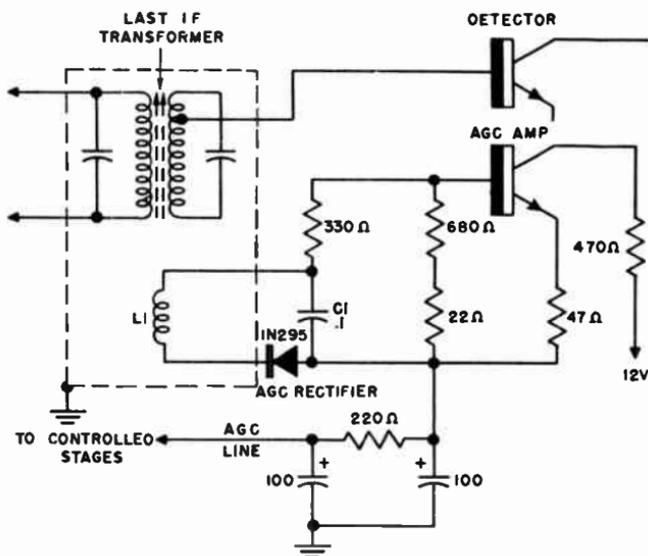
Fig. 913. *Some auto receivers use a separate crystal as the agc rectifier.*

signal voltage into coil L1, it will be rectified by the agc diode. The voltage produced by this action will be dc and will appear as a bias between the base and the emitter of the agc amplifier. The agc rectifier is placed into the circuit in such a way that the bias developed by the rectifier has the proper polarity. Capacitor C1
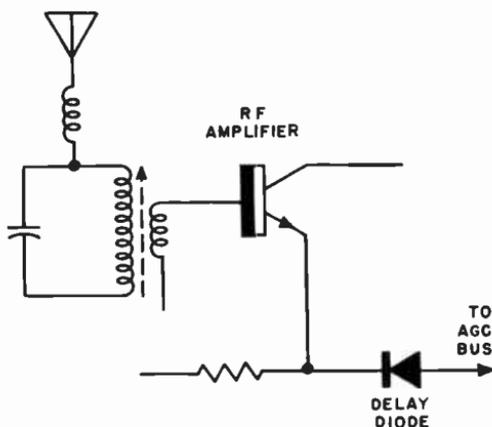
Fig. 914. *A crystal diode can be used to delay the application of agc voltage to the rf amplifier.*

is a filter unit, making certain that the output of the agc rectifier is smooth dc.

Agc delay

Sometimes a diode is used in series between the agc bus and the rf amplifier transistor. The gain of the rf amplifier is important since it is multiplied by the gain of all the following stages. In other words, the rf amplifier is much more sensitive to agc voltage and the results of the application of agc to this transistor are more drastic than those of the following stages. For this reason, it is advisable to delay or prevent the application of agc to the rf amplifier for weak signals but to permit it for strong signals.

A simple delay arrangement is shown in Fig. 914. It is just a diode connected between the agc bus and the emitter input of the rf amplifier. The diode acts as an open circuit or very high resistance until the agc voltage reaches a certain point, produced by a moderately strong signal. When the agc voltage becomes strong enough, the high resistance of the diode suddenly becomes

2-67

very low, connecting the emitter of the rf amplifier into the agc line.

Audio amplifier (driver)

Practically all auto receivers use push-pull output. While it is true that portable transistor receivers also have push-pull output, many of the less expensive portables do not. The output of the detector stage in an auto radio, even though an amplifying transistor is used as the detector, is not enough to drive push-pull transistors. For this reason, auto radios insert an audio amplifier stage (known as a driver) between the detector and the push-pull power output circuit.

A typical audio driver circuit is shown in Fig. 915. Resistor R1, placed across the primary of the audio input transformer, helps maintain stability and prevents possible ringing or oscillation. It lowers the Q of the transformer and helps broaden its bandpass.

A feature of interest in the output transformer (this is really the interstage transformer for the following stage) is winding L1. This winding is inductively coupled to the output winding L2. Because of the coupling, a voltage is induced across L1. This voltage is injected into the emitter or input of the audio transistor.
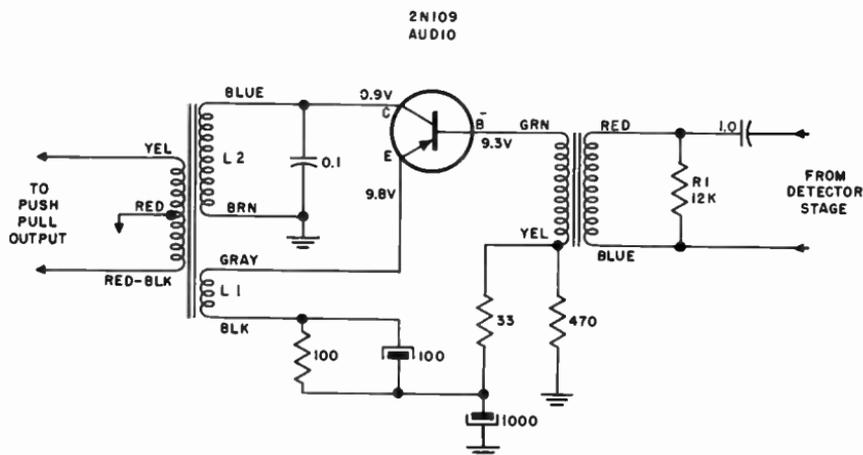
Fig. 915. *Audio driver circuit used in some auto radios.*

This fed-back voltage is degenerative, providing negative feed-back and stabilizing the audio amplifier. The capacitor placed across L2 is a simple form of tone control. It bypasses higher
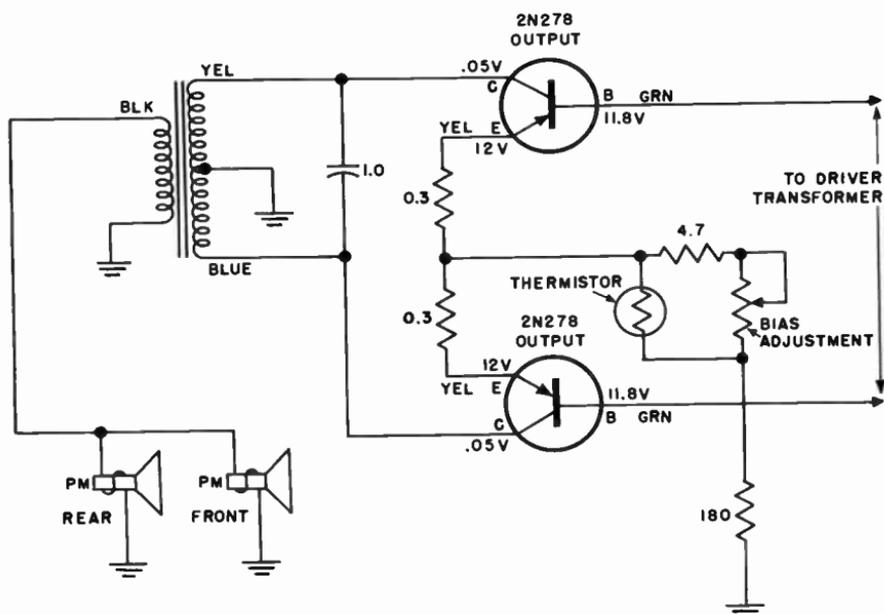
Fig. 916. *Push-pull power output circuit.*

frequencies, giving the output a low-audio-frequency emphasis that many persons find quite pleasant.

In the previous chapter, we discussed audio transformers used in home and portable receivers and mentioned that these had either four or five leads. In the case of an auto radio, however, we see that at least one of the transformers (the one between the audio driver and the push-pull output) can have seven leads.

Audio output stage

The audio output stage is similar to those we described for portable and home receivers (Fig. 916). There are a few differences, however. This stage uses a thermistor, described in an earlier chapter. The push-pull circuit operates two speakers, one for the front of the car while the other is a rear-seat speaker.
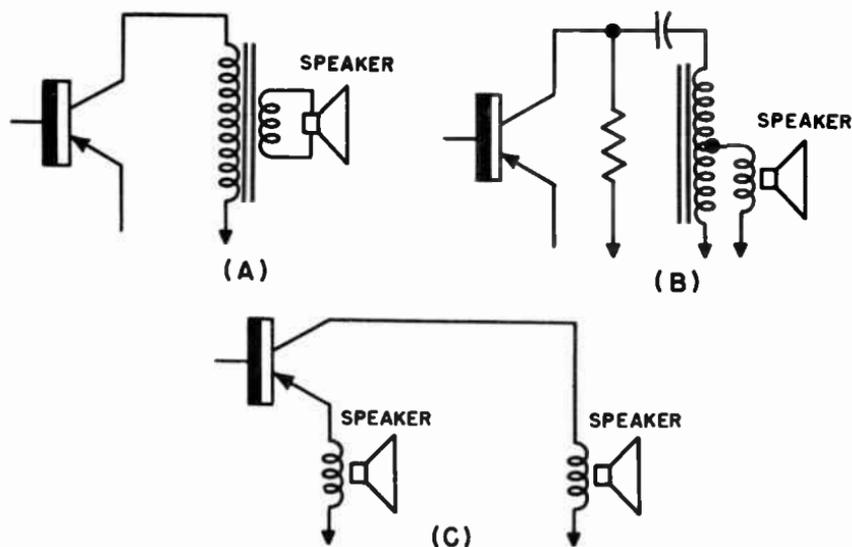
Fig. 917. *Three methods of coupling a speaker to the output stage. That shown in (A) is most common. (B) is rarely used while (C) is a possibility being explored for future sets.*

Idling current

The amount of current that a power output transistor will draw will depend upon its class of operation. If a transistor is operated in class A, its idling current (current in the absence of a driving signal) will be about ½ ampere. If a transistor auto radio has a single power output transistor, it will most probably be operated class-A. If two transistors are used in a push-pull circuit, the arrangement will undoubtedly be class-B. The idling current for a class-B stage will be less than 100 ma, with 50 ma as a common value.

Power output circuits in transistor auto receivers come equipped with a bias adjustment control (Fig. 916). When replacing a power transistor, vary this resistor until the power stage draws the amount of idling current recommended by the manufacturer.

Coupling arrangements

There are a number of ways in which a transistor can be connected to the voice coil of a speaker (Fig. 917). The most common technique is to use an output transformer. In some instances, however, a choke is used. This is impedance coupling. The speaker is connected to a tap on the choke for better impedance

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matching. Finally, the voice coil can be connected directly in the emitter or collector circuit.

Transistor power supply

Where an automobile radio uses transistors only or where the receiver makes use of 12-volt tubes in conjunction with transistors, the 12-volt battery serves directly as the power supply itself. However, in hybrid receivers, where tubes that are used require plate voltages in excess of 100, a dc-to-dc converter is needed.

The primary source of power can be either a 6- or 12-volt system. Chokes and capacitors are used in the power line to keep hash picked up by the 6- or 12-volt bus from getting into the set. The capacitors that are used generally have a large value — 15 μf or more. One or more pilot lights are generally shunted across the power line coming from the automobile battery. Immediately preceding the on-off switch, you will find a plate (spark plate). This operates as a filter capacitor in the dc bus.

The dc-to-dc converter

As we mentioned earlier, you will find the dc-to-dc converter only in hybrid auto radios in which ordinary tubes (those requiring plate voltages in the order of approximately 250) are used. Actually, the dc-to-dc converter behaves like a conventional vibrator power supply. However, it does not have any moving parts and so the noise and hash produced by a vibrator are conspicuously missing.

A representative dc-to-dc converter is shown in Fig. 918. Note that the circuit makes use of a pair of transistors. The arrangement in the primary is that of a blocking oscillator. The emitters of the transistors are tied together, and this common line is connected to the battery in the automobile. The return connection is made through the center tap of the primary of the transformer. Since each of the collectors of these two p-n-p units is tied to the negative side of the 12-volt supply, the transistors will conduct. The design is such that collector saturation current will be reached.

However, the transistors will not reach saturation current simultaneously. As long as collector current increases, the magnetic field around the primary of the power transformer will continue to grow and will induce a voltage. Each of the transistors will help induce a voltage across the secondary of the power transformer. At the same time, the magnetic fields caused by
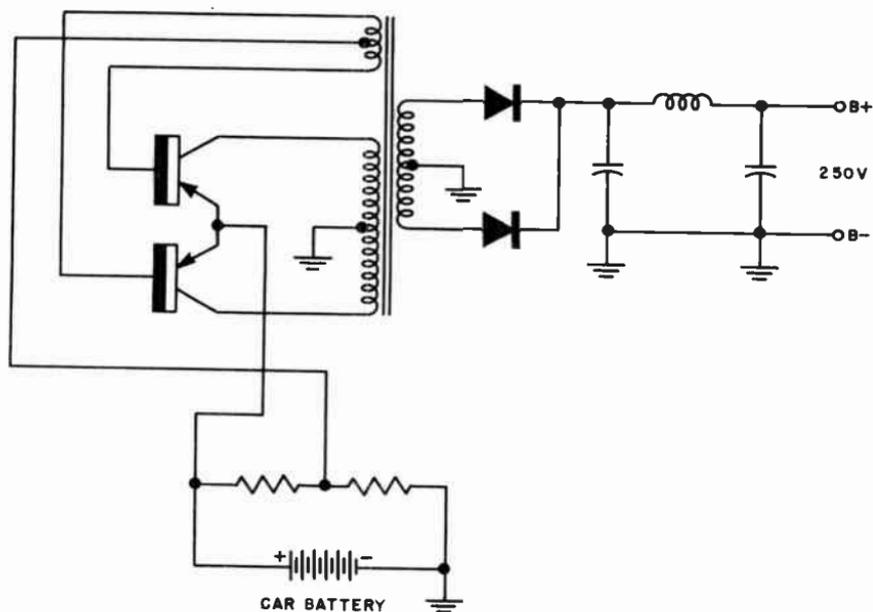
Fig. 918. *Dc-to-dc converter changes 12-volt dc input to 250-volt dc output. This arrangement is a substitute for a vibrator.*

collector current flowing in the primary will affect transistor operation. That is, the magnetic field initiated by the first transistor will determine the operation of the second transistor, and vice versa. Each transistor will run the range from cutoff to saturation.

For example, let us suppose that the upper transistor functions. It helps produce a magnetic field which induces a voltage across the lower half of the primary winding, but the lower half of the primary winding is connected to the collector of the lower transistor. This induced voltage opposes the negative voltage of the battery and, as a result, the lower transistor is cut off. However, when the upper transistor reaches its saturation level, its magnetic field reaches a steady-state value, and can no longer induce any voltage. This releases the lower transistor from cutoff and it begins to conduct. The lower transistor current induces a voltage into the upper winding, such as to drive the upper transistor into cutoff. Thus, each transistor conducts alternately. This, in turn, produces a magnetic field that will induce a voltage across the secondary. The secondary consists of a pair of rectifiers, connected as a full-wave rectifier unit.

The frequency of operation in the primary of this circuit is about 20 kc. Since we are using a full-wave rectifier, this operating frequency is doubled and so the ripple frequency is about 40 kc. As a consequence, filter components and filter chokes can be small and compact. For example, the filter capacitors may range anywhere from 0.5 to 1 µf, while the choke can be an air-wound coil having an inductance of about 100 millihenries. The voltage produced by this arrangement is about 250 volts dc, suitable for typical vacuum tubes. We can now see how the term dc-to-dc converter is obtained. The input is dc and so is the output.

Reducing automobile interference

There are two types of interference which can hinder the operation of the automobile radio. One of these comes from within the receiver itself and is due to a moving mechanical rectifier such as the vibrator. In the transistor auto radio, as we know now, this has been eliminated. The other source of interference comes from the engine of the auto.

Interference to an automobile radio can come from the generator and can be caused by a dirty commutator at the point where the segments make contact with the brushes, poor fitting brushes or brushes that are worn out. You can easily tell if you are getting trouble from the generator by listening to the radio while varying engine speed. The sound will come through as a whine, which varies in pitch as the speed of the car is changed. This trouble can be cured by replacing the brushes, by cleaning the commutator segments, by readjusting the brush holder or the position of the brushes, or (much easier) by putting a capacitor across the armature of the generator.

You will find several terminals on the generator. One of these terminals will be identified as the armature terminal. Connect one lead of the capacitor to this terminal. The capacitor should then be fastened directly to the generator so that it makes contact with its metal body. Special suppressor capacitors are manufactured for this purpose. If the generator already has such a capacitor, try replacing it to see if the condition can be cured.

In some cars (especially those of foreign make) no provision is made for a suppressor capacitor. In such instances, you may not be able to mount the suppressor on the generator. In this case, you will have to use some ingenuity. You may also have to run a ground lead from the capacitor to the frame of the car. When using the generator as a ground return, make sure that the

ground terminal of the capacitor makes good contact. If there is any paint or oil slick or dirt near where the capacitor is to be mounted, scrape this away to make sure that the ground connection is a good one. If it isn't, you might just as well not mount the capacitor in the first place.

In severe conditions where the commutator segments are badly worn or you can do nothing with the brush holders or the brushes, it may be necessary to replace the generator. Sometimes, placing a choke in series with the lead coming from the armature terminal (terminal marked A on the generator) will help reduce generator whine. This choke has to be the same type that you used in the dc bus going to the receiver. These chokes are small, are usually heavily taped and wound with heavy wire on an iron core. Remember that the turns of wire on this coil must be heavy enough to carry the current.

Static

If the receiver operates well while the auto is in a standing position, but you hear a sound like rapid firing when the automobile is in motion, then what you are listening to is a constant buildup and discharge of voltage by the wheels. This can be cured in several ways. You can install static-collector springs. These can be mounted right on the axle locknut, thus making contact between the axle and the dust cap. Another technique that you may find somewhat easier is to inject graphite powder into the inner tube of the tire. You can buy a complete set of static eliminators consisting of powder and springs, available commercially.

A common method for eliminating ignition noise is to use a suppressor resistor connected between the distributor and the ignition coil. Place the suppressor resistor as closely as possible to the distributor. Suppressor resistors are made of carbon and generally have a value in the region of 10 kilohms. The use of a suppressor resistor will not affect engine performance. However, in some modern cars, the distributor is not easily accessible, so you may have some difficulty in using this technique.

Sometimes interference is picked up by the battery cable coming from the dash to the dc input at the receiver. In some autos, this lead is fairly long and, even though there are filter capacitors hanging from this line, and chokes in series with it, the spark pickup is enough to get past these guardians. In such cases, put this lead into metal conduit, turn the receiver on and
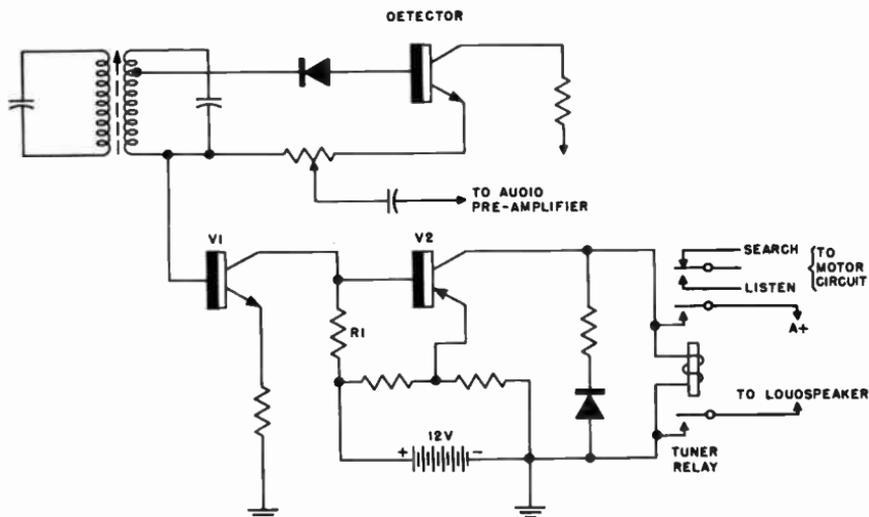
Fig. 919. *Automatic tuner or search system. The unit uses a pair of directly-coupled transistors.*

then, with a wire, probe the most logical point at which to ground the conduit. You will generally find that there is one point at which grounding the conduit will most effectively reduce spark interference. The conduit should not touch the metal frame of the car at any point other than the one at which you make the ground contact.

