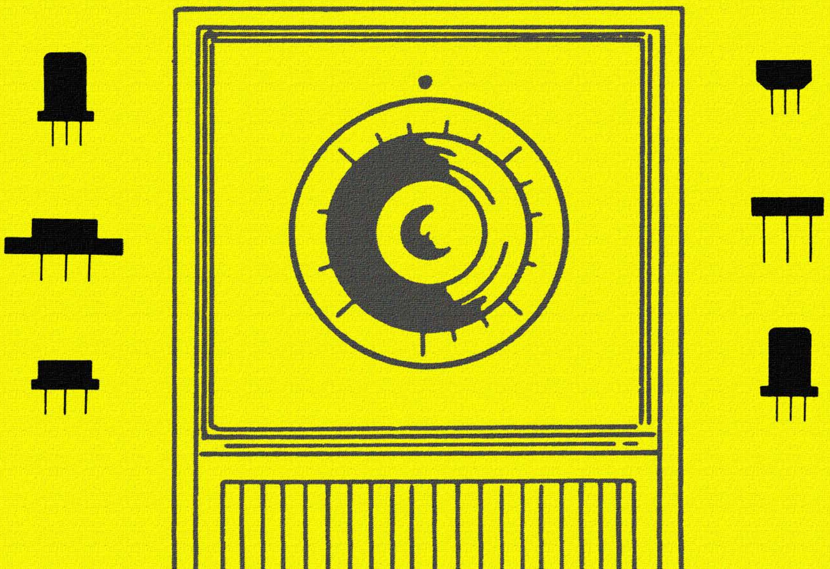
Howard W. Sams® PHOTOFACT PUBLICATION 20314

practical TRANSISTOR servicing

by William C. Caldwell



practical TRANSISTOR servicing

by WILLIAM C. CALDWELL

HOWARD W. SAMS & CO., INC.
THE BOBBS-MERRILL CO., INC.
INDIANAPOLIS • KANSAS CITY • NEW YORK

SECOND EDITION

THIRD PRINTING — 1967

Library of Congress Catalog Card Number: 65-24556

Preface

Most of you undoubtedly have experienced the wonderful sensation of having the entire concept of a complex subject suddenly become clear and meaningful . . . or, as they say, "comes the dawn."

Many magazine articles and books have been published about transistors and transistor-circuit servicing. Yet, from the hundreds of questions asked me at technical lectures and service meetings, I could see that a truly down-to-earth, practical presentation of the subject was sorely needed. It was with this thought in mind that this book was prepared.

There are two subjects of interest to almost everyone—making money, and enjoying the work he must do for it. Those in electronics servicing will not find it difficult to do both, provided they have an open mind and the desire to learn.

The introduction of the transistor has made additional study necessary if technicians are to keep abreast of new developments. This book presents a simple and logical explanation of transistors, how they work, and how to service transistorized and all-transistor equipment. By following definite and straightforward procedures, the reader will be able to save himself much servicing time. And, in the servicing business, time saved is money earned.

Troubleshooting transistor radios can be quick and simple . . . or it can be painful and time consuming—it depends on the method used. The procedures in this book have been tested on hundreds of radios and taught to thousands of technicians. In fact, they probably are the most tested principles ever to be published on the subject.

Anyone can change parts! The forte of a real technician is his ability to accurately and rapidly track down a defect. Diagnosis is everything. Yet this is where many a service technician stubs his toe.

This is a practical book because it was written from experience . . . not from pure theory. Furthermore, experience has shown that technicians (and even many engineers) do not have to know all the complicated theory involved in the inner workings of transistors. Thus, the reader has been spared the boredom of learning about tracking holes and electrons.

Following the simple explanation of how transistors work, and the information on the best methods of testing transistor radios, are actual trouble experiences. Step by step, these experiences lead the reader to a logical solution. By this method, he is given a clear and workable understanding of the subject.

This book will help you "see the dawn," for it was written for that purpose—to bring the fascinating subject of transistors out into the bright and clear area of real understanding.

My special thanks to Jack Parry of Parry Radio Repair, Anderson, Indiana, for the use of his shop, and the Delco Radio Division of General Motors for their assistance.

BILL CALDWELL

Contents

CHAPTER 1

UNDERSTANDING THE TRANSISTOR 7
Basic Transistor Function—Identifying the Transistor Elements —Transistor Types

CHAPTER 2

CIRCUIT COMPONENTS AND THEIR FUNCTIONS 21
Basic Circuit Limitations—Eliminating the Bias Battery—The Input and Output Transformers—A Typical Amplifier Stage—Feedback for Oscillators

CHAPTER 3

LEARNING TO TROUBLESHOOT AM TRANSISTOR RADIOS 41
Schematic Familiarization—Checking the Power Supply—Stage Isolation Methods

CHAPTER 4

LEARNING TO TROUBLESHOOT AM-FM TRANSISTOR RADIOS .. 79
Schematic Familiarization—Isolating Troubles

CHAPTER 5

NORMAL TRANSISTOR VOLTAGES 91
Comparison of Tube and Transistor Elements—NPN Transistors —PNP Transistors—Summary

CHAPTER 6

DEFECTIVE VOLTAGES AND THEIR MEANINGS 111
Causes of Voltage Errors—Sample Defects in Actual Circuits

CHAPTER 7

TESTING TRANSISTORS 129
DC Tests—Testing Transistors with an Ohmmeter—In-Circuit Tests—Out-of-Circuit Tests—Checking Transistor Gain—Identifying Transistor Types—Special Tests for Power Transistors

CHAPTER 8

TROUBLESHOOTING AM AUTOMOBILE RADIOS 147
Schematic Familiarization—Tracking Down the Troubles—Troubleshooting Summary

CHAPTER 9

TROUBLESHOOTING AM-FM AUTOMOBILE RADIOS 167
Schematic Familiarization — Troubleshooting the Radio — Aligning AM-FM Radios

CHAPTER 10

CASE HISTORIES OF ACTUAL TROUBLES 179
The Dead Portable—The Dropped Radio—Intermittent and Weak Output—The High-Drain Portable—Case of the Unusual Short—AM-FM With No AM—The Fader Fixed Fast

INDEX 187

CHAPTER 1

Understanding the Transistor

Before servicing a watch, the watchmaker learns what makes the mechanism tick. Before diagnosing trouble in a human being, the physician spends many years learning how the body functions, for this knowledge is invaluable in the "troubleshooting" he must do later.

The radio technician must have some idea of how the transistor works in order to service transistor radios. This is probably more important than any other factor in reducing repair time, preventing callbacks, or just increasing his efficiency and professional reputation. This is why the first chapter is devoted to this subject.

BASIC TRANSISTOR FUNCTION

The basic purpose of the transistor is to control the flow of electrical current so that a signal is either produced, amplified, or changed in some manner. A transistor which produces a signal is called an oscillator. One which amplifies is simply an amplifier, although it may be further classified by the type of signal it amplifies, such as an audio-, IF-, or RF-amplifier.

We know that the function of a simple conductor such as a piece of wire is to provide the path for current in a circuit; and that the function of a nonconductor, or insulator, is to block current flow. The transistor allows a controlled amount of current to flow under certain conditions; it is therefore known as a semiconductor. The applied voltages, temperature, and circuit-resistor values, and the materials in the transistor itself, determine how much (or how little) conduction will take place.

One of the miraculous things about transistors is that they can do many of the same tasks a vacuum tube can do, but with much less effort. This means greater efficiency, lower operating voltages, less drain from the power source—all with a unit that is physically smaller than a vacuum tube.

Diode Action Is Basis for Transistor

The simple diode, which has long been used to detect or rectify signals, is the backbone of the fantastic transistor. A short review on how diodes work will help in understanding transistors.

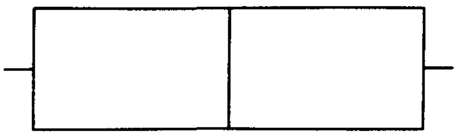


Fig. 1-1. The pure crystal material — a perfect insulator in its original form.

A typical modern diode may be made of germanium, silicon, or a similar material. These materials, in pure crystalline form (Fig. 1-1), make extremely good insulators; if no other materials were added, the diode would be unable to pass any current and would therefore be useless. However, the diode is actually divided into two sections (*di* meaning two) and a certain amount of "impurity" added to each section. The impurity is simply a different type of material which supplies current carriers (Fig. 1-2) of either negative or positive polarity, depending on the material added in the manufacturing process. One type of impurity will produce *N* type carriers, which are negative; and another impurity will provide *P* type carriers, which are positive.

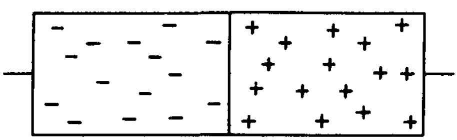


Fig. 1-2. Adding impurities to the crystal material produces charged carriers.

It is the presence of these free current carriers that allows the diode to become a fairly good conductor under the conditions shown in Fig. 1-3. When a battery is connected in the proper direction, the junction between the *N* and *P* sections are literally flooded with current carriers. This means the resistance of the diode to current flow is very low. The reason the diode allows current to pass is that there are plenty of free current carriers at the junction of the two diode sections.

To understand the principle of conduction through a diode more clearly, refer to Fig. 1-3 again. The negative battery terminal is connected to the *N* section of the diode, which contains free, movable electrons. Since like polarities repel each other, the negative field of the battery pushes the electrons toward the junction. Likewise, the positive pole of the battery repels the positive carriers toward the junction. It takes only a small voltage to give the charged carriers sufficient energy

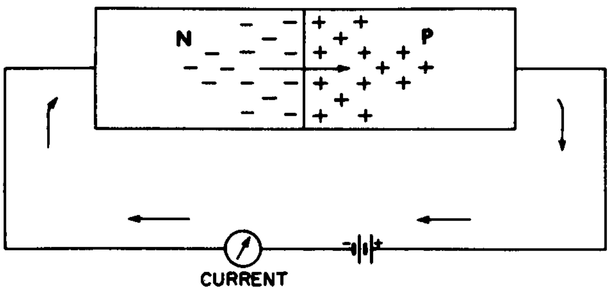


Fig. 1-3. Current will flow through the diode when a battery is connected in the proper direction.

to cross the junction; and once they start moving, a constant exchange takes place. As negative carriers move into the *P* region, positive carriers cross into the *N* region (a fact which will become important later on). For the moment, however, the main thing to remember is that the negative carriers (electrons) move through the diode and back into the battery. An ammeter placed in the circuit (Fig. 1-3) will indicate current is flowing.

The Nonconducting Diode

But let's suppose the same diode is connected to the same battery, except that the polarity is reversed as shown in Fig. 1-4. The negative electrons in the *N* section are now attracted by the charge at the positive terminal of the battery, and the

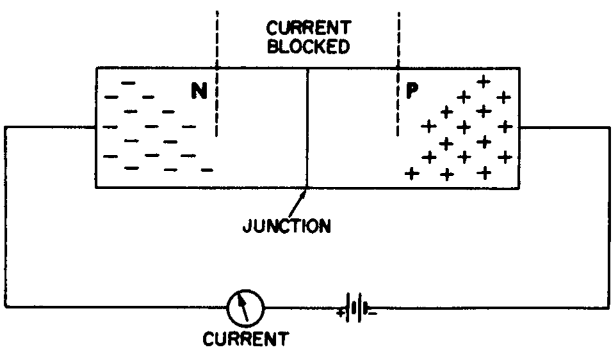


Fig. 1-4. Reversing the battery connections blocks the current through the diode.

positive current carriers in the *P* region are attracted by the charge at the negative terminal. The result is that both varieties of current carriers in the diode are pulled *away* from the junction, instead of toward it. This leaves no free carriers in the center of the diode; so this area again becomes an insulator, just as it was before the *N*- and *P*-forming materials were added to the pure crystal. The battery current is now blocked, and current flow ceases. Even if the battery voltage is increased, practically no current will flow. We say "practically" because a very minute "leakage" current does exist because of heat or moisture.

Ohmmeter Causes Diode Action

When an ohmmeter is placed across a diode, the resistance shown will be low or very high, depending on which way the leads are connected. The reason is that the ohmmeter is really just a milliammeter connected in series with a battery. (Fig. 1-5.)

The negative lead of the ohmmeter in Fig. 1-5A is connected to the *N* side and the positive lead to the *P* side of the diode. This forces *N* and *P* current carriers across the junction, creating a low internal resistance. Current from the ohmmeter battery can now flow through the circuit, and the meter indicates a fairly low resistance (usually under 1,000 ohms). This reading is actually a result of the current flow through the conducting diode and the meter, but the meter face is marked in ohms. In other words, a lower ohms reading indicates a greater current flow through the meter.

Now examine the circuit in Fig. 1-5B. The only difference between it and the one in Fig. 1-5A is that the ohmmeter has been turned so the positive lead is connected to the *N* side of the diode, and the negative lead to the *P* side. The polarity of the internal battery is such that the free current carriers are attracted away from the center of the diode. This creates an insulated area in the diode, making it void of all current carriers, both positive and negative. Battery current is now blocked; so nothing flows through the meter. The ohmmeter now reads a very high ohms value and theoretically would read infinite resistance, except that there is always a very slight leakage. This will be read as a high resistance value if the meter is sensitive enough.

So we have now proved that a diode can be made a high or a relative low resistance, depending on the polarity of the voltage connected to it. But what does this mean as far as a transistor is concerned? The answer will become evident very shortly.

(A) With negative terminal of ohmmeter connected to N-type material.

(B) With positive terminal of ohmmeter connected to N-type material.

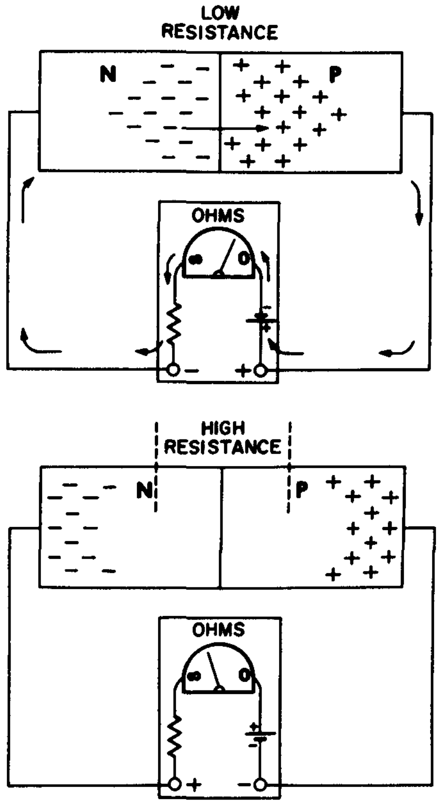


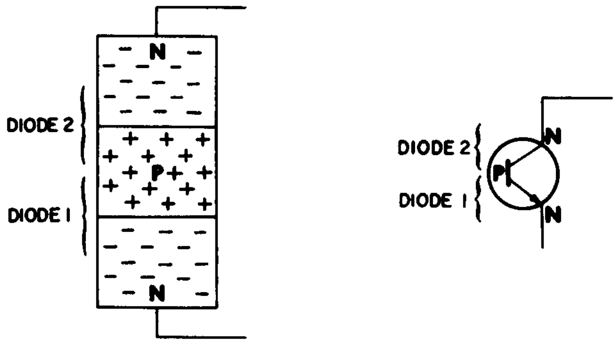
Fig. 1-5. Action of the carriers when an ohmmeter is connected across a diode.

The NPN Transistor

A curious and interesting effect occurs when three instead of two diode sections are placed together. Fig. 1-6A shows a *P*-type section, containing free positive current carriers, positioned between two *N*-type sections. Actually, two diodes have been formed—diode 1 and diode 2, both using a common *P* section in the middle. The schematic symbol for this arrangement is shown at the right in Fig. 1-6B.

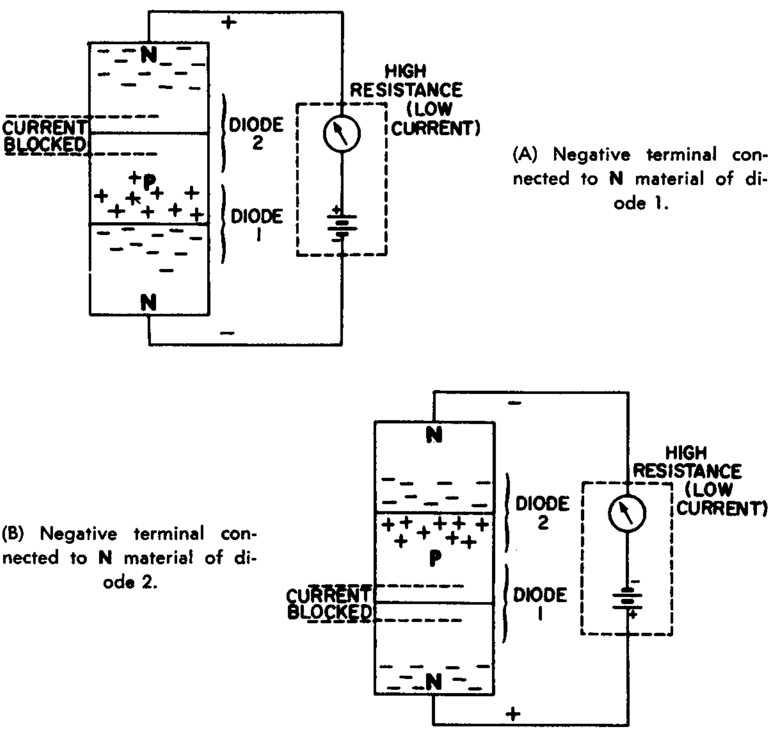
The first question that arises is, "What happens when a battery is connected across this structure?" Fig. 1-7A shows the battery connected in one direction, and Fig. 1-7B shows it connected in the other direction. Note that in both examples, one of the diodes is biased in the high-resistance direction, causing free current carriers to be pulled away from the junction and thus leaving a blank area which blocks the flow of current. The reason is that the positive pole of the battery is always connected to one of the *N* sections, attracting *minus* carriers toward the outside edge and away from the junction. This produces an insulated area.

If the battery and meter shown in Fig. 1-7 were both part of an ohmmeter, a similar action would take place. The cur-



(A) Equivalent diode structure. (B) Schematic symbol.

Fig. 1-6. The NPN transistor.



(A) Negative terminal connected to N material of diode 1.

(B) Negative terminal connected to N material of diode 2.

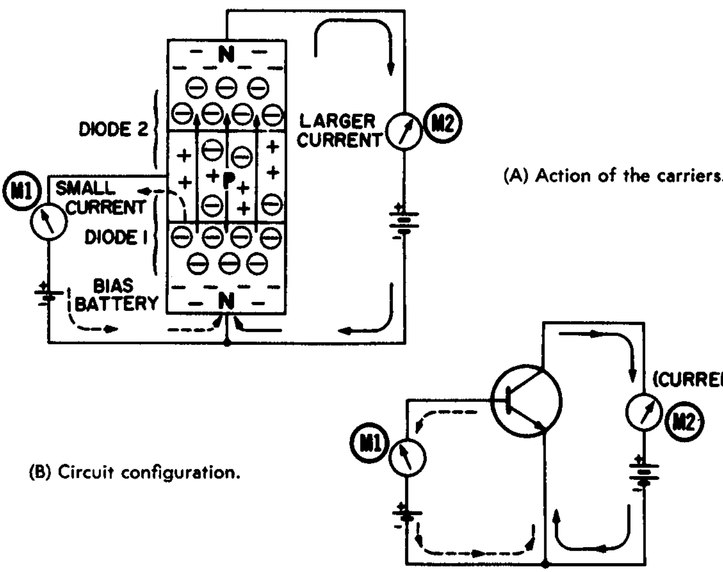
Fig. 1-7. Action of the carriers when a battery is connected across the NPN structure.

rent getting through the circuit would be quite small and the resistance would be fairly high. This is called the leakage resistance and is the basis for one of the transistor tests described in a later chapter.

The battery voltage in Fig. 1-7 can be increased to several volts and still very little current will flow. With increased battery voltage, however, there is a good source of current—but the blocked area must be unblocked before it can flow. The very simple method generally used to unblock the insulated area is the secret of transistor action.

Adding "Forward" Bias

The easiest way to make current flow through an area where there are no free current carriers is to send some current carriers into the area. This is done very simply in Fig. 1-8A.



(A) Action of the carriers.

(B) Circuit configuration.

Fig. 1-8. Forward biasing the NPN transistor.

A small voltage is connected across diode 1. The battery is connected so the polarity is in the forward, or low-resistance, direction (negative pole connected to the *N* material, and positive pole to the *P* material). This causes negative carriers to be pushed upward and into the *P* area. Most of these carriers will travel on through the narrow *P* area and enter the formerly blocked area. Once the carriers have filled the upper *N* area, the larger battery keeps them moving into the output circuit, as indicated by the current flow in meter M2 in Fig. 1-8A. The electrons continue to flow through the larger battery and back into the bottom *N* region, their point of origin.

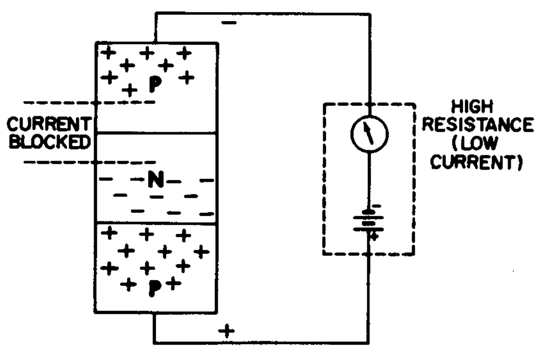
A very small current will also flow in the input circuit (see meter M1), but it is much less than the M2 current because the input voltage is less. The result is transistor current gain. This circuit is shown using a transistor symbol in Fig. 1-8B. There are several reasons why this NPN transistor has gain:

1. The *P* area is made much narrower than the *N* areas, allowing negative carriers to cross it easily once they are started.
2. The negative carriers are easily pushed out of the bottom *N* area because the small battery is connected across diode 1 in the forward, or low-resistance, direction—the direction which makes current flow easily.
3. The output battery being larger than the input battery, is able to draw more current once the transistor has been unblocked by the smaller battery.

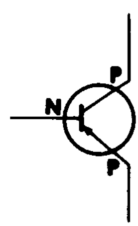
Variations of this circuit will be shown later, but this is the basic NPN circuit.

The PNP Transistor

The PNP transistor is similar to the NPN unit, except that the diode sections are arranged as shown in Fig. 1-9. An *N* section is sandwiched between two *P* sections, and the positive current carriers now become more important.



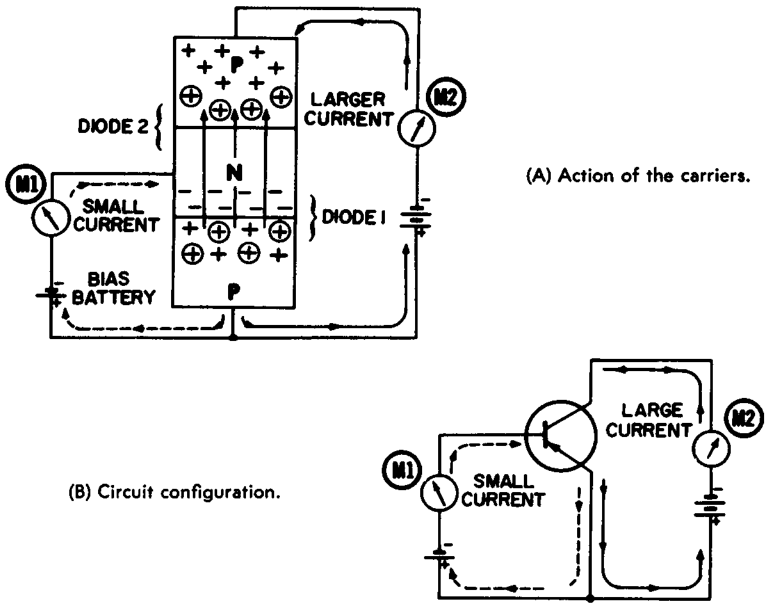
(A) Equivalent diode structure.



(B) Schematic symbol.

Fig. 1-9. The PNP transistor.

Again, regardless of which direction the battery is connected, one of the diodes will be biased in the high-resistance direction—that is, the positive carriers will be attracted away from the center, and battery current will be blocked. However, if a small battery is connected across diode 1 in the forward direction as shown in Fig. 1-10, that diode will start conducting slightly. (Notice that the positive battery terminal is connected to the *P* section and the negative terminal to the *N* section.) Even a small voltage in the forward direction will force positive current carriers out of the lower *P* section.



(A) Action of the carriers.

(B) Circuit configuration.

Fig. 1-10. Forward biasing the PNP transistor.

Most of the positive carriers pushed out of the lower *P* section travel upward and through the narrow *N* section. This means they will flood the upper *P* section and unblock the transistor. With current carriers available at all points in the transistor, the larger battery can now send its own current through the transistor and into the output circuit, as evidenced by meter M2.

As with the NPN transistor, the output current is larger than the input current because the voltage required in the input is extremely small. Since diode 1 is biased in the low-resistance direction, carriers are easily sent upward from the lower *P* area, even though the small battery may be only 0.1 or 0.2 of a volt. These carriers unblock diode 2 so current from the larger battery can flow through.

Since the diode sections were reversed to make the PNP transistor, the batteries were also turned around when they were connected to the PNP transistor. This is the reason the arrows depicting input and output current are reversed; electrons always leave the negative pole of a battery and enter the positive pole. The arrows show electron flow from the batteries.

Although it will be varied slightly later, this is the basic PNP circuit.

IDENTIFYING THE TRANSISTOR ELEMENTS

The bottom section of the input diode is called the *emitter* because it emits current carriers, very much like the cathode of a tube emits electrons. The opposite end of the transistor, to which the output circuit is usually connected, is known as the *collector* because it collects the carriers which come out of the emitter; this simulates the plate of a tube. The middle section is known as the *base* because, in the manufacture of the transistor, it is usually made first, forming a base for the other two elements. The base in some ways acts like the grid in a vacuum tube, in that it controls the flow of current through the transistor.

In some schematics the emitter, base, and collector are labeled *E, B,* and *C;* in others, no letters are used. The emitter always has an arrow; the base is in the middle; and the collector is always at the end opposite the emitter, but contains no arrow.

When the emitter arrow points toward the base, the transistor is a PNP unit; when it points away from the base, it is an NPN unit.

TRANSISTOR TYPES

In working with transistor equipment, it is important to know what types of transistors are used in the various circuits.

Practically all transistors in commercial equipment today are junction types—a description of how they are constructed, not how they are used in the circuit.

Fig. 1-11 shows several typical transistors and some of the functions each might perform in the circuit. The cases which house the lower-power types are usually either small rectangles or cylinders, whereas high-power types are usually found in larger diamond-shaped or circular cases.

The transistor type will usually determine the amount of output current it will handle under no-signal conditions. This current is called idling, or DC static current, because it represents the DC current drain of the transistor at rest, with no signal applied.

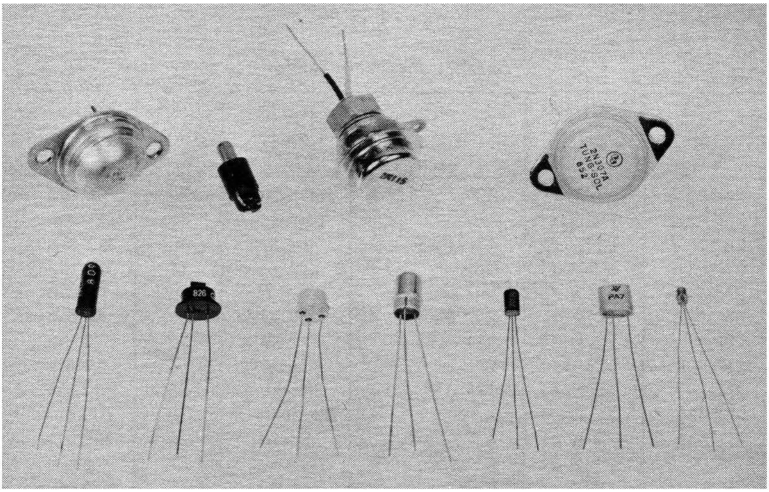


Fig. 1-11. Typical transistors.

The values in Table 1-1 are not maximum current ratings but typical operating currents for amplifiers. Maximum ratings are seldom used in actual practice, except in some missile or similar application where it is important to get everything possible out of the transistor. Switching circuits, where the transistor is alternately turned on and off, can utilize maximum ratings because the unit is allowed to rest or cool during a portion of each cycle.

TABLE 1-1.

Typical DC Idling Currents

Low-power RF-IF types	0.3 to 3.0 ma
Low or medium-power audio types ...	1.0 to 20.0 ma
High-power types	200 ma to 1.5 amps (Class A) 30 to 100 ma (Class AB) 3 to 20 ma (Class B)

Note in Table 1-2 that other important ratings are listed for transistors. These are maximum ratings, and do not represent typical circuit operating values. For example, the maximum ratings for power transistors are achieved by utilizing large heat sinks under special laboratory conditions, where the room temperature and other variables are carefully controlled. Trying to operate the same transistors at these ratings on the workbench could damage them permanently.

TABLE 1-2.