If the noise refuses to yield to any of these measures, it may be necessary to replace the spark plugs or to adjust the gap. However, the power of the engine is critically dependent upon the distance of separation of the two electrodes of the spark plug. So, unless you are a trained garage mechanic, you had best obtain the help of an expert. In any event, spark gaps must be adjusted with the help of suitable feeler gages.

Automatic tuners

The automatic tuner, also known as the search tuner, is not new. It has been used in conjunction with vacuum-tube type automobile radios. However, the search tuner, as shown in Fig. 919, can be completely transistorized. It consists essentially of two transistors and a relay. The relay controls the power to a motor, which operates the tuner in the receiver. The signal voltage for the search tuner comes from one end of a volume

control. The first transistor, marked V1, is called a trigger amplifier. The trigger amplifier is so biased that, in the absence of the signal, it conducts continuously. However, when a signal is received, the polarity of the signal is such that it cuts down the forward bias of the trigger amplifier, thus stopping conduction in the transistor.

Since the trigger amplifier under these conditions no longer conducts, the voltage drop across the trigger-amplifier load resistor (R1) disappears and the voltage on the collector of the trigger becomes the same as that of the battery voltage (12 volts). This voltage is applied to the base of relay control transistor (V2), but, when the relay control transistor receives this voltage, it too is cut off and as a consequence current stops flowing through the tuner relay coil. The tuner relay de-energizes, and the relay armature moves to its open position. This shuts off the tuner motor, leaving the receiver tuned in to the maximum station signal.

By pressing a control (usually a foot button switch) the driver of the car can start the search device on its way to selecting the next station. The moment the audio signal across the volume control disappears, the trigger amplifier goes into conduction. A voltage drop appears across the trigger-amplifier load resistor, and this, in turn, takes the relay control out of cutoff. The relay control transistor will now draw collector current, and this collector current must pass through the tuner relay. When it does, the armature of the relay is closed and this, in turn, operates the motor rotating the tuner dial.

If the speaker were permitted to remain connected during this operation, the transition from one station to the next would be a very noisy process. For this reason, the speaker is automatically disconnected but is turned on again by the relay when the search tuner is operated by the audio signal.

There are other types of signal-seeking circuits, of course, but this one will give you an indication of their general operation.

alignment and measurements

MANY of the servicing techniques and certainly all of the test instruments you normally use in working with vacuum-tube receivers can also be employed for transistor radios. However, as we have mentioned earlier, you will have to revise some of your thinking since a transistor receiver does not mean that transistors have been substituted for tubes. You are now going to deal with very low voltages and so a small shift in voltage, unimportant in a vacuum-tube receiver, means the difference between working or not working for a transistor radio. Screw-driver mechanics will have to throw away that indispensable tool and learn to follow a few of the more regular servicing procedures. Fooling around with the underchassis section of a transistor receiver can be an expensive habit — resulting in the loss of expensive transistors.

The first thing to do with any radio receiver, whether it uses tubes or transistors or both, is to look at it. Sometimes, just an examination of the wiring or the printed-circuit board will reveal the difficulty. Do not take for granted, if a receiver stops playing, that a transistor must be defective or the battery must be dead. These are possibilities, but there is also the chance of a broken wire, a poor connection or a bit of conducting element on a printed-circuit board coming apart. (Troubles in printed-circuit boards are covered in the next chapter.)

Signal generator

Your signal generator should be capable of covering the broad-

cast band, the if of most home and portable receivers (455 kc), and the intermediate frequency of most automobile radios (262.5 kc). It should also be able to provide an audio voltage.

There are several ways of coupling the signal generator to the receiver for alignment or tests. You can put a small capacitor (generally 300 µµf or less) (Fig. 1001) in series with the hot lead
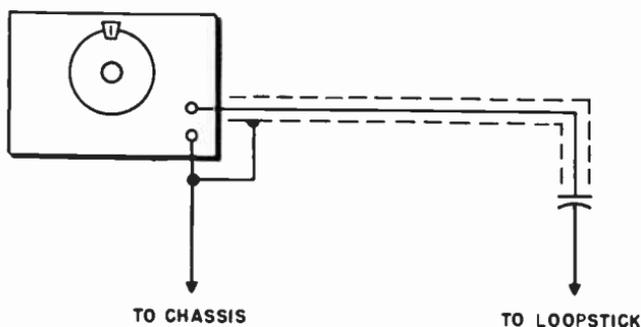
Fig. 1001. *The signal generator can be connected to the receiver input through a small coupling capacitor. Some service technicians simply clip the hot lead close to the loopstick, but no actual physical connection is made. Keep signal generator level as low as possible.*

of the generator cable or you can use a small loop of wire to act as a coupling coil. The loop can be about a dozen turns or more of insulated wire, either enameled or cotton-covered. This coil can then be brought close enough to the loopstick in the receiver to permit signal pickup. Keep the coupling between the signal generator and the receiver fairly loose, since we do not want the generator to overload the receiver (Fig. 1002). If this happens, either the receiver will be unstable or you will find that the overloading effect will detune the receiver. You will also learn that transistor receivers are not as sensitive as vacuum-tube sets.

Transistors, even more than vacuum tubes, are susceptible to hum fields. Since many generators used by service technicians are not too well shielded, there is generally a strong magnetic field surrounding the generator or leaking from it. A good common ground connection between the generator case and the receiver chassis is always helpful (Fig. 1003). A good practice is to run a heavy clip lead between a contact on the generator and

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a contact on the chassis being serviced. This is in addition to the usual ground connection which is part of the test leads.

Vacuum-tube voltmeter

Most vacuum-tube voltmeters have input impedances ranging from about 11 to 25 megohms. The instrument should have a
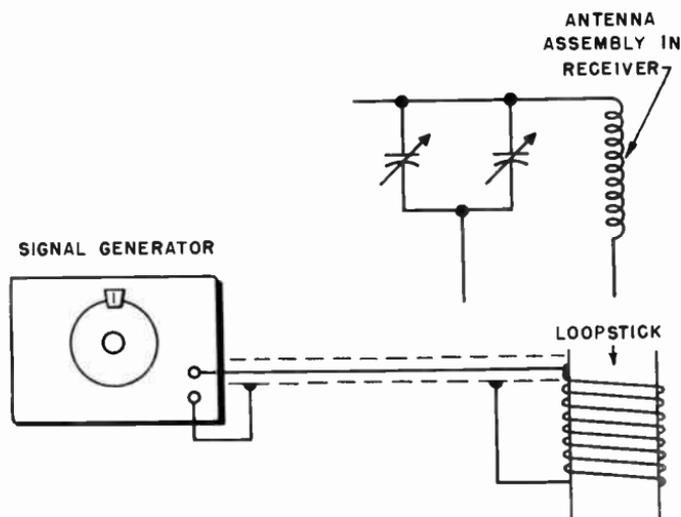
Fig. 1002. *You can use a home-made coil to couple the rf signal into the receiver. A spare loopstick will do the job very nicely.*

low voltage scale and it is preferable that it have a scale reading 1 volt on full-scale deflection.

You will probably have an isolation probe (also known as a dc probe) as part of your vtvm.

The probe (Fig. 1004) consists of a 1-megohm resistor placed inside a probe housing. The probe resistance is counted as part of the input resistance of the vtvm. Thus, if your instrument is rated at 11 megohms, 10 megohms is part of the instrument itself and 1 megohm is in the probe. Use the probe when making dc voltage measurements if you want to get maximum isolation between the receiver and the instrument. Also, the meter has been calibrated for use with the probe. Thus, if the probe isn't used, your readings will be incorrect.

Dc voltage measurements in transistor receivers are quite low. However, you must still be careful. For example, when measuring

between base and emitter, you will be checking just a fraction of a volt and will probably be using the 1-volt scale of the instrument. If you then decide to make a battery test (assuming a 9-volt supply) and do not change the range selector on the vtvm, you can easily damage the needle of the meter (Fig. 1005).

Range scales will vary, depending on the instrument. Some have 1-, 10- and 100-volt scales; others have 3-, 30- and 300-volt scales.

These two instruments, the signal generator and the vtvm,
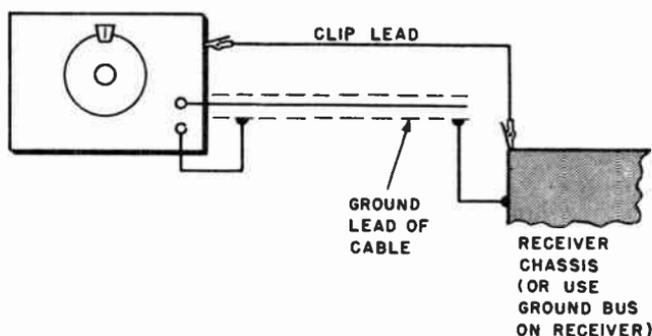
Fig. 1003. *Make sure that the receiver and signal generator are common — that is, the chassis or metal frame of the generator is connected to the receiver chassis. Use a wire with alligator clips at both ends. Connect one end to any metal screw on the generator, other end to ground bus of receiver. It is advisable that the generator have a transformer type power supply.*

are fundamental instruments in any service shop and are practically indispensable. There are other instruments which are desirable because they are servicing time-savers. These would include the oscilloscope, a signal tracer, substitution boxes (capacitor and resistor types) and a substitute speaker.

There is one piece of test apparatus that will be very helpful for transistor radios and which is not ordinarily used for vacuum-tube receivers. This is a 12-volt storage battery. The reason for requiring this is fairly obvious. If you are going to service automobile receivers, you will find that some auto radios are hybrid types, using 12-volt tubes (that is, approximately 12 volts on the plate) and using a power transistor for the output stage. These receivers are designed to work from a 12-volt storage battery.

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A good servicing technique is to bring leads from the storage battery up to a panel on your servicing bench so that you can tap off either 12 volts or fractions of it. Remember, however, that storage batteries can give off corrosive fumes, so the place for the storage battery is not as a foot rest under your bench. The best way to make sure that the battery will have long life is to put a trickle charger across it and to take regular specific gravity readings with a hydrometer. A voltage check of a storage battery (except under a heavy load) is practically useless. Even a dead storage battery will show a voltage reading with a high-impedance voltmeter. This is a snare and a delusion, and means absolutely nothing.

Some technicians prefer using low-voltage power supplies in place of the storage battery. This is fine, except that most of these low-voltage supplies cost as much as, if not more than, the storage battery and some do not supply enough current to operate receivers using power transistors (auto receivers).

There are a few other considerations you should remember. If you have been accustomed to servicing tube sets, you know that certain voltages are critical, others are less so. A difference in plate voltage of, say, 15 or 20 volts will not generally affect the operation of the set by much. But in a transistor receiver voltages
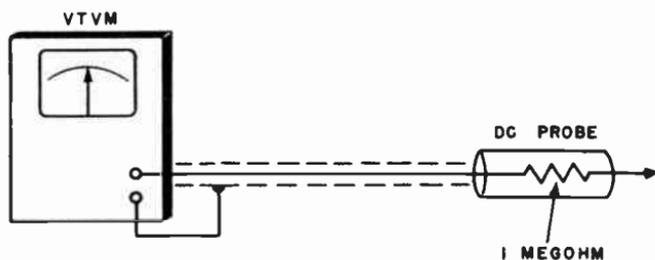
Fig. 1004. *The dc probe contains a 1-megohm resistor. This is part of the input resistance of the instrument.*

are low, hence a very small change in voltage might mean a large percentage difference. If a receiver needs 9 volts to operate, a 30% drop would be 2.7 volts. Subtracting this from 9 volts gives us 6.3 volts. This would be about the limit you could go and expect the set to work. This means that you should not only have a voltmeter shunted across the output of the low-voltage supply,

but the meter should have an easy-to-read scale so that you can see what you are really getting.

If you do decide that you would prefer using a low-voltage supply instead of a battery, keep a few precautions in mind. Make sure that the supply is adequately filtered. It is important that the output of the supply be as nearly pure dc as possible. Also, do not use a transformerless supply. Get a transformer type so that you have adequate isolation from the power line. And don't

VTVM

FUNCTION   RANGE

SET TO READ
D C VOLTS

SET TO 10 VOLTS
THEN SWITCH
TO 1 VOLT
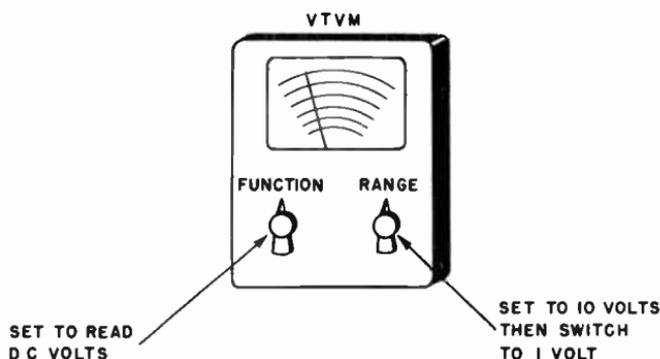
Fig. 1005. *When measuring dc volts, first set your function selector to the proper position. Put your range selector so that the meter will read 10 volts full-scale deflection. Then switch to the lower range if necessary. Always keep the range selector set at the higher range so that you will not accidentally damage the meter needle.*

take for granted that the electrolytic filters in such supplies will remain good forever. Every now and then, connect the output of the supply to the input of your scope and note if the ripple voltage is normal or if it has increased since you made your last test.

Now let us go back to the storage battery for just a moment. As the battery is used or as it gets older, its internal resistance increases. This internal resistance (or impedance) can affect your tests. For example, the impedance of the battery can act as a common element between stages. This common element is a sort of coupling unit, causing an undesired transfer of signal voltage between receiver stages. Generally, this trouble does not exist with a good, freshly charged battery.

You can avoid this difficulty by shunting the battery with a low-voltage, high-capacitance unit as shown in Fig. 1006. The

capacitor should be about 2,000 µf and have a working rating of at least 12 volts dc. The plus side of the capacitor is connected to the plus terminal of the battery. You do not have to disconnect this capacitor when charging the battery. However, you must be sure that the peak ripple voltage of the charger does not exceed the working voltage rating of the capacitor.

When a receiver uses carbon penlight cells or mercury cells,

TO TEST PANEL

STORAGE BATTERY

2000 MFD
12 W V DC (OR MORE)
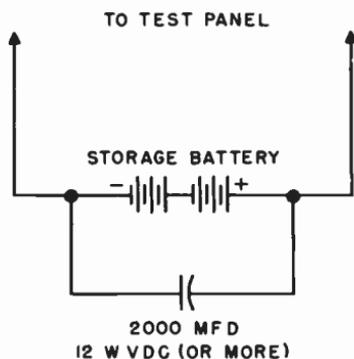
Fig. 1006. *A high value of capacitance shunted across the test storage battery keeps the overall impedance low.*

discard them when they have served their purpose. Attempts have been made to recharge such cells, but they have not been very successful. A few receivers do use rechargeable batteries of the nickel-cadmium type. Such sets come equipped with a charging unit as shown in Fig. 1007. These have a rating of 2.5 to 3 volts. If the batteries show a drop in voltage when checked under load, all you need to do is to plug the charging unit into the ac power line. The charger shown in Fig. 1007 uses a germanium rectifier. The unit is a half-wave rectifier and uses a single resistor to lower the voltage and limit initial charging current surges.

Alignment

When aligning a receiver, you need some sort of output indicator to let you know just how alignment is progressing. With a transistor receiver, you can use one of five types of indicator, two of which are generally provided by the receiver itself (Fig. 1008). You can use a speaker or you can plug in a pair of ear- phones in a jack generally provided on the set or you can connect

an output meter, scope or ac vtvm across the voice-coil leads. A plug with the load resistor connected can be inserted in the phone jack.

Of these indicators, the speaker is the least sensitive. The meter or scope are best; sensitive, responding to small signal changes, and quiet. Earphones are also sensitive and relieve you of the necessity of keeping one eye on the meter and the other on the receiver, sometimes a difficult bit of eye acrobatics.

Most receivers of the transistor type permit alignment without removing the receiver from the cabinet. You will generally find that the receiver has a case which opens out, making the various trimmers readily accessible.
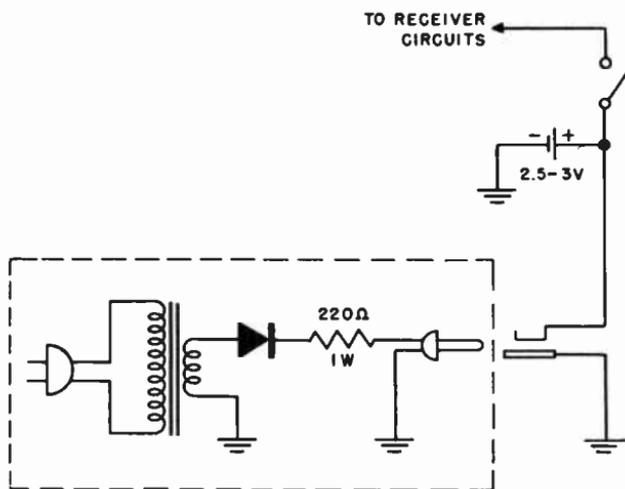
Fig. 1007. *Charging unit is used in receivers having nickel-cadmium batteries.*

Fig. 1009 shows the location of the if transformers, oscillator transformer, oscillator and antenna trimmers in a typical receiver. Couple the signal generator to the receiver, making certain that the frequency of the receiver and that of the signal generator are the same. Set the receiver volume control to maximum. The signal generator modulation control should be turned on — that is, the rf signal coming out of the signal generator should be modulated by the audio tone. If you use an output meter across the voice coil of the receiver, adjust the attenuator of the signal generator so that the output, as indicated on the meter, is approximately 1 volt. If you are using the speaker or headphones as an

indicator, adjust the attenuator for a comfortable (not too loud) tone.

If the tone coming from the speaker is very weak or if the meter reading is very low, even though you may have set the attenuator on the signal generator for maximum output, then it is entirely possible that the if section of the receiver needs realignment. (We are assuming, of course, that there is no receiver defect.)
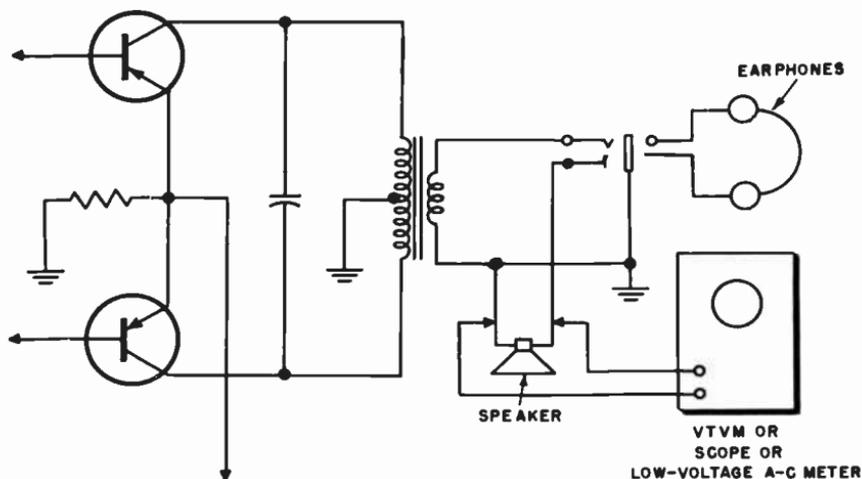
Fig. 1008. *Five types of indicators that can be used during alignment: speaker, earphones, vtvm, scope or low-voltage ac meter.*

Set the signal generator to 455 kilocycles, modulation turned on. Rotate the tuning dial of the receiver to the high-frequency end. Starting at the output if transformer, adjust the slugs and, in turn, the interstage and input if transformers, similarly. As the volume increases, adjust the attenuator to bring the volume down to a low level. Do not work with a strong output signal. The lower the signal used out of the signal generator, the better, since under these conditions, agc will either be very weak or completely absent, thus permitting the receiver to be in its most sensitive condition. When aligning the receiver, it is always best to use the batteries in the receiver as the power supply. That is, you should not use external batteries that do not form part of the receiver proper.