Absolute Maximum Ratings

Type No.	*Type**	*Use*	*Max. Power @25°C*	*Max.* V_{CB}	*Max.* I_C
2N109	PNP-G	AF	150 mw	25	70 ma.
2N168A	NPN-G	Conv.	65 mw	15	20 ma.
2N176	PNP-G	AF Pwr.	10 watts	40	3 amps.
2N194A	NPN-G	Conv.	50 mw	18	100 ma.
2N254	NPN-G	IF	65 mw	20	5 ma.
2N278†	PNP-G	AF Pwr.	55 watts	50	12 amps.
2N591	PNP-G	AF	50 mw	32	20 ma.
2N1638	PNP-G	IF	80 mw	34	10 ma.
2N1747	PNP-G	FM-IF	60 mw	20	50 ma.
2N2712	NPN-S	AF	200 mw	18	100 ma.
2N3241	NPN-S	AF	.5 watt	25	100 ma.
DS25	PNP-G	RF-Conv-IF	80 mw	32	5 ma.
2SA72	PNP-G	RF	55 mw	18	5 ma.

* G = Germanium S = Silicon † Replaced by DS-501 for Auto Radios

To learn how to interpret this type of chart, let's see how the various ratings are applied. The 2N109 in Table 1-2, for example, is a PNP germanium transistor (PNP-G). Some transistors are made of silicon instead of germanium, and those are designated "S." The 2N109 is used as an audio-frequency amplifier (AF), and has a maximum power dissipation rating of 150 milliwatts at room temperature (25° C). The voltage between collector and base (V_{CB}) must *never* exceed 25 volts, and the maximum current (I_C) rating is 70 milliamperes. This was one of the early audio amplifiers, but was typical of the many similar audio transistors which were developed later.

Transistors are seldom operated near their maximum ratings. For example, a typical collector voltage for the 2N109 when operating in most circuits would be 5-10 volts, instead of maximum rated voltage of 25 volts. The typical operating current would be about 1 milliampere, even though the maximum rating is shown as 70 ma. in the table.

Note that some transistors are only recommended for audio-frequency applications (AF), while others are called out for higher-frequency applications in radios (IF, converter, RF, etc.). Some rating tables list the actual frequency cut-off point in megacycles. This is the point where the gain of the transistor begins to decrease noticeably when used in a particular type of circuit, and the radio would be weak if the transistor were operated at higher frequencies.

Audio power transistors have much higher ratings than the smaller transistors, as can be seen by examining the 2N176 and 2N278 ratings in Table 1-2. Nevertheless, the same general rules hold true: in typical amplifier circuits, the maximum ratings are seldom used. Power transistors in audio-output stages seldom have more than 12 volts applied between emitter and collector, and they operate at approximately one ampere DC or less. The 2N176 would probably draw 400 to 500 milliamperes in a typical Class-A circuit, whereas the 2N278 or DS501 would draw about one ampere of collector current.

One reason for never operating transistors too near their maximum voltage ratings is that there will be audio-voltage peaks or "spikes" when an audio input signal is applied. This is especially true in the audio-output stage, where the signal has been amplified many times before it reaches that stage. The DC voltage supplied by the battery, plus the audio signal voltage, must never exceed the maximum rating of the transistor.

CHAPTER 2

Circuit Components and Their Functions

Circuit components such as coils, transformers, resistors, and capacitors are just as important to transistor as they are to vacuum-tube circuit operation. In fact, without coils or transformers, no signal could be tuned in or coupled from one circuit to another. Without resistors, voltages could not be stepped down and the current might exceed the transistor ratings. If capacitors were omitted, most circuits would become so unstable that oscillations, whistles, motorboating, and other noises would have a heyday.

It is a known fact that transistors generally do not fail as often as tubes. This places more importance on the other circuit components used with transistors. Instead of immediately suspecting a transistor when equipment failure occurs, we should ask ourselves, "I wonder if something has happened to one of the circuit components which is preventing a transistor from working properly?" Then, if checks indicate that the supporting components and connections *are* functioning as they are supposed to, the transistor itself can be suspected. Note that this is exactly opposite from the approach used in working with vacuum-tube equipment.

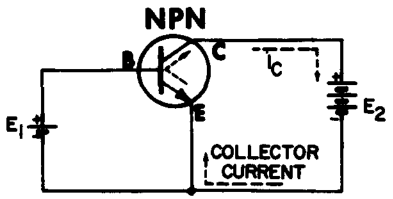
So, before we can quickly analyze the circuit in order to tell whether it is functioning properly, we must thoroughly understand the role of each component. In other words, the whole is only as good as its individual parts. So the parts will be our next subject of study.

The various components will be placed into our basic circuit, one at a time; then their effect on the circuit will be studied.

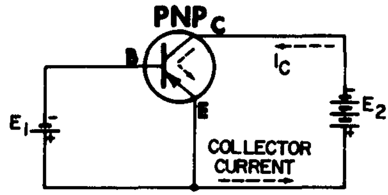
BASIC CIRCUIT LIMITATIONS

The basic transistor circuits in Fig. 2-1 must be modified somewhat to make them useful and safe for the transistor.

Without some form of current protection, the transistor current would tend to "run away," and may go far enough to ruin the transistors. The components which prevent this are known as *stabilizers* or *protection resistors.*



(A) NPN transistor circuit.



(B) PNP transistor circuit.

Fig. 2-1. The basic transistor circuits.

After the transistor current has been set and stabilized at the proper point (depending on the type of transistor), some method of adding the signal into the transistor circuit must be employed so it can be amplified.

Stabilizing Resistors

We know that the collector current (I_C) in Fig. 2-1 follows the path shown by the dotted lines. The amount of current which will flow for any given transistor depends on:

1. The amount of bias voltage E_1 (usually 0.1 to 0.3 volt).
2. The temperature inside the transistor.
3. The amount of voltage in collector battery E_2 (usually 3 to 12 volts).

The third item, collector voltage, has the least effect of all the variables. Temperature and bias voltage have the most effect; therefore, they must be carefully controlled.

Both bias voltage and temperature, when increased, produce a greater collector current. That is, when E_1 is increased, collector current will also increase; and when the temperature inside the transistor is increased, the collector current will again rise. So the thing which tells us we have too much bias voltage or too hot a temperature for our transistor is the collector current flowing in the output circuit. Any increase in collector current I_C above the normal operating point must be discouraged. The circuit components that check an increase in collector current are the stabilizers, which we are now going to discuss.

It is not practical to insert a meter in the output circuit of every stage and watch for excessive current, as shown in Fig. 2-2. However, we know that current flow in a circuit produces a voltage drop across any resistance inserted into the

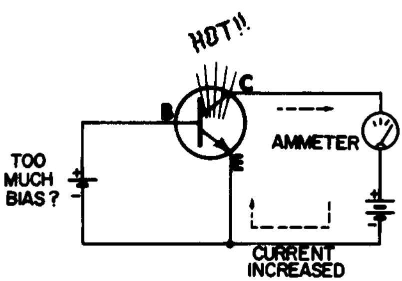
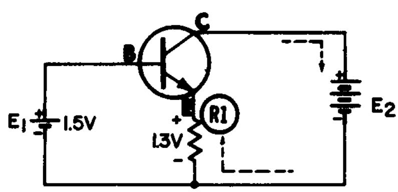


Fig. 2-2. Excessive collector current can ruin a transistor.

circuit. For instance, resistor R1 in Fig. 2-3 has been added in series with the transistor emitter. The path of collector current is then through the resistor, transistor, and battery, as shown by the dotted lines. Since it takes energy for the electrons to travel through resistor R1, a voltage drop appears across the resistor. The greater the current, the larger the voltage drop. (An easy way to remember the polarity of the voltage drop is that the resistor is always negative at the end where the electrons enter.)

We now have a measuring stick for collector current: The greater the current, the greater the number of electrons which

Fig. 2-3. A resistor in the emitter lead helps stabilize the collector current.



try to "push" their way through the resistor, and therefore, the greater the voltage drop across resistor R1. Note the effect of this voltage drop in Fig. 2-3. Let's assume that 1.3 volts are dropped across R1, and also that the bias battery has a value of 1.5 volts. Now, what is the actual bias voltage between the base and emitter of the transistor? It is 1.5 volts minus 1.3 volts, or 0.2 volt. The 1.3 volts across R1 actually bucks the voltage from battery E_1 and must therefore be subtracted from it.

The equivalent circuit is shown in Fig. 2-4. The voltage produced across R1 is shown as a battery; this is the way it actually appears to the transistor. Remember, however, that the voltage at R1 is not a battery voltage source, since the 1.3 volts change as the collector current changes. For example, if the collector current increases, the voltages at R1 will also

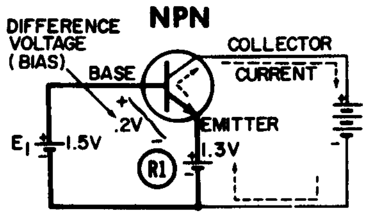


Fig. 2-4. Equivalent circuit of Fig. 2-3.

increase, maybe even to 1.4 volts. This would leave only 0.1 volt of bias, which would tend to "cool" the transistor and thus prevent any further increase in collector current. This is what is meant by collector-current stabilization.

Another way of stating it is this—as the collector current increases, the transistor temperature may also rise. But the increased collector current also produces, at R1, a greater "bucking" voltage which prevents further increases in current. This voltage also prevents a further increase in temperature by slowing down the flow of current through the transistor.

Next, refer to the PNP circuit in Fig. 2-5. Stabilization resistor R1 has been added. The only difference between this circuit and the one in Fig. 2-3 is that the battery polarities are

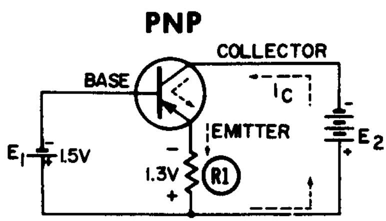


Fig. 2-5. Current flow through a basic PNP transistor circuit.

reversed, because of the PNP transistor connections. Electrons in Fig. 2-5 now flow out of the negative terminal of E_2, down through the transistor, through R1, and back into E_2, as shown by the dotted lines.

This means the polarity of the voltage produced across R1 is reversed, now being negative at the top and positive at the bottom. However, this voltage still bucks the one from battery E_1 because the positive end of E_1 is connected to the positive end of R1. The net result is that the actual voltage measured between base and emitter is still only 0.2 volt. This is clearly illustrated in the equivalent circuit in Fig. 2-6.

As the collector current and the temperature try to increase, the increased current produces, across R1, a greater "buck-

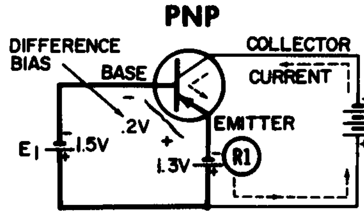


Fig. 2-6. Equivalent circuit of Fig. 2-5.

ing" voltage which reduces the 0.2 volt to a smaller net voltage, preventing any further increase. The PNP transistor is, therefore, current- and temperature-stabilized.

Other Stabilizing Tricks

A resistor in the emitter lead is the most widely used "stabilizer" because it is such a simple and efficient way to control the collector current at very little cost. But it is not the only method.

Some circuits also use a resistor in the collector lead (R2 in Fig. 2-7). Since the collector current also flows through this resistor, a voltage will be developed across it, in proportion to the amount of collector current flowing through it—the greater the current, the more the voltage drop. As a result, the voltage at the collector of the transistor is automatically adjusted with changes in current flow. A change in the collector voltage does not have too much effect on the collector current, although it

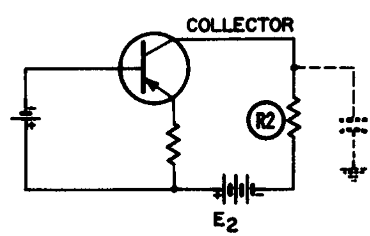


Fig. 2-7. A resistor in the collector lead will provide even better collector-current stability.

does help control the voltage to some extent. The collector resistor is very seldom used by itself, however; circuits which use it will probably also have an emitter resistor.

The collector resistor (R2) has another advantage. We sometimes find RF voltages floating around in the lead between the output circuit and the battery. This can cause oscillations and unwanted noises in a radio. Increasing the resistance in that lead makes these unwanted signals easier to capture and "shunt" to ground before they can reach the battery. This is the purpose of the bypass capacitor shown in dotted lines across resistor R2 in Fig. 2-7. This is often called a decoupling network.

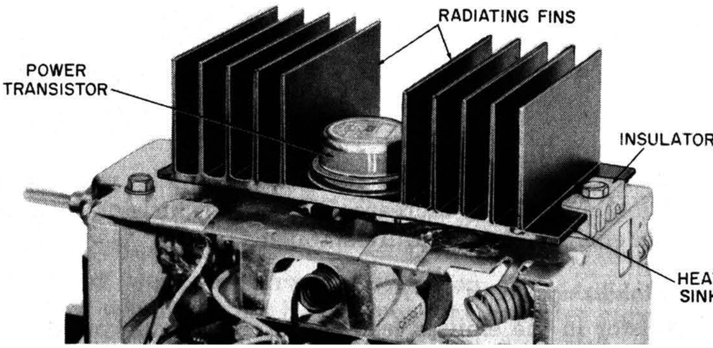


Fig. 2-8. Typical power transistor and heat sink used in an auto radio.

Another type of stabilizer is the heat sink (Fig. 2-8) or convector found in many high-power transistor circuits. The power transistor mounts on the heat sink, which is usually aluminum; the heat from the transistor flows into the metal and is then dissipated into the air. The heat sink thus prevents the concentrated heat from remaining in the transistor and destroying it. Also, since the flow of current through the transistor depends to a great extent on how hot the transistor is, the heat sink helps to keep the collector current at a safe value. Small transistors generally do not require heat sinks because their current and power requirements are usually very small, compared to the mode of operation of a power transistor.

Still another form of stabilizer, called a *thermistor,* is sometimes inserted in the base lead of a transistor circuit. The thermistor is a resistance which varies with temperature. (Its operation will be discussed later.)

ELIMINATING THE BIAS BATTERY

In early radios, old-timers will remember that three separate batteries were used—one for the filaments (called the *A* battery), one for the plate supply (called the *B* battery), and the third for grid bias (the *C* battery). In transistor circuits, the *A* battery is automatically eliminated because a transistor has no filament. The *B* battery, in the collector circuit of the transistor, is usually of a much smaller voltage than the *B* supply in most vacuum-tube circuits. The *C* battery is in the base circuit. As with the tube, we would like to eliminate this battery if at all possible.

Biasing By Voltage Divider

We know that a voltage source, such as a battery, is needed in the collector circuit of the transistor. So the ideal situation would be to tap some voltage from that battery and use it for the base-voltage requirements. But since actual battery taps are not practical, another method is generally used.

If several small batteries are connected in series, several voltages can be obtained by connecting between them. An example of this is shown in Fig. 2-9, where four 1.5-volt cells are connected in series to provide 6 volts for the collector. If the base happens to require exactly 1.5 volts, such a system might be used. But it is usually not too practical for several reasons. For one thing, the chances are pretty slim that the

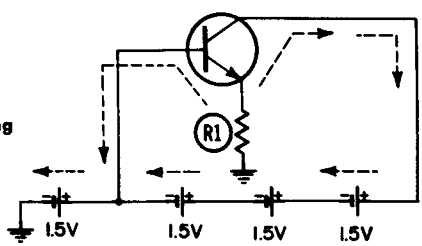
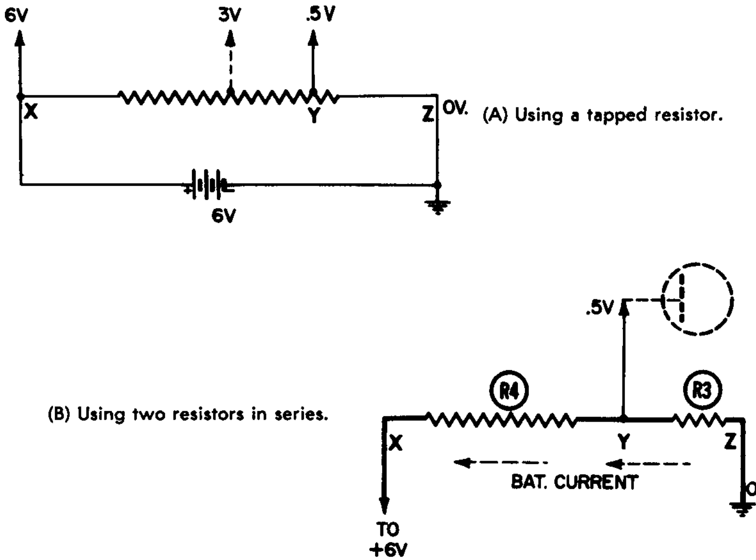


Fig. 2-9. A poor method of obtaining bias voltage.

transistor will need exactly that voltage on the base. Besides, other transistors in the radio will also need some form of bias, each of a different voltage. But even if all base leads could be tied into that point, there is still a disadvantage: One battery would have more current passing through it than the others.

There is one very simple method of getting exactly the right voltage for each transistor in the radio without using any extra batteries. In Fig. 2-10A, we see a 6-volt battery supply with a resistor connected across it. This resistor has several taps where different voltages are obtained. The midway tap has 3 volts on it because the resistance from there to the negative terminal is the same as it is to the positive terminal. The battery current will therefore produce the same voltage—3 volts —across each half.

By putting a tap near the ground end, we can obtain smaller voltages. For example, note that a tap is connected at the 0.5-volt point. Suppose we had a transistor circuit that required 0.5 volt on the base. The base could be connected near that point on the resistor, and the resistance measured between points x and y and y and z. The same resistance could



(A) Using a tapped resistor.

(B) Using two resistors in series.

Fig. 2-10. Obtaining bias voltage from a divider network.

be obtained from two fixed resistors (R3 and R4 in Fig. 2-10B). They could then be placed across the battery, instead of using the tapped resistor.

The resistance of R3 in Fig. 2-10B is much lower than that of R4, meaning that point y is electrically much closer to ground than to +6 volts. This is why there is only 0.5 volt at point y. In other words, as the battery current flows through R3 and R4, a much smaller voltage is produced, or "dropped," across little R3. So only 0.5 volt is found across R3; the balance of 5.5 volts is across R4 (measured between points x and y).

Connecting the Voltage Divider in a Circuit

We are now ready to connect the voltage divider into our transistor circuit. Remember that we are using the divider to replace the extra bias battery (the so-called C battery).

In Fig. 2-11A the voltage divider is connected into the stabilized transistor circuit previously studied. The same circuit using battery bias is shown in Fig. 2-11B. By the addition of two simple resistors, R3 and R4, we have eliminated the necessity of an extra battery for base voltage. R3 and R4 are merely connected across the 6-volt battery, and the point between them is connected to the transistor base.

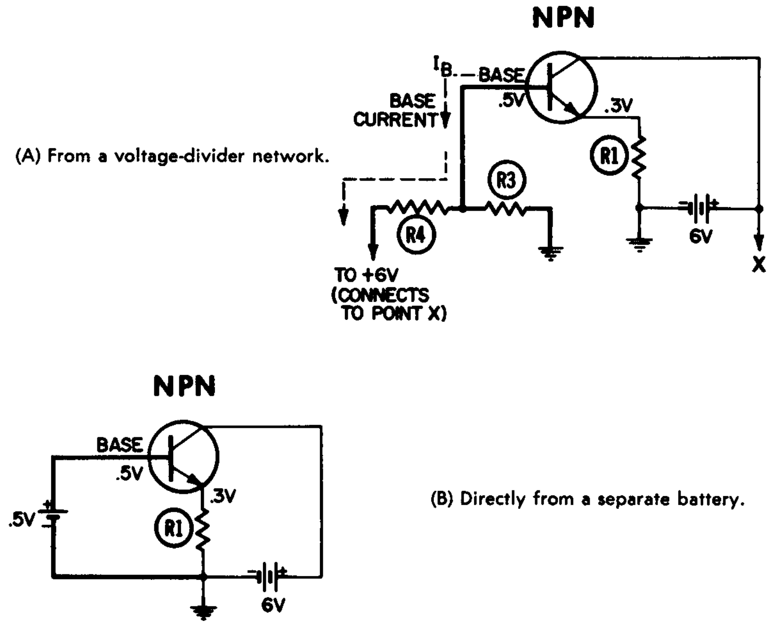


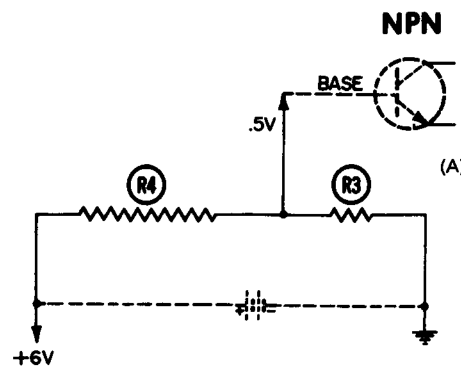
Fig. 2-11. Obtaining the bias voltage for an NPN transistor circuit.

When the voltage divider is actually connected into the transistor circuit (Fig. 2-11A), the 0.5 volt may change slightly. The reason is that the transistor will probably draw a small base current, which will have to flow through part of the voltage divider in the base circuit. For example, if some electrons from the transistor flow into the base lead (see the arrows in Fig. 2-11A), they will also flow through R4, toward the positive 6-volt battery terminal. This will cause a greater voltage drop across R4, and thus leave a little less voltage across R3. The values of R3 and R4 are calculated so the desired base voltage is produced when the transistor is connected to the voltage divider. These values depend on the transistor and how it is used. Some circuits even use a variable control to adjust the bias—but only when absolutely necessary, because a potentiometer costs considerably more than a fixed resistor.

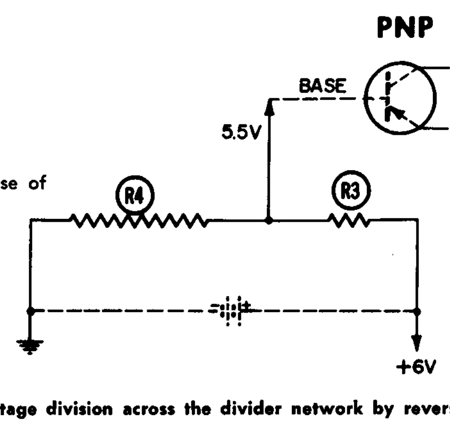
The Voltage Divider in a PNP Circuit

The same general principles can be applied to PNP circuits. In the PNP transistor, however, the voltage required for the base is slightly less than the most positive voltage in the circuit. This means if a 6-volt battery is used in the output circuit, the base voltage will usually be a little less than 6 volts (such as 5.5 volts, for example).

In Fig. 2-12, the base voltage for the PNP transistor is increased by turning the battery around. This puts the connec-



(A) Supplying 0.5 volt to the base of NPN transistor.



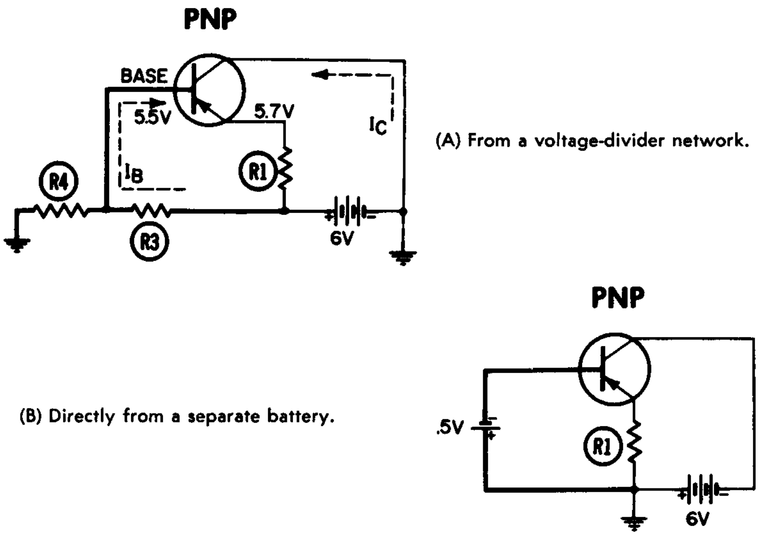
(B) Supplying 5.5 volts to the base of PNP transistor.

Fig. 2-12. Reproportioning the voltage division across the divider network by reversing the battery connections.

tion between resistors R3 and R4 at approximately 5.5 volts, because R3 has a much smaller resistance than R4. The exact base voltage, of course, can be varied for different transistors by using different values for R3 and R4. The new battery polarity is no problem because the collector battery is reversed in PNP circuits anyway.

Now let's connect the emitter and collector leads to complete the PNP circuit. This is done in Fig. 2-13A. Resistors R3 and R4 are connected across the 6-volt battery, but since R3 has the lesser resistance, the base voltage is fairly high. An easy way to see why it is relatively high is to think of the base-lead connection as a movable tap across resistors R3 and R4. As the base tap is moved to the right, it gets closer to the positive pole of the battery and so the voltage goes up.

The circuit in Fig. 2-13B looks much like the NPN circuit in Fig. 2-11B, except for one major change. The battery polar-



(A) From a voltage-divider network.

(B) Directly from a separate battery.

Fig. 2-13. Obtaining the bias voltage for a PNP transistor circuit.

ity is now reversed, so the negative terminal is connected to the collector lead, and the positive terminal to the emitter lead through resistor R1. The positive terminal also is connected to the base lead through resistor R3, making the base and emitter voltages more positive in the PNP circuit.

Summary of Biasing Action

Small currents in the base circuit are amplified by the transistor, producing a much larger current in the output (collector) circuit. The small current is started by applying to the base a voltage slightly different from the one on the emitter. This difference of potential produces an electric field which exerts a force or pull on the carriers in the emitter element of the transistor. The transistor then conducts, causing current to flow in the output circuit. This DC collector current (usually labeled I_C; see the arrows in Fig. 2-13A) does very little good, however, unless we have some way of utilizing it.

In other words, after the DC idling conditions have been set up, a method must be provided for inserting a signal into the input circuit, as well as capturing the amplified signal in the output circuit.

THE INPUT AND OUTPUT TRANSFORMERS

When injected in the base circuit, the signal will be added to the forward bias on one half-cycle and subtracted from it during the other half-cycle. When the signal is added, the output (collector) current will rise; and during the other half-cycle, it will drop.

To explain how the signal becomes larger in the output circuit, we will cite an example. Suppose the DC bias is adjusted so that 1 milliampere flows in the collector circuit, as shown in Fig. 2-14. If the transistor has a DC current gain of 10 (a very conservative figure), our base current would be 0.1 milliampere. (This would be the steady value of current before any signal is applied.) Assuming the maximum amount of signal were added before clipping occurs, the base current would then swing from 0.1 to 0.2 milliampere. In other words, the signal voltage would swing the base current to twice its idling value for a 100% increase, and then down to zero for a 100% decrease.

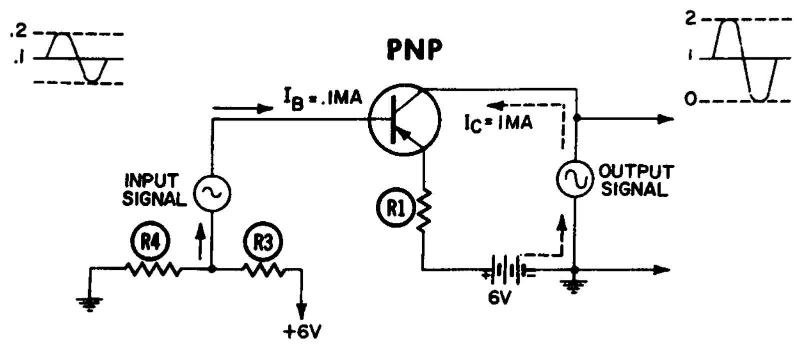


Fig. 2-14. How amplification is accomplished in a transistor circuit.

The collector current will also try to increase and decrease by about the same percentage. But a 100% increase in 1 ma makes the current go to 2 ma; and a decrease by the same amount will make it dip from 1 ma to zero. So, although both the output and the input currents change by the same percentage, the output signal is larger because it had a larger

DC value in the beginning. In other words, there was a signal gain in this stage.

Probably the most efficient method of inserting the signal into the DC circuit is by a transformer, as shown in Fig. 2-15. The reason is that the transformer also can be used as a matching device. The input diode of the transistor normally has a very low resistance because it is biased in the forward

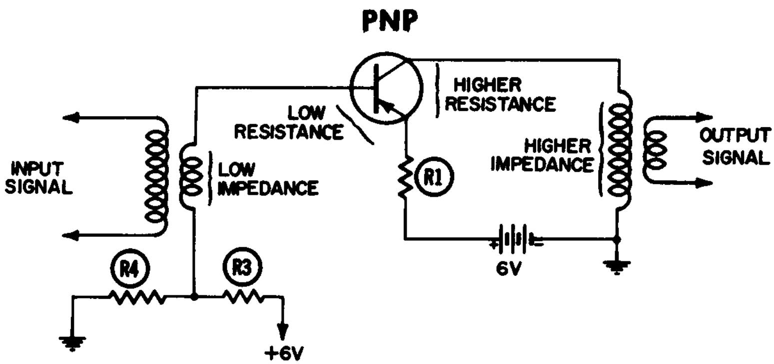


Fig. 2-15. Transformer method of coupling input signal to transistor stage.

(low-resistance) direction. On the other hand, the collector diode usually has a higher internal resistance. For maximum transfer of energy from the input transformer to the input of the transistor, a low-impedance winding is therefore desirable. For maximum energy transfer from the transistor output to the output load, a transformer which matches the transistor output impedance is desirable. The latter can be taken care of by using fewer turns in the base and more in the collector winding of the transformer.

Simple resistance coupling is more economical and, for this reason, is sometimes used despite a sacrifice in efficiency. Direct coupling, where an element of one transistor is connected to an element of the following transistor, is also used in some circuits. However, coupling by transformer is still the most popular.

After forming our basic DC circuits in the first chapter, we later found it necessary to add certain resistors to prevent the transistor from being ruined by excessive heating. Specifically, we added a stabilizing resistor in series with the emitter lead, explaining that sometimes one is also used in series with the collector lead. The latter resistor prevents excessive collector current, and therefore, excessive heating of the transistor.

Resistors, in the form of a voltage divider, were also added in the base circuit. By adjusting the resistor values, it was possible to obtain any desired base voltage, which in turn produced the proper bias and transistor collector current. This eliminated the necessity for a C battery in the base circuit.

Although these resistors serve the very important functions of setting up and controlling the DC or idling conditions, they actually become somewhat of an obstacle for the signal when it is coupled into the stage. This can be easily understood if one point is remembered: the signal merely causes fluctuations in the DC idling current which was flowing before any signal was added. Then doesn't it stand to reason that if the idling current produces certain voltage drops across the resistors in the circuit, the signal current will also produce voltage drops across the resistors? In other words, as the signal tries to increase the idling current, the voltage drops will also increase, and vice versa.

Let's take an example. Fig. 2-16 shows the basic NPN transistor amplifier circuit, with stabilizing resistor R1, collector resistor R2, and bias resistors R3 and R4. Also shown (by arrows) are the paths taken by the base- and collector-current electrons. Now what happens when the signal is fed in across the input transformer? During one half-cycle (the positive

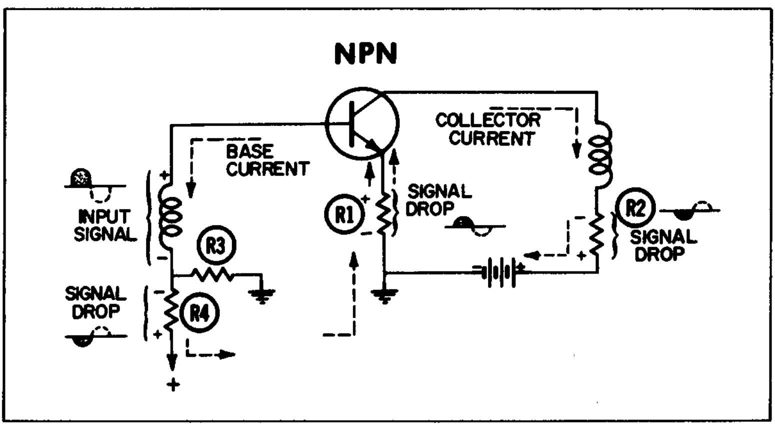


Fig. 2-16. Points where degeneration occur in the basic NPN transistor circuit.

half here), the base current will go up because the signal voltage increases the base bias. As the base current rises, so does the drop across resistors R4 and R1 in the base-current path.

This causes an increase in the voltage drop across these resistors. If these voltage drops are considered as small batteries placed in the circuit, will they oppose the input signal voltage or add to it? They will oppose, or buck, the signal and thus cause a loss of signal voltage reaching the transistor.

The same is true of the resistors in the path of the collector current. Remember, however, that collector current also flows through R1. So R1 actually gets a double dose of voltage drop —most of which is caused by the collector current, since it is much larger than the base current. This effect is sometimes referred to as *signal degeneration*, or simply *degeneration*.

How is degeneration combated? One way is by adding bypass capacitors across the points of signal drop. This has been done in Fig. 2-17. The capacitors are large enough to hold their charge so the signal does not produce any voltage drop across

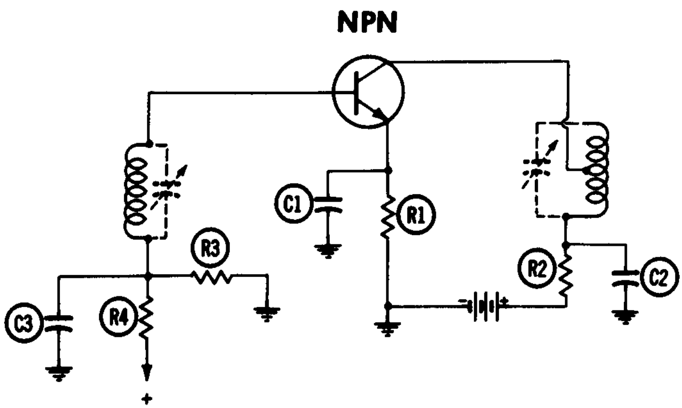


Fig. 2-17. Using bypass capacitors to prevent degeneration.

the resistors. The voltage drops established by the DC idling currents are held steady. Another way of stating this is to say the signal is "bypassed" around the resistors. This lets all the signal be applied between the transistor base and emitter, where it can be amplified without getting lost in the circuit resistors.

These capacitors serve another useful purpose: they prevent stray signals from floating around in the various leads. These wandering signals could easily cause oscillations, resulting in unwanted whistles, motorboating, or squeals.

A TYPICAL AMPLIFIER STAGE

The circuit just covered (Fig. 2-17) is a typical amplifier stage. If it is to amplify RF or IF signals, the coupling transformers in the input and output circuits will be RF or IF tuned circuits. The circuits will probably use capacitors to tune them to the proper frequency (as shown in dotted lines), and possibly, adjustable iron cores or slugs. When tuned to a specific frequency, these coils become a very high impedance as parallel tuned circuits at resonance. It may therefore be necessary to tap down on the coil for the collector lead (as shown in Fig. 2-17) in order to match the moderate output impedance of the transistor.

If the untuned input and output transformers were used in the circuit in Fig. 2-17, it would resemble an audio-amplifier stage.

Capacitor and resistor values will vary, depending on the type of transistor, the frequency of the signal being amplified (RF, IF, or audio), and the battery voltage. This circuit could be turned into a PNP one by simply changing the transistor and reversing the battery. If the new transistor has different ratings from those of the NPN transistor, there may have to be some component value changes, too, of course.

Adding Variable Bias (AGC) to Amplifiers

When the bias on an amplifier stage is changed automatically as the strength of the incoming signal changes, we call this *AGC* (automatic gain control).

There is really no mystery about AGC. It is indeed very simple. Assume we want to apply AGC to our sample amplifier circuit. All we have to do is find some way of changing either the base or the emitter voltage as the strength of the incoming signal changes. One way is shown in Fig. 2-18.

Fig. 2-17 differs from Fig. 2-18 in one respect: instead of being tied directly to ground, R3 in the base circuit goes through the volume control first. This causes the base bias to change in step with the signal strength because the DC voltage across the volume control also changes.

As the signal gets stronger, a larger voltage is developed across the IF output coil. This causes the detector diode to conduct harder and thereby send more current through the volume control. The diode can conduct in only one direction; so electrons are sent down through the volume control. This current flow produces a negative voltage at the top of the volume control, which is connected to resistor R3. As a result, the base voltage becomes less positive. (It will probably never go negative because the voltage at the bottom of resistor R4 keeps it positive.) Strong stations will cause the base voltage to dip and thus adjust the bias on the transistor to the strength of each incoming signal.

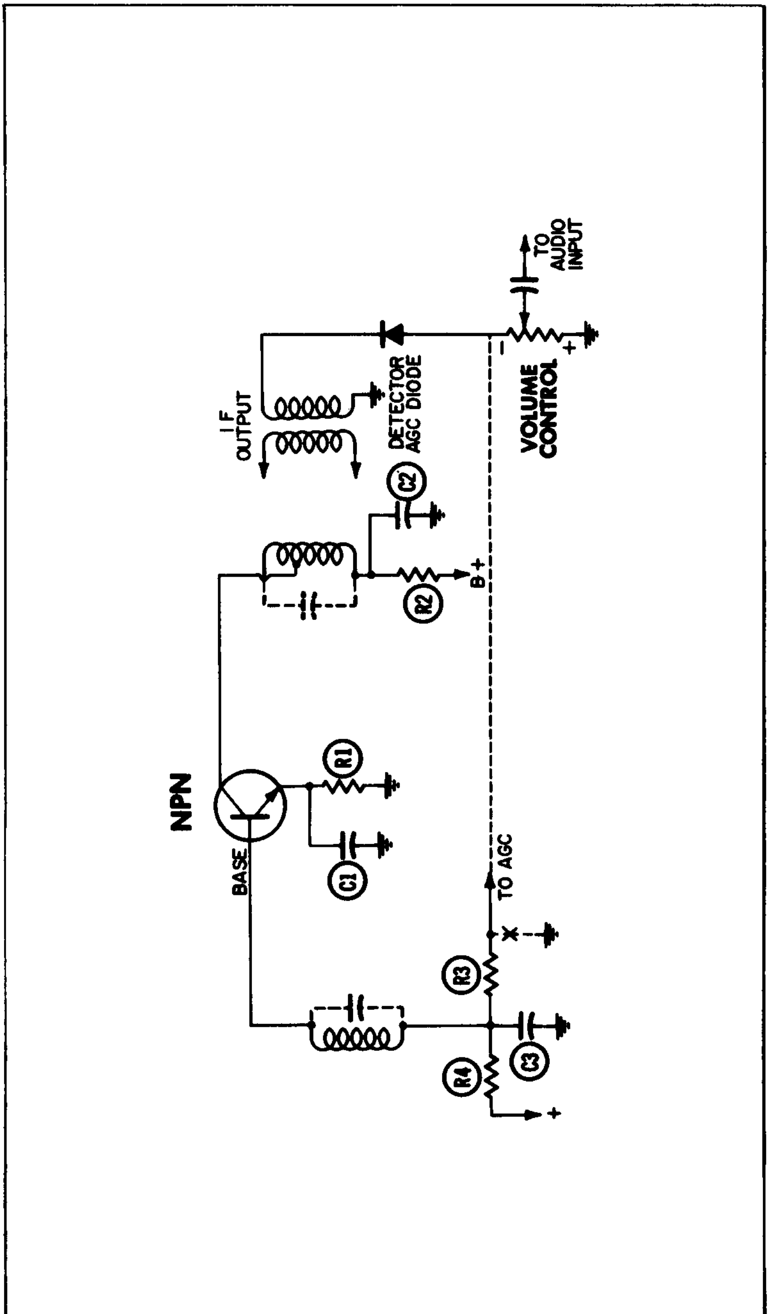


Fig. 2-18. An AGC-controlled transistor circuit.

The volume control is not always used for the source of AGC voltage (although it is a convenient point). In some circuits, a separate AGC resistor and diode are employed.

AGC can be applied to PNP amplifiers in a similar manner. It is sometimes connected to the emitter instead of the base circuit. The major reasons for the AGC system are to prevent overloading and distortion on strong signals, as well as excessive signal fading.

FEEDBACK FOR OSCILLATORS

It is sometimes necessary to make a stage oscillate. This is true in converter circuits, where a signal is needed which will combine with the one from the incoming station to produce

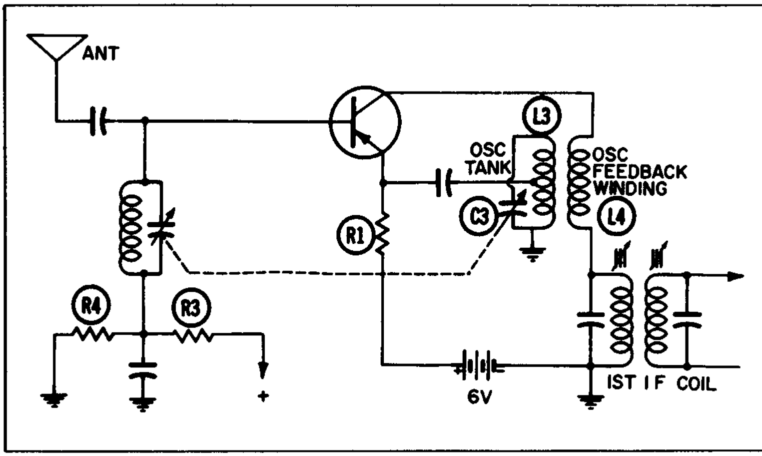


Fig. 2-19. A transistor oscillator circuit.

the IF signal. This is the function of an oscillator—to produce an AC signal.

In Fig. 2-19, two items have been added to our basic transistor circuit—oscillator coil L3 and feedback winding L4. Otherwise, it is almost identical to an amplifier circuit.

When the battery is connected, the first surge of collector current shocks oscillator tank circuit L3-C3 into the normal flywheel type of oscillation. The oscillations are replenished during each cycle by regenerations (this is the purpose of the feedback winding). Some of the oscillator-coil voltage is thus coupled back into the input circuit in phase, in order to give the oscillator tank circuit a boost of replenishing energy exactly when needed. The feedback coil may be in either the base or emitter lead, as in Fig. 2-19. Nevertheless, the feedback voltage gets into the input circuit, between the base and emitter, where it can be amplified and sent back into the collector circuit at just the right instant. Oscillations are thus maintained, and a signal is generated at a frequency determined by the oscillator tuned circuits.

Practical methods of determining whether or not a transistor oscillator is functioning are covered in a later chapter.

CHAPTER 3

Learning to Troubleshoot AM Transistor Radios

It is now time to roll up our sleeves and take a good look at some all-transistor radios. Two important steps are behind us—knowing how transistors work, and being familiar with the function of the various components used with them.

This knowledge will now be applied by studying actual radios, since it is good operating procedure to know the type of circuit before tackling it. This is no different from the driver of an automobile who wants to see a road map before starting out on a trip to an unfamiliar place. Several aids will help the electronics technician map the best course:

1. Information printed on the radio, including model and serial numbers, and any special instructions or parts layout charts.
2. Service manuals and schematics.
3. Previous experience with the same model.

A quick review of the schematic is usually helpful, even though similar models may have been encountered in the past. This allows you to collect your thoughts before diving blindly ahead, and will usually save time in the long run. After becoming familiar with transistor schematics, it will take you only a few seconds to size up a radio by glancing at the schematic. These few seconds can save you many valuable minutes later.

After checking the batteries and glancing at the schematic to familiarize yourself with it, you will be ready to isolate the trouble to a stage. The mechanics of doing this—of pinning the trouble down to one stage or section—will be the major topic of this chapter. The chapter will begin, however, with some practice in schematic familiarization, since it plays such an important role in helping you isolate troubles efficiently.

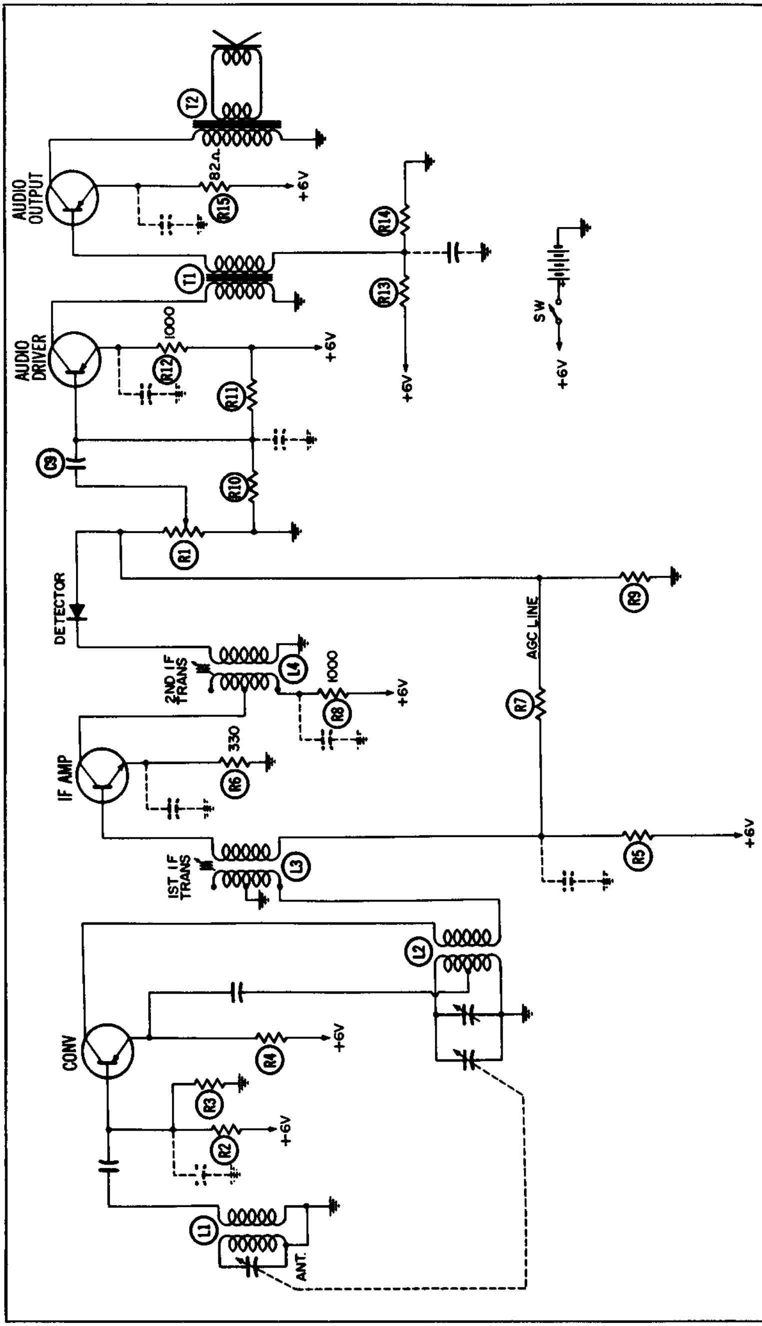


Fig. 3-1. Schematic of a typical AM transistor radio.

SCHEMATIC FAMILIARIZATION

The experienced technician can glance at a schematic and, in a few seconds, plan his whole trouble shooting approach. To demonstrate this, let us examine the schematic in Fig. 3-1, in an effort to learn the greatest number of facts about the radio in the shortest possible time.

Two steps always precede a study of the schematic—listening to the radio and checking the battery voltage. From the schematic in Fig. 3-1, we learn there are four transistor stages —a converter, an IF, and two audio. Three of the transistor emitter arrows point toward the base and one points away from it, indicating there are three PNP transistors and one NPN transistor, the latter in the IF stage.

From the very beginning, we mentally divide the radio into five stages, each with a distinct job to do. These jobs are:

Converter	Changes the incoming signal from RF to IF.
IF Amp	Amplifies, or builds up, the IF signal.
Detector	Removes the IF and brings out the audio (accomplished by a diode, M2).
Audio Driver	Amplifies the audio received from the detector.
Audio Output	Builds up the audio still further until it can drive the speaker.

The power supply, which consists of batteries totaling 6 volts, could be considered a sixth stage. So the whole radio actually becomes a series of blocks, each one representing a stage as shown in Fig. 3-2. Our trouble will first be isolated

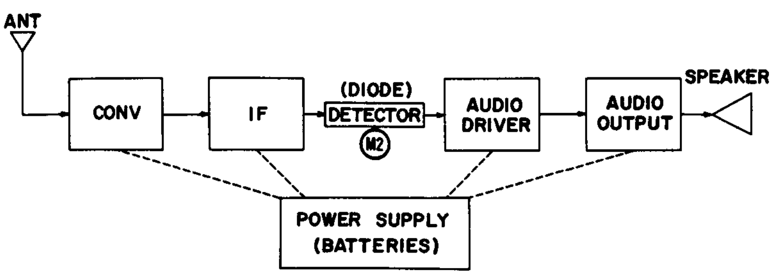


Fig. 3-2. Block diagram of the receiver in Fig. 3-1.

to one of these stages and then pinpointed to a defective part or connection within that stage.

Most of the bypass and filter capacitors in Fig. 3-1 are shown in dotted lines to indicate they should be more or less overlooked when the schematic is first viewed. On the other hand, the parts which set up the DC *idling conditions* should be noted. This is the way the individual transistor circuits were progressively constructed before.

For example, a quick glance at Fig. 3-1 tells us all transistors have a resistor in their emitter leads for current stabilization. The converter has R4, the IF stage has R6, the audio driver has R12, and R15 is in the emitter lead of the audio output.

Base bias is provided by a voltage divider across the battery supply. In addition, the IF amplifier provides some AGC voltage. The following voltage-divider resistors provide bias in each stage:

Converter	R2 and R3
IF Amplifier	R5, R7, and R9, plus a connection to volume control R1
Audio Driver	R10 and R11
Audio Output	R13 and R14

Also in series with each base lead is a transformer winding to couple the signal into the input of each stage, (except the audio driver). The signal is coupled from the detector to the audio driver by means of a resistor-capacitor coupling network consisting of volume control R1 and coupling capacitor C9.

How about the collector lead of each transistor? We know the collector of an NPN transistor must go to the positive terminal of the battery, just as the plate of a vacuum tube is connected to a positive voltage. Conversely, the collector of a PNP transistor must go to the negative battery terminal. This checks out for the schematic in Fig. 3-1, where the collector lead of the NPN IF amplifier terminates at the +6-volt terminal, whereas the collector of all other stages returns to −6 volts via ground. (In this radio, the negative battery terminal is grounded. In others, however, the positive terminal may be grounded.)

A transformer, in series with each collector lead, couples the signal into the following stage or to the speaker. The converter has two transformer windings in its collector lead, one being a feedback winding, L2, for the oscillator tank circuit, and the other a primary winding, L3, for the IF coil.

It is not important to note the value of the various parts at this time, but only to get an over-all picture of the circuit to assist you in mapping out the best troubleshooting approach. For example, questions to be answered are:

Does the radio have an RF amplifier stage between the antenna and the converter? . . . This one does not.

Does the radio have one—or two—IF amplifier stages? . . . This one has only one.

Does the radio use a diode detector? Or a transistor detector? . . . This one uses a diode.

Does the radio have an audio driver stage? . . . This one does.

Does the radio have single-ended or push-pull output? . . . This one has a single-ended output stage.

Are the circuits conventional in design? . . . Yes, they closely follow the basic amplifier and converter circuits discussed in Chapter 2.

Is the signal fed into the base of each transistor and sent out from the collector circuit? . . . Yes, it is.

Does the radio use a negative or a positive ground? . . . This one uses a negative ground.

Once these questions have been answered, it is time to isolate the trouble to a stage.

CHECKING THE POWER SUPPLY

The power supply of the receiver in Fig. 3-1 consists of four penlight batteries which provide a total potential of 6 volts, plus some filter capacitors. This is the rating of four brand-new batteries under a no-load condition. With the radio turned on, the voltage should not drop below 5.4 volts, which represents a 10% decrease. This allows for a certain amount of aging, plus some voltage decrease due to current going through the batteries under the radio load. Fig. 3-3 shows

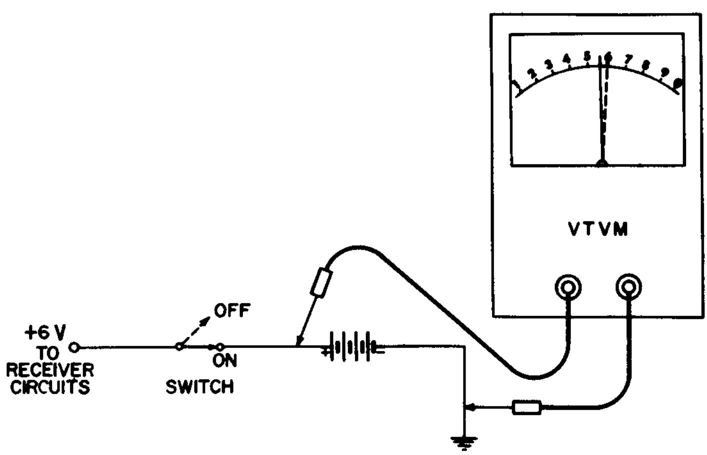
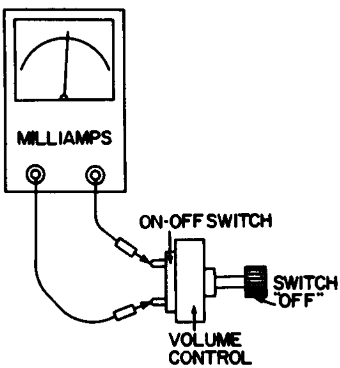


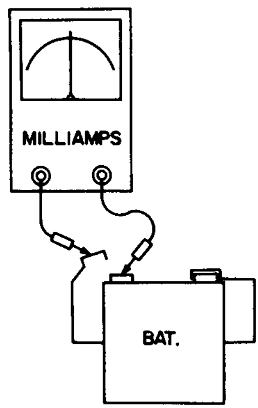
Fig. 3-3. Checking the battery voltage under load and no-load conditions.

the battery voltage readings with and without the receiver turned on. Incidentally, mercury batteries do not put out the same voltage as standard flashlight batteries. They usually run about 1.3 volts apiece. So four of them would measure about 5.2 volts. However, they hold their voltage much longer and steadier. For this reason, we become suspicious of more than a 5% decrease in their ratings. This means the voltage should not drop below 4.9 or 5.0 volts when mercury batteries are used.

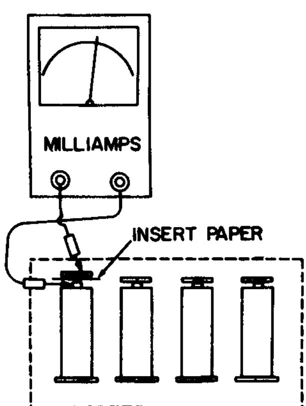
Even if the batteries are normal, there could still be trouble in the power-supply system—especially if the radio is motor-boating, squealing, rumbling, or whistling, or if the current drain through the batteries is above normal. The noises could indicate an open electrolytic filter capacitor on the battery



(A) At the on-off switch.



(B) At a clip-on battery terminal.



(C) With cells connected in series.

Fig. 3-4. Measuring the battery current.

line, and the high current drain, probably a shorted one. The best check for an open electrolytic is to shunt a new one across it and listen for improved performance.

Fig. 3-4 shows three ways of checking the battery current. One is to place a milliammeter across the On-Off switch (Fig. 3-4A) while the switch is off. However, this is not always easy to do because its terminals may not be readily accessible. If the battery is a one-piece unit instead of penlight cells, it will usually have clips which snap on to the top. Simply remove one of them and insert a milliammeter between the detached clip and its terminal (Fig. 3-4B).

Then turn the radio on and note the current drain. If the batteries are penlight cells mounted in clips, simply insert a piece of paper between one end of any cell and its clip. Then turn the radio on and measure the current from the insulated battery terminal to its clip (Fig. 3-4C).

The milliammeter should alway be inserted in series with the batteries so it measures the current the radio draws from them. A drain of several times normal indicates a short on the battery line or in the electrolytic capacitor. Normal values are usually given in the service information. If not, an estimate can be made. Some of the larger table-model portables may draw up to 15-25 milliamperes. Most portables, however, are in the 4-15 milliampere range. Readings are always taken with no signal entering the radio and the volume control at minimum, because loud audio will increase the drain. This point should also be realized so you can answer the customer who asks, "Why do Mrs. Smith's batteries last longer than mine?" If the current drain is not excessive, your customer may be playing the radio too loudly. This is more noticeable in radios with push-pull output, since the output transistors are biased primarily by the input signal—the louder the input signal, the larger the bias voltage.

Current drain, unless quite excessive, should not be a source of concern. There are cases where several variables, including the idling currents of the various transistors, may make a 25 percent increase or decrease from the normal rated current not excessive at all. Separate power supplies, called battery eliminators, are quite handy for testing portable radios. They usually contain a milliammeter as well as a voltmeter so that current is constantly monitored.

STAGE ISOLATION METHODS

Assuming the battery voltage and current are fairly normal and there are no undesirable noises in the radio, the batteries and battery-line electrolytics can be considered in good shape. The next step is to find out what stage or section of the radio is not operating properly.

The methods most commonly used to localize trouble in a radio circuit are signal injection, signal tracing, and personal observation. The simplest and most convenient method—personally observing and listening to the radio—is probably the most neglected of all. The proper use of test equipment to inject or trace signals in a radio is extremely valuable to know, but should never be used until the radio has been given expert personal observation. Then if the trouble is not localized, test equipment is brought into action without delay. The test equipment (such as signal generators and signal tracers) is used on transistor radios in much the same manner as on vacuum-tube radios. However, there are some tricks which will not only save a lot of time, but also prevent serious errors in localizing the trouble spots.

Isolation by Personal Observation

Most of us have two very valuable pieces of "test equipment" that are always with us and cost us nothing. These are our eyes and ears—a most precious gift which, properly used, can become your best detective and greatest timesaver.

Can you imagine how difficult it would be to try to describe, by words alone, what the inside of a radio looks like to someone who had never seen one? One glance, according to a Chinese proverb, would be worth 10,000 words to that individual. Or think how hard it would be to explain what music sounds like to a deaf person. Ten seconds of sound would be worth 10 million words. Yet we are sometimes prone to dive into a radio without giving it those few precious seconds of personal observation.

Listening Checks

What might the technician in Fig. 3-5 learn by holding the portable to his ear? First of all, he will find out what the radio really sounds like, instead of relying solely on the customer's word description of it. This does not mean the customer's description should not be obtained, because the radio may not act the same at all times. But word descriptions should always be followed by a careful listening test, which may bring out defects the customer was not even aware of. An example of this would be when a customer complains his radio is weak, but had not noticed that it is also distorted, or perhaps that the volume control is scratchy when moved. Customer approval for the repair of all these defects would be desirable, because it will mean better customer satisfaction and more profit for you.