After the if's have been aligned, it is always well to repeat the procedure, since the adjustment of one if stage will often affect

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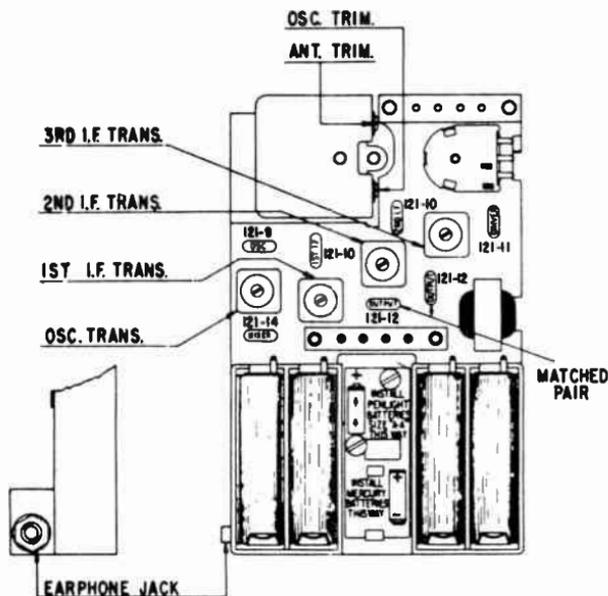
Fig. 1009. *Layout of alignment adjustments in a typical receiver.*

the adjustment of the preceding or adjacent stage. After the if section has been aligned, the only change you will need to make will be in the frequency setting of the signal generator and the receiver. The coupling loop or coupling capacitor from the generator to the receiver need not be disturbed.

If you find that the alignment of the if section has produced a condition in which the signal is extremely loud, simply make the coupling between the generator and the receiver much looser. Just move the coupling coil away from the antenna loop of the receiver. Now set the signal generator at approximately 600 kc. Set the receiver to the same frequency. The local oscillator of the receiver will probably have a slug adjustment and this should be rotated for maximum volume while rocking the tuning capacitor back and forth around this frequency, simultaneously. After you have obtained maximum volume, set the signal generator and the receiver to the high-frequency end of the dial, generally around 1500 kc. Locate the oscillator trimmer capacitor and adjust this for maximum volume.

It is generally best to repeat this procedure at least two times, working back and forth between the low- and high-frequency ends of the tuning scale to get best tracking.

Set the receiver and the signal generator to 1,000 kc and make sure that the signal from the generator is very weak, either by adjusting the attenuator on the generator or by making the coupling very loose. Locate the small trimmer capacitor, connected in series with the antenna lead; that is, between the antenna and the primary of the rf input transformer. Adjust this little capacitor until you get maximum signal output from the receiver.

Now that we have completed our discussion of alignment, let's consider it once again, but this time in a step-by-step fashion.

1. Loosely couple the signal generator to the receiver loopstick. You can use a home-made coupling coil for this (as described in an earlier chapter) or a spare loopstick as the coupling coil. If you prefer, you can use a 0.1-µf capacitor in series with the hot lead of the generator cable. Connect the capacitor to the stator of the tuning capacitor (rf section). The ground lead of the cable should go to the receiver chassis. Set your rf signal generator to the if frequency of the receiver (this will be either 262.5 or 455 kc in most cases). Rotate the tuning capacitor until it is completely unmeshed (open). Connect your vtvm (set to read 1 volt ac full-scale deflection) across the voice coil of the speaker. Do not disconnect the speaker leads. Set the volume control of the receiver to its midrange position.

2. Turn the receiver on. Set the modulation control of your signal generator to the ON position. Set the attenuator control on the signal generator for small signal output. Carefully and slowly rock the signal generator dial back and forth. You should hear a tone out of the speaker, and the meter needle of your vtvm should give you some indication. If the signal is too loud, reduce the strength of the signal generator. Rotate the signal generator attenuator for less output. Also move the coupling coil farther from the receiver. Now turn the volume control of the receiver to maximum.

3. At this time, examine your signal generator tuning dial and make sure that you have the pointer set exactly on the intermediate frequency of the receiver. Do this even though' the receiver output sounds much louder at some other frequency.

4. Starting with the last if transformer (the one feeding the detector), adjust the slugs or trimmers for maximum signal out-

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put. Then adjust the second if transformer and finally the first if transformer. After you have completed this job, go back and adjust the if transformers once again (and in the same order) until you cannot possibly improve or increase the output. (If your vtvm reads more than about 0.5 volt, your generator output is too high. Fig. 1010.)

5. Note that we have not asked you to disable the agc bus, a procedure quite common in the alignment of vacuum tube
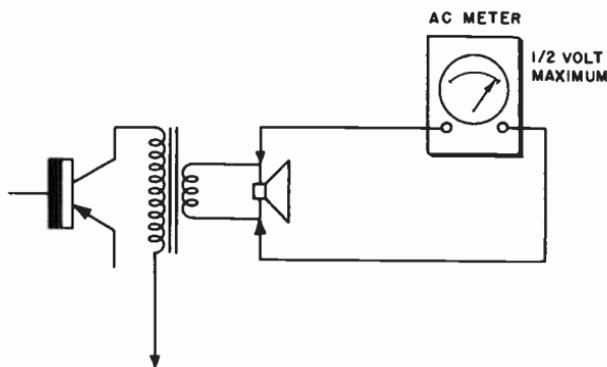
Fig. 1010. *The maximum voltage indicated by your output meter should be about 0.5 volt. If it is more than this, your generator output is too high or one of the stages in the receiver (such as an if) is oscillating.*

receivers. For this reason, it is necessary for you to keep the signal generator output very low. If you do not, you may find that the if's tune very broadly and you will have trouble finding the peak point.

6. In aligning the if's, note that some transformers will give you a double peak. This means that, as you turn the adjustment screw or slug, your output meter will reach a peak, dip and then reach a second peak. The higher of the two peaks is the correct one (Fig. 1011).

7. Set the receiver dial to a high-frequency point such as 1500 kc. Set the signal generator to this frequency, with the modulation turned on. The vtvm should remain connected across the voice coil. Use minimum generator signal and keep the volume control of the receiver at maximum. Now adjust the oscillator trimmer until you get maximum output as shown on the vtvm.

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8. Set the receiver and the signal generator to 1000 kc and adjust the antenna trimmer until you get maximum output on the vtvm. Remember, the volume control is at maximum and signal generator output as low as you can use.

9. Set the receiver and the signal generator to 600 kc. Adjust the oscillator slug for maximum signal output as shown on the vtvm. Rock the variable capacitor in the receiver back and forth on each side of 600 kc while you adjust the oscillator tuning slug for maximum output.

10. Set the receiver and signal generator to 1500 kc, just as described in step 7. Carefully adjust the oscillator trimmer. If you cannot possibly increase the output (as indicated by the vtvm) at this time, you can consider the receiver aligned. If, however,
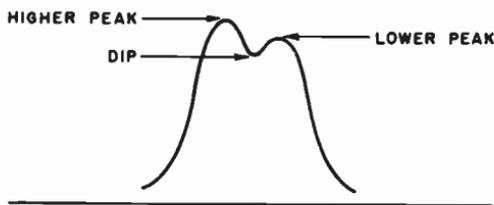
Fig. 1011. *If the if response curve has two peaks, tune for the higher of the two.*

an adjustment of the oscillator trimmer does increase the output, you should repeat steps 7, 8, 9 and 10. You may have to repeat this procedure a number of times.

You may sometimes experience trouble with alignment if you need to replace the converter transistor. In some cases, the receiver will not operate at the low end of the band. This is due to the fact that the transistor has changed the inductance of the loopstick in the receiver to such an extent that the tuned circuit no longer covers the broadcast band. If this does happen, there are a number of cures at your disposal.

You can try a number of different converter transistors until you find one that more nearly duplicates the characteristics of the original unit. If the loopstick has an adjustable iron core, turn the core so that less of it is in the form — that is, move it out of or away from the coil. As a general rule, the inductance of the coil will need to be reduced, and pulling the iron core out will do this. After you make such an adjustment, be sure that the receiver

covers the entire band by tuning the dial to stations at the bottom and top end.

If the loopstick is the type that has a fixed core, your only choice is to remove turns until the stations at the bottom end (low-frequency end) of the broadcast band fall into place.

You will note that we have actually given you two sets of alignment instructions. Our step-by-step procedure does not fully agree with our earlier explanation of alignment. You will also find differences in manufacturers' alignment instructions. In all instances, however, it is best to follow the manufacturer's specific procedure. What we have given you here are general instructions. The step-by-step procedure can be used since it is fairly well detailed.

In or out of the set?

Transistor receivers are so constructed that they can be aligned without taking the receiver out of its cabinet. Do not remove the set from the cabinet unless, for some reason, you have no choice. There are two very good reasons for this: (1) You may be making unnecessary extra work for yourself and (2) you may very well find that a receiver aligned outside of its cabinet does not behave as though it's aligned once it has been put back in again.

Sometimes, to get at trimmer adjustments you will need a special tool. For example, you may find that even your smallest screwdriver isn't tiny enough to permit you to get at the oscillator and antenna trimmers. A tiny bit of metal bent at a right angle will do the job for you. Another easy method is to use a paper clip. Pull out one end of the clip so that it makes a 90° angle with the rest of the clip. Put this end in a vise and squeeze it flat. Then use the flattened end of the paper clip as a tool for the adjustment of the trimmers, as shown in Fig. 1012.

Servicing precautions

There are a few precautions which you must follow in servicing or aligning transistor receivers. Do not use test instruments which are ac-dc types or which are transformerless. If you do have such test instruments and use them in conjunction with an isolation transformer, make sure that the isolation transformer is at some distance beneath your bench or away from it. (We are referring to isolation transformers connected in the primary between the instrument and the power line).

Be very careful not to ground the base lead of any transistor,

since this invariably results in collector-current runaway and a burned-out transistor.

Remember that leakage current from signal generators, defective soldering irons, isolation transformers, soldering guns or test instruments which are poorly shielded can cause excessive currents to flow in transistors.

When using your signal generator, always make sure that your attenuator control is so set that minimum signal comes out of the generator. If you don't wish to be bothered using the series capacitor or loop that we mentioned earlier, then just clip the hot lead (that is, the alligator clip) to any nearby component and you will get enough leakage signal moving into the antenna loop

FORM PAPER CLIP AS
SHOWN AND FLATTEN TO
FIT TRIMMER SCREW SLOTS

ANT   OSC   TUNING
TRIM   TRIM   GANG
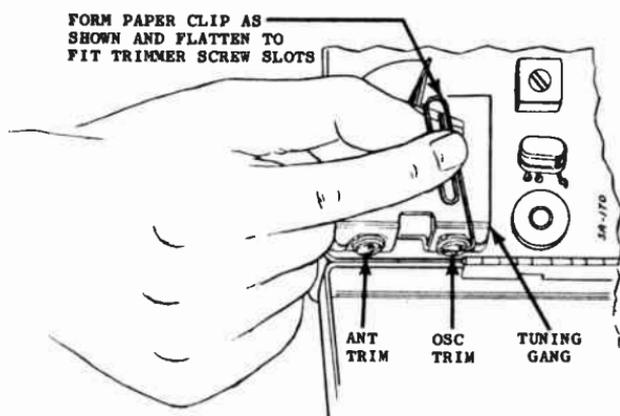
GANG TRIMMER ADJUSTMENT
TOOL DETAIL

Fig. 1012. *A paper clip can be used for adjustment of the trimmer.*

of the receiver. Never clip onto any metal component. Attach the alligator clip to any bit of insulating material. This technique will keep the signal generator voltage from overloading or swamping the receiver input.

Make a voltage check of the battery before and after alignment, with and without signal input. Proper alignment may not be possible if battery voltage has dropped much more than 25% to 30% below normal.

Measurement of local-oscillator voltage

In vacuum-tube receivers, local-oscillator voltage can be measured by connecting a vtvm across the oscillator grid leak. This cannot be done in a transistor receiver. You can make the check by using an oscilloscope connected between the base of the converter transistor and the chassis. A calibrated scope will be required. The voltage measured will be determined by the type of transistor, the circuit arrangement and the setting of the oscillator tuning capacitor or slug. As a general rule, where the dial of the receiver is set to 1500 kc, you should read approximately 0.5 volt peak to peak. This technique for checking the local oscillator is just one of several we have covered.

Regeneration

The process of alignment increases the sensitivity of the receiver. It is entirely possible for the if stages to break into oscillation after alignment has been completed. If such is the case, a small amount of misalignment may cure the trouble. If not, it may be necessary for you to check any feedback resistors or capacitors that may be present in the receiver.

Transistor pin sequence

Transistors come in quite a variety of packages (this is the name for the case around the body of the transistor). Here are a few techniques for identifying the pins of a transistor, depending upon the type and the manufacturer. One type, shown in Fig. 1013-A, has what is known as an unsymmetrical pin arrangement. The center pin is the base lead. The pin that is closer to the center pin is the emitter. The remaining pin is the collector lead. Another view of an unsymmetrical pin arrangement is shown in Fig. 1013-B. The socket for this transistor is shown in Fig. 1013-C.

Another make of transistor has evenly spaced leads, as shown in Fig. 1013-D. A red dot is placed on the side of the case. The lead nearest to the dot is the collector. The center lead is the base, and the remaining pin is the emitter.

A typical power transistor arrangement is shown in Fig. 1013-E. The shell of the transistor is the collector connection. Hold the transistor so that the pins face you. When you do so, the emitter pin will be the one to the left and the base pin will be the one to the right.

A number of commonly used transistors are shown in Fig. 1014. A few power transistors are shown in Fig. 1015.
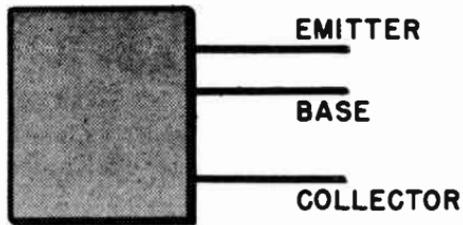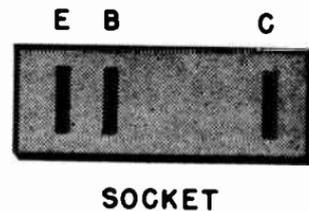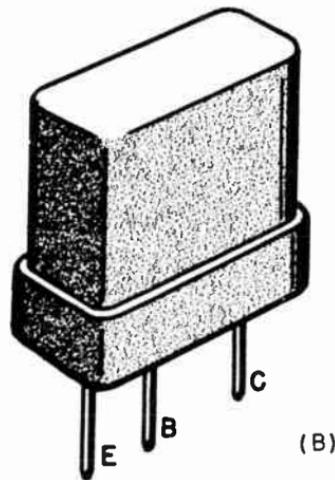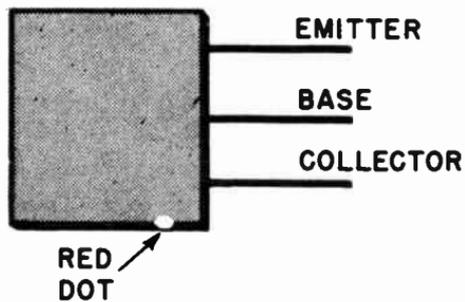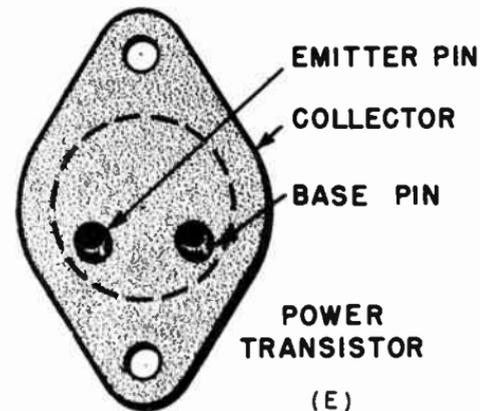
Fig. 1013. *These drawings represent some examples of transistor pin arrangements; others are used.*

Fig. 1014. *Some transistor types.*

Emitter voltages

By making voltage measurements across the emitter resistor (Fig. 1016), you can determine if the associated transistor and its circuit are working properly. But before you decide to make such tests, there are a few things you must determine.

First, these tests are of no value if the battery is run down or if it is on the border line of replacement. Your next step, if the battery is good, is to determine if you are dealing with an n-p-n or p-n-p transistor. Do not assume that p-n-p units are used throughout if you notice that one of them is such a type. Both types can be used in one receiver.

Finally, the only intrument you can use to make such measurements is a high-impedance vtvm. If you have an isolation probe, use it. Do not bother trying to make this test with an ordinary vom.

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Fig. 1015. *Power transistors.*

When checking the emitter resistor of an n-p-n transistor, touch the positive lead to the emitter and the negative lead to the grounded end of the emitter resistor (Fig. 1017). Of course, for p-n-p transistors, the test leads should be transposed — the negative lead should go to the emitter, and the positive lead to ground. In the n-p-n transistor, current flows through the emitter resistor in one direction, and in the opposite direction for the p-n-p unit.

If you have ever measured voltages across cathode resistors in a vacuum-tube radio, you know as well as we do that they range

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from small amounts of voltage to large. Every receiver has its own set of bias voltages and it would be physically impossible to prepare such a list of voltages to use as a guide which could always be consulted. The same is true of transistor receivers. The following list shows average voltages (across the emitter resistors) for a typical receiver. These may not necessarily be correct for the set you are working on, but at least they will give you some idea of
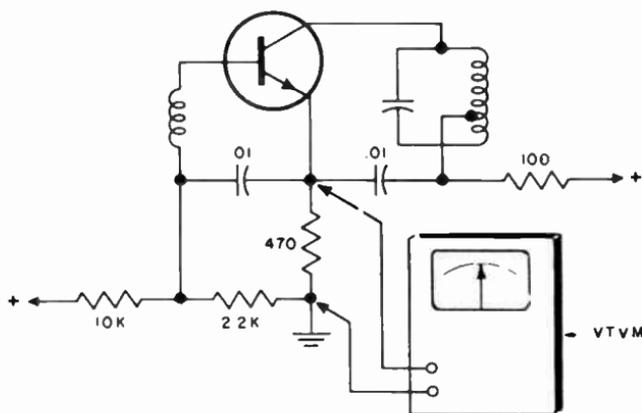
Fig. 1016. *Method for making voltage measurements across the emitter resistor.*

the amounts you should learn to expect. These values are for no signal input, except where otherwise indicated:

Converter: 1-2 volts
First if: 0.22 volt
Second if: 0.7 volt
Audio driver: 0.28 volt
Push-Pull: 0.25 volt (with large signal input).

Whether these values of voltage are positive or negative will depend entirely on whether you are checking p-n-p or n-p-n units. Note also that the voltages are quite small, so you must use a suitable range on your vtvm to be able to read them. Be sure that your vtvm is set to read dc volts.

Converter stage

Let us assume you have your vtvm connected across the emitter resistor of the converter. The current flowing through the emitter resistor will average about 0.5 ma. The amount of current will
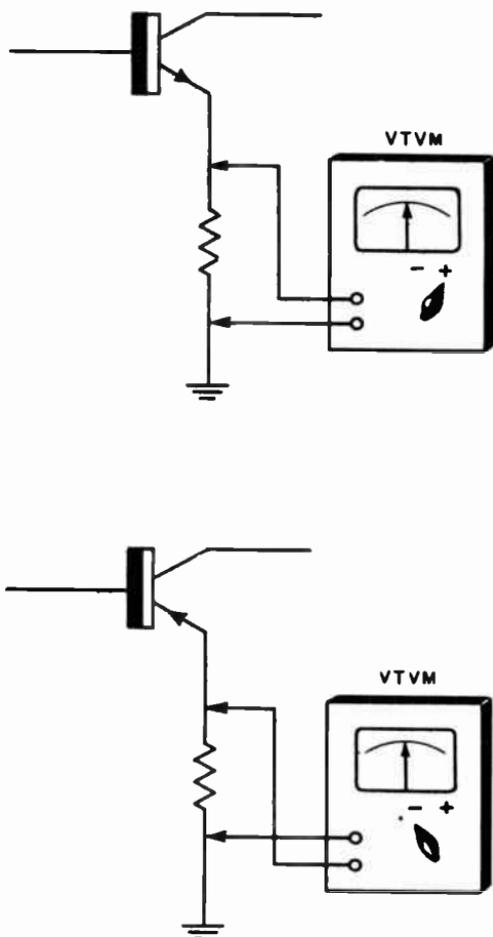
Fig. 1017. *Methods of connecting the vtvm across the emitter resistor for n-p-n and p-n-p transistors.*

vary with the setting of the tuning capacitor. More current will flow when the tuning capacitor plates are unmeshed (that is, at the high-frequency end of the band) and less current at the low-frequency end. Do not expect tremendous differences in current swing — you won't find them. For example, if you measure 0.5 ma with the tuning dial set to 600 kc, emitter current will increase to 0.55 ma when the dial is set to 1,400 kc. The difference isn't startling, but it exists.

There is one peculiarity of the converter stage that we men-

tioned in an earlier chapter that is important enough to bear repetition. Normally, in a p-n-p unit, the base is negative with respect to the emitter. In the case of a converter transistor, however, the base is positive with respect to the emitter because of the injection of oscillator voltage. If this condition does not exist, the local oscillator section of the converter isn't working.

The voltage which appears across the emitter resistor can give you some clue as to the possible cause of trouble in that stage.

If you want to check local oscillator operation quickly, connect your vtvm across the converter emitter resistor and observe the needle position carefully. Now short the oscillator tuning capacitor plates and note the meter. If the needle kicks back, the oscillator is functioning.

To determine the actual amount of emitter current flowing, you will need to do one of two things: You can measure the current by inserting a 0-1 dc milliammeter in series between the emitter resistor and the emitter. To do this, remove the transistor from its socket, disconnect the resistor from the emitter connection and then insert the leads from the meter. If the transistor is not the type that has a socket (it is soldered into place), do not try to unsolder the transistor lead. Instead, disconnect the end of the emitter resistor that is connected to ground. Insert the meter between ground and the resistor. In either method, you will be measuring the same amount of current. If the meter needle swings backward, transpose the meter leads.

If you don't want to bother with a meter, you can determine the amount of emitter current by doing a bit of arithmetic. Current (I) is equal to voltage (E) divided by resistance (R). You know the value of emitter resistance or can measure it. You know the voltage simply by looking at the vtvm when making the emitter voltage meaurement. Divide the voltage by the resistance and you have the amount of current. There is just one precaution; an error which experts sometimes make. All your units must be basic — if the resistance is in ohms and the voltage is in volts, the answer you get will be in amperes. This will usually be a very small decimal. To change your answer to milliamperes, multiply it by 1,000.

Arithmetic doesn't appeal to many technicians and so, if you are one of this group, you still have a source of comfort. Inexpensive, easy-to-understand Ohm's law slide rules are available which will do practically all of the arithmetic for you. These rules can be purchased at many radio jobbers or direct-mail catalog houses.

In making voltage checks across the emitter resistor, remember that the amount of voltage you read is an indication of the trouble you may encounter. For example, if you read zero voltage when checking across the emitter resistor, it is possible that the resistor is disconnected or open. Examine the resistor to make sure that it is in good condition and check the soldered connections. Remove the transistor from its socket and test the resistor. If the resistor is good but you still read zero volts, examine the base and collector circuits. Check forward bias and also the voltage between collector and the emitter.

Sometimes it is easy to get fooled. You may imagine that you are reading zero voltage, but there will actually be a small emf across the emitter resistor. Make sure you are on the correct range of the vtvm. For example, if there is a defect in some component such that the voltage across the emitter resistor is very low (0.1 or 0.2 volt) and you are on the 10-volt scale of your vtvm, it will be very easy to think that the voltage is zero.

If emitter resistor voltages are extremely low or much higher than normal, check all capacitors connected to the emitter or to the lead of the resistor which is connected to the emitter.

Emitter-current values

Now that we have learned just what we can expect in the way of voltages across the emitter resistor, let us see what currents produce these voltages. Here is a useful check list:

Converter stage: average current about 0.5 ma

First if amplifier: Average current about 0.5 ma (no signal)

Second if amplifier: Average current about 1 ma (with signal)

Audio preamplifier or driver: Average current about 2 ma.

It is rather difficult to give values of emitter current for output stages. The amount of current will depend upon whether a signal is being applied to the push-pull transistors (we are assuming a typical class-B stage) and whether the signal is weak or strong.

Aligning the automobile radio

The alignment procedure for an automobile radio is very much the same as that for a home or portable receiver. However, the auto radio receiver requires a few precautions of its own. For example, earlier in this chapter we mentioned the use of a storage battery as a power source, a necessary item since you will have to pull the receiver to work it. A storage battery is an innocent looking device, but it packs a tremendous wallop. For this reason avoid spark-testing the auto radio. This sort of technique calls

for a heavy current flow — and a storage battery is always ready, willing and able to supply amperes, hundreds of them, if necessary. The only trouble is that, when making a spark test, this heavy current will flow through various components in the receiver, probably burning them out in the process. Of course, if you short the base of the transistor, especially in the output stages, you will be removing the base bias. The resulting heavy current flow will permanently damage the transistor.

While alignment instructions will be the same as those we have outlined, remember that auto radios have a radio-frequency amplifier preceding the converter. The amplifier's slugs and capacitors are adjusted for maximum receiver output with the signal generator and the receiver set at the high end of the band. After the receiver is installed in the car, tune in on a weak station, somewhere around 1000 kc. If the antenna is a telescoping type, extend it as far as it will go and then adjust the antenna trimmer until the station signal is at a maximum.

No special instruments are needed for auto receivers. You can use your signal generator and vtvm just as you would for an ordinary portable set. There is just one other precaution, however. Because auto radios have an rf amplifier stage, their overall gain and sensitivity are much higher than for ordinary radios. For this reason, the coupling between the signal generator and the receiver must be much looser. Otherwise you may overload the receiver or you may find alignment difficult. If you find that you cannot cut down on the gain of your generator sufficiently, even though the gain control on the generator is set for minimum output, move the generator as far from the set as the coaxial cable between generator and receiver will permit. Sometimes signal leakage from the generator will be enough to overload a sensitive set if the generator is placed too near the receiver.

When removing auto receivers, be sure to take the speaker along with the set. Do not forget to plug the speaker leads into the speaker receptacle when testing the set. In other words, do not operate the set without its speaker.

printed circuits

I F you ever get the opportunity to examine a real old-timer among radio sets — preferably one manufactured around 1931 — by all means do so. Some of these "antiques," especially those that had more than one tuned rf stage, looked like and were constructed like battleships. Some of them weighed more than a modern television receiver. The underchassis view was especially interesting since it looked like a jungle of wires and parts; a sight that frightened many a potential servicing student right out of the electronics industry.

By comparison, modern radio receivers (and some television sets) look as though they have practically no components whatsoever. This is especially true if the receiver makes used of a printed-circuit board. A printed circuit is nothing more than a sort of prewired arrangement. It consists of conductors so arranged that, when the parts are mounted, they are automatically connected. In this sense, the conductors on the printed-circuit board take the place of connecting wires in the receiver.

Wiring in a receiver can look messy because the wires not only go from one side of the chassis to the other, but are connected in an up-and-down fashion as well. The result is that components are sometimes buried beneath the wiring, and sometimes wiring that is perfectly good must be removed to get at a defective part. In addition, a wiring maze looks confusing, making point-to-point analysis of the receiver a time-consuming job.

A printed-circuit board, on the other hand, has all its conductors in one plane, resulting in a simpler-appearing set. The con-

nections from one part to the next are the same, but because the "jungle look" has been removed, servicing is easier.

Printed-circuit boards lend themselves very nicely to transistor receivers. Transistors are compact little units, and, when combined with a printed circuit board, the entire receiver can be made to occupy a fraction of the space required by an ordinary receiver. Naturally, all the other parts are made proportionately smaller.

The printed-circuit board

There are quite a number of techniques for making printed-circuit boards. The conductors on the printed-circuit board can be put on by spraying, plating, hot-die stamping, printing, painting, embossing, etching, etc.

The board itself is generally a sheet of laminated plastic or phenolic board. In one method a thin sheet of copper is placed over the board and then the copper is fastened to the plastic by a bonding process. The conductors are then made by removing a part of the copper by one of the methods mentioned in the previous paragraph. Holes are then drilled in the boards. You will usually find four holes — one at each corner — for mounting the board. Holes are also drilled in the board for mounting components such as resistors and capacitors. Sockets are also made part of the printed-circuit board assembly.

After the various parts are mounted, component leads are clipped and fastened into place. By means of a dip-soldering technique, the manufacturer is able to make all of the required connections at the same time. (Other manufacturing methods are also used).

Working with printed-circuit boards

We know we need not tell you that every radio part requires its own special handling. If you consider a printed circuit as just one more radio component that requires a little special treatment all its own, then you will have less trouble with it.

First examine the four mounting holes on the board. In almost all cases, some of the printed-circuit wiring goes directly to these holes so that, in mounting the printed circuit on the metal chassis, you have an electrical connection between the chassis and the conductors on the board. The board should drop easily over the four mounting screws. If it does not do so and if you try to force the board into place, tightening the nuts on the holding screws for the board will crack it. Tightening the board's mounting or

holding screws and nuts should not place any stress on the board itself. In replacing a board, it may be helpful to hold the board up to a light (such as an electric light bulb) to see if it has any cracks in it before you make any replacement.

There is nothing particularly special about a printed-circuit board that cannot be taken care of by using some thought and care. For example, the conductors on the board are generally fastened fairly securely to it, yet they can be lifted off through improper handling. The conductors can be scored, broken, lifted off, severed, cut off (producing an open-circuit condition). Dropping solder blobs, using too much solder or sloppy soldering can produce a short circuit — and quite easily at that. On most boards you will find the conductors fairly close together. Any excess solder will run right between the conductors, probably fusing them beautifully. If you do run into this trouble, you will need to use your soldering iron and a sharp-pointed tool to clear the short.
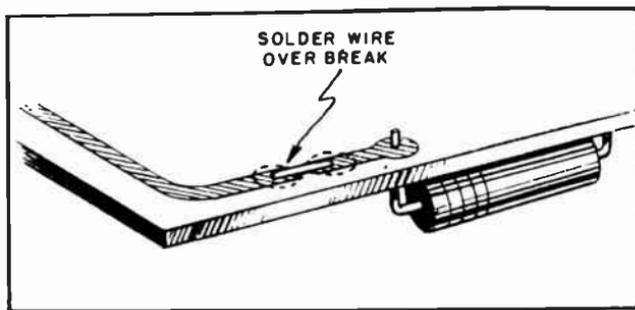
Fig. 1101. *Method for repairing a break in printed-circuit conductor. Solder a small piece of tinned wire right over the break.*

If, by accident, you should break one of the conductors, you can make a repair by bridging the break with a small piece of copper wire as shown in Fig. 1101. Make life easy for yourself. Use tinned wire. Don't use stranded wire unless you are accustomed to doing everything the hard way.

It isn't advisable to remove the board from the receiver unless you feel that you will save time and trouble by doing so. You can mount the board in a vise to leave your hands free to do your work, but remember that a vise can exert a tremendous pressure. Some technicians use a soft copper covering for the vise to prevent marring or damaging the printed-circuit boards. This

is good since it prevents the serrated jaws of the vise from tearing the conductors on the board, but you must still be careful not to use excessive vise pressure.

Finally, you should remember that brute force isn't required. Use one of the lighter irons, rated anywhere between 25 and 35 watts. A pencil type iron, light in weight, will give you the necessary hand control for working in close spaces. A heavy iron is not only difficult to control, especially for fine work, but the heat it
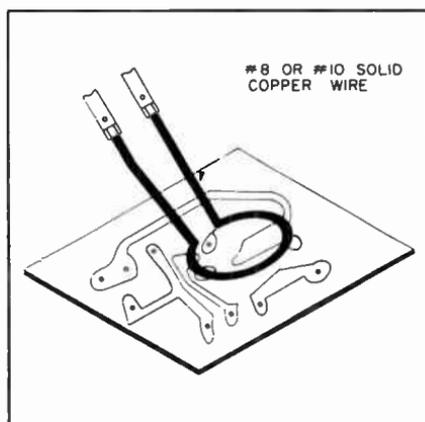
Fig. 1102. *Some No. 8 or No. 10 copper wire can be used as a special tip.*

produces may actually cause the conductor to pull away from the board. Before using the iron, file the tip to a wedge shape and tin the iron. Keep a cloth handy so you can wipe the tip frequently to keep it clean and shiny.

If you prefer a soldering gun, you can make a special tip for work on printed-circuit boards. Remove the existing tip by loosening the holding screws. Get some No. 8 or No. 10 solid copper wire and fashion it into the shape shown in Fig. 1102. Use tinned wire. If the wire doesn't come pretinned, tin the circular loop portion of the new tip. Insert into your soldering gun and you are ready to go to work, first making certain that transistors have been removed from their sockets.

If you do not have a soldering gun but have a high-wattage iron, take some No. 8 or No. 10 wire and wrap it around the iron as shown in Fig. 1103. Make a good tight wraparound so that the wire doesn't slide off the iron. The copper wire will now form

the new tip for the iron. Sharpen the end of the wire to a point. Do this by rubbing the end of the wire against a file. Use a file having very fine teeth and roll the wire with a circular motion. Tin the end of the tip, just as you would an ordinary soldering iron.

Some technicians prefer using a 100-watt iron instead of the lighter-weight iron we have just recommended. This is fine, provided you keep in mind that it isn't the iron that produces the damage but the man behind the iron. If you use a lightweight iron, you can damage the wiring on the board if you keep the
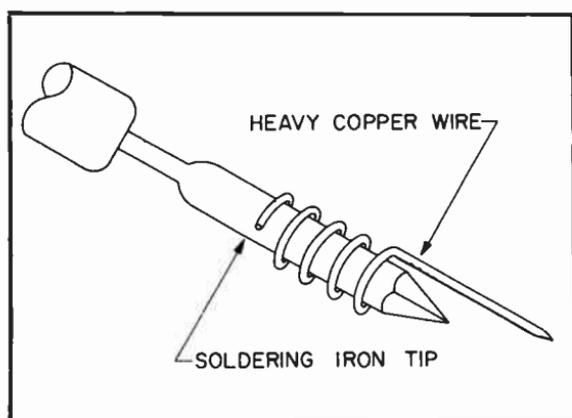
Fig. 1103. *Wrap some heavy copper wire (such as No. 8 or No. 10) around the shank of a heavy-wattage iron to convert it into the equivalent of a low-power iron.*

iron touching the board for too long a period of time. Soldering — and unsoldering — require some skill and know-how.

A 100-watt iron in the hands of an experienced man will cause much less damage than a 25-watt iron in the hands of a beginner. And finally, keep the iron well tinned, well tapered, and thoroughly clean.

Later we will discuss a different soldering technique, using a soldering pot.

Some technicians have the idea that solder is solder and that is that. Why make your work any more difficult than it must be? If you have the proper skill and ability you could use bar solder, but then you would probably be better off connecting heavy telephone cables. Use thin, lightweight solder having a low melting point. High-melting-point solder and 25-watt soldering

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irons belong together as much as pickles and ice cream. Use rosin-core solder containing 60% tin and 40% lead. Stay away from acid-core solder unless you're the type that likes nonpaying callbacks.

A small wire brush will also be of great help. You can use this
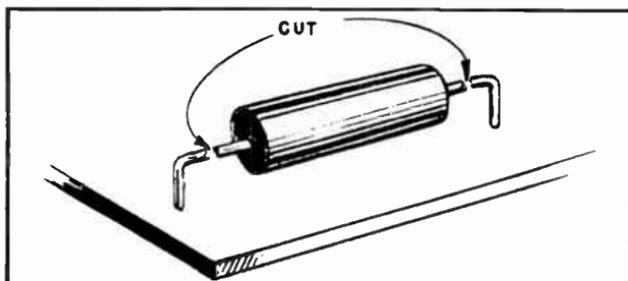
Fig. 1104. *To remove a resistor or capacitor, cut the leads as close to the body of the component as possible.*

to clean away very fine dots of solder that conceivably could cause trouble. Use gently! The idea is to remove unwanted solder and resin and not to buff the printed board to a high gloss. Care-
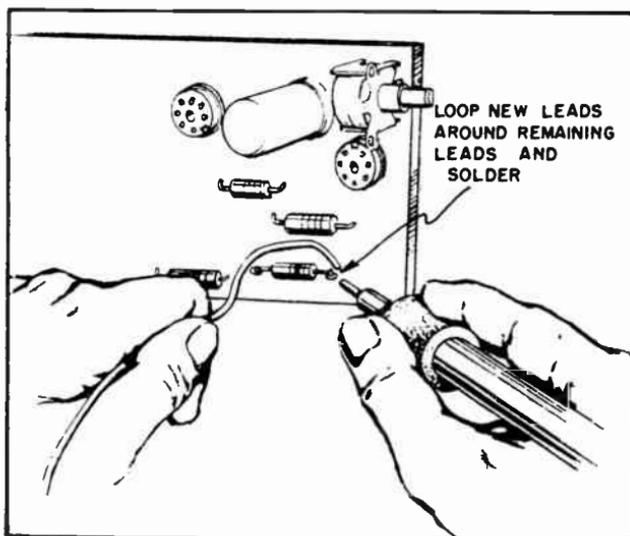
Fig. 1105. *After the old component has been removed, loop the new leads around the remaining leads of the old part.*

less handling of the brush can also remove some of the printed-circuit-board conductors.

Various solvents are made for cleaning printed-circuit boards after working on them, but ordinary denatured alcohol (such as that used to thin shellac) can be used. Put some of the alcohol on the brush and swab the board around the area where you have soldered. This will remove excessive resin.

Other tools you will find extremely helpful include a wire pick and pocket knife. If you do not have a wire brush, use a toothbrush in its place. Be sure to buy a toothbrush having stiff bristles. Also, the needle-nose pliers and "dykes" (diagonal cutters) you use for your other servicing work can be very helpful for printed circuits.

Component replacement

You can save yourself a considerable amount of time by not removing defective components completely. If you try to do so, you may pull away some of the printed-circuit-board conductors. The better technique is to cut away the body of the defective
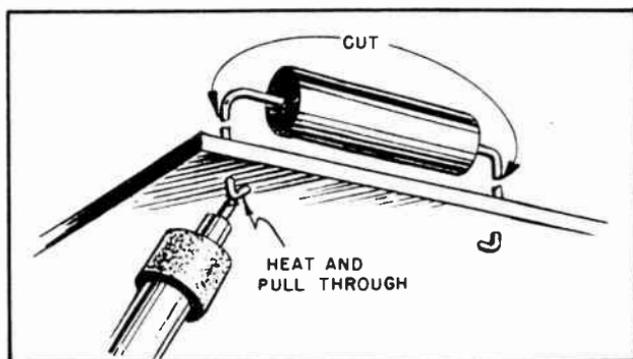
Fig. 1106. *To remove a component such as a resistor or capacitor, cut the ends as shown and then heat the remaining leads, pulling them through the board when they become sufficiently loose.*

part (resistor or capacitor) and allow the leads to remain (Fig. 1104). You will now have two moderately stiff wires sticking up out of the board, to which you can loop around and solder the leads of the new part. Since you will not be soldering to the board itself, the job will be that much easier (Fig. 1105).

However, there will be times when you will not be able to avoid removing the entire defective component body and its con-

necting leads. This requires some care and patience. Make sure the iron is clean and tinned. Heat the joint or the hole through which the lead of the part is mounted. Before the joint has a chance to cool, use the wire brush to remove some of the solder. Then reheat the joint and use the wire brush once again on the other side of the board. With most of the solder removed, you should now be able to apply the iron and wiggle the component loose. The component should come out smoothly. You must be careful since it is very possible to lift up some of the conductors when removing a part. After the part is removed, clean the mounting holes of any solder threads.

Another technique, as shown in Fig. 1106, is to cut the leads of the defective part. Then heat the remaining bit of lead material on the bottom side of the printed-circuit board. When the lead becomes loose, pull it through from the bottom side, using a pair of long-nose pliers.

A little earlier we mentioned using a small bit of wire to repair an open break on the printed-circuit board. If you have trouble with this method, you might try some silver conducting paint made especially for repairing printed circuits. With a knife or razor, scrape the area of the break. Draw a line of silver conducting paint between the two points to be connected. Don't try to make a heavy conducting line with one stroke of the brush. Instead, build up the conductor by first drawing a faint line, then making it heavier by going over it a number of times.

If a component (such as a resistor) is mounted directly against the board and it is too difficult to cut the leads as described previously, you should not assume immediately that you will have to remove it completely (if a replacement is to be made). Instead, cut the part in half with a pair of diagonal cutters. Using a pair of gas pliers, crack each half of the cut component so that the body is smashed, leaving only the connecting lead. If you do this, you will find that you have enough lead left to mount the new part. Of course, you will have to clean the lead so as to be able to make a good soldered connection.

Whenever you make a repair on a board, always be sure to examine it after you have finished, just to make sure that you don't have any shorts (caused by excess solder) and that there are no breaks in any of the conductors. If there is a break, and the open ends of the printed-board conductors aren't too far away from each other, you might try making a connection just by run-

ning some solder between the ends (Fig. 1107). If the distance is too great, use a connecting wire as described earlier.