Some transistor radios have a "thump" (or "pop") loud enough to be heard when the speaker is held to the ear and

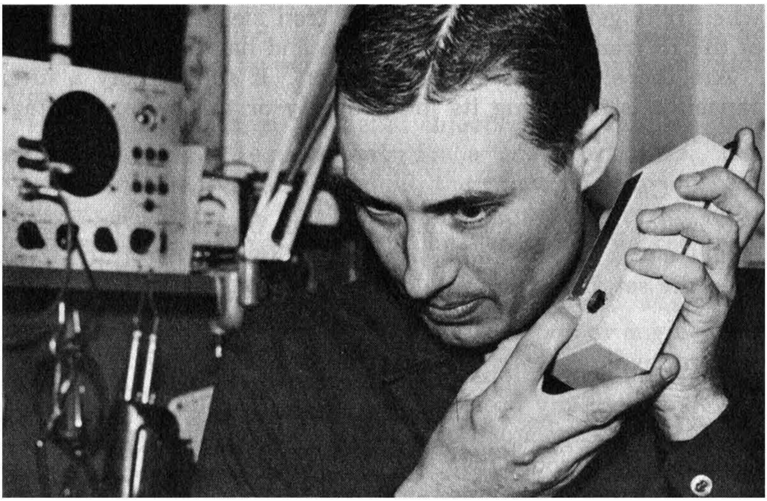


Fig. 3-5. Listening to the receiver can often give a clue to the trouble.

the radio turned on and off. The "thump" indicates the speaker and output stage are working. (This is not true in all portables, however.) It occurs because transistors require no warm-up time, but are ready to start conducting the instant voltage is applied. Enough current is sent through the speaker to cause a slight noise when the switch is turned off or on (although it may not be heard with some circuit designs or in noisy rooms).

What else can be learned by listening to the radio? In many transistor radios, a small "hiss" is produced by the transistors in the front-end of the radio (RF or converter stage). If there are IF and audio-amplifier stages, this "hiss" may be heard in the speaker when the volume control is turned all the way up. Since the "hiss" requires considerable amplification before it can be heard in the speaker, the presence of a normal amount usually means all amplifiers are working. If so, the trouble may be due to a defective oscillator or antenna—items which would not affect the normal hiss level. An extra loud hiss, however, may be due to a defective transistor.

Jarring or shaking the radio while listening to it will often show up intermittents. The best practice is to carefully remove the covers and try to keep the radio inoperative long enough to locate the trouble. If the radio starts playing again before the covers are removed, tapping at various points will probably make it cut out again later.

If the radio operates in one position but suddenly quits when it is gently turned over, an iron sleeve or core in one of the IF transformers may be loose and has changed position.

Are there whistles on each station? If so, possibly a filter capacitor is not doing its job properly or the battery voltage is low.

Visual Checks

Now for some of the things that can be learned by a good *visual check* of the radio. As the technician carefully looks over the set, here are some of the questions he will be asking himself:

Are all connections good?

Are there any breaks in the printed circuits?

Do any capacitors or batteries show signs of having leaked or corroded?

Are any parts charred or burned?

Is the radio case cracked or dirty?

Is the dial calibration reasonably accurate; if not, possibly the oscillator alignment has been tampered with, or the dial indicator has slipped?

Are there any loose solder chips, pieces of wire, or screws which could cause a short?

Are there any metal chips lying on the speaker cone which could cause speaker buzz?

Is the speaker cone torn or damaged?

The sight and sound checks mentioned in this chapter would probably lead to the discovery of at least 25%, and possibly more, of all the troubles encountered. They require the easiest-to-use and most readily available test equipment—our eyes and ears. Their proper employment can help us not only locate troubles in a direct manner, but also form the strategy for the other tests to follow.

Isolation by Signal Injection

If personal observation for visible and audible symptoms does not uncover the defect, signal injection is one of the best means of isolating the trouble to a stage or small area of the radio. This applies when the radio is dead or weak and the battery checks outlined previously are perfectly normal.

Signal injection (also known as signal substitution) means to insert test signals at various points and compare the results with those which would be expected from a good radio of the same type. The test signals are amplified by the stages being tested in the radio, provided the stages are working properly. They are then picked up at the speaker, where they can be heard and checked by ear, or even viewed on an output meter if desired.

From our definition of signal injection, we can see that there are several requirements for a good test. First, test signals must be available. Second, the proper points to insert them must be known; and third, the approximate result to be expected from a normal radio of that type should be known so deviations from normal can be easily recognized.

Signal generators which generate RF, IF, and audio test signals are found in every modern service shop or engineering laboratory. Except for tube or transistor testers and voltmeters, they are probably the most popular commercial test instrument. Fig. 3-6 shows a generator being used to send a signal into the audio stages of a transistor radio.

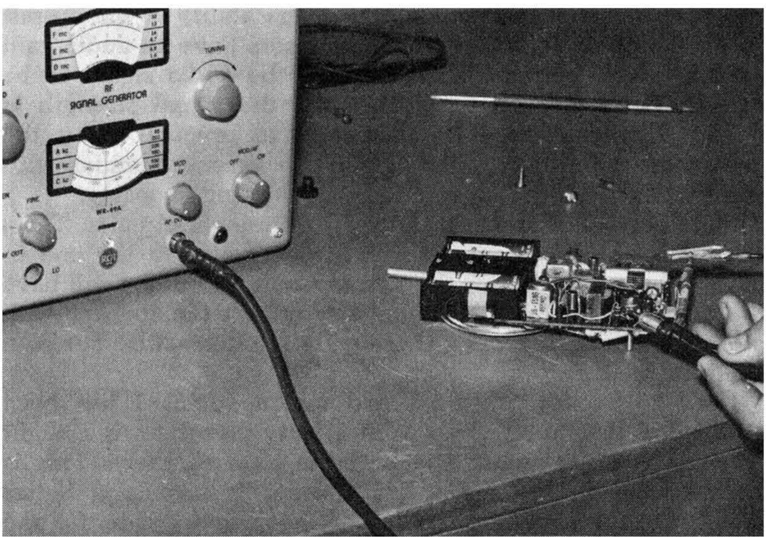


Fig. 3-6. Injecting a signal into the audio stages of a transistor radio.

There are other means of sending test signals into the radio. These include noise generators and circuit-disturbance "click" tests, which will be covered in detail later. Although very convenient, these tests have certain limitations which must be realized when they are used.

Signal-Generator Test Points

The user of the signal generator thinks in terms of blocks and simplified schematics. He sees the basic circuit of the stages being checked at the time, but only visualizes the blocks for the remaining ones. For example, in Fig. 3-7 the signal is first inserted at the input, or base, of the audio-output transistor (point 1). Most signal generators send out a 400-cycle audio note, which would be sent into the output transistor through the test probe. Normally, of course, audio from radio stations would be sent to this point by the audio driver stage. But during our test, we are substituting the signal generator for the regular audio signal to determine if the audio-output stage is working. If the trouble is in another stage, the signal generator will be heard on the speaker—indicating the output stage is doing its job. However, if the trouble is in the audio-output stage, the signal at point 1 will not be heard in the speaker, or else will be weaker than normal.

From this discussion, we see that there are two factors which will determine how loud the signal will sound when injected at point 1 in Fig. 3-7. They are the strength of the signal from the signal generator and the ability of the output stage to amplify it. Most signal generators have an audio gain control which allows the strength of the audio signal to be varied. (In some simpler generators, the signal strength is fixed.) Nevertheless, it is important to practice using the generator on various radios so you can become familiar with the results obtained when a stage is working properly.

Most portable radios use fairly conventional circuits. Thus, the output stage of one radio will be similar to the one in many others. This means the signal-generator output will have the greatest effect on the signal strength at the speaker—another reason for becoming thoroughly familiar with your own generator.

Let's go back to Fig. 3-7 and assume point 1 has been checked. Going to injection point 2, note that there is a slight increase in signal when the probe is touched there. This is normal because the driver transformer is usually a better match for the signal generator on the primary side. So the result indicates the transformer is all right. When the probe is moved to point 3, a still greater signal should be heard, indicating the audio driver stage is working. At points 1 and 2 there was only one transistor between the test point and the speaker; so the signal would be fairly weak. At point 3 another transistor is in the signal path; so the amplification should be greater. When, after practice, it is learned what type

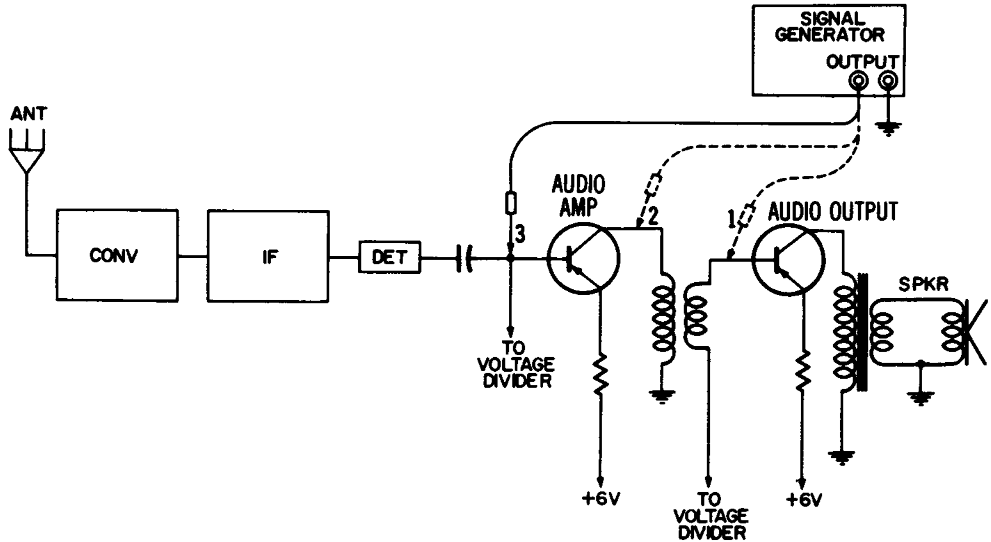


Fig. 3-7. Method of injecting a signal into the audio stages.

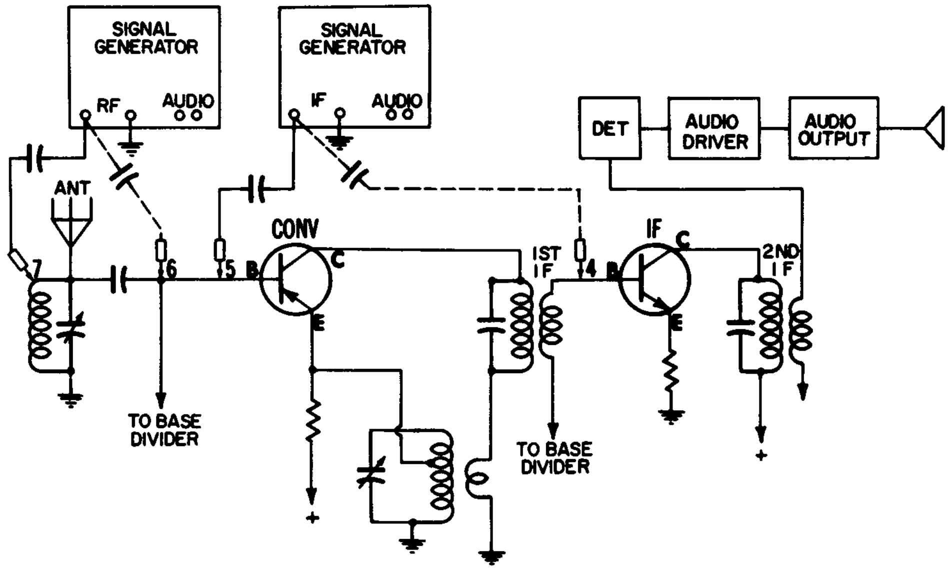


Fig. 3-8. Injecting a test signal into the RF and IF sections of a transistor receiver.

of signal can usually be expected at point 3 for a given signal-generator setting, this point will usually be the first one chosen. Test points 1 and 2 can then be ignored, unless the audio signal applied at point 3 is very weak or is dead.

After the audio amplifiers are checked and found to be working properly, it must be assumed the trouble is in one of the other stages. The audio system is then thought of as several blocks which are good, and the troubleshooter visualizes the major parts of the remaining circuits, as shown in Fig. 3-8. Test points 4 and 5 test the ability of the IF and converter stages to pass the IF signal, and test points 6 and 7, the ability of the radio to receive RF signals. A capacitor of about 0.1 mfd must be inserted in the test lead to protect the transistors; otherwise, they may be grounded through the signal generator. This is called an "isolation" capacitor, which most signal generators already have in series with the audio output internally, but not with the RF-IF output. For this reason, one must be inserted for RF or IF checks. A glance inside the signal generator or at its schematic will prove this point.

If the IF signal from the generator is heard at point 4 but not at point 5, it can be assumed the converter stage or 1st IF transformer is defective. Again, it is important to become familiar with the normal output to be expected at each point. Of course, all tests are meaningless unless the proper settings are used for the signal generator.

Setting the Signal-Generator Controls

Most signal generators have two major types of output—RF and audio. The audio output is usually fixed at 400 cycles, whereas the RF output is variable over a wide range, including the IF frequencies. This range is on a large frequency selector dial with several bands of frequencies marked on it. A few signal generators, built only for radio use, have some of the popular frequencies available in a step-type, rather than a continuously variable control.

An audio signal is desired when *audio stages* are being tested. It is obtained from the generator in Fig. 3-9 by:

1. Turning emission selector (D) to the "audio" position.
2. Turning the audio gain control (A) to the position which gives the desired signal strength.
3. Connecting the red and the black leads to the radio being tested—black to the radio chassis and red to the test point.

That's all there is to it. As the audio gain control is turned clockwise, more audio signal will be injected into the radio.

When selector (D) is in the "audio" position, the only control connected into the circuit is the audio gain control (A). Controls B and C have no bearing on the signal at the audio-output jacks. The RF output jack is not used during audio checks, of course.

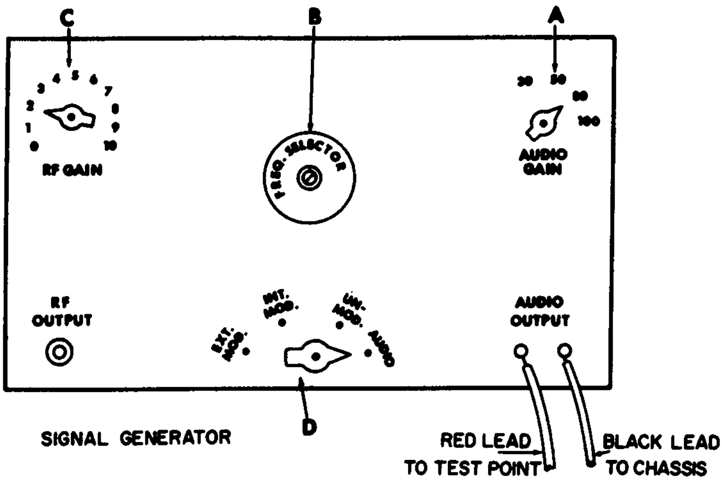


Fig. 3-9. Typical settings of the signal-generator control when the audio section is being tested.

In checking the IF system in a radio, the published IF frequency should be selected on the signal generator. Popular IF frequencies are 262, 455, and 465 kc for broadcast-band receivers. The most widely used one is 455 kc. The proper IF frequency can be found in the radio service literature. A pure, unmodulated IF signal cannot be heard in the speaker. It must be modulated, which means some form of audio must be mixed with the IF signal.

To obtain a modulated IF signal from the signal generator shown previously, proceed as follows:

1. Turn emission selector (D) to the "internally modulate" position (see Fig. 3-10).
2. Turn the frequency selector dial to select the IF frequency of the radio being tested. (This also requires a band selection on a band-selector switch when more than one band is marked on the dial.)
3. Set the audio gain control (A) to a moderate setting. (If the control is marked in per cent of modulation, use 30%. Otherwise, use about half the maximum audio gain.)

4. Set the RF gain control (C) to the position giving the desired signal strength. If it is not known, start at a low value.
5. Connect a coaxial shielded lead to the RF output jack. Ground the shield to the radio chassis, and insert a 0.1-mfd capacitor in the main lead to serve as a test probe.

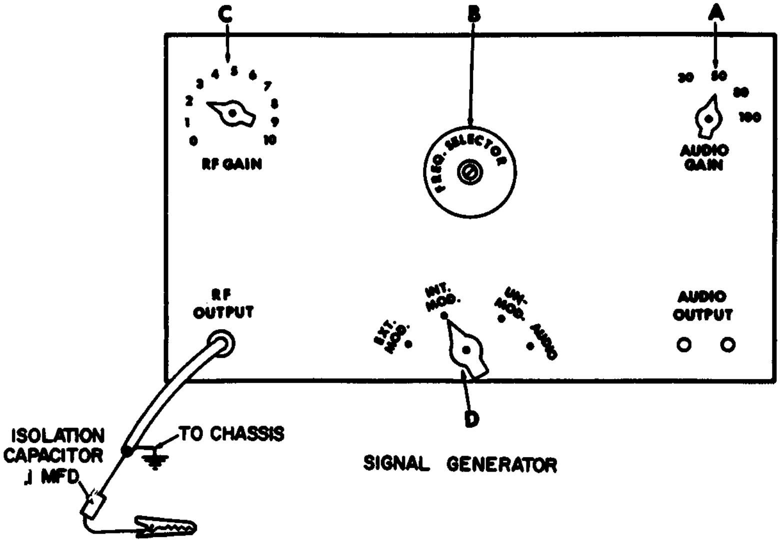


Fig. 3-10. Generator setup for checking the RF and IF sections of a receiver.

You are now ready to connect the test probe to a radio. The reason for starting with a low RF gain setting is to prevent overdriving and "blocking" of the transistors. Blocking makes the transistors sound as if they are not amplifying the

TABLE 3-1.

Signal-injection test points.

Step	*Check Point*	*Selector "D"*	*Signal-Generator Frequency "B"*	*Note*
1	Output Base	Audio	—	Signal
2	1st Audio Collector	Audio	—	Signal Gain
3	1st Audio Base	Audio	—	Signal Gain
4	1st IF Base	Int. Mod. (RF)	IF	Signal
5	Converter Base	Int. Mod. (RF)	IF	Slight Gain
6	Converter Base	Int. Mod. (RF)	Dial	Signal
7	Antenna	Int. Mod. (RF)	Dial	Signal

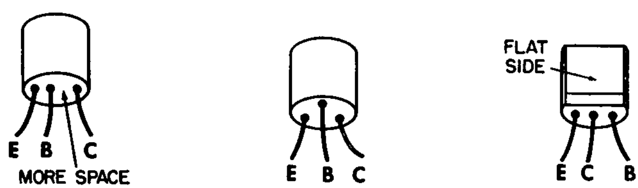
signal, when they are actually just being overdriven. A reduced setting of the RF gain will unblock the transistors and allow the signal to come through better. Tubes are not subject to this condition nearly as much as transistors.

Table 3-1 is a summary of the signal-generator settings for each test point discussed so far.

Locating the Test Points

After the signal generator has been set to produce the desired type of signal, the proper point to inject it in the radio must be found.

Test points are easily located by using transistor leads, provided they are long enough and not crowded by other nearby parts. The base leads of IF transistors, for example, are usually easy to locate because they are near the IF transformers. Once the transistor is located, it is simple to find the desired lead where the generator is to be connected. As shown in Fig. 3-11, most small transistors use one of three lead spacings. Most germanium transistors use the triangle pattern, with base lead in the center. Some manufacturers use that same case for their silicon transistors, but others use a molded plastic case with one flat side and collector lead in the center. The service literature will usually specify the lead orientation, and also show where the various transistors are located.



(A) Uneven spacing. (B) Triangle pattern. (C) Flat side.

Fig. 3-11. Three methods of identifying transistor leads.

In some very compact radios, it is almost impossible to reach a transistor lead from the top of the circuit board because other parts are mounted so close to the transistor. It is therefore advisable to troubleshoot the radio from the bottom of the circuit board. This is not really as difficult as it might sound, provided adequate service literature is available.

Fig. 3-12 shows a schematic of a transistor portable with two IF, a converter, and two audio-amplifier stages. Fig. 3-13 is a photograph of the bottom of the circuit board, showing the copper conductor rails. Note that certain conductors are numbered and pointed out by arrows. Those same numbers can also be found on the schematic (Fig. 3-12), showing the points where the various conductors are connected into the circuit. Thus, it is very simple to find the transistor test points on the bottom of a circuit board.

Let us assume we want to inject a signal at the 1st IF transistor base element. The schematic tells us this is check point 9. This number is then found on the circuit board picture (Fig. 3-13). It is then easy to locate the same conductor on the circuit board, provided the radio and the circuit-board picture are facing in the same direction on the bench.

Isolation by Noise Tests

Large signal generators are not always required to track down troubles. Small noise generators also can be used, provided certain limitations are realized. In fact, some technicians prefer to use simple generators on almost all radios, reserving the larger ones for very tough troubles and for alignment.

One type of noise generator is shown in Fig. 3-14. It consists of a transistor oscillator which generates a signal sounding much like a doorbell buzzer. The fundamental output frequency is in the audio range, but the signal is rich in harmonics. This means that IF as well as RF signals are produced, allowing the buzzing noise to pass easily through the RF, converter, and IF tuned circuits. So this is actually an audio, IF, and RF generator combined into one, and no frequency selections are required because all signals are produced at the same time. The noise generator is built into a rectangular box and has a volume control to allow the output signal strength to be adjusted.

A pencil-type noise generator is shown in Fig. 3-15. It has no volume control, although its output can be increased somewhat by grounding the generator case to the radio being tested.

This unit and the one in Fig. 3-14 are battery-powered, the pencil unit containing a small battery at the top of the cylinder. Because the noise it makes resembles the buzz of a mosquito, the popular pencil-type generator in Fig. 3-15 carries the trade name *Mosquito.*

Test Point for Noise Generators

The test points where noise signals can be injected are about the same as the ones for a signal generator. This means the noise can generally be injected at the base and collector elements, although there are some exceptions to this.

The first logical check would be to determine whether or not the audio stages are working. We are assuming, of course, that the battery voltage and current have been checked and are normal; also, that personal observation checks have been made

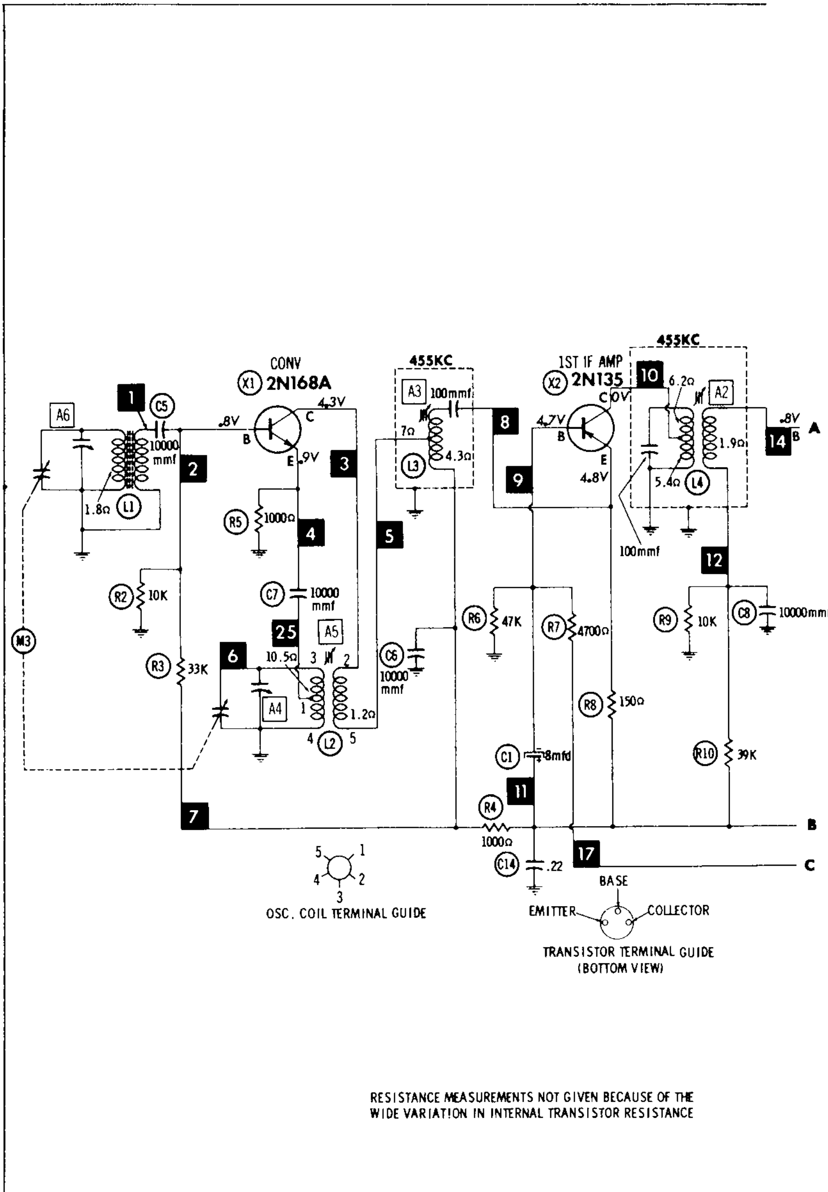
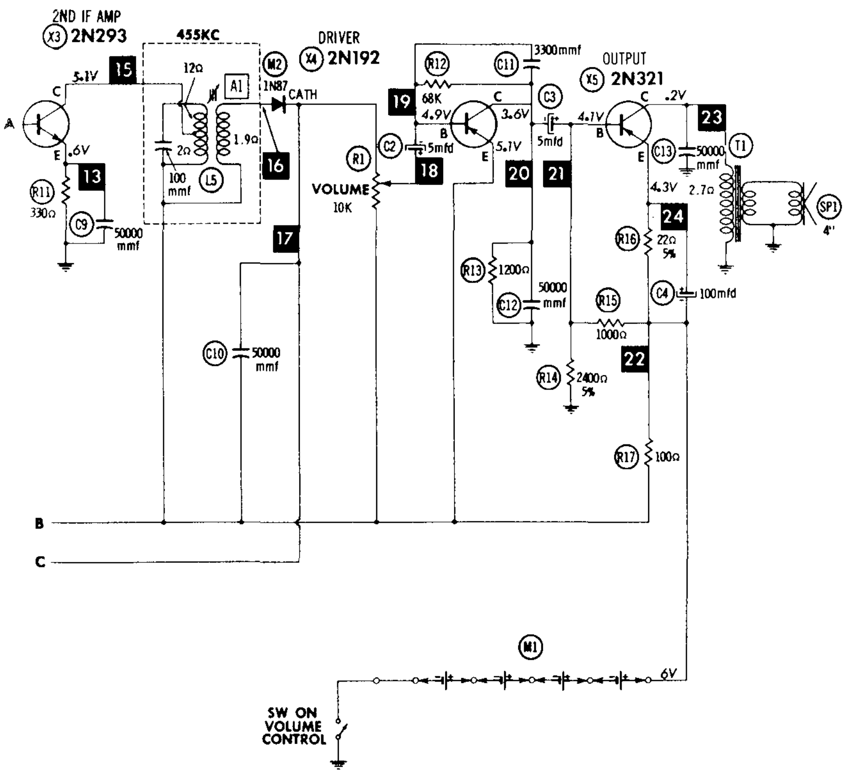


Fig. 3-12. Schematic of a typical



five-transistor AM receiver.

PRINTED BOARD

A Howard W. Sams CIRCUITRACE* Photo *TRADE MARK.

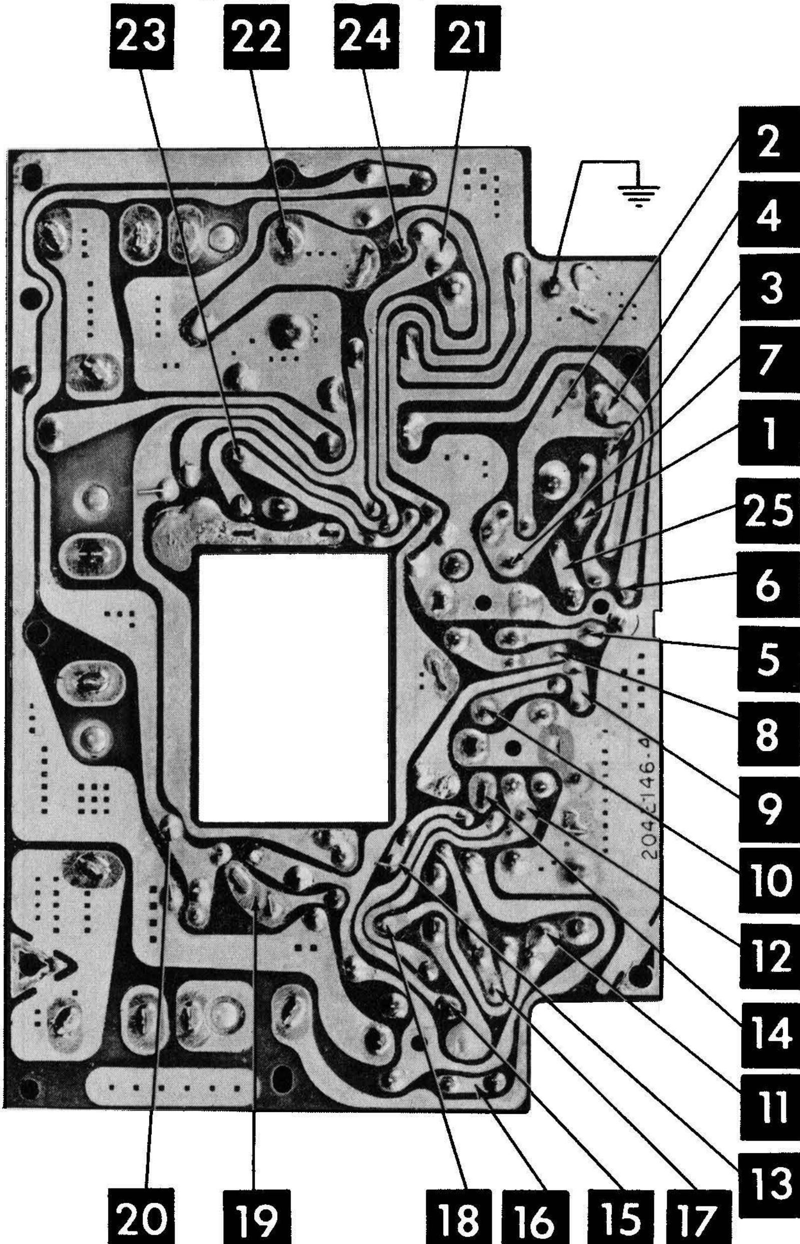


Fig. 3-13. Circuit board of receiver in Fig. 3-12, showing check points.