If, for some reason, the printed-circuit conductor lifts away
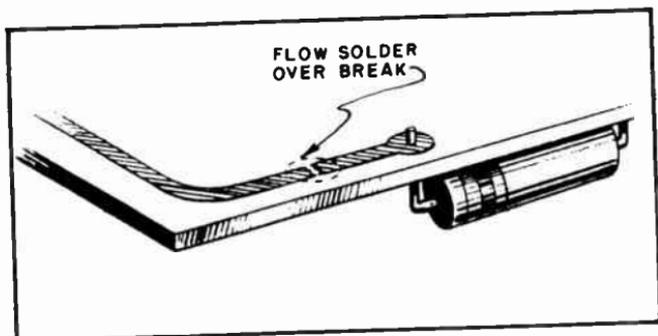
Fig. 1107. *If the break in the conductor is small enough, you can repair it by flowing some solder between the two open ends.*

from the board, cut away the section that has raised. Then solder a small bit of wire between the end of the cut section and the component, as shown in Fig. 1108. Use tinned wire so that you
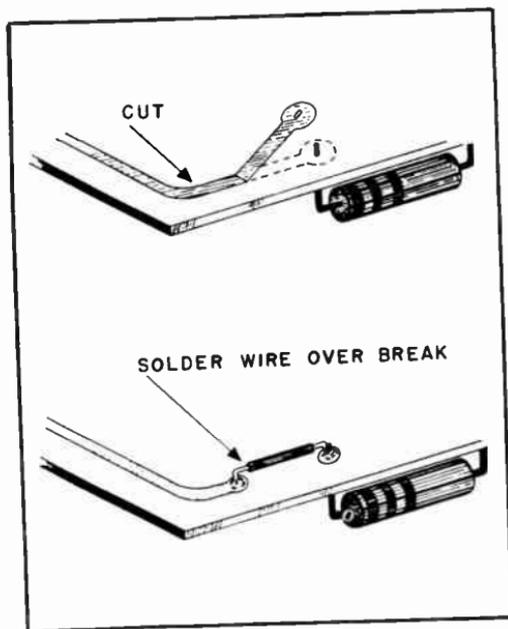
Fig. 1108. *If a small bit of the printed-circuit conductor lifts up, cut it away and replace it with some wire.*

can make a connection with the minimum amount of trouble. Don't use wire that is too heavy. Generally, No. 22 or No. 24 wire will be satisfactory. Use bare wire for short breaks, but, to fix a large break, use insulated wire as shown in Fig. 1109. Insulated wire is needed in this case to keep from shorting against any of the other conductors on the board.

After your repairs are finished, use a toothbrush (or any stiff bristle brush) and a solvent to clean the board. Denatured alcohol is cheap and is a good cleaning solvent. Pour a small amount of alcohol on the area that you have just soldered and scrub gently with the brush. You can use a rag if you wish but a brush is easier, faster and does not leave any tiny pieces of lint. If you have carbon tet available, you can use it in place of the alcohol. Remember, however, that carbon tet fumes are poisonous. Work in a ventilated room and, if possible, use a small fan to blow the fumes away.

After you have cleaned the board with the solvent, cover the under side of the board (the foil side) with a silicone resin spray. This comes in pressurized cans so the only work involved is pushing a button. Spray lightly and gently. When spraying, hold the component side (top side) against the palm of your hand so that only the bottom side (foil side) of the board gets the spray. As further protection, you can cover the component side with masking tape.

Replacing rf and if transformers

You must first of all make up your mind just what it is you want to do. If you plan to replace the defective rf or if transformer, clip away the transformer soldering lugs. These lugs come through holes in the board. Remove the solder from each of the lugs, then cut the lugs with diagonal cutters. You should then be able to remove the transformer. Be careful when pulling the transformer can. Work the can back and forth so that it comes out easily. If it does not, then one or more lugs may require some additional treatment with the soldering iron. After the transformer is removed, clean the through holes so that the lugs of the new transformer will fit through easily.

After mounting the new transformer, twist the soldering lugs to keep the unit firmly in place while the lugs are being soldered.

If the transformer is to be repaired (instead of being replaced), you will have to be a bit more careful. Remove all solder from the soldering terminals. Then straighten the terminals. You may

have to file the terminals to remove the last little bit of solder and to make it easier to remove the transformer.

If transformers are symmetrical — that is, they usually have as many terminals on one side as on the other. For this reason, when removing a transformer for repair, make sure that you do not turn the transformer around when putting it back. There are any number of identifying methods you can use — a scratch mark or a dab of ink. It doesn't make any difference which technique you use, just so long as the transformer is inserted in the proper way.

Some if transformers will have a color dot on one of the lugs. The idea of this color dot is exactly the same as the color dot
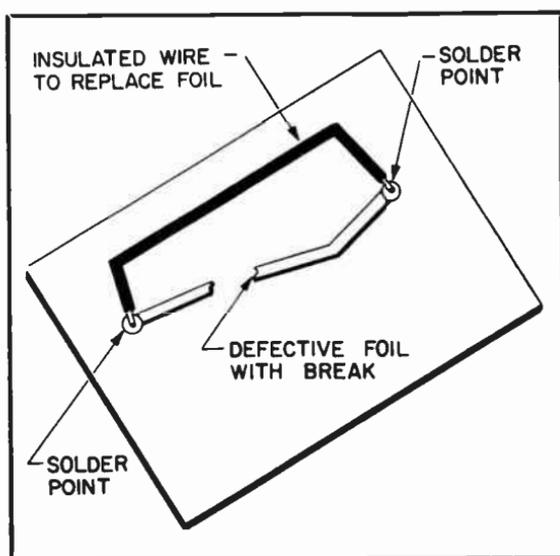
Fig. 1109. *Use insulated wire to avoid causing a short by touching other conductors on the board.*

you will find on the side of the package (or case) of a transistor having a symmetrical lead arrangement. All you have to do is to remember the position of the lug with the color dot on it and then to insert the new transformer in such a way that the colored lug occupies the same position. Sometimes you will find that the manufacturers has put a part number on the side of the can. Do not use this as a positioning guide since the number may be put on any one of the four sides of the can. The number is for component identification only and not as a positioning aid.

One final caution: In soldering, as in almost everything else, you must use some restraint. Don't use too much solder and do not overheat the soldering lugs. Make sure that the solder does not flow into the transformer. There is nothing more exasperating, time- and money-consuming than to replace a component such as an if transformer and to damage it in the process.

Replacing volume controls

Cut the leads going to each terminal on the volume control. Some receivers will have two leads, most will have three. Cut the leads close to the volume-control terminals. After cutting these connections, you will need to free the volume control from the printed-circuit board. This is shown in Fig. 1110. Heat each
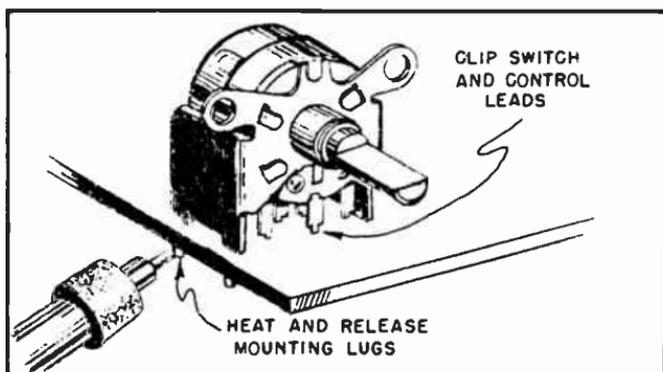
Fig. 1110. *Method of removing a volume control.*

mounting lug and, while you do, brush away the solder on the lug with a toothbrush. Do this with each lug. After all the solder has been removed, straighten each lug (if necessary) with a pair of long-nose pliers.

Now, in turn, heat each of the mounting terminals and pull the volume control up and away from the printed-circuit board. You will not have to use much heat, just enough to free the control from the board. Once the volume control has been removed, you will still have three more terminals to work on. These are the terminals from which you clipped the wires as your first step in doing this job. These terminals on the board were connected to the terminals on the volume control. Just heat them from the bottom side (foil side) of the board and pull them through from the top side (component side) with a pair of long-nose pliers, as shown in Fig. 1111.

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After you have removed the volume control, examine the mounting holes and the soldering terminal holes on the board. Make sure they are clean and not filled with any solder before trying to mount the replacement unit.

Troubleshooting

You can make resistance and voltage measurements with printed circuits in the same way and using the same techniques as with regular circuits. However, components are all usually mounted on one side. It will help to shine a light against the reverse side of the board when making servicing or voltage checks. It all depends on how the board is mounted. The printed circuit board is translucent (permits light to shine through). The light will help you trace the conductors from one component to the next.

Because of the closeness of the conductors and because, in some cases, the conductors are rather thin, a magnifying glass will be
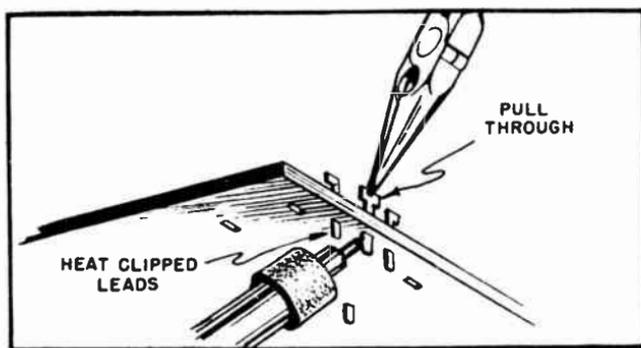
Fig. 1111. *This drawing illustrates the method for removing volume-control connecting terminals.*

helpful. If a continuity check shows a break in the conductor but a visual examination fails to reveal it, look at the board with the magnifier until you find the break.

In ordinary servicing, one of your test leads is equipped with a fastener of some kind, such as an alligator clip. For circuit-board work, it would be helpful to fill the jaws of one of the alligator clips with solder. After the jaws are filled, file them down until they are fairly smooth. The teeth of the jaws will then be unlikely to damage the board while the larger contact area of the filled-in jaws will make good contact with the wiring on the

board. The other probe should be a needle-point type to permit good contact to be made in tight places.

Printed-circuit-board troubles

A printed-circuit board should be regarded as a radio component. We might consider it as a resistor or a capacitor or a tube (in the sense that these are also radio parts). And so we cannot be too surprised to learn that this new component, the printed-circuit board, has a few ailments of its own. A printed board might look good but then a tube or transistor might also appear to be in top-notch working condition only to show up as defective when tested.

Leakage resistance

This old bugaboo seems to lift its ugly head everywhere we go. It shows up in capacitors, especially electrolytics. It causes instability in high-voltage circuits. It is a common affliction. And it can cause trouble in transistor receivers using printed-circuit boards.

You can check for leakage with a vtvm. The instrument must be able to read high values of resistance, up to 1,000 megohms. Leakage can be caused by dirt, by a defect in the plastic plate, by resin between conductors on the board. Fortunately, voltages in transistor receivers are quite low so that, if a leakage problem does exist, you should be able to run it down fairly easily with the vtvm. If you do find evidence of leakage, brush the area clean with a stiff brush (and some solvent) and then repeat the test. Sometimes bits of metallic dust or extremely tiny particles of solder will imbed themselves between the conductors. The brush will remove them quite readily.

Poor connections

Printed-circuit boards are mass-produced and, as in any mass-production system, a few clinkers will always get through. It is possible for a connection to be poor as, for example, between a through eyelet on the board and the connector or connectors going to it. Here again, about the only method of checking is to use an ohmmeter.

Intermittents

These are as difficult to find on a printed board as in an ordinary type of receiver. Examine the board carefully before trying any continuity or voltage checks. If you can hold the board up to a strong light, do so. Look for any tiny breaks in the conduc-

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tors. Also make sure that no part of any conductor has lifted away from the board. Tapping the board gently while the receiver is turned on will sometimes help localize the defect. Some of the conductors on the board will be connected to through eyelets. These may look good, but often the slightest vibration will cause them to make and break contact. Gently tapping each eyelet with an insulated tool will help.

High-resistance conductors

The conductors on the printed-circuit board are supposed to make a low-resistance connection between radio components. However, while the conductor might look good upon casual examination, a magnifying glass might show a lack of uniformity. This means that there might be breaks in the length of the conductor. These breaks do not cause an open circuit, but since they reduce the amount of conductor material, they result in increased resistance. If you measure resistance between two points on the board, when the circuit shows that there should be a direct connection (zero resistance), then a high-resistance conductor might be on the board — especially if there is no other component between the two measured points.

Reading printed-board diagrams

A printed-board diagram shows the various parts in schematic or symbolic form with the printed-circuit conductors as a solid or shadowy outline, or both. See Fig. 1112. The diagram is unusual in some respects. It will show you the location of parts with respect to each other. This is quite contrary to usual circuit diagram practice where the positions of the electronic symbols have no relationship whatsoever to the actual positions of the parts in the receiver. A diagram such as the one shown in Fig. 1112 is of considerable help in servicing.

While the illustration of the printed-circuit board is that of a vacuum-tube receiver, those used for transistor sets are similar.

Replacing tube sockets

Sometimes a tube socket on a printed-circuit board will become defective. You are then faced with the problem of deciding whether to replace the entire board or just the socket. If you put in a new board you will either have to buy it, in which case the repair would be an expensive one, or you might decide to salvage the parts, in which case the repair would be time-consuming. We are emphasizing this so you will realize that, while
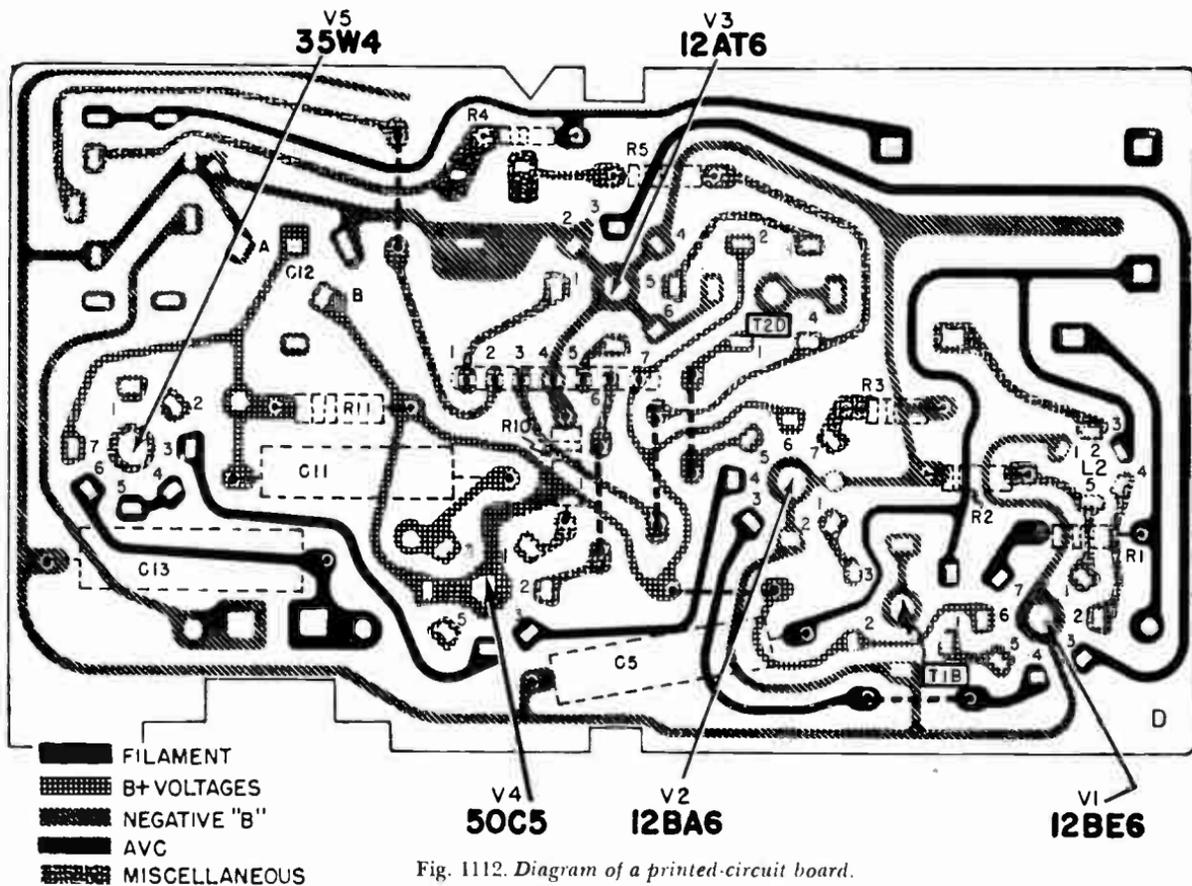
Fig. 1112. *Diagram of a printed-circuit board.*

FILAMENT
B+ VOLTAGES
NEGATIVE "B"
AVC
MISCELLANEOUS

putting in a new socket isn't the fastest job you might ever do, yet it is often the least bothersome of a number of possible alternatives.

To put in a new socket, you will first have to get rid of the old one. Cut the old socket with a pair of "dykes". Don't get too ambitious. Cut away a small bit at a time. If you don't, you will find that you have a handful of printed-circuit board and its assorted conductors all over your bench. Remember that the copper foil conductors on the board connect to the pin contacts, so go easy with the diagonal cutters at these points. You can remove the pins by heating the lugs. Do this on the printed side of the panel. Now gently pull the pins through the hole from the component side.
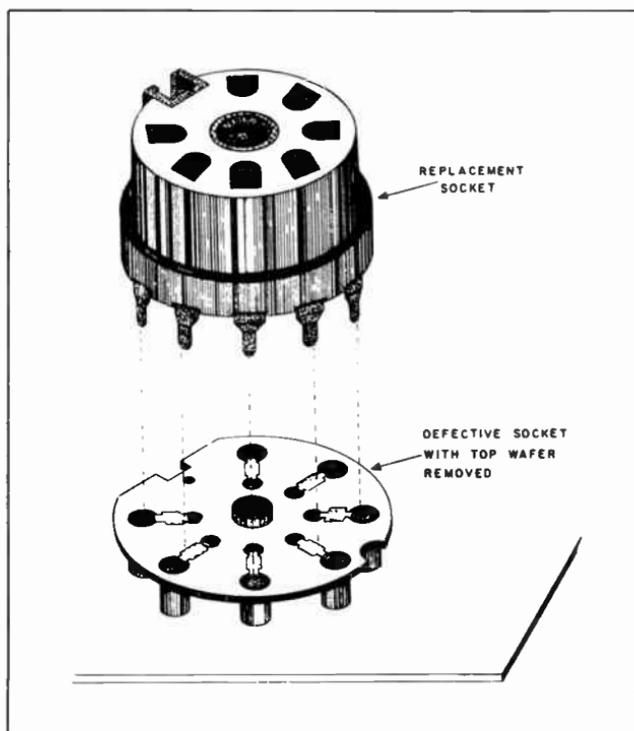
Fig. 1113. *Repair without removal of defective socket by insertion of printed-circuit socket.*

Don't try to do this job holding the printed-circuit board, the soldering iron and a pair of long-nose pliers in your hands. You would need more hands than you have to be successful. Mount

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the board in a small vise. Put two pieces of cardboard over the jaws of the vise so that the serrated edges of the vise don't cut into the boards. And remember that the purpose of the vise is to hold the printed circuit board, not to crush it. Go easy on the pressure you put on the vise.

After the pins are out, remove the center post in just about the same way. Heat the soldered point and push it through from the component side. With the new socket in place, solder the lugs and the connector to the center post.

Fig. 1113 shows how you can go about replacing a wafer socket. All you need do is to peel off the top layer of the wafer. You will then have a partial socket as shown in the illustration. A replacement socket can then be inserted in the openings.

You may be wondering why we bother telling you about tube sockets in a book dealing with transistors. The answer is quite simple. First, some receivers (such as auto sets) make use of both tubes and transistors. Second, with an eye to the future, no one knows as yet whether tubes or transistors will ultimately take the lead in electronics equipment. Most likely, however, both tubes and transistors will be used side by side in test equipment, receivers, transmitters, industrial apparatus, etc. Transistors are wonderful — but so are tubes. Taken together, they make an unusual team.

Making voltage checks

Once you become experienced in working with receivers that use printed-circuit boards, you will note a number of advantages over ordinary wiring. You will be working with a flat surface with all connections readily visible. You won't have to worry about lead dress since the conductors are fixed into place. Voltage test points will be easily available and you won't have to probe around trying to find a suitable spot for a voltage check.