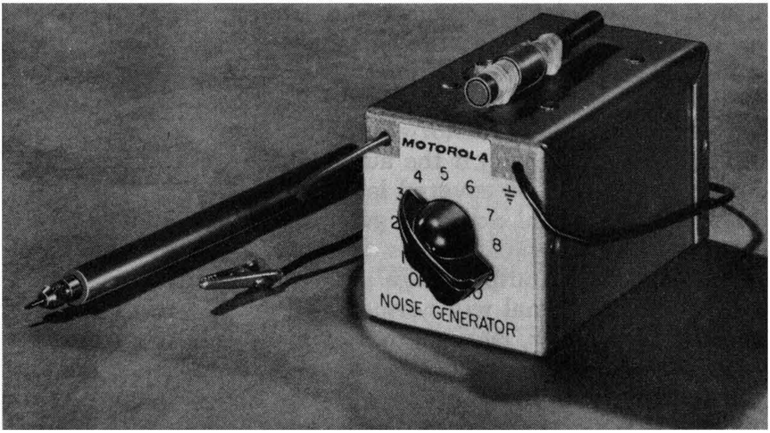


Fig. 3-14. A typical noise generator. (Courtesy of Motorola Communications and Electronics, Inc.)

to determine any obvious defects, such as loose wires, bad solder joints, cracks in the circuit board, etc.

In checking the audio system, one of two points should be used—the volume control or the base lead of the driver transistor. The choice here depends on which one is more accessible in the radio being checked. The high end of the volume control is a good place to start, or the center arm can be used if the control is turned to its maximum position.

If the volume control cannot be reached easily, the base (B) terminal of the driver transistor is a good place to start. If a fairly loud noise is heard when the noise generator is touched

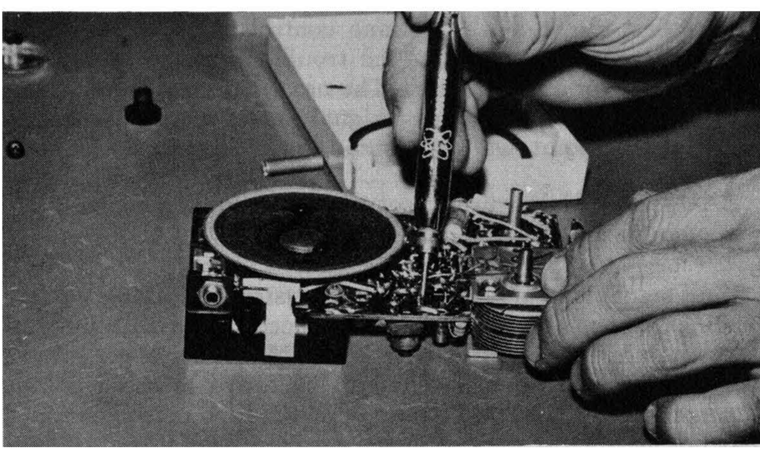


Fig. 3-15. The "Mosquito" noise generator in use.

to one of those two points, we can assume the audio stages are performing. This one little check practically "cuts the radio in half," allowing us to free our mind of the audio stages and concentrate on the rest of the radio. This check, of course, is not very reliable for distorted radios, since the sound will still come through even if the audio stages were at fault. Distortion checks will be covered later.

If the noise signal *does not* get through the audio system, the generator can be moved to the collector of the driver, or to the base of the output stage. However, at these points the noise-generator signal will normally be much weaker when it reaches the speaker, because there will be only one transistor stage between the generator and speaker. Some small generators can barely be heard at these points. Nevertheless, a weak signal does indicate the output stage is working—which is what we want to know. The trouble can then be assumed to be in the driver stage, since we previously determined that the audio system was not functioning.

Most audio generators have a fairly high impedance output. This means the noise from the speaker will probably be a little louder when the signal from the generator in Fig. 3-16 is applied to the collector of the driver than when applied to the base of the output stage. This is especially true in radios using transformer coupling between those two stages. However, neither test point is used unless the first test at the input of the driver stage fails to produce a good signal.

Do not expect to hear the signal if it is applied directly to the speaker or at the collector of the output stage, since there is no amplification at those points.

Now let us assume the audio system is working, as evidenced by the first check at the volume control or driver base. So we want to find out whether the trouble is in the IF system, or in the converter or antenna. The next main test point would be at the 1st IF base. If a good signal passes through when injected at that point, we can assume the IF system is working.

CAUTION: Make sure to set the radio volume control at maximum for all tests.

If no signal is heard, check the IF system by taking voltage readings and making other tests, in accordance with suggestions in later chapters of this book. Many noise generators will not produce enough signal to be heard at some points. For example, at the 2nd IF base, a pencil-type noise generator may not produce any signal at the speaker, even if the receiver is perfectly normal. Sometimes the same generator *may* pro-

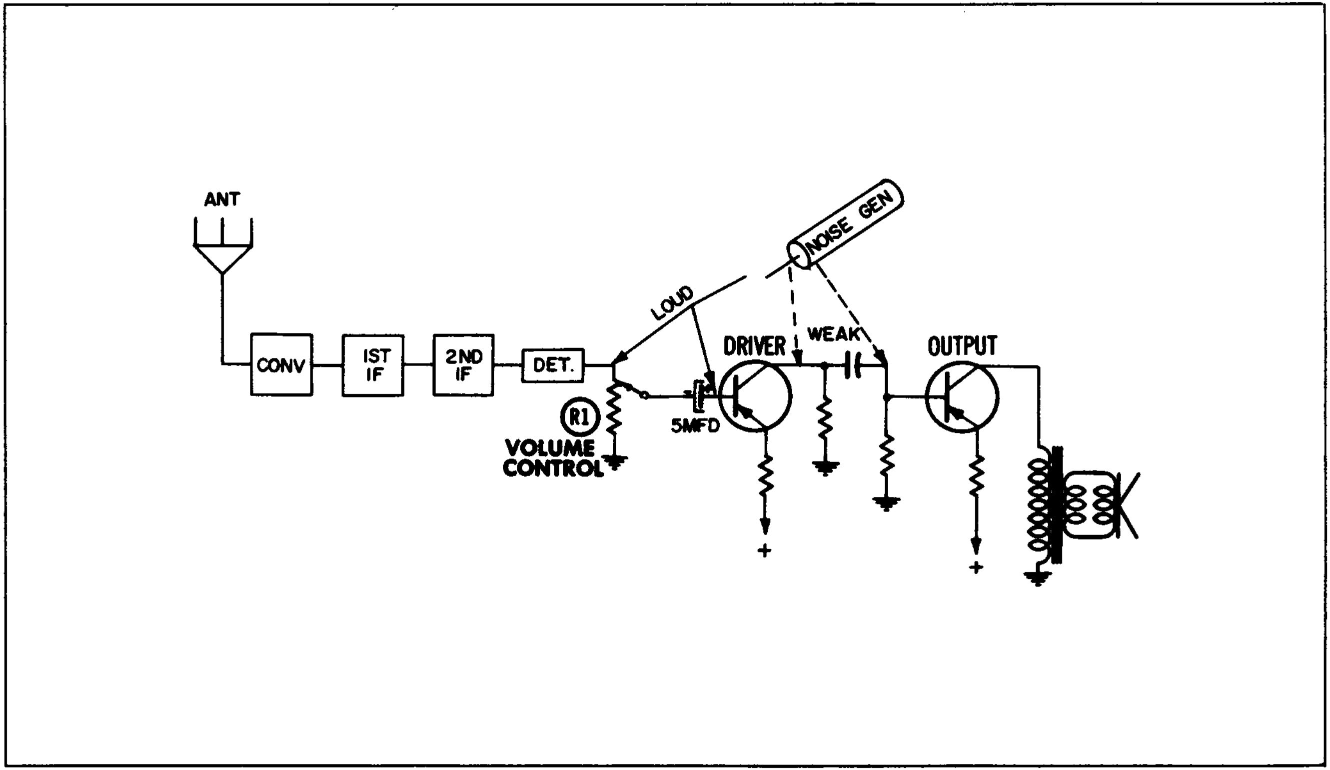


Fig. 3-16. Audio test points.

duce a weak signal at the 2nd IF base, provided its case is grounded to the radio chassis.

This again points out the importance of knowing the capability of your own generator, to prevent your being misled into suspecting trouble in the wrong stage of a radio.

If the IF stages are working, as evidenced by a fairly loud signal at the 1st IF base, check the converter stage. Usually, very little gain can be noted in here. That is, the signal injected at the converter base will probably produce about the same noise in the speaker as one injected at the 1st IF base. However, if the noise is greatly decreased or is lost, the converter stage should be checked.

Assuming good noise was heard when injected at each of the major test points—audio driver, 1st IF, and converter base —then where would the trouble be? Usually in one of three places—the antenna, the oscillator, or one of the IF transformers. Detuned IF transformers *can* allow noise signals to pass through, since the noise is a random frequency spread over a broad spectrum. (This also includes the ones detuned because of an open capacitor inside the can.)

Noise-Generator Summary

Small noise generators are easy to use because they require no adjustments—or at most, only a simple output-gain adjustment.

The major test points are (1) the 1st audio base (or volume control), (2) the 1st IF base, and (3) the converter base. Loss of signal at any of these points indicates a defect in that section of the radio. If you desire to further isolate the trouble before taking voltage measurements, here are several pointers you must remember:

1. Some small generators do not put out enough signal to be heard when injected in the output stage or the 2nd IF base.
2. The output of some noise generators with no gain control can be increased slightly by grounding the generator case to the radio chassis.
3. Noise can sometimes be fed through detuned or defective IF transformers.

Provided these precautions are kept in mind, the noise generator offers somewhat of a short cut to the larger, all-purpose signal generators for trouble isolation. But it should not be used for receiver alignment.

Probably the biggest advantages of the noise generator are that it does not have to be tuned and it usually cannot put out enough signal to severely "block" a transistor stage.

Simplified Signal Injection

The noise test can be simplified still further, since there are several other ways to produce noise in a radio.

One of the simplest—long used in vacuum tube radios, but strictly taboo for transistor sets—is the screwdriver method of directly grounding various points while listening for a click or pop. This technique cannot be used on transistor radios because the transistor could be destroyed by being shocked beyond its maximum limits. However, this method, sometimes given the sophisticated title of "circuit disturbance" or "shock injection," is very satisfactory for vacuum-tube circuits since they are not nearly as sensitive to bias changes.

By modifying this method slightly, the author developed what has proven to be one of the most popular methods of isolating trouble in very weak or in dead transistor radios, especially portables. It is called simply the click test.

The Click Test

The click test consists of grounding certain test points through a resistor and listening for a click. The resistor in the test lead should have enough resistance to prevent the transistors from being damaged and still allow the click or pop to be heard. A 10,000- or 12,000-ohm, ½- or 1-watt resistor is usually satisfactory. Many different makes of transistor radios have been checked without any damage to components. But if any doubt exists about damaging a particular radio, consult the manufacturer's information before performing the test.

Your own body resistance is perfectly safe to use as the click-test resistor. Simply ground one hand to the chassis as shown in Fig. 3-17, and hold the metal shank of a screwdriver in the other. Then touch the screwdriver repeatedly at the various test points and listen for a slight click.

As with signal and noise generators, the base or collector elements of the transistors can be used for test points most of the time. Sometimes, however, clicks will not be produced even when the radio is working normally. This will be discussed later.

If a radio is not familiar or has never been tested in this manner before, or if the manufacturer has not been asked about the safety of this test, the collector leads are the safest ones to use. The reason is that a change in the collector voltage has very little effect on the conduction of a transistor,

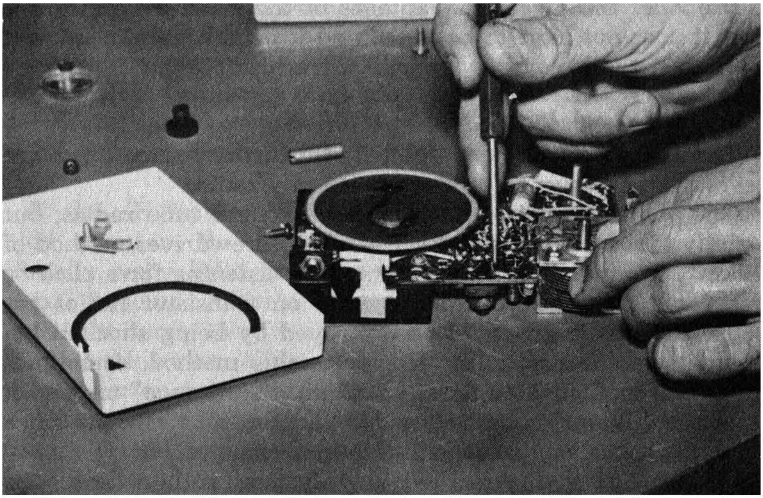


Fig. 3-17. Using the body resistance to protect the transistor when a "click test" is made.

whereas a change in the base voltage does. So a transistor with a very low current and power rating could conceivably be damaged as the "click resistor" is touched to one of the base leads. However, this has never happened in our tests.

The next step after checking the batteries is to make certain the audio amplifiers are working. Clip one side of the test resistor to the chassis, and touch the other end to the base of the 1st audio or driver transistor. Tap this point several times rapidly; if a click is heard, the audio stages are probably working. If nothing is heard, the audio stages should be checked. A click at the collector of the driver transistor probably indicates the output stage is working. But you should not expect to hear a click at the collector of the output stage because there is no amplification between that point and the speaker.

Next, how about the IF section of the radio? It can be easily checked by "clicking" the test resistor or test probe, which is grounded through your body resistance, on and off the converter collector lead. If clicks get through to the speaker from that point, you can assume the IF and audio stages are working. If nothing is heard, the IF stages should be checked.

If the IF stages are working, the next step is to check the converter stage. There are several ways to check a converter or oscillator stage. A click test could be made at the converter base, but a good click at that point does not tell us whether the oscillator portion of the converter is working. However, if

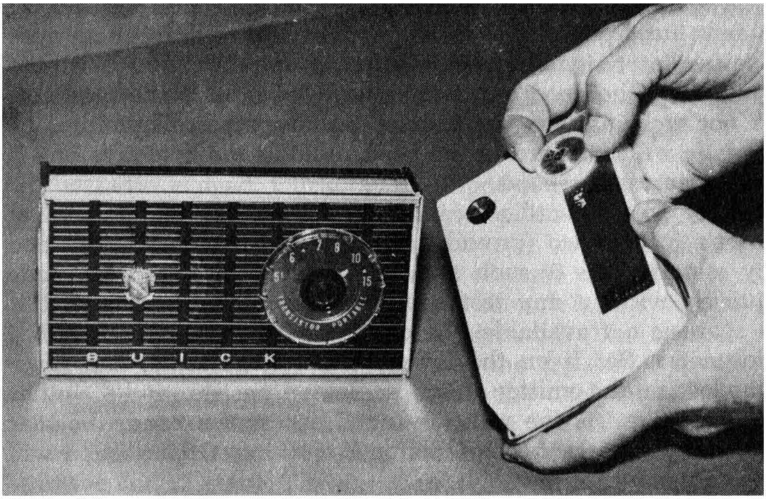


Fig. 3-18. A quick method of determining if the oscillator is operating.

the oscillator is oscillating, chances are the rest of the converter stage is also working.

Checking the oscillator in a transistor radio is one of the easiest checks to make, provided another radio is available.

The good radio is tuned to a fairly strong station in the upper, or high-frequency, half of the band. Then the radio being checked is held close to the good radio (Fig. 3-18) and slowly tuned across the band. When the oscillator in the defective radio passes the station on the good one, a whistle, or heterodyne, will be heard. It will usually occur when the dial of the defective radio is tuned approximately one IF frequency lower than the dial of the good radio (*not* when they are both tuned to the same spot). This is shown in Fig. 3-19.

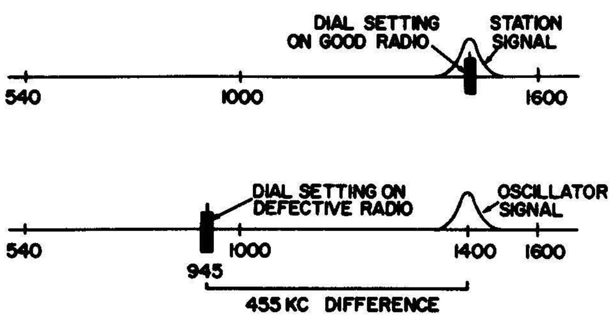


Fig. 3-19. Beat will occur at approximate position of dial pointers if the suspected oscillator is operating.

The reason is that the oscillator is usually generating a signal a few hundred kilocycles higher than its own frequency, so the oscillator signal from the defective radio will beat with the station on the good one and cause a whistle. If the oscillator is not working, the two cannot beat together. Therefore, no whistle will be heard in the good radio as the defective one is tuned across the band.

Most portable-radio oscillators will radiate their signal at least a foot or two (provided they are not completely shielded by metal). This is such a simple check that it can be made quickly without any test equipment except a spare radio. If a spare is not available, the oscillator can be checked with a voltmeter. Set it on the lowest DC voltage scale, and place one lead on the emitter of the oscillator transistor and the other on the base. As the radio is tuned across the band, the bias will vary slightly if the oscillator is working. Otherwise, it will stay constant.

A defective antenna circuit will not usually keep the converter from working. The antenna circuit can usually be given a quick check by "clicking" at the stator of the antenna variable. A simple way to do this is to hold your hand on the metal shaft of a screwdriver, and gently touch its tip on and off the ungrounded terminal of the variable. A continuity check of the antenna itself would also be in order. Clicks near the antenna end of the radio should never be made, of course, until the audio, IF, and converter have been checked.

This brings out the importance of *systematic* troubleshooting. Never jump around from one end of the radio to the other. Always check each section in order, starting at the audio section and working toward the antenna. This applies for any method of signal injection or substitution.

Table 3-2 lists the click test points on most transistor radios. The major test points, for checking the audio, IF, and converter sections, are in bold letters. As the troubleshooter be-

TABLE 3-2.

Points where click tests are made, and results to be expected.

Click Test Point	*What To Expect*	*What It Checks*
Output Stage Base	Weak Click	Output Stage
1st Audio Base	**Good Click**	**Audio Section**
1st IF Stage Collector	Weak Click	2nd IF Stage
Converter Collector	**Good Click**	**IF Section**
Antenna (High End)	**Good Click**	**Converter Stage** (Except Osc.)

comes more familiar with this method of trouble isolation, he may want to use some of the other check points to pinpoint the trouble before making stage voltage checks. However, an attempt to tie it down too closely by signal injection can sometimes cause *erroneous results.* Here is an example:

> The radio is dead. Clicks at the input of the driver stage show the audio amplifiers are working. However, no click is heard at the collector of the converter stage, indicating the test signal is not being passed through the IF stages. The collector of the 1st IF stage is then "clicked" by the 10,000-ohm resistor, but nothing is heard. The troubleshooter therefore logically assumes the trouble is in the 2nd IF stage, since it is not passing the click signal sent to it. So voltages are measured in the 2nd IF stage, but are perfectly normal. In fact, nothing wrong can be found in the 2nd IF stage. The question is, "What happened? . . . What went wrong with the test?"

The answer is *stage interaction.* The trouble was actually a partially shorted or a leaky 1st IF transistor which severely loaded down (and almost shorted out) the IF transformer between the 1st and 2nd IF stages. This, of course, prevented the test signal from entering the 2nd IF stage. So that stage appeared to be bad. In other words, it is not always profitable to try isolating the trouble too closely by signal injection.

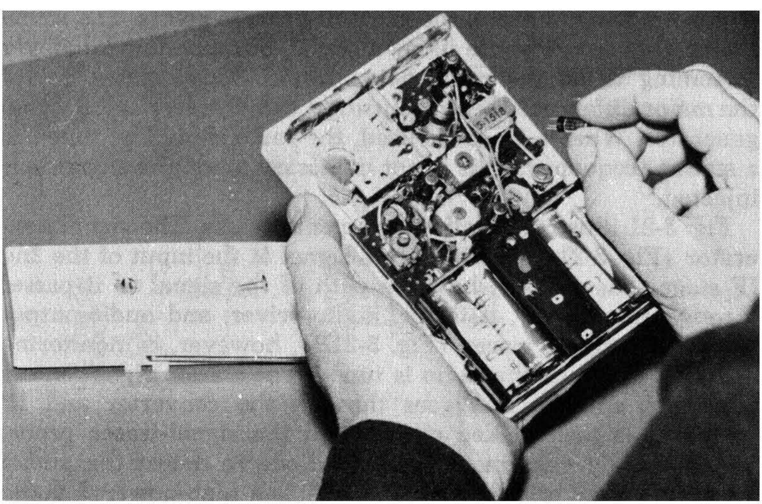


Fig. 3-20. Performing the click test by removing and replacing a transistor in its socket.

Isolation should be limited to a section—audio, IF, converter—instead of to a single stage. If the troubleshooter does isolate the trouble to a specific stage by using all of the test points, he should still remember that the trouble may actually be in an adjacent stage.

Another rapid and convenient method of click testing, in radios using transistor sockets instead of directly soldering the leads into the circuit, is to pull the transistors and plug them back in again while listening for a click. This is shown in Fig. 3-20.

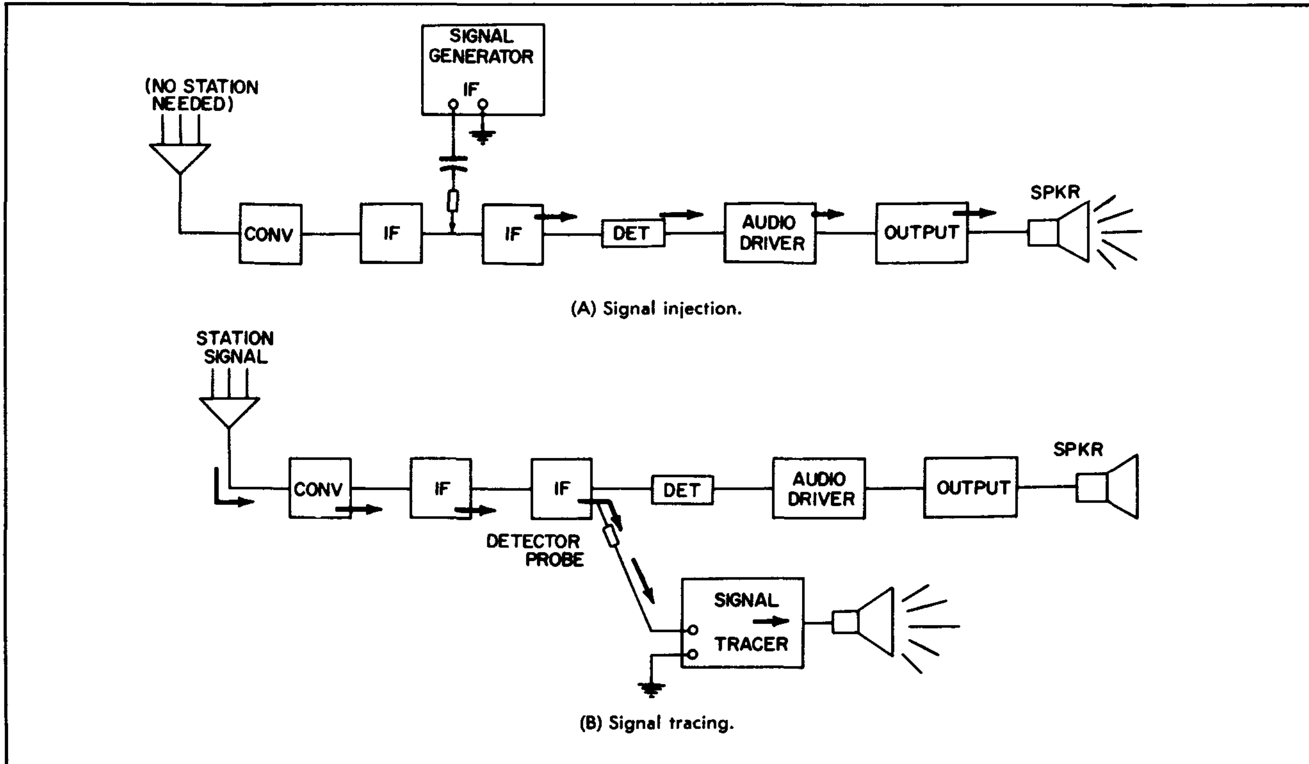
In radios containing two IF stages, the following transistors will usually produce a click—the 1st audio (or driver), 1st IF, and converter. The audio-driver click checks the audio stages; the 1st IF transistor, the IF stages; and the converter transistor, the converter stage (for noise only). The oscillator should still be checked by one of the previous methods, such as listening on a nearby receiver or monitoring the bias while tuning across the band.

Isolation by Signal Tracer

We have been talking about injecting a signal with a generator, or by using the click test, and listening for it in the speaker. The test signal is amplified by one or more transistor stages in the audio system before it reaches the speaker. That is why it was important to check this system first.

Another type of test, called signal tracing, does not rely on the audio system. It has its own audio amplifier and speaker, which are used to check the radio at various points. The signal tracer does not generate its own signal, but monitors whatever is coming in on the radio being tested. This creates one of the major differences between using a signal tracer and a signal generator. When a tracer is used, the radio should be tuned to a station frequency. This is not necessary when the signals are injected.

Fig. 3-21 illustrates both instruments in use. The signal generator (Fig. 3-21A) is injecting a signal at the input of the 2nd IF stage. The arrows show the path of the signal as it passes through the 2nd IF, detector, audio-driver, and audio-output stages. The signal tracer (Fig. 3-21B), however, is monitoring a station to which the radio is tuned. The station signal enters the radio antenna and goes through the converter and IF stages. It is then picked up through the signal-tracer probe, which usually contains a detector diode to detect the audio. The signal goes into the tracer, which is a high-powered audio amplifier. Here, it is amplified sufficiently to be heard in the speaker of the tracer.



(A) Signal injection.

(B) Signal tracing.

Fig. 3-21. Two methods of isolating the trouble to a stage.

One thing now becomes evident: The audio system of the radio being checked could be dead, and a station still be heard from the signal tracer in Fig. 3-21B. However, if the converter or one of the IF stages were dead, nothing would be heard. In other words, because the tracer has its own audio system, it can be used near the front-end of the radio first. It is then moved back toward the speaker, while we will listen for a point where the signal stops coming through, indicating a defect there. The station signal should become louder as the tracer is moved toward the output, since more stages of amplification are being added.

Test Points for Signal Tracers

Most signal tracers, unless designed for transistor radios, do not work when used too far forward in the radio. That is, if the tracer probe is placed on the antenna coil or converter stage, probably nothing will be heard. The first chance to pick up the signal should be at the collector of the 1st IF transistor, and even here it may be quite weak. However, from the 2nd IF collector to the speaker, a good signal can usually be heard.

One reason most signal tracers cannot be used too near the front-end is that there is a mismatch between the tracer and the transistor amplifiers in the radio. The tracer input has a fairly high impedance, whereas transistor impedance is relatively low. This makes it important to use the collector rather than the base leads for signal tracing, because the base impedance is usually much lower than the collector impedance. So, although the match is not good at the collector terminals, it is better than trying to pick up signals at the base terminals.

This may seem to offer a severe disadvantage for most signal tracers. Actually, it doesn't. Assume a radio is very weak. A signal tracer is first applied at the collector, or output, of the 1st IF stage. The radio being checked is tuned to a local station and is heard in the tracer as a weak signal. We know from previous experiments with our signal tracer that this is a normal output at this point. So we conclude that the converter and first IF stages are working properly. When the probe is moved one more stage to the right—to the 2nd IF collector—no improvement is noted. In fact, the station almost disappears in the tracer speaker. It is obvious that our trouble must be in the 2nd IF stage. Instead of an increase in signal here, we got just the opposite.

The next question might be, "But what if no signal at all is heard at the 1st IF stage? How can I tell whether the converter or the 1st IF stage is at fault?"

The answer is, "You can't." But by making an additional test, you can quickly identify the defective stage. You have two choices—either use a signal-injection test to determine which stage does not pass the injected signal properly, or check the converter to see if the oscillator is functioning. If it is, chances are the converter is working properly.

So, to those who have had good luck with signal tracers, don't discard them. But we recommend learning the signal-injection techniques, also, to supplement the signal tracer when it does not give sufficient information. This would be especially true in the front-end of a transistor radio.

Table 3-3 shows the test points where signal tracers can be used in most transistor radios. The most often-used test points are numbered 1 through 6. They are usually very easy to find because points 1, 2, 4, and 5 are transistor collector leads and 6 is the speaker.