There will be some disadvantages, too, especially if you have had considerable experience in working with ordinary wired circuits. The conductors on printed boards are close together. Since for most boards components are on one side and conductors on the other, it isn't always easy to see which conductor goes where. The arrangement of conductors on the board will appear strange — but try to remember the first time you saw the cluttered combination on the bottom of an old radio or not-so-old TV set.

As in ordinary receivers, you can take your voltage readings right at the pins of the transistor or tube sockets. Most boards will have components on one side only, others on both sides. In

either case, you can still use the exposed lead of a component, such as a resistor or capacitor, as a test point. Don't jab a test prod — even if it is a needle point — into any of the conductors on the board. Trace the conductor over to the nearest component lead and make that your test point. The conductors on a printed-circuit board won't absorb the punishment that copper wires in an ordinary receiver take in their stride.

Another reason for doing your testing in this way is that the printed board may be covered with resin. Because the conductors are so close to each other, it wouldn't take very much moisture or dirt to cause a short or to produce excessive leakage. The resin coating keeps moisture and dirt from causing leakage or shorts. If you make a test directly on the conductor, using a needle-point test prod, you will be breaking the resin seal. You may be able to make the measurement you have in mind, but the small puncture in the resin may lead to trouble later on.

Advantages of printed circuits

If you have the idea that printed circuits are just a passing fancy, all you need to do is to spend some time in servicing transistor radios. The printed-circuit idea has caught on so well that the modern ac-dc set also uses it extensively.

Printed circuits have quite a number of advantages. Probably one of the most important is that they eliminate errors in wiring. Since every printed board that goes into a particular model of a receiver is a "carbon copy" of the original, you can be quite certain that all of the "bugs" have been taken out of the original unit. At the same time, the manufacturer must make sure that his design is a good one. Changes based upon experience in the field aren't so easy to make when using printed-circuit boards.

With the printed-circuit board, you don't have a confusing jungle of wires. You can see all the leads (or conductors), and all of the capacitors and resistors mounted on the board can be reached easily. The board is just like a miniature chassis but, instead of being made of metal, this particular chassis is an insulating material. You cannot look through a board but, if you want to work on the top side of the board, just put an electric light bulb behind the board, turn it on and you will be able to see all the wiring. Use a 60-75-watt bulb, preferably a clear type so that you get the maximum benefit of the light.

Replacing components by using a soldering pot

A dip soldering pot is simply a small cylinder having a di-

ameter of about 1½ inches. Somewhat larger than a thimble (but having smooth walls), the solder pot holds just enough molten solder to make quick repairs on printed-circuit boards. The heat of the solder is regulated by a temperature control device so that you can get a solder temperature range of 300° to 600° Fahrenheit.

The soldering pot is extremely useful since with its help you can remove or replace components much more easily, much more quickly and professionally. To remove a part, all you have to do is to put the two soldered connections of the part right over the solder pot. The two connections must make contact with the molten solder in the pot. When you do this, the bottom side of the board will be facing the pot. Now, from the other side, gently pull on the component that is to be removed. Because its connections have been loosened by the hot solder, you will find it very easy to slide the component right out of its mounting holes.

Of course, when working with a soldering pot, you won't want to keep the printed-circuit board dipped into it any longer than necessary. If you do, you may damage the board.

Replacing a part such as a resistor or a capacitor is simple. Bend the leads of the component so that they fit into the mounting holes. If the holes are clogged with solder, just bring the holes (on the bottom side of the board) in contact with the solder in the pot while gently pushing on the component from the other side. You will find that the leads go through very easily. And now that you have the component in place, put the bottom side of the board right over the top of the solder pot so that the holes (through which you have just pushed the two leads) come into contact with the solder in the pot. Hold for a second or so, and you will then have two beautifully soldered joints. Clip away any excess solder or remaining leads. When using the soldering pot you may get a few stray wisps of excess solder or you may have missed a spot. If so, you can use your lightweight soldering iron for touchup.

Now you might very well ask whether a soldering pot has any great advantage over a soldering iron. To answer this question, remove a component (such as a resistor) by the soldering-iron method and then try a soldering pot.

When using a soldering iron, you know that a certain amount of common sense and caution are needed. You would never dip a soldering iron into water to cool it. To do so is dangerous and might also damage the iron. A soldering pot must also be handled

with respect. You must make absolutely sure that no water can get into the pot. Even a drop of water will produce a violent reaction, spattering hot solder in all directions.

When a soldering pot has been in use for some time, a surface film known as "scum" will form. Remove this with a small metal spoon. Hold the end of the spoon with a cloth or other heat-insulating material. Do not throw the scum into a sink since this is dangerous and can clog the sink. Let the scum cool and then you will be able to lift it off as a solder blob to be thrown away.

To be fully useful, the solder pot must be kept full. Use 60-40 bar solder for this. Bar solder, however, does not contain flux so occasionally put in some rosin-core solder.

Soldering pots come in a number of sizes and shapes to meet your working needs. Some are round, others are rectangular in shape.

Mounting of boards

You will find printed-circuit boards mounted in every possible way. In some receivers you will have the usual metal chassis, but
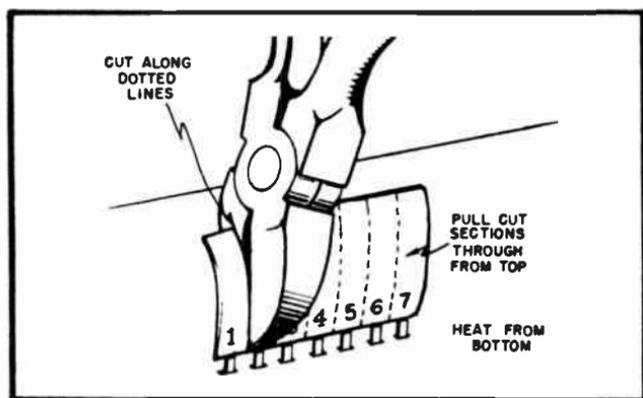
Fig. 1114. *Vertically mounted printed-circuit boards can be removed in sections, if necessary.*

on the metal chassis there will be a rectangular cutout. The printed-circuit board will be mounted on this cutout and will be generally held in place by means of mounting screws. In other arrangements the printed-circuit board will be vertical and will be held in place by mounting terminals at the ends. In some cases there will be a number of lugs as shown in Fig. 1114. To remove the board, heat each lug. Use a stiff bristle brush or a wire brush

to clean each of them. Disconnect each wire coming into the circuit board from other components in the receiver. Sometimes there will be no supplementary connecting wires, the only connections being made when the board is mounted. After the mounting terminals and the lugs have been heated and cleaned, gently tug on the board until you feel it working free. You may have to heat one or more lugs again to get the board out.

If you are removing the board and expect to put the same board back into the receiver, you will need to be quite careful that you do not damage the board. If you expect to replace the board, you will find it much easier to remove the board one section at a time. Do this by cutting vertically down the board as shown. After the board is removed, make sure the mounting holes are clean and free so that you can mount the new board.

transistor types

H ISTORY has a habit of going around in circles. If you want to know what's going to happen in the electronics industry in the near future, you can make a fairly good guess by considering what has happened in the past. For example, the most commonly used vacuum tube between 1920 and 1930 was the triode. It wasn't until the early 1930's that multigrid tubes came into use. Today, the most widely used transistor in receivers is the transistor triode. However, "multi-element" transistors are being made and it won't be too surprising to find the equivalent of the pentode at work in future transistor receivers.

However, we aren't so much concerned with the future as we are with the present and with what is going on at the moment. We have spent quite a bit of time studying transistor radios, but there are also many opportunities in the electronics industry for those who know a bit more than routine repair work. We cannot possibly hope to cover all of the new kinds of transistors (that would take a book in itself) but we can at least become acquainted with a few of the more important developments.

This last chapter is important for another reason. At the end of it you will find a chart covering many of the troubles you will meet in servicing transistor radios. Listing symptoms and their cures, the chart serves as a ready reference enabling you to cut

down on servicing time. Theory references, by chapter, are also given. This is done so that we can avoid a "cookbook" approach. We want to be able to service transistor receivers, but we should also know why the receiver behaves the way it does.

The phototransistor

If you are familiar with the phototube, you know that it is somewhat like a radio tube except that current flow is caused
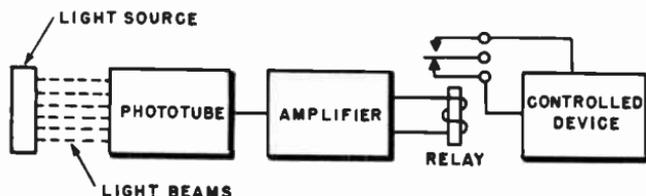
Fig. 1201. *An ordinary phototube must usually be followed by an amplifier to build up the current until it is strong enough to operate a relay.*

by a beam of light. We say that the tube is light-sensitive. Phototubes are widely used in industry. They are used on automatic door openers and light dimmers. They are used as silent guardians where valuables must be stored, or in any circuit where flashing a light on (or off) will cause some circuit to go into operation. The trouble with a phototube, though, is that it delivers a very small amount of current, hence it must be accompanied by suitable amplifiers. The output of the amplifier is then large enough to operate a relay. This is shown in block form in Fig. 1201.

The phototransistor does the same job as the phototube, but it has an important advantage. The phototransistor supplies more output current than the phototube, enough to operate a relay without an amplifier, as shown in Fig. 1202.

A drawing of the phototransistor appears in Fig. 1203. Fundamentally, it consists of an emitter, base and collector, just as in an ordinary transistor and, as you can see from the illustration, it is a p-n-p type. A bias battery is connected between the collector and base, with the negative terminal of the battery connected to the collector and the positive terminal to the base. Under these conditions, very little current flows in the collector circuit.

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The input circuit consists of the emitter and the base, although there is no physical external connection between them. The emitter is made of a light-sensitive (photosensitive) material. When a beam of light shines on the photosensitive emitter, the resistance of the *output* circuit decreases and more output current flows. The current carriers (electrons) move in the direction shown by the arrows. A relay coil can be connected in the output circuit. Then, by shining a beam of light on the emitter, we can cause enough current to flow in the collector circuit to operate the relay. The relay, of course, is nothing more than a switch and can be used to turn on a circuit (or turn it off). For example, the relay can be used to turn on a motor (operating a machine) or it can set in motion any number of other operations.

Surface-barrier transistor

Fundamentally, all vacuum tubes and transistors are alike — but so are human beings. However, tubes, transistors and human beings are individualistic so that, while they are basically alike, they also have enough characteristics of their own to make them different. Some transistors work well at low frequencies. Others work well at higher frequencies.

One of the transistor types that does very well at high frequen-
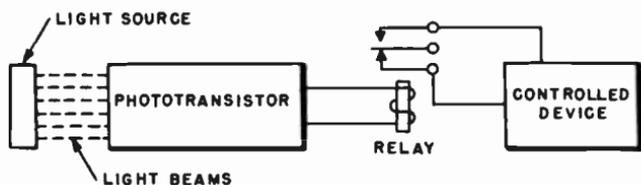
Fig. 1202. *Because the phototransistor supplies more output current, it can operate the relay directly, without the necessity of using an amplifier stage.*

cies is known as the surface-barrier transistor. A cross-section view of the unit is shown in Fig. 1204. The difference between this transistor and those we have studied is in the method of construction. The surface-barrier transistor is a triode, with an emitter, collector and base and has flat electrodes made of metal. These are plated on the transistor base material, forming the emitter and collector, respectively. Note the shape of the base. The unit is actually very small. The drawing is exaggerated in

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size to enable you to see what has happened. The region of the base located between the emitter and collector is extremely thin. Because of this, the time required for electron movement is very small; hence the transistor can be used for high-frequency work.

The surface-barrier transistor is identified by the prefix SB (surface barrier). Thus we have types such as the SB-101, SB-102, etc. However, EIA type numbers have been assigned to these
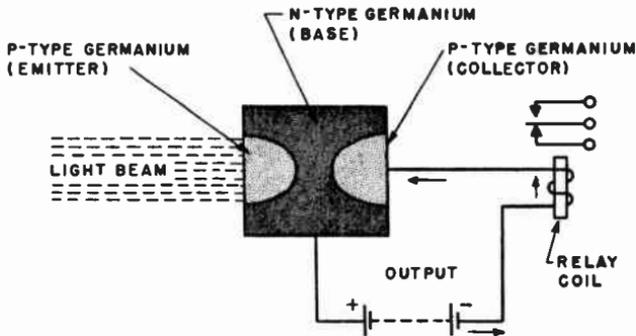
Fig. 1203. *Cross-section of the phototransistor.*

transistors so you will also find them as part of the 2N series. For example, the SB-101 is also identified as a 2N344, the SB-102 as 2N345, and the SB-103 as 2N346.

A surface-barrier transistor such as the SB-101 has a symmetrical lead arrangement, as shown in Fig. 1205. A red dot is placed on the side of the package (transistor casing) to act as a guide for lead identification.

Micro-alloy transistor

This transistor type may be classified in the surface-barrier family. The emitter and the collector electrodes are made by putting an impurity on the semiconductor, alloying a thin film of the substance on the germanium.

Micro-alloy diffused-base transistor

If the impurity is diffused instead of being alloyed, the transistor is then known as a micro-alloy diffused-base transistor (see also the section on diffused-junction transistors).

Silicon transistors

Like germanium, silicon (properly treated) is a well known

semiconductor. After the silicon is purified, controlled impurities are added to form silicon transistors.

Silicon has a number of advantages over germanium. It is capable of working in higher temperature ranges. Silicon transistors have lower leakage currents than germanium transistors.
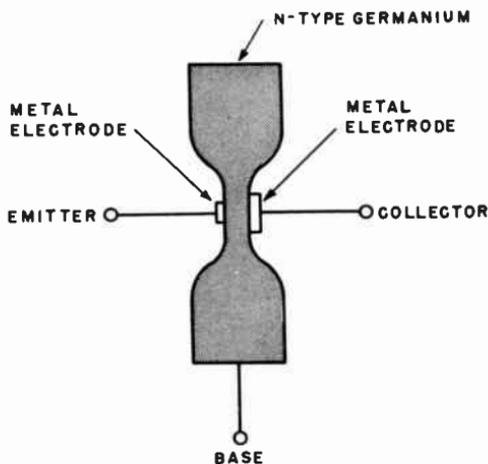
Fig. 1204. *Cross-section of the surface-barrier transistor. This is just one type of a group that have been developed for high-frequency operation.*

The circuit arrangements used for silicon units are the same as for germanium transistors, but the values of associated resistors and capacitors may be slightly different. Generally speaking, germanium transistors work better at higher frequencies; silicon works better at higher power levels.

Silicon transistors are useful for industrial applications. Such applications would include servo-motor control, magnetic core switching, solenoid operation, dc-to-dc converters (used in hybrid auto radios), and low- to medium-power oscillators in transmitters. In receivers they can be used in single-ended or push-pull output stages.

A drawing of a silicon transistor is shown in Fig. 1206. This is a medium-power n-p-n unit for switching applications, or it can be used as an amplifier. An index on the transistor package helps identify the position of the emitter lead. The center lead is the base, while the remaining lead is the collector. In some silicon transistors the collector lead is connected to the case of the unit.

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If the chassis is positive, this means that the case will have to be insulated from it.

Tetrode transistor

The very first vacuum tube was just about the simplest type you can imagine — a diode. A big forward step was made when the control grid was added. In time, the inside of the vacuum tube became quite a busy place with more and more elements being added. As you might suspect, history is busy repeating
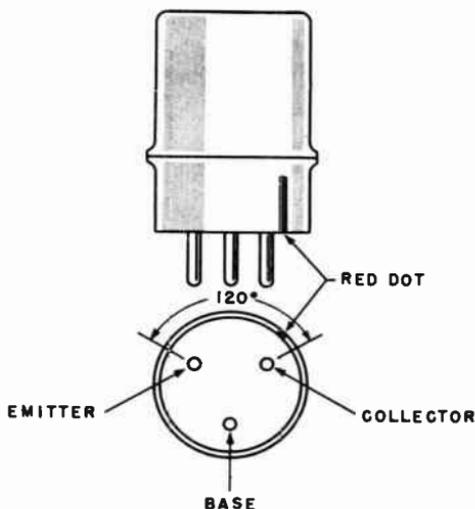
Fig. 1205. *Surface-barrier transistor.*

itself. And, while the triode transistor is used almost exclusively, we do have tetrode transistors, also known as double-base junction transistors.

A diagram of the tetrode transistor is shown in Fig. 1207. The transistor has the usual emitter, base and collector, but two connections are made to the base. The transistor is a p-n-p type, the base being made of an extremely thin layer of n-type germanium. N-p-n types are also made. The advantage of the tetrode transistor is that it can work at much higher frequencies than the usual triode transistor. For example, a type such as the 3N29 can work at 30 mc while the 3N30 operates at 120 mc. Fig. 1208 shows the bottom view, side view and the electronic symbol for the tetrode.

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Diffused-junction transistor

The diffused-junction transistor in itself is not a specialized type. The name of the transistor refers to the technique by which it is manufactured. Briefly, a diffused-junction transistor is made by permitting an impurity to melt into a thin region of germanium or silicon. The heated impurity will spread or diffuse into the semiconductor material — hence the name. The diffusion process is just one method for forming a p-n junction.

A diffused emitter-collector transistor is one in which both the
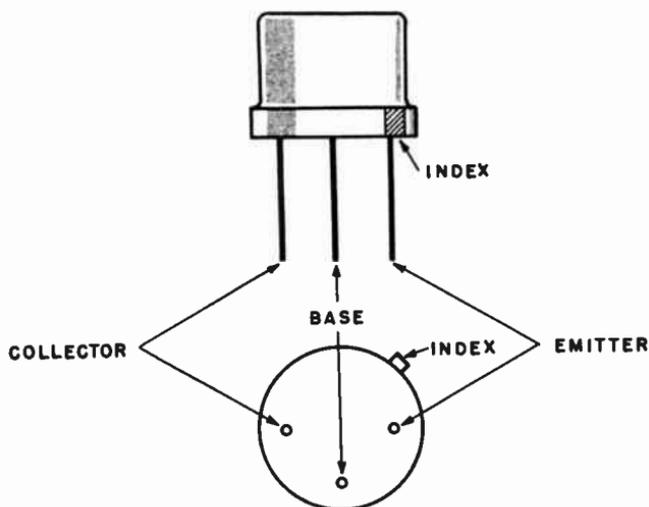
Fig. 1206. *Silicon transistor.*

emitter and the collector are formed by using the diffusion technique just described. A diffused-base transistor is one in which the base is formed by the diffusion process. From what we have said thus far, you can see that the diffused-base transistor and the diffused-emitter transistor come under the general heading of diffused-junction transistors.

Fig. 1209 shows the outline drawing of an n-p-n diffused-junction silicon power transistor. This transistor supplies high power output. As an example, a matched-pair working in class-B push-pull will supply as much as 15 watts of audio power. The transistor has four mounting holes for connection to an external heat sink.