TABLE 3-3.

Major test points for signal tracers.

Test Point	*What To Expect*
Converter Collector	No Signal (unless tracer is specifically designed for transistor radios; see text)
1. 1st IF Collector	Weak Signal
2. 2nd IF Collector	Louder Signal
NOTE: A detector probe is used for the above, but not for the following tests. Change tracer from "RF" to "Audio" position.	
3. Detector Output or Volume Control	Weak Signal
4. Audio Driver Collector	Louder Signal
5. Audio Output Collector	Louder Signal
6. Speaker Terminal	Slightly Weaker Signal

Using the Signal Tracer

The signal tracer is quite easy to use, the benefit derived from it depending largely on the user's familiarity with his instrument. Signal tracers, like signal generators, vary considerably from model to model. Knowing what to expect to hear at each test point is the greatest aid in this type of trouble-shooting.

The setting of the radio volume control will also affect the amount of signal heard in the tracer—especially when the audio stages are being checked. A good rule is to set it about halfway between minimum and maximum. Then use the gain control on the signal tracer to adjust the amount of signal at the tracer speaker. The reason for not turning the volume control to maximum is that distortion may be produced because a stage is overdriven, and this could throw the troubleshooter off the track.

Let us now take two sample problems to demonstrate the use of the signal tracer. (We will assume the batteries have already been checked.)

> The radio is dead. We turn its volume control halfway up and switch the tracer to the RF position. Then we use the detector probe in the IF stages as shown in Fig. 3-22. As the radio dial is tuned across the band, weak signals are heard at point 1 and good ones at point 2, indicating no trouble in the front-end or IF sections. We then switch the tracer to receive audio, and connect the leads to points 4, 5, and 6, where a good signal is picked up at each point. Now, we know the signal is getting all the way back to the radio speaker. But, since nothing is heard from the speaker, we can conclude that it is probably defective.

Now let's assume a radio has distortion. Signal tracers can be very useful in isolating distortion, as will be seen in the following example.

> We tune the radio to a station, and turn the volume control to about the normal listening level. A check at point 2 results in a clear, undistorted signal being heard in the signal tracer. A check at point 4, the audio-driver collector lead, still gives us a clear signal in the speaker of the tracer. However, when the tracer is moved to point 5, the collector of the output stage, the distortion is picked up. This means it is probably being produced in the output stage, since this is the first point where it is heard. On the other hand, if the distortion was not heard at any of the test points, including point 6, we can conclude that the radio speaker is at fault.

Signal-Tracer Summary

Some of the important points about signal tracers are:

1. They can be used to trace distortion, provided the output stage is not overdriven by excessive volume.
2. They can be used for troubleshooting weak or dead radios.
3. The front-end of the radio must be checked before the

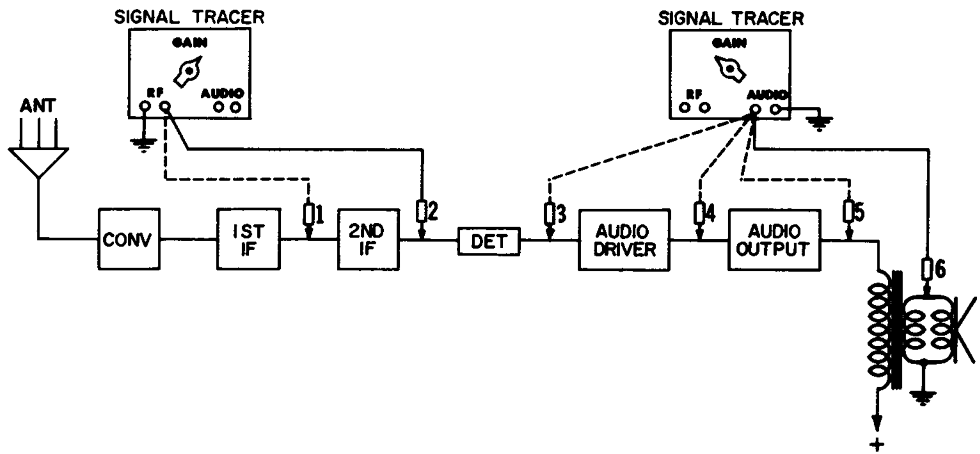


Fig. 3-22. Test-point sequence used in signal tracing.

audio system. This is the reverse of signal-injection tests, where the audio section is always checked first.

4. The signal tracer has certain limitations in the front-end of a transistor receiver. Because of mismatch between the tracer input impedance and the transistor output impedance, signals usually cannot be heard in the converter stage, and they may be weak in the 1st IF stage.
5. The tracer is usually used on transistor collector leads.
6. The success of a signal tracer depends largely on how familiar the operator is with his own instrument.

CHAPTER 4

Learning to Troubleshoot AM-FM Transistor Radios

Now that you are familiar with AM transistor radios and how signals pass through them, it is a simple matter to "chart the same course" in radios in which the FM provision has been added.

The basic circuits are almost the same—and the same principles apply. That is, transistors are used as amplifier or oscillator stages, and the circuits look very much like AM circuits in most cases. The DC circuits are set up in much the same manner, with a stabilizing resistor in the emitter, a voltage divider in the base to obtain "bias," and the collector returned to battery negative (NPN) or positive (PNP). The main difference is that some of the tuned circuits which couple signals in and out of each stage are wound with fewer turns to handle the higher frequencies.

In most AM-FM radios, the same audio system, except for the detector, is used for AM and FM. Since the purpose of the AM audio amplifiers is to amplify changes in amplitude (audio signals), and the purpose of the FM detector is to change frequency variations into amplitude variations (audio signals), the same audio amplifiers can be used. The amplifiers are simply switched to receive the output of the AM detector when listening to AM, or the FM detector when tuned to FM. Both detectors produce small, audio signals which need amplification before they can drive a speaker.

As with AM signals, the FM signals must be amplified before they can be detected. Most of the signal in any radio system is lost while traveling between the station and the receiver. This is especially true with FM because the signals are transmitted at higher frequencies (88 mc-108 mc) which are not reflected back to earth by the ionosphere. Only the direct (line of sight) signals are received. Any obstacles such as buildings or hills between the transmitter and the FM radio will tend to block the signal.

The section of the radio which builds up the FM signals received at the antenna is called the "FM Tuner." It employs one or more transistors which work at higher frequencies than AM transistors but are similar otherwise. The FM converter (oscillator) and IF amplifiers also must operate at higher frequencies.

As with the AM radio, after checking the batteries and looking the set over thoroughly for visible defects, the next step is to get out the schematic and become familiar with the general layout of the set. This only takes a few seconds and will save time in the long run.

SCHEMATIC FAMILIARIZATION

The schematic in Fig. 4-1 represents a typical AM-FM radio less the audio system. In this chapter, we will get you familiar enough with AM-FM radios, so that a quick glance at a schematic will give you all the road map you need.

From this schematic, we learn that there are two stages in the "FM tuner section" of the radio (the FM-RF amplifier and the FM converter). The tuner section is followed by the "IF strip," consisting of three stages. The three IF amplifiers are called dual purpose amplifiers, because they not only amplify the FM-IF signals, but they also amplify the AM signals. Note that the 1st FM-IF stage doubles as the AM converter; the 2nd FM-IF serves as the 1st AM-IF, and the 3rd FM-IF serves as the 2nd AM-IF amplifier. The way that this is accomplished will be described later. The combining of the AM- and FM-IF strips is quite common, since it saves transistors and other parts. Only the more expensive units have a separate converter and IF amplifier section for AM.

After IF amplification, the AM signals are detected by the AM audio detector (Fig. 4-2), and the FM signals are detected by the FM detector. They are then fed into the common audio system.

The individual stages and their functions are:

1. FM RF Amp.	Amplifies the FM signals.
2. FM Converter	Changes the incoming FM signals (88 mc-108 mc) to an IF signal (10.7 mc).
3. 1st FM-IF	Amplifies the 10.7-mc FM signal.
AM Converter	Changes the AM-RF signals to IF signals (455 kc).

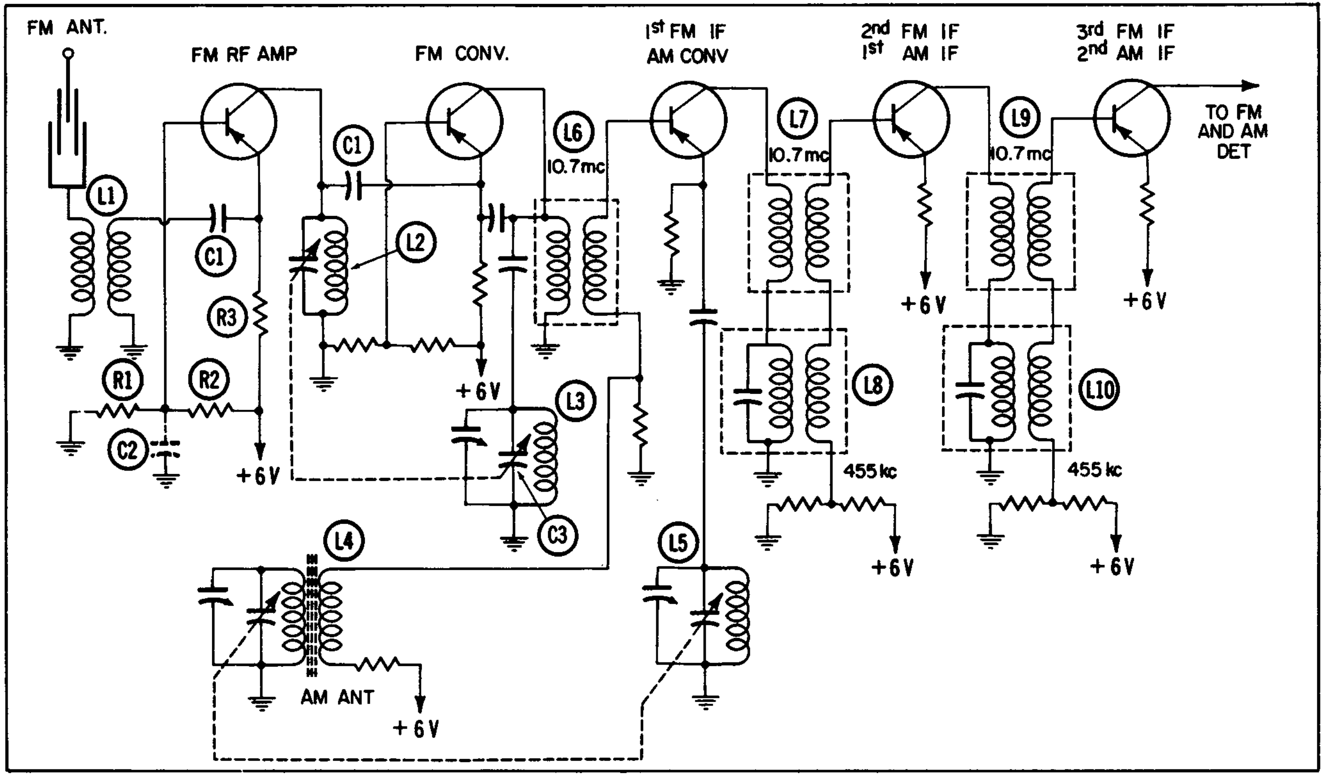


Fig. 4-1. Simplified AM-FM radio circuit (minus audio stages).

4.	2nd FM-IF	Amplifies the 10.7-mc FM signal.
	1st AM-IF	Amplifies the 455-kc AM signal.
5.	3rd FM-IF	Further amplifies the 10.7-mc signal.
	2nd AM-IF	Further amplifies the 455-kc signal.
6.	FM detector	Changes the FM signal to audio.
	AM detector	Separates the audio from the 455-kc signal.
7.	Audio Amp.	Amplifies the audio.
8.	Audio Amp. (driver)	Further amplifies the audio.
9.	Audio output	Builds up sufficient audio power to drive the speaker.

The block diagram (Fig. 4-2) shows the path the FM signal takes in dotted lines, and the AM signal flow in solid lines. Note that the AM portion of the radio is identical to the layout previously studied in Chapter 3. The only differences are:

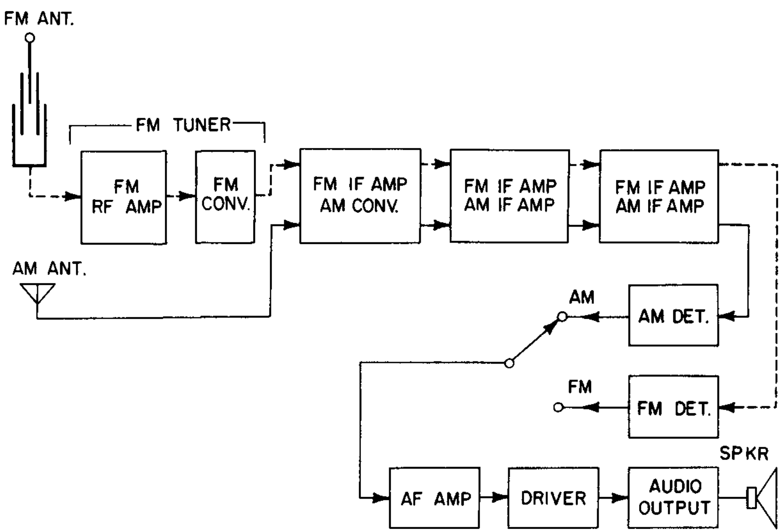


Fig. 4-2. Block diagram of the AM-FM receiver in Fig. 4-1.

1. A two stage FM tuner has been added.
2. An FM detector has been added.
3. Transformers tuned to 10.7 mc have been added in the IF stages to allow those stages to pass the FM-IF signal.

Circuit Description and Test Points

The circuits in Fig. 4-1 are almost identical to those in the AM receiver previously studied. In this case, all transistors happen to be PNP type, but many AM-FM receivers use NPN transistors in some stages.

As previously stated the emitter lead (in PNP circuits) goes through a stabilizing resistor to the positive side of the battery and the collector goes to the negative pole through some sort of "load." This holds true in every stage of this receiver. Also, the base lead of each transistor is connected to a voltage divider for its bias. For example, in the FM-RF amplifier stage, R1 and R2 form the voltage divider. R3 is the emitter stabilizing resistor and L2 is the collector load. In other words, the very same DC circuit conditions are set up here as we had in the basic amplifiers studied previously. This is important to remember when we start to troubleshoot this receiver.

But what about the AC circuits? By that, we mean the path that the broadcast signals (which are actually AC voltages) take as they pass through each stage. In the circuits studied in previous chapters, we found that the signal was injected, or inserted, in series with the base lead of each stage. That voltage is then either added to, or subtracted from, the DC bias voltage, depending on which half cycle it was on. This is where the first two stages of our AM-FM receiver differ.

FM Tuner

FM signals enter the RF stage through antenna coil L1 and coupling capacitor C1. Note that they are coupled to the *emitter*, not to base. The base is bypassed by capacitor C2, which holds it at ground potential and keeps it from varying with the signal. The signal is developed across R3; thus it is in series with the emitter lead instead of the base. This type of circuit—known as a common (or grounded) base circuit—has certain advantages in the FM tuner stages; it allows the transistors to operate efficiently at higher frequencies and provides better voltage gain. When the signal is coupled into the base, we call it a common (or grounded) emitter circuit. The latter is more popular for most applications, because it gives greater power gain.

When troubleshooting and injecting test signals into a stage, it is very important to first check the schematic to see where the signal is coupled in. If we pick the wrong point, it would appear that the stage is dead, because the test signal would be bypassed to ground. This would happen if we used the base of the FM-RF amplifier; we should inject the signal into the emitter where the regular FM signal enters (Fig. 4-1).

The FM converter is very similar to the AM converter discussed previously (See Fig. 3-1), except that the FM signal is coupled into the emitter along with the oscillator signal from

L3. Oscillator coil L3 and its associated capacitor C3 are tuned to a frequency which is 10.7 mc above the frequency of the FM station being received (Fig. 4-3).

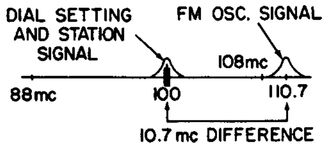
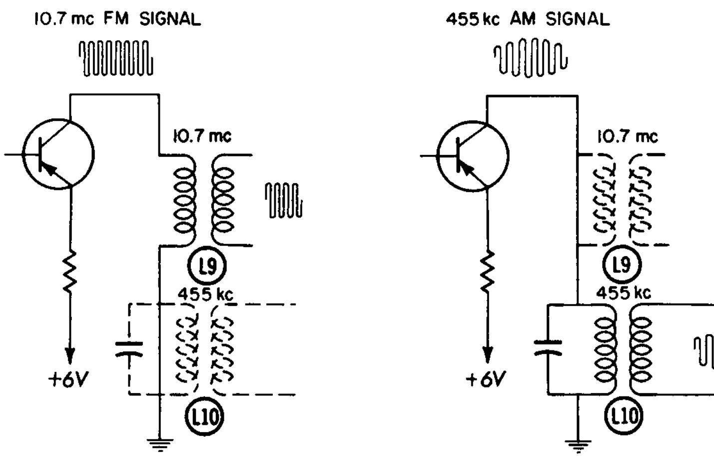


Fig. 4-3. The oscillator oscillates 10.7 mc above the incoming station frequency.

Dual-Purpose IF Stages

If two tuned circuits which are resonant at greatly different frequencies are connected in series and the same signal is fed to both of them, the signal will only "see" the circuit to which it is tuned. This is called electronic switching; it is accomplished automatically and no switches are needed in each stage.



(A) With FM signals.

(B) With AM signals.

Fig. 4-4. How the IF tuned circuits look to incoming signals.

Fig. 4-4A shows the collector circuit of one of the FM-IF stages. Note that the 10.7-mc IF transformer and the 455-kc IF transformer are in series. When the radio is tuned to an FM station and the 10.7 mc signal is produced (in the FM converter), L9 appears as a high resistance to the signal and literally "captures" it. It is then sent to the next stage. Transformer L10, however, looks like a complete "short" to the signal, since it is tuned so far off the signal frequency. L10 acts just like a piece of wire conductor (as shown in Fig. 4-4A). Another way of looking at it is that the capacitor across L10 bypasses the signal around the coil, since the 10.7 mc signal can pass through the capacitor very easily.

Now what happens when the radio is tuned to the broadcast band and AM stations are being received? The AM converter stage produces a 455-kc IF signal as shown in Fig. 4-4B. As the signal passes through the IF stages for amplification, it "sees" only the 455-kc transformer L10. Why? Because L10 acts like a high resistance, while L9 is so far off frequency it acts like a piece of wire. Actually, L9 is only a few turns of wire; therefore, it has a small inductance and doesn't react to the relatively low 455-kc frequency.

Thus, whichever type of signal being received is passed on to the next stage after amplification by the transistor. After passing through all IF stages, the signals are fed to one of the detector stages for conversion to audio.

AM and FM Detection

Conversion from an amplitude modulated 455-kc signal to audio is simple and is accomplished in the same manner as it is in a straight AM receiver. A diode (X3 in Fig. 4-5) removes one half of the envelope, and filters C33, C34, and R33 remove the 455-kc frequency. This leaves pure audio, which is then amplified by the audio system.

FM is different. Frequency shifts are present instead of amplitude variations. The FM detector must convert these frequency changes to amplitude changes, or audio. Note that L11 in Fig. 4-5 is tuned to 10.7 mc. Assume that a signal of exactly 10.7 mc is fed to L11 (by a signal generator or unmodulated FM station). The induced voltage in winding Z assists the voltage in windings X and Y equally, causing diodes X1 and X2 to conduct equal amounts of current (see arrows). This causes two currents of equal magnitude to flow through load resistor R1 in opposite directions, so no output voltage is developed across R1.

As the frequency shifts *above* 10.7 mc (due to modulation), a phase shift takes place, causing winding Z to assist winding X more than it does winding Y. Diode D1 now conducts more than diode D2, causing a positive voltage to be produced across R1. When the frequency shifts *below* 10.7 mc, winding Z assists winding Y the most, causing X2 to conduct heavier than X1. This causes a negative voltage to be developed across R1. Since R2 actually represents the volume control, the pulsating voltage is fed to the audio amplifiers. The voltage coupled via

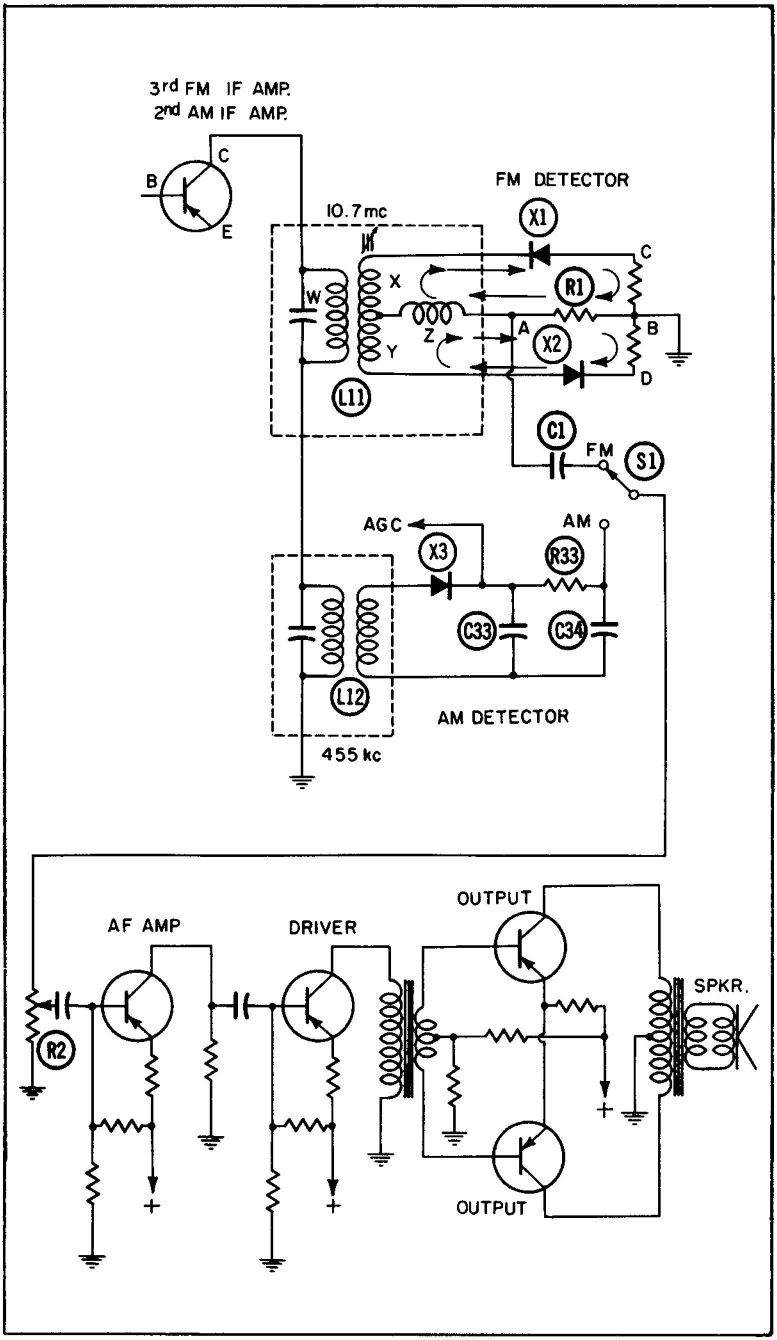


Fig. 4-5. Simplified schematic of detector and audio stages.

C1 and S1 to R2 is pulsating at the audio rate (in step with the shifts in frequency) and an audio signal is heard.

Balancing the FM Detector

In order for the detector to work properly, it must be balanced to make sure that 0 volts is obtained when exactly 10.7 mc is fed into the radio. Although a 10.7-mc IF signal can be obtained when a station signal is tuned in perfectly (assuming that the rest of the radio is aligned properly) there are too many variables for this to be accurate. It is best to feed in a 10.7-mc signal from a crystal-controlled signal generator.

Balancing is then accomplished by adjusting the slug for Coil X (detector transformer L11 secondary) for 0 volts on a meter connected between points A and B (Fig. 4-5). This prevents audio distortion by assuring a balanced plus and minus voltage during station modulation.

ISOLATING TROUBLES

When troubleshooting an AM-FM radio, approach it as you would a straight AM radio, by:

1. Checking batteries and battery current.
2. Looking the radio over carefully for obvious defects (batteries in backwards, cracks in circuit board due to dropping the radio, etc.).
3. Sectionalizing the radio, or getting an idea as to what section the trouble is in.
4. Reading voltages to pinpoint the exact trouble spot.

Since Step 4 will be covered in detail later the remainder of this chapter will be devoted to Step 3.

Listening Test

Usually by just listening to the AM-FM radio, you can tell what area the trouble is in. This is true because there are certain stages of the radio which function only when tuned to FM, and some which function only when tuned to AM. Other stages function during both AM and FM reception.

Once you have glanced at the schematic, think of it in terms of a block diagram (Fig. 4-6). When the switch is in the FM position, the FM tuner is in the circuit; during AM, it is not functioning. The IF section functions on both bands, except each tuned circuit is sensitive to only one frequency. Each detector functions on its own band only, and the audio system serves both bands.

Let's assume that the radio is dead on FM but works fine on AM. The trouble is probably in the FM-tuner section or in the FM detector. If the radio is dead on AM but performs all right on FM, the AM detector or the oscillator portion of the AM converter stage may be out (some radios have a separate AM oscillator transistor).

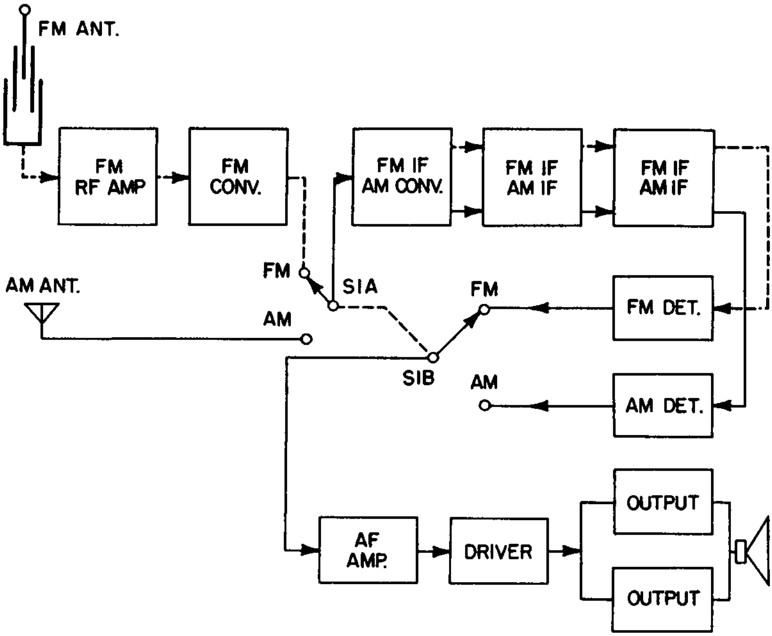


Fig. 4-6. Keeping the general layout in mind.

If the radio is dead on both AM and FM, the trouble is probably in one of the stages which functions for both—the IF or audio section. A weak radio may be due to a defective or detuned antenna, tuner, or IF transformer. (See Table 4-1.)

TABLE 4-1.

Probable Causes of Defects in AM-FM Receivers

Indication	*Probable Trouble Area*
FM Dead; AM OK	FM Tuner or FM Detector
AM Dead; FM OK	AM Detector or Oscillator
AM and FM Dead	IF or Audio Section
FM Weak; AM OK	FM Antenna, Tuner, or IF-Tuned Circuit
AM Weak; FM OK	AM Antenna or Alignment
FM Distorted; AM OK	FM Detector, Detector Transformer, or Alignment

Signal Injection

Signal injection can be used, as it was on straight AM receivers; however, there are some differences which will be noted.

Since noise is amplitude modulation (AM), noise generators will not work on FM. This is also true for "click" or shock tests. Many technicians, however, use noise generators with the radio in the AM position; this checks all the dual-purpose stages and the AM detector.

Starting at the volume control, we can inject noise to see if the audio stages are working. A noise generator can be used for this test, but the radio probably has its own noise generator located at that point—the volume control itself. After some use, the control usually gets a little noisy. This noise is amplified by all of the audio stages if they are working. Put your ear next to the speaker and turn the control back and forth near the high-volume setting. If a little noise is heard, the audio amplifiers are probably working.

If the audio stages are working, place a noise generator on the base of the first AM-IF transistor. This checks the AM-IF amplifiers and the AM detector. Next move to the AM converter or antenna. A loss of signal at any point indicates trouble. When this occurs, certain voltages, described in the following chapter, should be read.

AM-FM radios have another "built-in" noise generator which operates when the radio is switched to FM. The FM tuner produces a high-pitched hissing sound when the volume control is turned up and the radio is tuned between stations. This hiss is due to the increased noise level inherent in most high-frequency transistors. Before this hiss is heard, however, all of the FM-IF amplifiers must be working. Usually the FM converter must also be working because very little hiss is produced by the IF amplifiers.

If the FM-IF amplifiers *and* the FM converter are working, there will usually be a mild hiss with volume control turned all the way up. If the FM-IF amplifiers, FM converter, *and* FM-RF stages are all working, a louder hiss level will be heard. A loud hiss level but no audio usually points to a bad FM-antenna or FM-oscillator circuit.

Using a Signal Generator

Signal generators are seldom used on AM-FM radios; the trouble can usually be sectionalized by merely listening to the radio (on both AM and FM), by a noise generator (on AM), or by tuner noise (FM). FM signal generators, however, are often used for alignment of AM-FM auto radios. They require very precise alignment because it is difficult to obtain passable FM performance in a moving vehicle. This will be discussed in a later chapter.

Summary

Understanding how the AM-FM radio works and visualizing a block diagram as you glance at the schematic saves considerable time in localizing troubles. After checking batteries and listening to the radio—on both AM and FM—a pretty good idea of the trouble area can be determined. Four types of signals are available without even turning on a signal generator. They are:

1. Volume control "scratch" which can usually be heard with ear next to speaker as control is rotated. Checks: Audio amplifiers.
2. AM station signals. Checks: AM converter, IF amplifiers, and AM detector.
3. FM station signals. Checks: FM tuner, IF amplifiers, and and FM detector.
4. FM tuner hiss. Checks: Normal hiss with no FM signal points to FM oscillator or antenna circuit trouble. Weaker hiss with no FM signal points to FM-RF stage trouble.

In other words, we can automatically inject signals at the following points in the radio by simply utilizing what is already available to us: at the audio input (by rotating volume control); at the AM converter (by switching to AM stations); at the FM-IF (by switching to FM tuner hiss between stations); at the FM-RF (by tuning in FM stations).

CHAPTER 5

Normal Transistor Voltages

After isolating the trouble to a stage or section of the radio, such as the IF, audio, or converter, we are ready to pinpoint the actual cause. This can best be done by analyzing the voltages at the transistor elements in that section.

It is easy to read the various voltages and compare them with those on a schematic; but unless the troubleshooter knows the meaning of each voltage, he will be unable to determine anything from them. This chapter is devoted to normal transistor voltages—what they mean and how they are formed. The following chapter deals with incorrect voltages and their meanings.

The amount of voltage in the battery or power supply is one factor which determines how much voltage will be found at the various transistors.

This is why it is important to always check the battery voltage first, because if it is low, all transistor voltages will be low also. They will not correspond to the voltages listed on the schematic, since the later are almost always taken with fresh batteries.

Also, weak batteries can cause all sorts of troubles, including a weak, dead, or distorted radio, or even one with weird oscillations or motorboating sounds.

COMPARISON OF TUBE AND TRANSISTOR ELEMENTS

The emitter in a transistor (Fig. 5-1A) emits current carriers; the cathode in a vacuum tube (Fig. 5-1B) emits current carriers. Therefore, the emitter and cathode have a lot in common—the same basic purpose.

The base element in the transistor controls the current flow through the transistor, and the grid in the tube controls the electron flow through the tube. Therefore, they, too, have something in common. The signal is fed in at this point in most tube and transistor circuits.

The collector of the transistor collects the current carriers sent out from the emitter. The plate in a vacuum tube has the same function—to collect the electrons which come from the cathode. The signal is usually taken off (coupled) from this element and sent to the following stage.

(A) Transistor. (B) Vacuum tube.

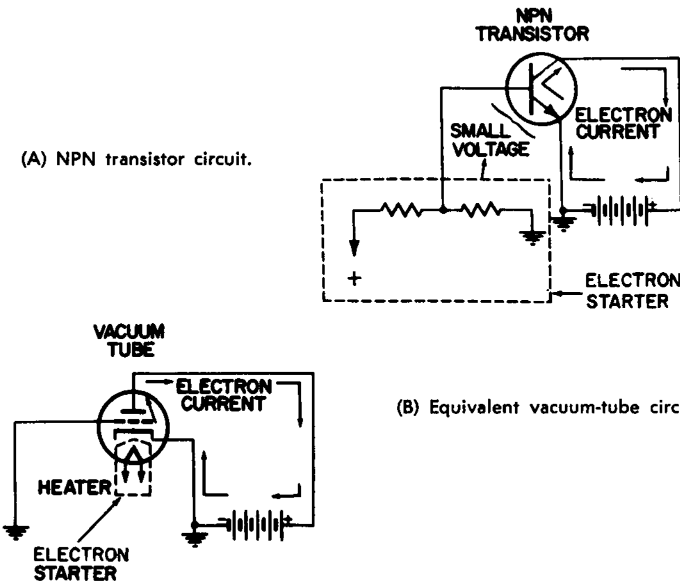
Fig. 5-1. Comparison of the elements.

One of the major differences between tubes and transistors is in the method of emitting current carriers from the cathode or emitter. The tube has a filament to "boil" electrons out of the cathode. But the transistor has no such filament. It uses a small forward bias voltage between base and emitter to start current flowing. This requirement in the transistor leads to the second major difference, the much lower input resistance in the transistor. The small forward bias voltage on the transistor causes a much lower resistance between base and emitter than the tube has between grid and cathode. Most tubes can have zero voltage between grid and cathode—or even a negative bias—and still conduct, because the heater is continuously "boiling" electrons out of the cathode. With this reversed voltage on the grid, no grid current will flow and the input resistance of the tube will be very high. In the transistor, however, a small base current does flow in order to make the current carriers start moving toward the collector; the input resistance is quite low because of the presence of electrons in the emitter to base region. A measurement of this low resistance is one test we will make later when we talk about testing transistors.

NPN TRANSISTORS

The basic NPN circuit is shown in Fig. 5-2A; Fig. 5-2B shows a similar vacuum-tube circuit. In both examples, the positive pole of the battery is connected to the element which attracts and collects electrons, and the negative pole to the one which emits them. In both examples, the electrons travel out of the negative pole, up through the tube or transistor, and into the positive pole of the battery, making the complete circular path shown by the arrows. Since the emitter is grounded, there is no voltage on it with respect to ground (Fig. 5-3A). The +10 volt potential is applied directly to the collector, and that's what is being measured there.

A quick glance at the input circuit tells us there is a difference between the vacuum-tube (Fig. 5-3B) and transistor



(A) NPN transistor circuit.

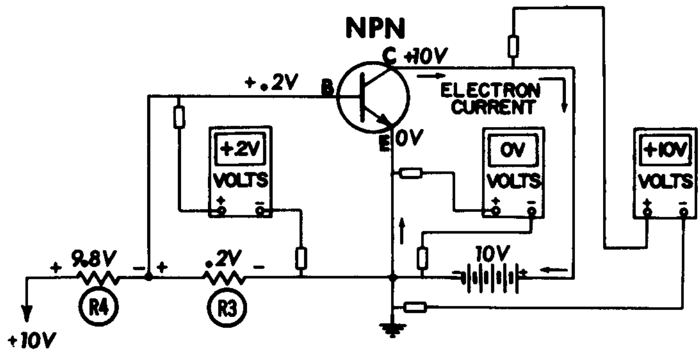
(B) Equivalent vacuum-tube circuit.

Fig. 5-2. The basic circuit.

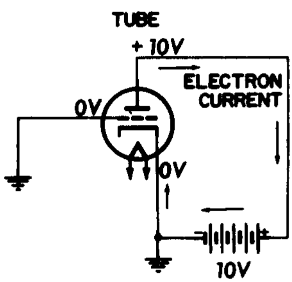
circuits. The grid of the tube is tied directly to ground because it needs no bias voltage to make it conduct. The transistor base lead, however, is connected to a voltage divider which, in a sense, replaces the filament the transistor doesn't have. This puts the base at a slightly positive voltage with respect to the emitter; so a small base current flows. This base current is usually so small it can be neglected for troubleshooting purposes. But after being amplified by the transistor, a larger readable collector current is produced.

Effect of Emitter Resistor

In Fig. 5-4A an emitter resistor, R1, similar to the cathode resistor in a tube circuit, (Fig. 5-4B) has been added. Since the output current travels through these resistors, a voltage drop is produced across them. With the electrons flowing up

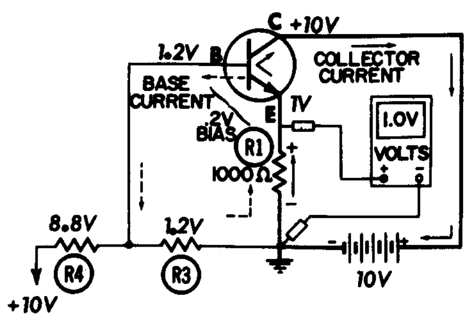


(A) The transistor circuit.

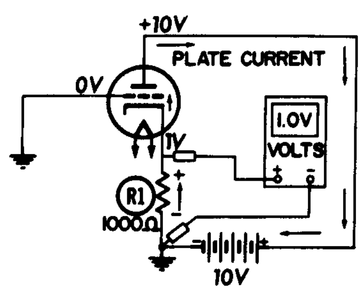


(B) Equivalent vacuum-tube circuit.

Fig. 5-3. Voltages present at various points within the circuit.



(A) The circuit.



(B) Equivalent vacuum-tube circuit.

Fig. 5-4. Adding an emitter resistor.

through R1, as shown by the arrows, the bottom becomes negative and the top positive (Rule: the end where electrons enter a resistance becomes negative with respect to the opposite end.) This gives us a positive voltage on the emitter or cathode when the meter is placed between that lead and ground. This is nothing new, for we have often been able to tell whether a tube is conducting by its cathode voltage (provided a resistor is used in the cathode circuit). The next question is, "How much voltage will there usually be across this resistor?" It depends on how much current is flowing, and on the value of the resistor. Ohm's law states that the voltage across a resistor is equal to the current flowing through it, multiplied by its resistance, thus, if R1 remains constant, the voltage will be directly proportional to the amount of current flowing through it.

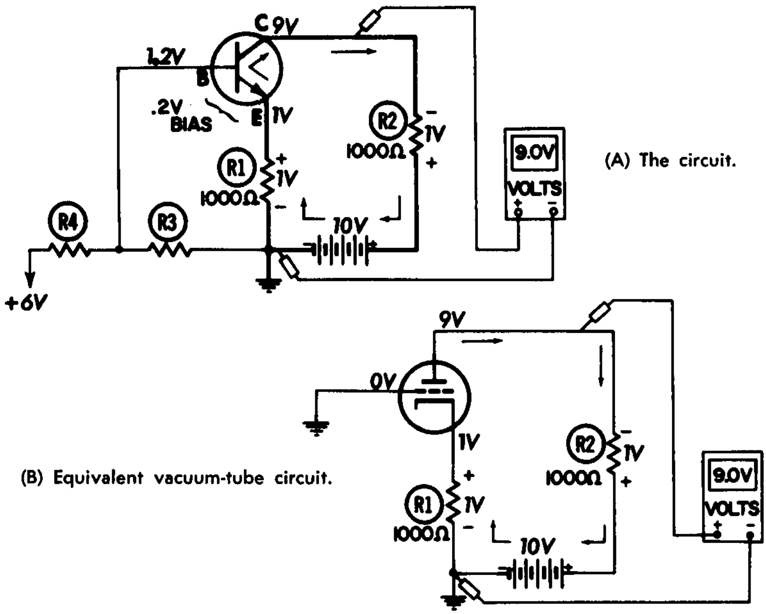
When the current increases, so will the voltage across R1. If no current is flowing in the circuit, there will be no voltage across R1.

Effect of Collector Resistor

In Fig. 5-5A, collector resistor R2 has been added. In Fig. 5-5B, a plate resistor of the same value is connected in series with the plate lead. It has been common practice in vacuum-tube circuits to judge the plate current by the voltage across the plate resistor, R2, or by a comparison of plate and battery voltages. In Fig. 5-5B, electrons travel from cathode to plate in the tube, *down* through resistor R2, and the battery, and *up* through cathode resistor R1 as they make their way back to their "home base," the cathode. This means that although the electrons traveled *up* through R1, they flow *down* through R2, producing a negative voltage across R2. The 1.0-volt drop across R2 is subtracted from the battery voltage, leaving only 9 volts on the plate. This is another indication that plate current *is* flowing. Otherwise, the plate voltage would be 10 volts because, with no current flowing through R2, no voltage will be dropped across it (voltage drop equals current times resistor value, which would be zero times 1,000, or zero). This method of estimating DC output current works fine except for one hitch—in low-voltage circuits, the plate resistor is usually a coil with insufficient resistance to cause a noticeable voltage drop.

The same principles hold true in Fig. 5-5A, the only difference being that the electrons are flowing through a transistor instead of a tube. This makes no difference as far as the resistors are concerned—if the same current flows, the same voltages will be produced.

Electrons leave the emitter, travel through the transistor to the collector, then go *down* through R2, and the battery, and *up* through R1 to the emitter, as shown by the arrows. This produces, across R2, a negative voltage which is subtracted from the battery voltage to leave 9 volts at the collector. If no collector current were flowing, there would be no voltage across R2 and the collector would read the full 10 volts.



(A) The circuit.

(B) Equivalent vacuum-tube circuit.

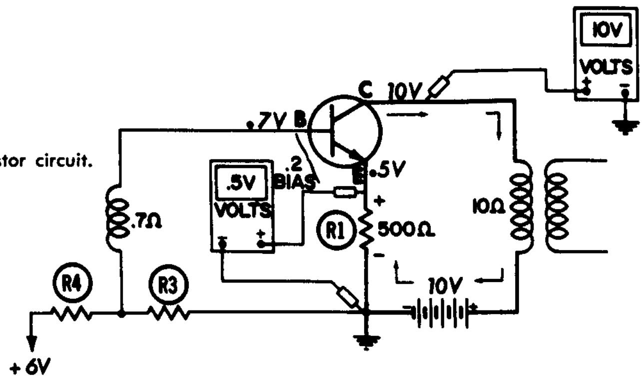
Fig. 5-5. Adding a collector resistor.

Since we know that all voltage drops in a series circuit must add up to the battery voltage, one might wonder where the other 8 volts are. There is 1 volt across R1 and 1 volt across R2; the remaining 8 volts are found across the transistor, from emitter to collector. A voltmeter placed between the emitter and collector in Fig. 5-5A would read 8 volts. The voltage between emitter and base would read about 0.2 volt, the base voltage being set primarily by voltage divider R3-R4.

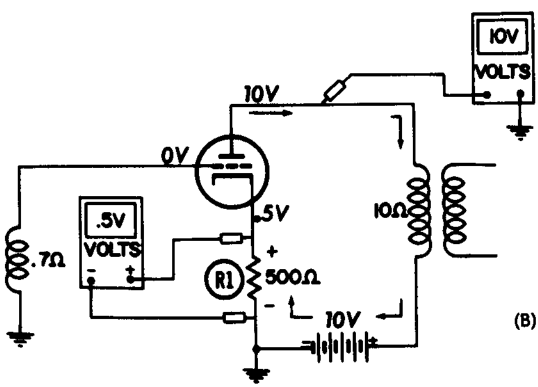
Estimating Collector Current

It was previously stated that the voltage drop across R1 and R2 depends on the amount of current flowing through them—the more the current, the greater the voltage drop. Thus, current is *directly proportional* to the voltage produced. We also know that the higher the resistance is in a circuit, the lower the current will be for a given battery voltage. This means the current is *inversely proportional* to the resistance.

Now let's figure the value of the collector current in Fig. 5-5A. The current through R1 is equal to 1 volt divided by 1,000 ohms, or .001 amp. To convert amps to milliamperes, move the decimal three places to the right; so the answer is 1 milliampere. The same figures hold true for the current through resistor R2, because its resistance and the voltage across it are the same. (A very small base current flows through emitter resistor R1, but it is too small to add any noticeable voltage across R1.)



(A) In a transistor circuit.



(B) In a vacuum-tube circuit.

Fig. 5-6. Replacing R2 with a transformer.

As in vacuum-tube circuits, a very low-resistance transformer is sometimes used in place of R2. If so, very little voltage will be found across the transformer.

Effect of Collector Transformer

Fig. 5-6A shows a circuit where the collector or plate resistor (R2) has been replaced by a transformer. Assuming the same current of 1 milliampere (.001 ampere) is flowing in the circuit, there will be no readable voltage across the transformer because this multiplies out to only .01 volt—so small it can be considered as zero. The collector and plate voltages now read essentially the full 10 volts because there is no noticeable drop in the positive battery lead.

Note also that the value of the emitter resistor in Fig. 5-6A and the cathode resistor in Fig. 5-6B have been changed. Assuming the collector current is adjusted to about the same as before, or 1 milliampere, the voltage drop across R1 will now decrease to half of what it was before. This is true because the voltage across R1 is equal to the current times the resistance of R1; if the resistance goes down and current remains the same, voltage is bound to go down. Emitter resistors vary in size, depending on the circuit design and the amount of stabilization needed. Common values are from 100 to 2,200 ohms in low-power transistor circuits. Transformer resistances also vary widely. Audio transformers usually have sufficient resistance to produce a voltage drop in the collector circuit, whereas RF and IF coils do not.

The addition of a transformer coil in the base lead has no affect on any of the voltages because the coil usually has a very low resistance (0.7 ohm for the one in Fig. 5-6) and there is practically no current flowing through it.

Voltages Between Elements

In most instances the voltages from one transistor lead to another mean more than the ones to ground, as will be seen in the next chapter. The difference between base and emitter, which we know as the transistor "bias voltage," is extremely important. The transistor cannot operate properly without it (except in some converter, oscillator, detector, and special push-pull circuits).

Fig. 5-7 shows the normal element-to-element voltage relationship found in most amplifier circuits. If the transistor is an NPN unit, the negative lead of the voltmeter is placed on the emitter; and the positive lead is touched first to the base and then to the collector lead. In other words, first the voltage between base and emitter is checked, and then the one between collector and emitter. Since the base-to-emitter voltage, or bias, is usually quite small, it should be read on the low-voltage DC scale. Notice that the bias for a germanium transistor (Fig. 5-7A) is less than that for a silicon transistor (Fig. 5-7B). The collector-to-emitter voltage should be larger, its value depending on the battery voltage, the resistance in the emitter and collector circuits, and the amount of collector current.

Assuming the NPN transistor is in a typical amplifier circuit, with a small forward bias between base and emitter, the base voltage will be slightly positive with respect to the emitter; the collector voltage will be much more positive. In both instances, the emitter is used as a reference instead of ground. Here is an easy way to remember which meter lead to place on the emitter—it is the same as the *first* letter in the transistor type, NPN. We will find out later that, in PNP circuits, the *positive* meter lead is placed on the emitter—corresponding, of course, to the first letter in PNP.

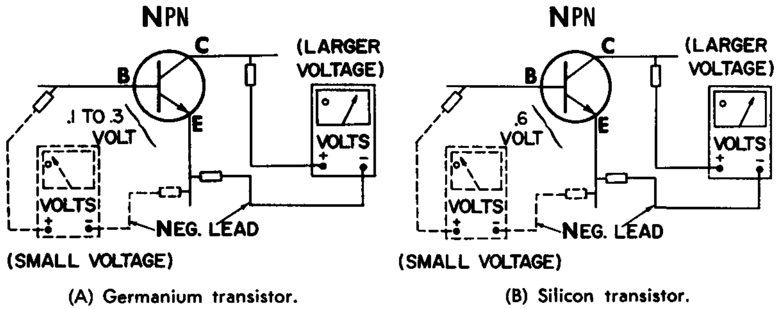


Fig. 5-7. Typical element-to-element voltage relationship in a basic transistor amplifier circuit.

When troubleshooting a stage, the first step is to determine if the transistor is conducting (by checking for voltage across the emitter or collector resistor). If not, the bias should be checked to see if the transistor is being "told" to conduct. This will be described in more detail in later chapters.

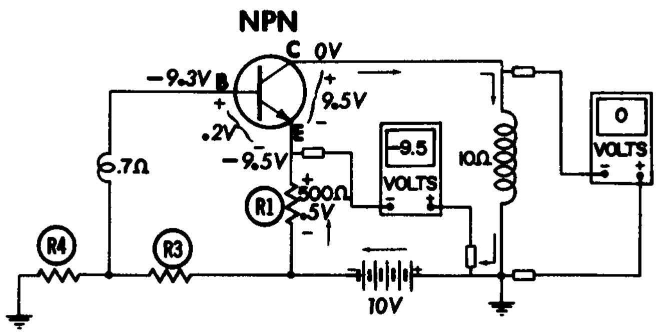
NPN Circuit with Positive Ground

So far all circuits have had a negative ground; that is, the negative side of the battery has been grounded. If the positive side is grounded instead, all voltage will read negative with respect to ground, as shown in Fig. 5-8A.

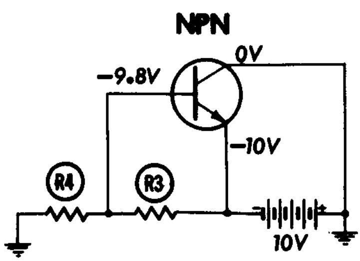
The circuit in Fig. 5-8B shows the basic NPN amplifier before any resistances have been added in the emitter or collector circuits. The battery is therefore connected directly across the transistor, and it is easy to see that the collector voltage will be zero with respect to ground. The emitter voltage will be −10 volts since it is tied directly to the negative side of the 10-volt battery. The circuit in Fig. 5-8A has resistances added in series with all leads to the transistor. The 10-ohm transformer winding in the collector lead does not produce a noticeable voltage drop, so the collector voltage remains at zero.

Emitter resistor R1 in Fig. 5-8A is 500 ohms and there is 0.5 volt across it. Since the electrons are flowing *up* through R1, the voltage across R1 will be negative at the lower end and postive at the top. In other words, this voltage opposes the battery voltage, so it subtracts from the latter, leaving only −9.5 volts between emitter and ground.

The base voltage is set by voltage divider R3-R4, so it is about 0.2 volt positive with respect to the emitter. This makes the base voltage −9.3 volts with respect to ground.



(A) Complete circuit.



(B) Basic circuit.

Fig. 5-8. A positive-ground NPN circuit.

The important thing to note in Fig. 5-8 is that the voltages, if measured between elements, are the same as they were in the negative ground system. In other words, the rules that applied in Fig. 5-7 still hold true: When the negative voltmeter lead is placed on the emitter, all voltages will read positive. The base voltage will read about 0.2 volt (for a germanium transistor), compared to that of the emitter, and the collector voltage will be 9.5 volts. Thus, the fact that a positive ground is used will not change circuit operation nor the voltages when read with respect to the emitter.

Actual Radio Voltages

All the principles we have learned so far about voltages in NPN circuits will now be applied to an actual radio schematic.

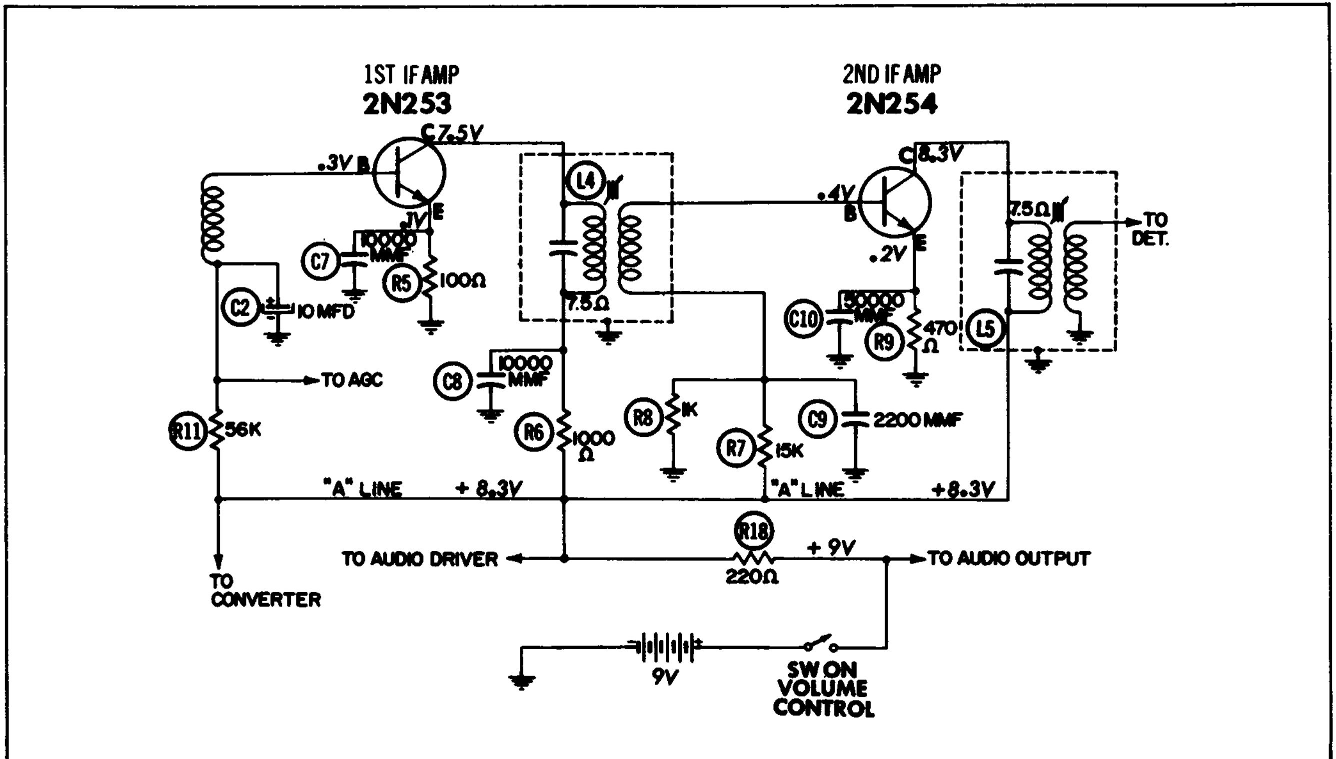


Fig. 5-9. Typical IF section of a transistor radio.

The 1st and 2nd IF stages of a typical transistor portable using NPN transistors is shown in Fig. 5-9. A 9-volt battery with negative ground is used. The full battery voltage is applied to the audio-output stage, but the voltage to the other stages is dropped to 8.3 volts by a 220-ohm resistor, R18 in the "A" line.

The 2N253 transistor has a 100-ohm resistor, R5, in its emitter lead; 0.1 volt is produced across this resistor by the collector current. The collector of the 2N253 is connected to a 7.5-ohm IF transformer winding, which produces no noticeable voltage drop. However, there is also a 1,000-ohm resistor (R6) in series with the collector lead, and 0.8 volt is dropped across it, leaving 7.5 volts on the collector. It is important to note that sufficient resistance values and collector current flow produce voltage drops across the emitter and collector resistors.

The 2N254 transistor (2nd IF) in Fig. 5-9 has more resistance in the emitter circuit, but less in the collector lead. Emitter resistor R9 is 470 ohms, and 0.2 volt is developed across it by the flow of collector current. The collector lead has no resistance except the 7.5-ohm IF coil, so essentially the full 8.3 volts from the "A" line reach the collector. The base voltage is set by a voltage divider, R7-R8, in the usual manner. The base voltage of the 2N253 (1st IF) transistor is varied slightly by the AGC voltage, which in turn varies the collector current of that stage. This will change all voltages if the radio is tuned to a strong station; thus, voltages should always be measured with the radio tuned "off station." If this is done, the AGC system need not be disabled.

The 2N253 transistor in Fig. 5-9 is drawing about one milliampere, and the 2N254 transistor is drawing slightly less than half this much.

PNP TRANSISTORS

The basic PNP circuit is shown in Fig. 5-10. The emitter voltage now becomes the most positive, because the battery has been turned around—the positive pole connected to the emitter and the negative pole to the collector.

If a vacuum tube were turned around so the electrons had to flow in the opposite direction from normal, the battery would have to be turned around also. In other words, for the electrons to be pumped counterclockwise, around the circuit, the battery must be connected as shown in Fig. 5-10. Since PNP transistors are designed to pass electrons from collector to emitter, the battery must be connected to send electrons into the collector, through the transistor, and then out of the emitter as shown by the arrows. This is why, in PNP transistor circuits, the emitter is usually connected to the most positive voltage.

If there are no resistances in the emitter and collector circuits, the full battery voltage will be found across the tran-

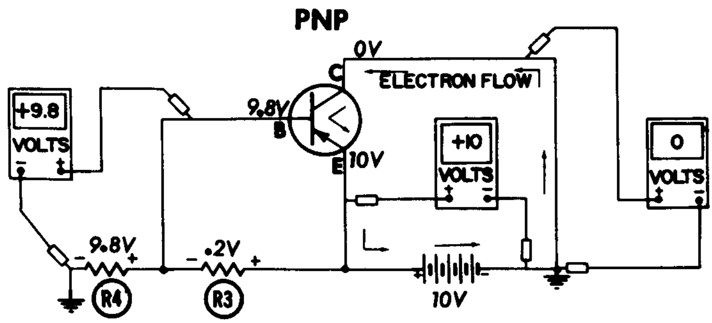


Fig. 5-10. The basic PNP transistor circuit.

sistor, from emitter to collector. The base voltage is usually maintained by a voltage divider, R3-R4, at a slightly less positive voltage than that of the emitter.

Effect of Emitter and Collector Resistors

In Fig. 5-11, the same circuit is shown, except emitter and collector resistors have been added. The flow of electrons

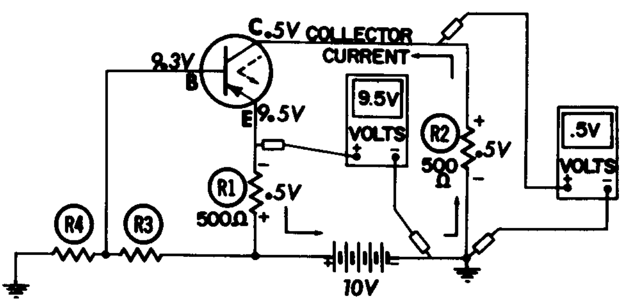


Fig. 5-11. Voltage distribution in the PNP transistor circuit.

through these resistors causes voltage drops of the polarities shown.