Keep in mind that transistors can be made in many different

ways, and that there might be just slight differences in manufacturing techniques between transistor types. In some cases the manufacturers have named the transistor after the technique used
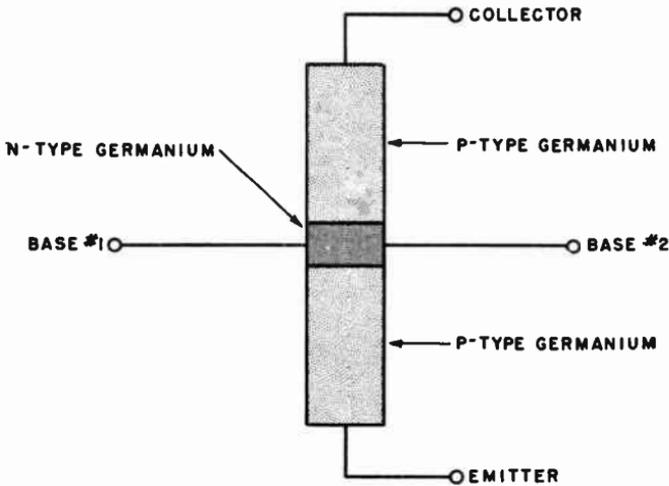
Fig. 1207. *Cross-section of the tetrode transistor.*

in its production. Other manufacturers have identified their transistors from the way in which the transistor operates, and in some
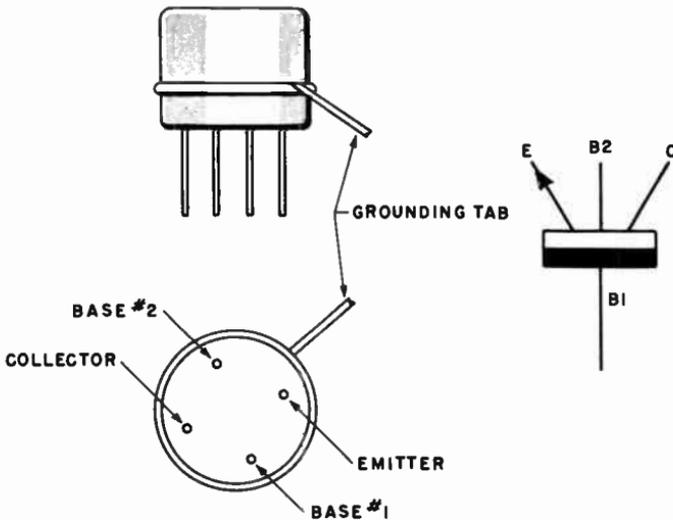
Fig. 1208. *The tetrode transistor and its electronic symbol.*

2-130
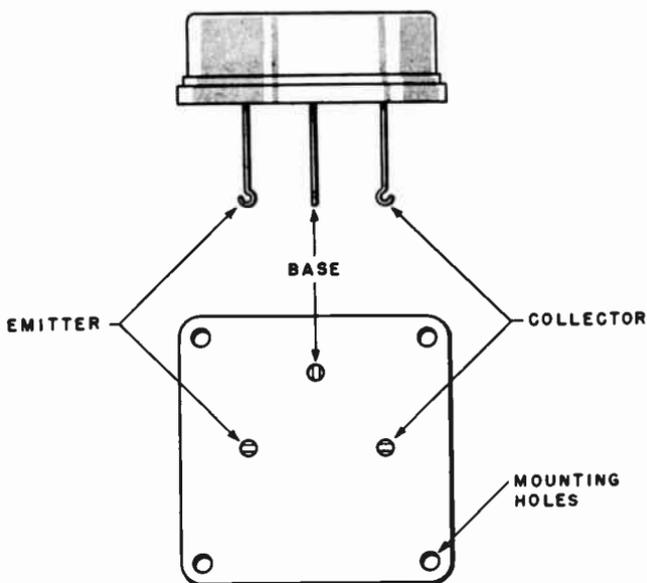
Fig. 1209. *Outline drawing of an n-p-n diffused-junction
silicon power transistor.*

cases the transistor is named after both its production method
and its operating technique.

Now add to this the fact that new processes and manufacturing
methods are constantly being developed, and you can easily see
that identifying the transistor by name is getting to be quite a
mixed-up business. For example, transistors can be known as
fused-junction, diffused-junction, diffused, alloy-junction, fused-
alloy, diffused-alloy or diffused-alloyed, micro-alloy, grown dif-
fused-junction, micro-alloy diffused-base, etc. These do not rep-
resent all of the names and certainly, as time goes on, the list will
expand. We cannot describe all of these for you, but we can cover
enough of the various types to give you an idea of what is going
on in this industry.

Grown-junction transistor

During one stage in the manufacture of pure germanium it is
in molten form. The material is not allowed to cool but remains
in a melted state in a crucible. A small bit of pure, solid germa-
nium — known as the seed — is attached to the end of a rod and
is then dipped into hot germanium. The hot germanium sticks
to the seed and is pulled up and out of the crucible. The germa-

nium, during this process, cools and forms a crystal. However, before the germanium crystallizes, certain impurities are added. Thus, a grown-junction transistor is one in which the junctions are made by putting controlled impurities into the melt during the time of formation of the germanium crystal. Germanium n-p-n grown-junction transistors supply high gain in the if stages in automobile receivers.

Grown-diffused transistor

We can take a grown junction and, by using the diffusion process, obtain a grown-diffused transistor. Some of these have
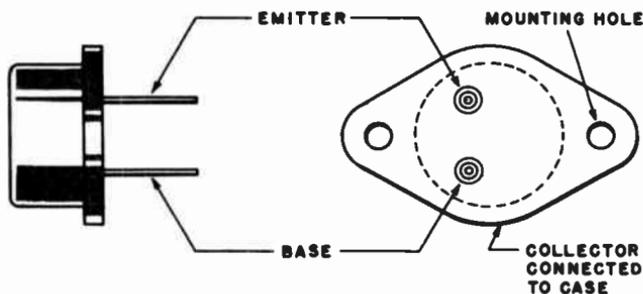
Fig. 1210. *P-n-p high-frequency power transistor for use in television deflection circuits.*

been designed for application in television circuits. Such a type is the 2N1046, a p-n-p high-frequency power transistor made for use in vertical and horizontal deflection circuits in television receivers (Fig. 1210). The package or case of the transistor is made of welded metal. The emitter and base leads are brought in through a glass-to-metal seal on the bottom side of the transistor. The collector is connected to the case. The transistor is rated at 15 watts.

Color-coded transistors

One type of transistor has a shape somewhat like a crystal diode. This is the HA7501 shown in Fig. 1211. The unit is a p-n-p silicon type designed for switching, control and audio applications. The color coding is used to identify the transistor, different colors being used for different transistor types in this series.

Hook transistor

A hook transistor, shown in Fig. 1212, is one having two layers of p-n germanium. This special arrangement is designed to

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supply an amount of amplification greater than that of the usual triode arrangement. The hook transistor resembles the point-contact type in that it has an alpha greater than one — that is,
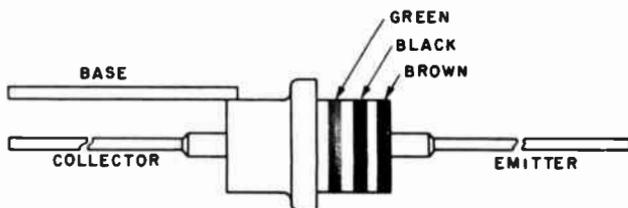
Fig. 1211. *P-n-p silicon transistor identified by color coding.*

the collector current is many times greater than the emitter current. But like the point-contact transistor, the hook transistor does have some instability in certain circuits.

The intrinsic semiconductor

When we started this book, we learned that by using acceptor or donor impurities we could make either p-type or n-type ger-
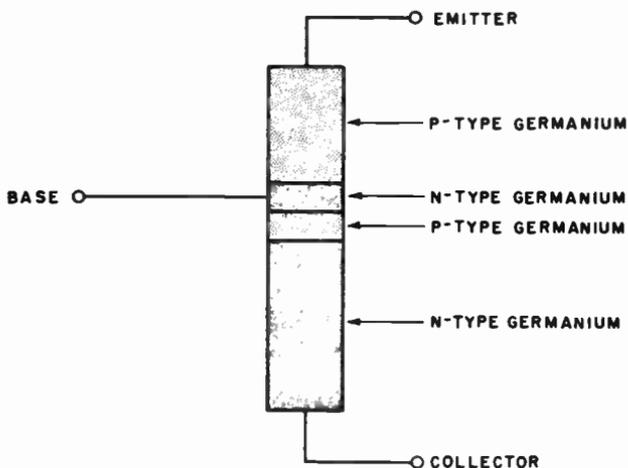
Fig. 1212. *The hook transistor is a two-layer unit.*

manium and that our current carriers — holes or electrons — would be determined by the type of impurity added to the pure germanium. However, the doping process can be so controlled that the germanium contains, approximately, an equal number

of both types of current carriers — holes and electrons. We cannot call germanium treated in this way as p-type or n-type since it is actually neither. This type of semiconductor is called an intrinsic semiconductor or i-type. Thus, we now have three types of semiconductors available — p-type, n-type, and i-type.

Intrinsic-junction transistor

As you might suspect, the i-type semiconductor wasn't developed without putting it to work. As a result we now have the intrinsic-
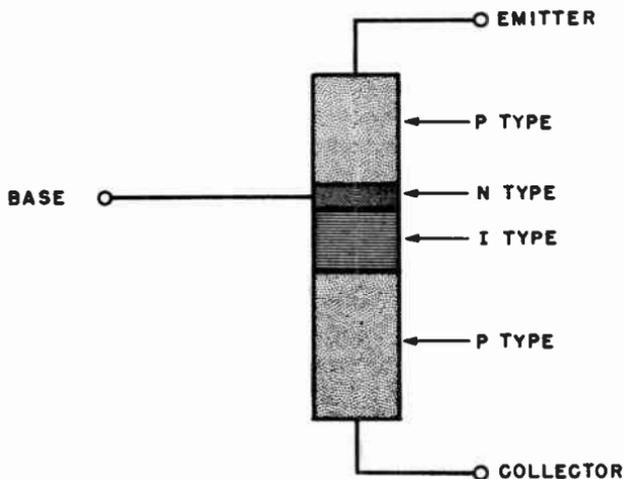
Fig. 1213. *Intrinsic junction transistor.*

junction transistor, illustrated in Fig. 1213. This is really a p-n-p transistor with a layer of i-type material sandwiched between the base and the collector. This makes it a four-layer transistor or a p-n-i-p type. Intrinsic-junction transistors are also made in the form of n-p-i-n.

Drift transistors

One of the big problems confronting transistor designers and engineers has been the need for getting the transistor to work at higher and higher frequencies. The surface-barrier transistor and the intrinsic-junction transistor are big forward steps in this respect. Another transistor that represents a big improvement in high-frequency response is the drift transistor (also known as the diffused-base transistor).

You will recall from our earlier descriptions that transistors are

made conductive by doping them with selected impurities. In the drift transistor, an impurity is added to the base. The amount of impurity is carefully controlled so that the maximum amount is close to the emitter, gradually decreasing so that there is only a small amount near the collector. The impurity material that is added is of the type that has excess electrons. When these electrons move away they will leave holes. But holes, as we have learned, represent positive charges. The base region is then said to have
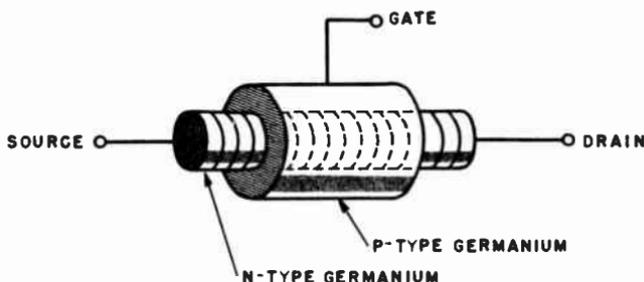
Fig. 1214. *Field-effect transistor.*

an electric field (somewhat resembling a charged capacitor). This electric field will accelerate the movement of current carriers from the emitter to the collector. And because the current carriers have been speeded up, the drift transistor can operate at higher frequencies than ordinary types. At high frequencies the movement of current carriers must be fast. In technical language we say that we have shortened the transit time. The difference is like going cross-country by auto or by plane. Both will get you there, the only question being "How long will it take?"

Field-effect transistor

The use of an electric field to control the flow of current carriers may sound new to you, but it really should not be. Consider the more familiar vacuum tube. The current flow between cathode and plate is controlled by an electric field. You know it more familiarly as the input voltage on the control grid. In the drift transistor described in the previous paragraphs, the electric field is actually "built in" the transistor, but there is no reason why an external electric field cannot be used. The field-effect transistor, shown in Fig. 1214, is such a unit.

The field-effect transistor is somewhat unusual and has a few names for its component parts that are new. Current starts at the

source and flows to the *drain*. Consider source as emitter or cathode, and drain as collector or plate and you'll have no difficulty. Going from the source to the drain, we have a cylinder of n-type germanium. Surrounding the n-type germanium is a sort of sleeve made of p-type germanium. A lead going from the p-type germanium is called the gate. This corresponds to the base in the transistor or the control grid in the vacuum tube. A voltage is placed on the gate to control the flow of current from the source to the drain.

The current carriers in the field-effect transistor are electrons.

Unijunction transistor

This transistor is another one of a rapidly growing group of unusual types. A cross-section view of the Unijunction transistor
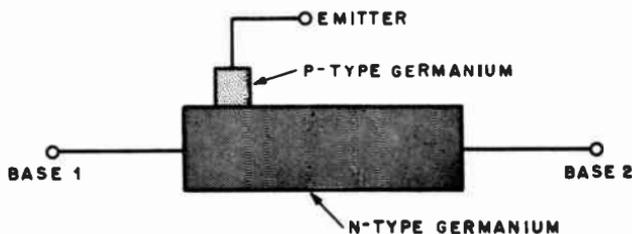
Fig. 1215. *Cross-section of the Unijunction transistor.*

is shown in Fig. 1215. The transistor consists of an emitter and, instead of having a collector, has a double base connection. For this reason, the transistor was originally known as a double-base diode. As shown in the drawing, the body of the transistor is made of germanium or silicon. An n-type semiconductor material is used. Coming out of the ends of the semiconductor are two leads, one for base 1 and one for base 2. The emitter, p-type material, forms a junction with the n-type base.

Thus, as indicated in the drawing, we have two diodes with a common emitter. Actually, the two base leads could be soldered together, resulting in an ordinary diode rectifier. To operate the unit as a transistor, a bias voltage must be connected between the two bases. The negative terminal of the bias battery is connected to base 1 and the positive terminal to base 2. The emitter is also biased positively with respect to base 1.

With this arrangement, the transistor has a very high resistance and so the amount of current flowing is negligible. But when the

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emitter voltage is increased (this voltage is between the emitter and base 1), the resistance will suddenly drop to a very low value, resulting in a very sharp increase in current. This "all or nothing at all" arrangement means that the Unijunction transistor is very well suited for use as an oscillator.

Spacistor

One of the chief efforts of transistor manufacturers has been directed toward getting the transistor to work at higher frequencies. The Spacistor was designed to supply high gain at frequencies
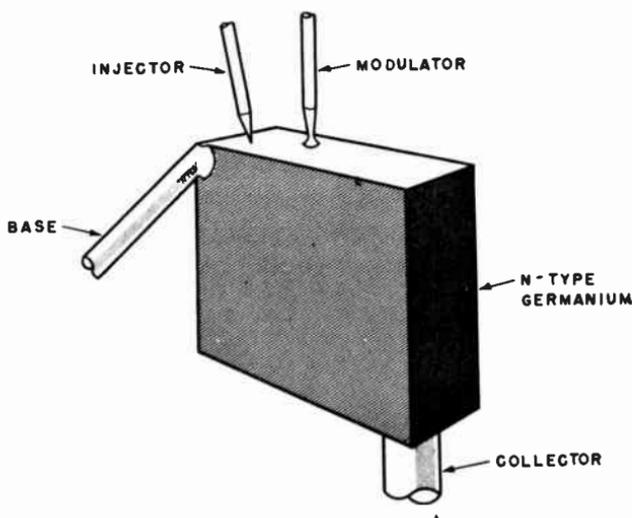
Fig. 1216. *The Spacistor resembles a vacuum tube in its operation.*

above 1,000 mc. Unlike other transistors, the collector operates at a comparatively high voltage. The Spacistor is a four-terminal device, having a base and collector. In place of the usual emitter, this transistor has an injector (Fig. 1216). The final electrode is called the modulator. Electrons are injected by the injector. Because of the high voltage on the collector, electron movement between injector and collector is speeded considerably.

The body of the transistor consists of n-type germanium. The modulator electrode forms a small p-n junction in the n-type germanium.

The Spacistor seems to resemble a triode vacuum tube much more closely than other types. The injector can be compared to

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the cathode, the modulator to the control grid and the collector to the plate.

The input signal is applied to the modulator. This, in turn, varies the number of current carriers passing at any moment between the injector and the collector.

Transistors at work

The number of commercial and industrial jobs a transistor can do is limited only by the ingenuity of technicians and engi-
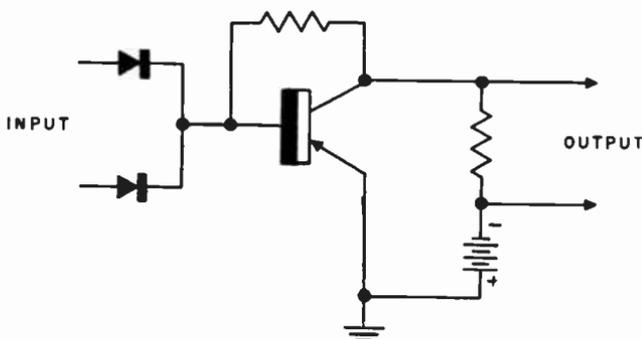
Fig. 1217. *Simple transistor gate circuit.*

neers. A transistor is often developed because a particular industrial problem cannot be solved through the use of existing units. The newly developed transistor is explored fully and is then made applicable to many new jobs. Quite often, you will find the same transistors used in radio receivers at work in industrial applications.

Here are a few of the many possible uses to which transistors can be put: analog computer circuits, flight simulators, Geiger counters, garage-door openers, hearing aids, vibration measurement devices, servomechanisms, digital computer circuits, missile control, instrumentation (test instruments), counting circuits, pulse-forming circuits, trigger circuits, electronic organs, FM transmitters, radio teletype, mobile radio units, telephone-line amplifiers, etc.

Gating circuit

A gating circuit is an electronic on-off switch. Where a device must be switched on and off several thousand (or many more) times per second, a manual switch is obviously impossible. Fig. 1217 shows a simple gating circuit using a p-n-p transistor. There

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are two inputs, tied in parallel. The signal voltages for the inputs could come from a multivibrator or from any other electronic device that could supply a driving voltage. The transistor gate circuit is normally nonconducting. When a pulse is applied to the input, an output voltage is developed across the collector load resistor. The gate can be used to put a particular circuit into action or to keep it from operating. For example, a gate is used in color television receivers. When only a black-and-white
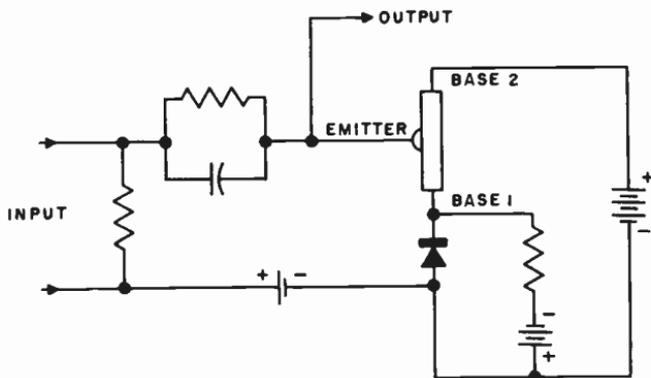
Fig. 1218. *Pulse amplifier using Unijunction transistor.*

signal is received, the gate is "closed," preventing the color circuitry from operating and interfering with the black-and-white picture. When a color television signal is picked up, signal voltage is used to "trigger" the gate. With the gate in action, the color circuits are permitted to do their job.

Unijunction transistor pulse amplifier

The Unijunction transistor described earlier can be used as an amplifier to build up pulses. Pulses are widely used in television transmitters, in counting circuits and in radar units. Pulses are also used in television receivers.

A simple Unijunction pulse amplifier circuit is shown in Fig. 1218. The pulse (or trigger voltage) is applied across a small resistor. This resistor is connected in series between the emitter and base 1. When a voltage (such as the trigger voltage) is put across the resistor, the polarity of the voltage is such that the resistance of the emitter-to-base circuit is drastically reduced, permitting a heavier flow of current. The output current is fed into an R-C network, the charge and discharge thus adding a sawtooth component to the pulse.
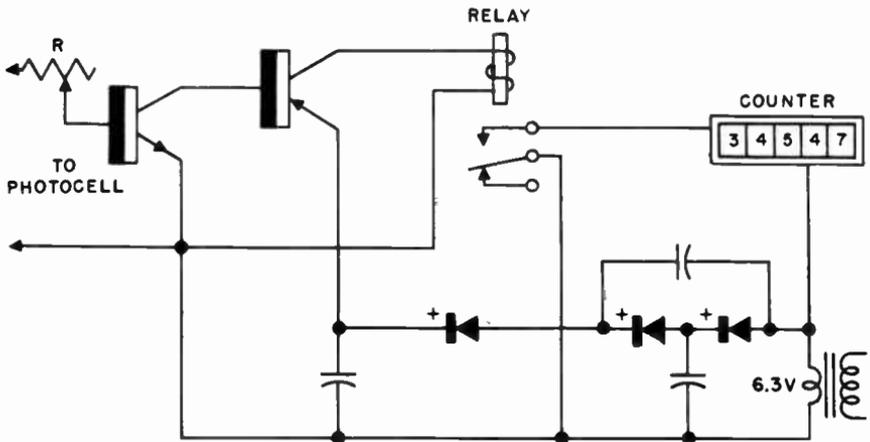
Fig. 1219. *Photocell and transistors operating to work a mechanical device, such as a counter.*

Counting device

A pair of transistors can be used in conjunction with a photocell and a relay to operate a mechanical type of counting device. This is illustrated in Fig. 1219. Every time a beam of light strikes the photocell, the transistors go into operation. The two transistors are direct-coupled. Enough current flows in the collector circuit of the second transistor to operate a sensitive relay. The mechanical counter is of the type that will work from low-voltage ac. Every time current flows through the relay, the relay armature moves, closing the counter circuit. A record can thus be kept of the number of times the photocell is illuminated by a beam of light.

Spacistor amplifier

A simple circuit arrangement for a Spacistor amplifier is shown in Fig. 1220. Three bias supplies are shown, one each for the injector, the modulator and collector electrodes. The input signal is supplied between base and modulator. The output circuit is standard, the amplified signal being taken from across the collector load resistor.

Tetrode amplifier

An amplifier circuit using a tetrode transistor is shown in Fig. 1221. The transistor is a p-n-p alloyed-junction type, actually a power type capable of supplying up to 5 watts output. The variable resistor is adjusted for optimum collector-current output.

The stage can be connected directly to a speaker as shown and has the advantage that no output transformer is required. The circuit can also be used as a modulator in transmitting circuits.

Your servicing chart

A service technician is an electronic detective. A competent service technician doesn't need too many clues to help him find the villain. We have given you many clues as to why a transistor receiver will become defective. But we cannot possibly expect
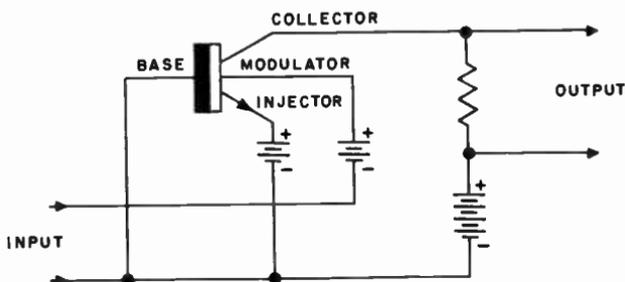
Fig. 1220. *Simple Spacistor amplifier circuit.*
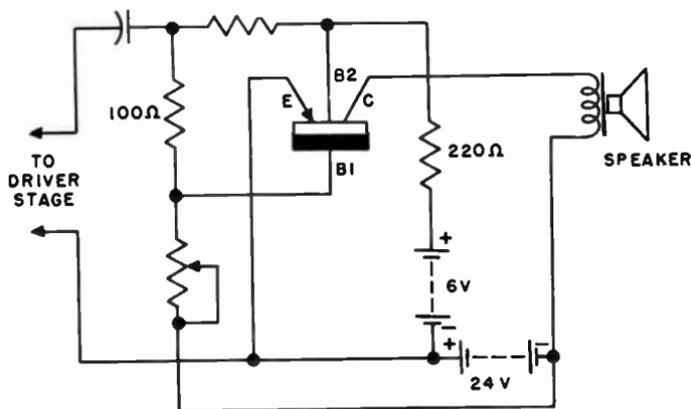
Fig. 1221. *Amplifier circuit using a tetrode transistor.*

you to remember every page of every chapter. We know you will want to refer to this book from time to time to help you in your work. Since we have been preaching constantly about "saving time," we cannot expect you to waste time looking for information. And so, for your benefit and convenience, we have compiled a servicing chart.

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AGC voltage missing
Ref. Chapter 4
    Chapter 5
    Chapter 9

Make sure that the receiver is tuned to a station. If you are using an output meter but have the speaker disconnected, a meter reading doesn't necessarily indicate the presence of a station. The receiver may be oscillating (one of the if stages may be regenerative).

If, however, you do have a station but no agc voltage, check the agc filter resistors and capacitors. If the set seems unusually sensitive, overloads easily and distorts, but agc voltage is missing, trouble is definitely caused by some defect in the agc network. The crystal diode will sometimes pass enough audio signal to make you think that it is good, but, if a check of the agc system does not reveal the trouble, try replacing the diode.

Missing agc voltage may not necessarily indicate a defect. The set may be using delayed agc, in which case no agc voltage would appear until the signal level is strong enough to overcome the amount of delay voltage.

Audio instability
Ref. Chapter 8

Refer to the section on Motorboating.

Audio output, low
Ref. Chapter 3
    Chapter 5
    Chapter 6
    Chapter 8

Usually caused by some defective component in the detector, driver or push-pull (or single-ended) output stage. Check the battery. This must be done under full-load conditions. Use signal tracing, starting at the detector. Tune receiver to a number of different stations. If all stations come in loudly, except one, then trouble is not in the receiver. Weak audio can also be caused by defects preceding the detector. Connect audio generator across the volume control. Set the control for maximum audio output. If signal is strong, then trouble is not in the battery or the audio section but exists somewhere before the volume control.

If trouble is in audio section, check components; also voltages at transistor elements. Make sure speaker is in good condition by click-testing it or by using substitute speaker. Earphones, sometimes used, may have defective jack. Put on earphones. If volume is

Audio output low (continued)
Ref. Chapter 3
　　 Chapter 5
　　 Chapter 6
　　 Chapter 8

Battery life too short
Ref. Chapter 7

good but sound of speaker is weak, then check the speaker.

Transistors are usually the last item to check.

The battery in portable transistor receivers is usually shunted by an electrolytic. If excessively leaky, this could put a severe drain on the battery.

The on-off switch might be defective. These switches are small devices and sometimes have mechanical difficulties. For a quick test, turn the receiver on and tune in a strong station. Put on the receiver earphones (if set is so equipped) or keep your ear close to the speaker. Now turn the set off. The switch should make a definite clicking sound as it is turned off and the sound should be absolutely dead. If you hear weak sound faintly in the background, you are getting leakage through the switch.

Put a dc milliammeter in series with either side of the switch. Turn the receiver on and note if the current is as recommended by the manufacturer. Now turn the set off and note if current drops to zero.

Short battery life is sometimes caused by improper operation of the audio section of the transistor receiver. If the audio transistor or transistors draw excessive idling current, battery life will be shortened. In a class-B amplifier, the idling current should be less than 5 ma. This will rise to about 40 ma (or more) with signal.

Some sets use batteries which can be charged. If battery voltage is weak, it may simply mean that the battery has run down. Rechargeable nickel-cadmium batteries can be recharged repeatedly.

Remember also that penlight type cells will not last as long as mercury batteries. Mercury batteries should have a life expectancy at least several times as long as penlight cells.

When making voltage checks on mercury or nickel-cadmium batteries (where these have

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Battery life too short (continued)
Ref. Chapter 7

been used to replace penlight cells), keep in mind that mercury and nickel-cadmium types supply about 15% lower voltage.

B-plus voltage too low
Ref. Chapter 2
      Chapter 7

Batteries may be weak. Check batteries under full load. Do this by turning receiver on and tuning to loud station. If battery voltage is 30% below no-load voltage, replace.

If batteries are of rechargeable type, try giving full charge and then make full-load test. If batteries will not take a charge, replace them. If, however, batteries take a full charge and maintain voltage under load but batteries get weak very rapidly, look for defective component that puts heavy load across the battery.

Low B-plus voltage can also be caused by a short in the receiver or leaky electrolytics. If the voltage across the battery terminals is good but you get less than normal voltage at the transistor pins, then some component has either changed its value or become defective. Transistors are the last item to suspect.

If the set uses transformers, resistance check from each winding to the transformer shield. A high-resistance leak here will put a drain on the battery.

In auto receivers, if B-plus is too low, check the storage battery and the dc-to-dc converter in hybrid sets.

Birdies
Ref. Chapter 8

Refer to the section on Tweets

Dead receiver
Ref. Chapter 7
      Chapter 8

Refer to the section on Inoperative receiver

Distortion
Ref. Chapter 3
      Chapter 5
      Chapter 6
      Chapter 7
      Chapter 8

This symptom may or may not be accompanied by weak signals. If the signal is distorted on all stations then the trouble is usually in the detector, audio driver or output stages.

Distortion can be caused by a changed value of emitter resistor, by an incorrect replace-

ment value of emitter resistor or by a shorted emitter bypass capacitor. To check, measure the voltage across the emitter resistor.

Check resistance-capacitance decoupling filters where used. If the capacitor is open, the distortion may be accompanied by motorboating. If the capacitor is leaky, there will be a heavier than normal voltage drop across the decoupling resistor. The collector voltage will then be insufficient.

If the receiver distorts only when the set is tuned to a strong signal, check the automatic gain control circuit. Shunt the existing agc filter capacitor with a similar unit. If the distortion clears, then the original capacitor is at fault.

If the detector also supplies agc, try replacing the detector. Make sure the detector hasn't been inserted with reverse polarity.

Distortion can also be caused by a battery which just about needs replacement.

If the receiver uses earphones and the signal as heard in the earphones sounds good, but is distorted when the speaker is used, check by using a substitute speaker.

Check the base bias of each transistor. It doesn't take much of a change in bias to produce distortion. If the voltages are incorrect but the battery voltage is good, then resistance-check the bias voltage divider network. Do not make this check with the transistor connected.

Distortion can also be produced if the rf bypass capacitor at the detector output is open. This causes overloading of the first audio amplifier stage.

Electrolytics are often used as coupling capacitors. If these become excessively leaky, the base bias of the following stage will be changed. Shunting the capacitor with a known-good unit is of no use. Open one end of the suspected capacitor and then connect in the new unit. Suspect coupling capacitors especially if the bias of the following stage is incorrect but voltage divider and battery check OK.

Distortion (continued)
Ref. Chapter 3
　　　Chapter 5
　　　Chapter 6
　　　Chapter 7
　　　Chapter 8

Distortion can be caused by the speaker. The cone may be torn or the voice coil can be rubbing against its pole piece. Cones have a habit of drying out. To extend the life of a cone, moisten the cone with a sponge. Do not soak the cone but wipe it gently once or twice with the sponge. The sponge should be damp, but squeezed out. Putting lacquer or shellac on the cone will help extend its life. Keep the lacquer from running into the space between the voice coil and the pole piece.

Distortion can be caused by a defective driver or output transformer. This may be caused by a shorted turn or excessive leakage or a high-resistance short between the winding and the case. A shorted turn is almost impossible to detect with a resistance check.

Distortion can be caused by misalignment. Screwdriver-happy customers are often responsible for this condition.

Fading

If the receiver fades after it has been on for a short while, the trouble is usually due to a weak battery. This is sometimes deceiving since a weak battery, if not used or loaded, often seems to regain its strength. To check, turn the set on until you notice the fading condition. Then turn the set off for at least an hour. If the fading condition repeats again after you turn the set on, replace the battery.

A condition resembling fading is caused in car radios when the car passes near a structure containing a large amount of metal. In passing through a tunnel, the signal may disappear completely.

A portable transistor receiver will often operate inside a car provided you are not too far distant from the station. You will get best results if the portable is kept close to the window.

Do not confuse fading with an intermittent condition. In fading, the change is a gradual one, but the condition in an intermittent is much more abrupt. With an intermittent, the sound may go suddenly from full volume to a whisper.

Inoperative receiver
Ref. Chapter 4
    Chapter 7
    Chapter 8
    Chapter 10

Check the battery. If it has dropped below 30% of its full-load voltage, replace it.

Check to make sure that the entire receiver isn't dead. Inject a signal (audio) across the terminals of the volume control. If you get a signal output, the trouble precedes this point. Signal-trace through the entire set. Any stage that doesn't pass the signal is at fault.

If the local oscillator isn't functioning, there will be no signal output.

The receiver may be inoperative if transistor voltages are incorrect. If signal tracing shows a particular stage to be at fault, check bias voltages. If these are not correct and battery is good, check all resistors and capacitors going to the transistor of that particular stage. The trouble may be due to an open decoupling resistor, open or changed values of voltage-divider resistors, open emitter resistor, open collector resistor, open if transformer winding (or a short in the if).

Check the ferrite-core antenna. It may be open or the connections to it may be broken.

Every receiver will show a certain amount of resistance across the battery clips. To check, remove the battery. Connect your vtvm (set to read ohms) but make sure that the plus lead of the meter goes to the plus wire clip of the battery. If the resistance as measured agrees with that indicated by the manufacturer, the trouble is in the battery or else the battery connections are broken or corroded or the on-off switch is broken. If the resistance is much lower than normal, look for a shorted condition in the set.

The trouble may be caused by an open or shorted phone jack.

Interference
Ref. Chapter 9

Interference in an auto receiver can be caused by any mechanical component in motion and by many electrical components as well. Noise can be produced by the distributor, generator, spark plugs, ignition coil, wheels. Noise voltages are often radiated by the wiring of the car.

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Interference (continued)
Ref. Chapter 9

Since auto radios have a tuned-radio-frequency amplifier stage, interference between stations is not particularly noticeable. However, in portable receivers having low selectivity, you may get such interference. If this is due to the design of the receiver, there isn't much you can do about it. Try turning the portable in one direction or the other to favor the desired station. In a home receiver, usually occupying a fixed position, it may be necessary to move the receiver to a different spot.

Realignment may help. If the customer prefers certain stations, realignment can be done to favor those stations, but at the expense of others.

Intermittents
Ref. Chapter 11

Rotate the volume control. If the set operates best at one particular spot of the control, the control is dirty or worn. Clean with carbon tet or commercial lubricant cleaner. If pressing hard on the volume control knob removes the trouble, the wiper arm inside the pot has pulled away from the resistance element. It may be easier to replace than to fix.

Intermittents are often caused by poor mechanical contacts. Spot-soldering of any and all riveted connections may help. Make sure that the battery is securely mounted in its holder and that the battery snap connections are tight and secure. If the battery is corroded, replace it. Before inserting the new battery, clean away all corrosion, using steel wool. Make sure no fragments of the steel wool drop into the set.

Intermittents can be due to poorly soldered connections, either produced during the original manufacturing of the set or because of prior servicing. Spot-solder any doubtful connections.

With the receiver turned on and the volume turned down partially, put your ear near the speaker and then rotate the tuning dial from one end of the broadcast band to the other. If you hear any scratching during this time, either the rotor and stator plates are scraping or else the tuning capacitor mounting has become loose. Sometimes the trouble

Intermittents (continued)
Ref. Chapter 11

is simply due to dirt or metallic dust or particles that have become imbedded between the stator and rotor plates. Examine both the oscillator and rf tuning sections of the variable capacitor. Also check the wiper contact of the capacitor.

Some sets have switching arrangements. Listen to the set while manipulating the switch. You will hear a crackling sound or the set may become completely inoperative if the switch contacts are dirty, worn or loose or poorly soldered.

If the set has an earphone jack, make sure that its contacts are clean.

An intermittent can be caused by a loose lead going into some component. Check by tugging gently on all component leads. You can also do this easily by tapping on the leads with the rubber end of a pencil. If the volume changes or breaks when any lead is so touched, check that component.

Motorboating
Ref. Chapter 6
      Chapter 8

This is an intermittent sound, often accompanied by squealing. Check for an open decoupling capacitor. Also check the electrolytic shunted across the battery. If the electrolytic is leaky and the battery has begun to age, you have a combination that can produce this trouble.

This condition is sometimes produced by a change in the value of the feedback resistor or capacitor.

Motorboating is also caused by high-resistance joints. Spot-soldering the rivets on the printed-circuit board or on the battery holder will help cure this trouble. Make sure that the tuning capacitor is securely mounted.

No output signal
Ref. Chapter 8

Refer to the section on Inoperative receiver.

Noise (See Interference)
Ref. Chapter 9

Noise but no signal
Ref. Chapter 8
      Chapter 10

The local oscillator may not be functioning. You can check the local oscillator by any of the techniques previously described in detail

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Noise but no signal (continued)
Ref. Chapter 8
     Chapter 10

in these chapters. If the oscillator isn't working, check the voltages at the base and emitter of the converter transistor. Also check the voltage at the collector of the converter. If any of these voltages are missing or are incorrect, check voltage-divider and dropping resistors connected to these elements.

The trouble might be due to a defective oscillator coil. Check all other oscillator components also.

Sometimes the trouble is due to a defect in the oscillator section of the tuning capacitor. Rotate the capacitor to the high-frequency end of the dial. If stations come in at this point but not at the low-frequency end of the dial, the capacitor plates are shorting. If the reverse is true—that is, if the set works for low frequency station but not for the higher frequency ones—then the rotor plates of the oscillator tuning capacitor are shorting against some metal component.

One station only over
entire tuning range
Ref. Chapter 8
     Chapter 10

The if stages may be severely misaligned. Someone may have tampered with all alignment slugs and screws.

This condition can sometimes happen when the local oscillator isn't working. The misaligned if can pick up a broadcast station, with the entire receiver acting as a fixed-tuned rf receiver. Check the local oscillator.

Oscillation
Ref. Chapter 4
     Chapter 8

The symptom in this case will be squealing. The set may be very touchy and sensitive. Look for an open in the neutralizing network (resistor or capacitor or both) if the set has such a network.

The trouble may be in the agc system. Make sure that the detector diode isn't reversed. Check all agc filter capacitors.

This trouble may be caused by a weak battery.

Oscillation can be caused if the ground connection of the printed circuit doesn't make good physical contact with the ground of the receiver.

troubles	*servicing techniques*

Poor sensitivity at low end of broadcast band
Ref. Chapter 10

This may be caused by misalignment of the oscillator or rf section. It sometimes results also when the converter transistor is replaced.

Poor sensitivity at the high-frequency end of the broadcast band
Ref. Chapter 10

This trouble may be caused by poor alignment in the front end of the receiver. It can be caused when the converter transistor is replaced.

Regeneration
Ref. Chapter 8

Refer to the section on Oscillation

Scratching sound
Ref. Chapter 6

Sometimes due to controls that are worn or dirty. Check by rotating the volume control. Some sets also have variable tone controls, although these are less likely to produce this trouble since they aren't used as much as the volume control. Clean all controls with a lubricant cleaner.

Some tone controls use a switching arrangement. Dirty, loose or broken contacts can cause this trouble.

Sound distortion
Ref. Chapter 6

Refer to the section on Distortion

Sparking
Ref. Chapter 9

Refer to the section on Whine

Squealing
Ref. Chapter 8

Refer to the section on Motorboating

Static in auto sets
Ref. Chapter 9

This is a noise produced only when the car is in motion and is caused by wheel friction. Eliminate by using static-collector springs or graphite powder. The powder is injected into the inner tube.

Refer also to the section on Interference

Tweets
Ref. Chapter 8

This condition can be caused by defective lights, particularly fluorescent fixtures. Turn the light off but keep the receiver turned on. If the condition disappears, the trouble may be due to the light or to the fluorescent starter.

This trouble can also be caused if the local-oscillator voltage is too high.

Volume changes considerably as receiver is tuned from one station to next Ref. Chapter 5	Check the agc system, including all filter resistors and capacitors. Try replacing the detector.
Weak signal Ref. Chapter 5	Refer to the section on Audio output, low
Whine Ref. Chapter 9	This is a condition in automobile radios. It is generally noticed as the car is accelerated or slowed.

In this case the trouble is caused by the generator. It can be eliminated in several ways. The easiest is to put a suppressor capacitor on the generator. Connect one lead of the capacitor to the terminal marked A on the generator. The other lead of the capacitor should go to the metal frame of the generator or the car. Some capacitors have only one lead and depend on the mounting clamp for making a good ground connection. The single lead coming out of the capacitor should go to the A-terminal on the generator.

Another method of eliminating whine is to replace the generator brushes. Try cleaning the commutator segments. Sometimes the mica segments between the commutator segments work their way up. The mica must then be ground down. In severe cases, it may be necessary to replace the generator.

Make sure that the line connecting the armature of the generator to the regulator is kept away from the antenna lead to the receiver.

Whistling

This condition may appear on all stations. It can be caused by a weak battery.

The trouble can also be caused by a receiver that is misaligned or by a defective neutralizing capacitor or resistor. Also check the agc circuit.

Examine the antenna coil. If the polyiron slug is cracked, replace it or put in a new antenna coil.

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