Now, when the collector voltage is measured with respect to ground, the meter is actually being placed across collector resistor R2. This means that if the transistor is conducting, a voltage will be read at the collector; but if not, the collector voltage will read zero because R2 does not have a voltage drop across it.

The emitter reads 9.5 volts because the same current also makes a circular path and passes through emitter resistor R1. The voltage drop across R1 is subtracted from the battery voltage, leaving 9.5 volts at the emitter. A base current will also pass through R1, but it is usually so small it does not add significantly to the voltage drop across the resistor.

The voltage drops across R1, R2, and the transistor add up to the battery voltage. This follows the rule for series circuits (0.5 volt plus 0.5 volt plus 9 volts = 10 volts).

Effect of Coupling Transformers

As with NPN transistors, transformers often do not cause a readable voltage drop. This is especially true of IF transformers, where the resistance and the collector current are rather small.

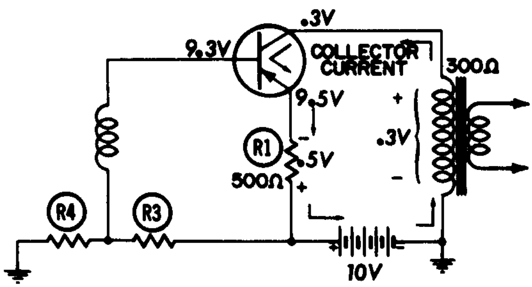


Fig. 5-12. A noticeable voltage drop occurs when there is an audio transformer in the collector circuit.

Audio transformers often do produce a noticeable voltage drop. The collector transformer winding in Fig. 5-12 has a DC resistance of 300 ohms; a current of only 1 milliampere would cause the collector voltage to rise to 0.3 volt. The same current, as it passes through emitter resistor R1, causes a little larger voltage drop there because R1 has a little more resistance than the collector winding. The fact that the emitter voltage is not 10 volts and the collector voltage is not zero indicates the transistor *is* conducting in that circuit.

Base voltage is not affected by the transformer winding in the base lead because that winding usually has such a low resistance and base current is so small that no significant voltage is dropped there.

Estimating Collector Current

Usually the troubleshooter only wants to know whether or not the transistor is conducting—the exact amount of current is not too important. In some audio amplifiers, however, the value of the collector current *is* important, and a potentiometer may even be provided in the base circuit so the current can be adjusted.

The current in Fig. 5-12 can be figured from Ohm's law, by dividing the voltage drop across a resistance by the value of that resistance. We know the voltage across the collector transformer is 0.3 volt and the resistance is 300 ohms, so collector current must be 1 milliampere.

Collector current is sometimes adjusted by using the collector voltage as an indication. When the voltage is right, the current will also be about right. This makes it unnecessary to break any leads to measure current. In those circuits where the collector current is adjustable, R4 will usually be a variable instead of a fixed resistor.

Voltages Between Elements

The voltage the transistor sees is the one between its elements, and this is what it operates on.

Most PNP transistors will have the most positive voltage applied to the emitter; therefore, when the emitter is used as

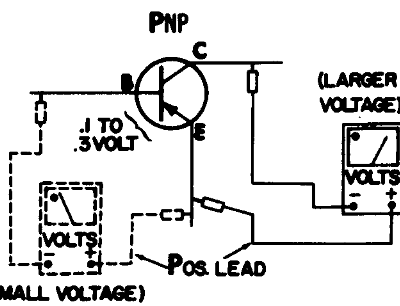


Fig. 5-13. Voltages measured with respect to emitter in a PNP transistor circuit.

a reference, the base and collector will be negative. This means that if the positive meter lead is placed on the emitter and the negative lead is used as a probe, as shown in Fig. 5-13, the voltages will usually read *up* the scale. Exceptions are sometimes found in certain converter, detector, and push-pull output stages, where the base-to-emitter voltage may be zero or even reversed in polarity. In converter circuits, the oscillator signal may reverse the bias, but this is normal if the voltages are listed that way on the schematic.

PNP Circuit with Positive Ground

As with NPN circuits, a positive ground may be used on some sets. When checked with respect to ground, all voltages will then be negative.

In Fig. 5-14, the emitter is the least negative because it is nearest to ground. The only reason any voltage is read on the emitter is that there is a voltage drop across emitter resistor R1; otherwise, the emitter voltage would be zero.

Collector voltage reads −10 volts because it is almost directly connected to the negative pole of the battery (collector transformer resistance is quite low). Voltage divider R3-R4 keeps the base slightly more negative than the emitter. The impor-

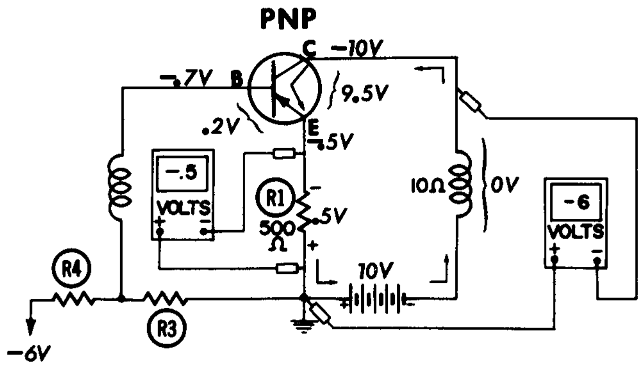


Fig. 5-14. A typical positive-ground PNP circuit.

tant point is that the transistor elements still see the same voltage polarities with respect to the emitter.

Actual Radio Voltages

In Fig. 5-15 the 2N252 converter has a 4,700-ohm resistor, R4, in the lead between the emitter and the 8.3-volt "A" line. Collector current flowing through the resistor causes a drop of 1.3 volts across R4, leaving 7 volts on the emitter. If the 2N252 transistor were not conducting, no voltage would be dropped across R4 and the emitter reading would be considerably higher.

Voltage divider R2-R3 keeps the base voltage about 0.2 volt less positive than the emitter, as is customary for most PNP circuits. As mentioned previously, however, some PNP converter circuits operate with the bias reversed—that is, the base may appear to be more positive than the emitter as long as the oscillator is oscillating. If the schematic calls for a reversed bias between base and emitter, that is one way to tell if the oscillator is oscillating. The only reason for a bias reversal in this type of circuit is that the oscillator signal is sometimes strong enough to reduce the emitter voltage below normal. If the oscillations are stopped, the bias will return to a normal forward bias. The oscillator tank circuit sends its

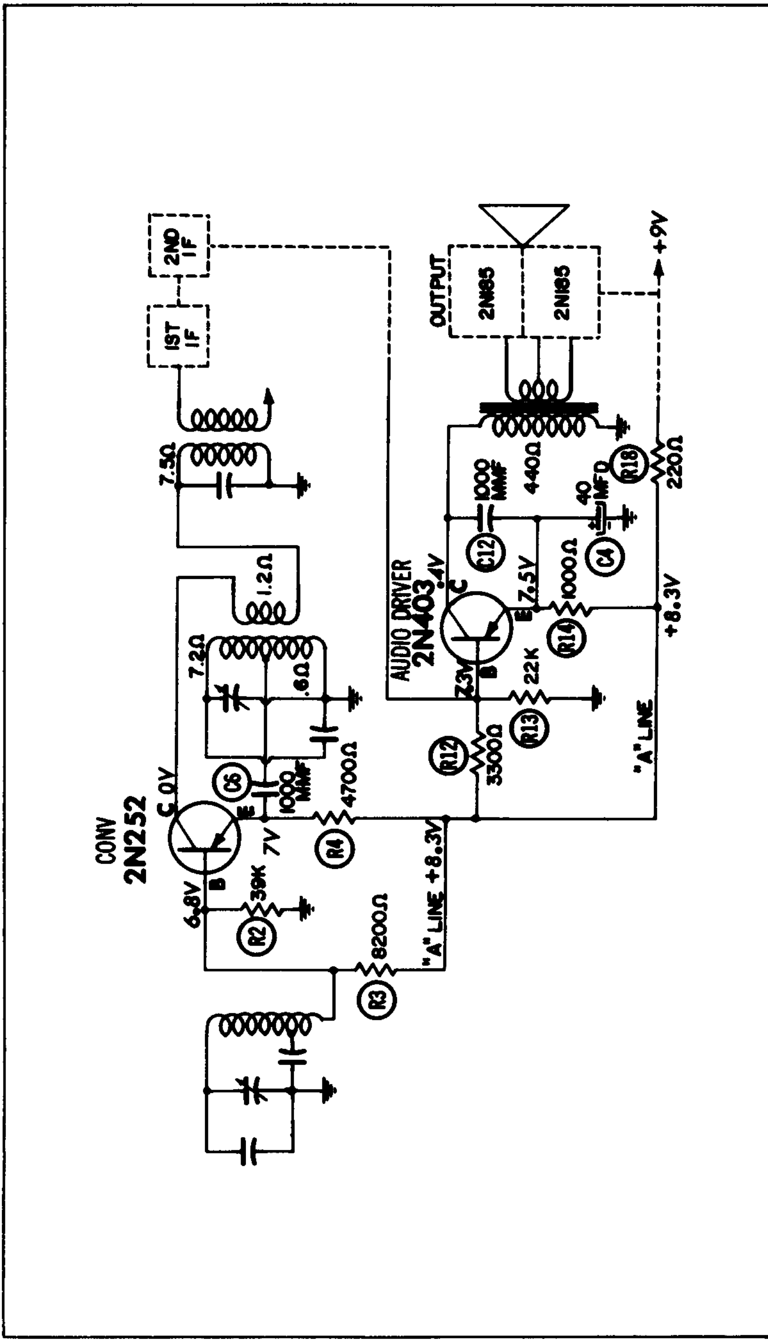


Fig. 5-15. Normal voltage distribution in typical PNP converter and driver stages.

signal voltage to the emitter through a 1,000-mmf capacitor, C6, where the signal is detected by the emitter diode. In Fig. 5-15, however, the oscillator does not cause a bias reversal.

The collector circuit contains two transformer windings—the 1.2-ohm oscillator feedback winding and the 7.5-ohm IF primary. Neither coil has sufficient resistance to cause any noticeable voltage drop, so the collector voltage reads zero.

Fig. 5-15 also shows the audio driver stage, which employs a 2N403 transistor. The collector has an audio transformer winding with a DC resistance of 440 ohms; thus, a voltage drop of 0.4 volt is produced as the collector current passes through that winding. This causes the collector voltage to read 0.4 volt positive with respect to ground.

The emitter of the driver transistor is tied to the 8.3-volt "A" line through R14, and 7.5 volts are measured at the emitter. Base resistors R12 and R13 keep the base slightly negative with respect to the emitter.

SUMMARY

Schematics show normal voltage readings between each transistor element and ground but these are not the most important voltages in a transistor radio. Although it is important to understand what produces those voltages, the readings which mean the most in troubleshooting are:

1. The battery voltage under load (radio on).
2. The voltage across the emitter resistor, which tells if the transistor is conducting or drawing current. (In some circuits, this voltage may be measured across the collector resistor or coil.)
3. The bias, or voltage between base and emitter, which "tells" the transistor to conduct by pulling current carriers out of the emitter.

These three voltage checks (Fig. 5-16) are the first ones made when searching for trouble in a stage. After we learn all we can from those checks, voltages to ground may be read, but they are made only to confirm what we already suspect the trouble to be.

The reason the "conduction test" is so important is that it tells so much about the condition of the stage. By this one simple test we can learn if anything is open in the collector current path—resistors, coils, leads, or the transistor itself. It even tells us more than that, for if any of the leads, resistors, or coils in the base circuit are open, the bias would not be normal. And the collector current will be upset. So, by this

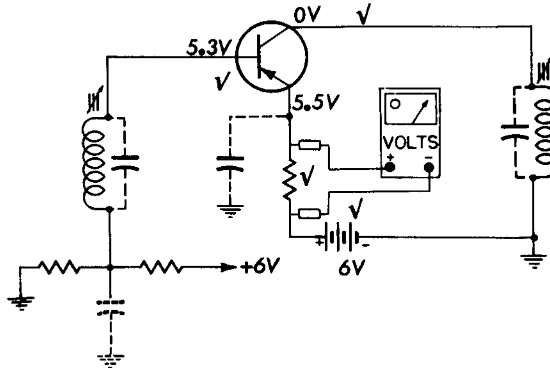


Fig. 5-16. Normal voltages usually indicate that DC conducting components are OK.

one check we can tell about the condition of all components which pass DC, whether they be in the collector circuit, the base circuit, or the transistor itself. This saves much time over what it would take to check all of those components individually.

If conduction is normal and the stage still won't pass a signal properly, a capacitor may be open or a coil detuned. But, by making the voltage checks, we at least know where to look for the trouble. This system, along with the method of isolating the trouble to one section of the radio saves an incalculable amount of time. Systematic troubleshooting makes a lot more sense (and cents!) than the old "hunt and poke" technique ever did.

The next question is, "What happens to the conduction, bias, and other voltages when certain components open or short?" How can we tell which component is defective by making these measurements? The next chapter is designed to give you a feel for this. It will probably be the greatest aid in diagnosing troubles we could possibly give you.

CHAPTER 6

Defective Voltages and Their Meanings

Voltages can usually pinpoint the trouble to one particular part of the circuit, provided they are read carefully and their meanings interpreted properly. This can save still more time, because the technician can often go directly from the voltage readings to the defective part or conductor.

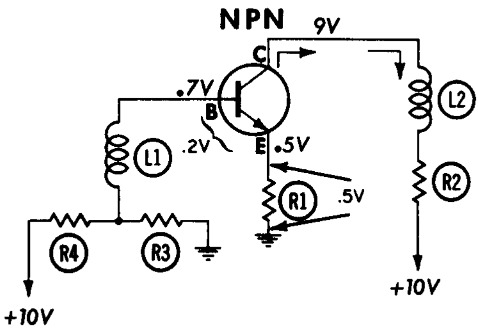
Some defects affect only one voltage in a stage, whereas others cause more than one to be wrong. Some defects will cause a loss of collector current, but others can cause it to be much higher than normal. The base-to-emitter voltage, or bias, will go to zero in some cases, or it may reverse in polarity. Other troubles cause the bias to increase until it is higher than normal, but at the same time cause a loss of collector current flow instead of the expected increase. All these conditions mean something to the alert technician, leading him directly to the trouble area in a minimum of time.

Naturally the voltage change for each defect will depend on the type of circuit and the value of the components. However, if the popular common-emitter types of amplifier and oscillator circuits shown previously are studied, the basic principles can be learned and applied to almost any transistor circuit encountered. Troubles will be placed in the circuits and the voltages noted for each type of trouble. The drawings and charts in this chapter will serve as a handy reference when a radio with defective voltages is encountered in the shop. Later, after enough experience has been gained in measuring and analyzing transistor voltages, this will also become routine.

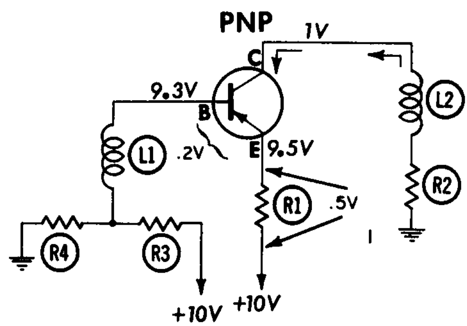
CAUSES OF VOLTAGE ERRORS

The first part of this chapter will show various voltage errors and the troubles which can cause them to be that way. The second part will discuss various components and show what happens to the signal and the voltages when each component becomes defective.

We will always assume the battery voltage and current have already been checked, so no trouble can exist from a defective battery. Voltages are read by a meter with a resistance of 20,000 ohms per volt or higher, and the radio is tuned off the station frequencies to prevent signals from entering it.



(A) In an NPN circuit.



(B) In a PNP circuit.

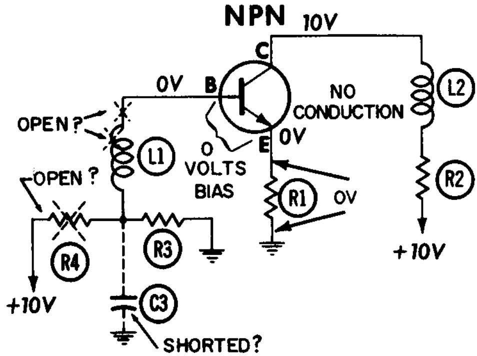
Fig. 6-1. Normal DC voltages.

Before any defects occur, we'll assume the voltages in the NPN circuit (Fig. 6-1A) and the PNP circuit (Fig. 6-1B) read as shown.

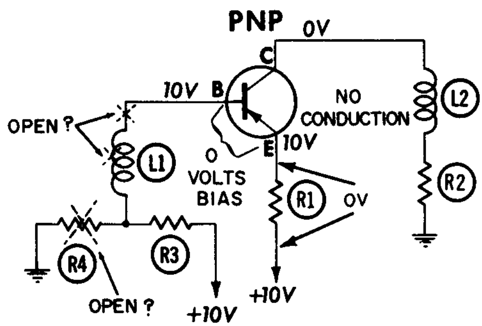
Wrong Base Voltage

Very few defects will cause the base voltage to be far from normal when measured with respect to ground, except those in the base circuit itself. The reason is that the base voltage is usually obtained from a voltage divider; and unless the base is disconnected from this divider, or the divider itself is defective, the base voltage cannot change by a very large amount. Small variations in base voltage do not usually cause the circuit to be inoperative, provided the base-to-emitter current is normal.

In Fig. 6-2A the NPN transistor has lost its base voltage, and also its bias between base and emitter. When the base voltage is lost in an NPN transistor, the transistor no longer conducts. Current ceases to flow through emitter resistor R1; so there



(A) In an NPN circuit.



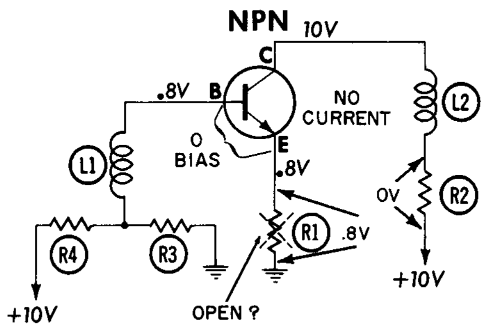
(B) In a PNP circuit.

Fig. 6-2. Open base circuit.

is no longer any voltage drop across R1. Current through L2 and R2 will also stop flowing, causing the collector voltage to read the same as the positive supply voltage fed to that stage. In other words, a loss of base voltage in an NPN circuit causes loss of conduction, which can also affect the emitter and collector voltages. Possible defects which can cause these conditions are an open conductor in the base circuit, open coil L1, open base resistor R4, or shorted capacitor C3.

If the base lead should open in the PNP circuit in Fig. 6-2B, the base voltage will go more positive instead of negative. The reason is that the emitter has 10 volts on it and the resistance inside the transistor is very small between the base and emitter. The base, therefore, goes to the emitter voltage when it loses connection with its own voltage divider R3-R4. The base "assumes" the emitter instead of collector voltage because the internal resistance between base and collector is quite high.

The loss of base-to-emitter bias voltage in Fig. 6-2B causes the current through R1, R2, and L2 to stop. The voltage drop across the resistors therefore disappears, causing the emitter to go to 10 volts and the collector to zero or ground. This set of conditions is due to the open base conductor, open transformer L1, or open voltage-divider resistor R4. The base voltage to ground may not actually read the full 10 volts as shown be-



(A) In an NPN circuit.

(B) In a PNP circuit.

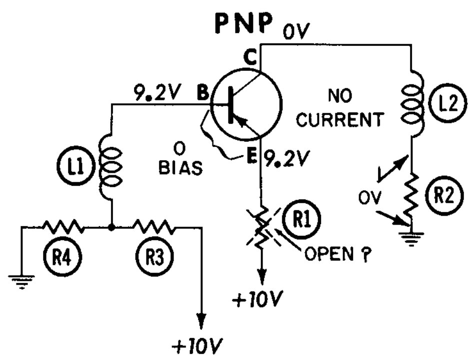


Fig. 6-3. Open emitter circuit.

cause of the voltmeter resistance, but it will not be normal. The lack of conduction, the loss of bias, and the wrong base voltage point to trouble in the base circuit.

Loss of Base-to-Emitter Bias

The loss of normal voltage between base and emitter can be due to another defect—namely, an open in the emitter circuit. This is shown in Fig. 6-3, where emitter resistor R1 or one of its connections has opened. The results are very similar to the open base circuit, except the base voltage now is nearer normal when measured with respect to ground.

In the NPN circuit (Fig. 6-3A) the base voltage remains very close to normal, rising only slightly because the base current has stopped flowing. The floating emitter now takes on, or assumes, the neighboring base voltage of about 0.8 volt. Again this is due to the very low internal resistance between base and emitter, which tends to keep the voltages very close together on those two elements. Actually, when placed between base and emitter to measure the bias, the voltmeter will read zero or very slightly negative on the base with respect to the emitter. Normally, of course, it is slightly positive.

The transistor cannot possibly conduct while the emitter circuits are open, so no voltage is dropped across collector coil L2 or collector resistor R2. By looking at emitter voltage only, one might assume the transistor is conducting. But here the floating emitter is getting its voltage from the base. This is why it is important to read all voltages on a transistor, including its bias, before making any conclusions about the stage.

In the PNP circuit (Fig. 6-3B) the emitter resistor has also opened. As might be expected, the floating emitter element takes on the neighboring base voltage through the low internal resistance in the base-emitter diode. The base voltage to ground stays fairly close to normal, since the base is still attached to its voltage-divider resistors R3 and R4. There may be a slight variation in base voltage because no base current is flowing, but it would appear to be well within normal limits to the troubleshooter. The emitter voltage to ground might also be considered within normal limits. But when the meter is placed between the base and emitter, the bias will read zero or slightly reversed from normal. Collector voltage to ground reads zero because there is no collector current; therefore, no voltage is produced across L2 or R2.

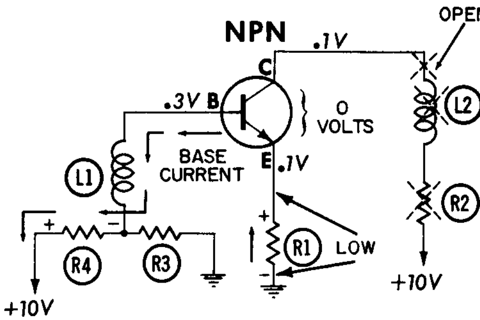
An open emitter resistor is a quite common defect in power-output stages, where the resistor also serves as a fuse for the transistor.

Remember, when checking the resistance of a resistor or coil in a transistor circuit, that the ohmmeter has an internal battery which will affect the resistance of the transistor diodes. The latter resistance will therefore shunt the resistance being measured. However, whenever a transistor is reverse-biased, its resistance becomes very high. So, when the resistance of the coil or resistor is measured, and the ohmmeter leads are then reversed and the resistance measured again, the resistance reading probably will change. The higher reading will be the one least affected by the transistor. It is therefore the more accurate one.

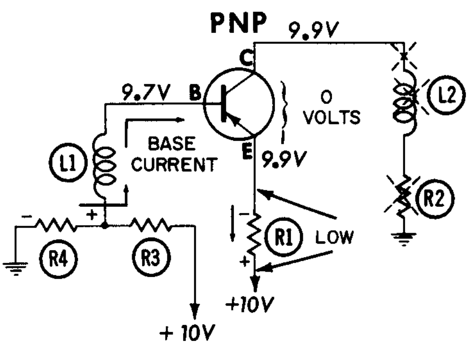
Loss of Emitter-to-Collector Voltage

The loss of voltage between the emitter and collector leads is very easy to spot because all elements appear to have about the same voltage on them. This condition is shown in Fig. 6-4, where the collector circuit has opened.

In the NPN circuit (Fig. 6-4A) with an open collector lead, the collector voltage drops to a very low value. This acts like a vacuum-tube circuit with an open plate lead, where the plate voltage drops to zero. In the transistor circuit, however, the collector voltage may not drop all the way to ground because



(A) In an NPN circuit.

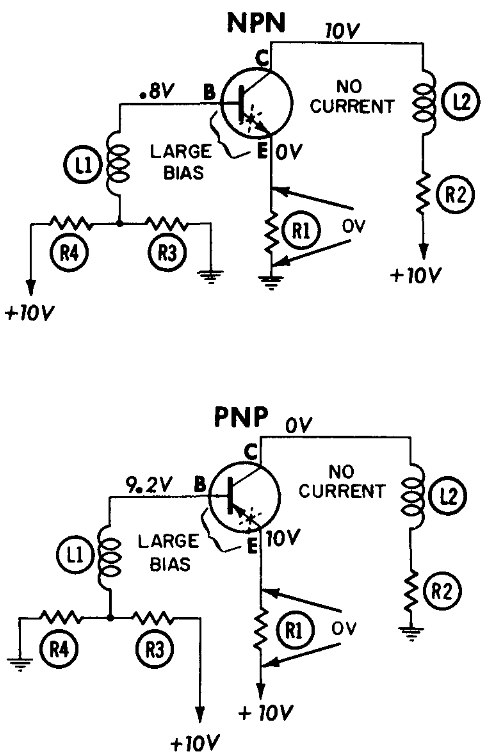


(B) In a PNP circuit.

Fig. 6-4. Open collector circuit.

the emitter may still have a slight voltage on it. Collector current, of course, stops flowing. But because electrons cannot flow into the collector circuit, more of them flow into the base circuit and cause an increase in base current. This base current flows through emitter resistor R1, and may now cause a readable voltage drop across R1—in this instance, 0.1 volt.

What happens next is quite interesting. As the collector voltage drops below the base voltage, the transistor becomes a low resistance between base and collector. (The collector diode is now forward biased.) The base-to-emitter diode already had a low resistance; so now the resistance across the whole transistor, from emitter to collector, becomes very low. The collector will take on, or assume, whatever voltage is on the emitter, leaving no difference between those two elements. This condition could be caused by open collector transformer L2, open collector resistor R2, or an open connection in the collector circuit.



(A) In an NPN circuit.

(B) In a PNP circuit.

Fig. 6-5. Open emitter lead within the transistor.

The PNP circuit in Fig. 6-4B has a similar defect, causing all voltages to read almost the same in that stage. However, since the positive side of the battery is connected to the emitter through R1, all voltages go in a positive instead of negative direction.

The emitter voltage goes up slightly because less voltage is dropped across R1, and the base voltage does likewise because the base current increases (see the arrows). The collector voltage assumes the emitter voltage because of the low internal resistance between the emitter and collector elements. Thus, there is no voltage difference between emitter and collector, making this a very easy trouble to spot.

Open Lead Inside the Transistor

So far we have learned what happens to voltages when either the base, emitter, or collector circuits are opened, either by a defective part or by a broken conductor. A different set of voltages will be read, however, if one of the leads inside the transistor should open.

In Fig. 6-5 the emitter lead has opened in the transistor. The effect of this on the NPN transistor circuit (Fig. 6-5A) will be studied first. The flow of current through the transistor stops because the transistor has become an open circuit. Since the voltage at the emitter was produced by the normal current flow through emitter resistor R1, the emitter voltage will now drop to zero. Also, since collector current stopped flowing through L2 and R2 in the collector circuit, there will be no voltage drop across them. Collector voltage rises to the full battery voltage of 10 volts. The base voltage is not affected much because it is still connected to its voltage divider R3-R4. This causes a very odd-looking situation; namely, the transistor has a very high forward bias (0.8 volt) between base and emitter, but shows no sign of drawing any collector current. This is very unusual, indeed, because we would normally expect the transistor to conduct very well with such a large bias. This leads us to suspect an open lead within the transistor.

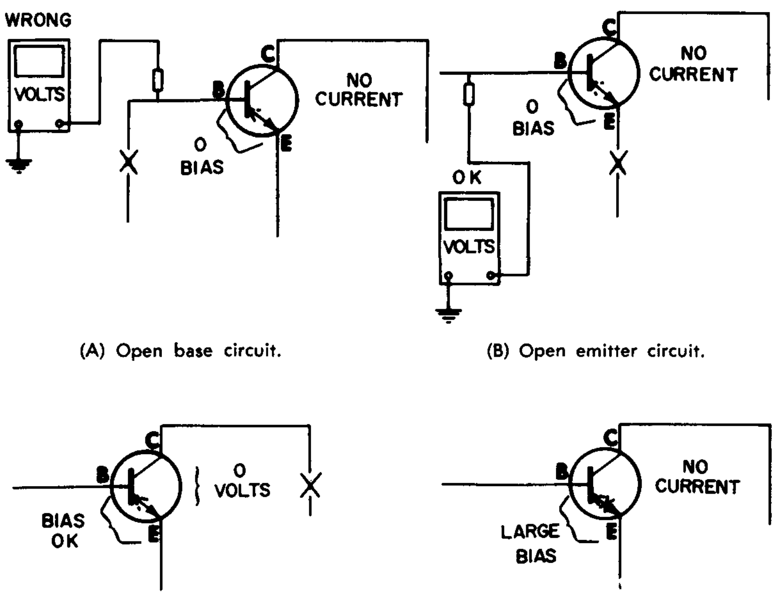
The PNP circuit (Fig. 6-5B) demonstrates a similar defect. The base voltage remains very close to normal because it is still connected to its voltage divider R3-R4. When the transistor is open, however, collector current does not flow; so the voltage drops that were present across the emitter and collector resistors disappear. This puts the emitter at the same potential as the supply voltage, or 10 volts. The collector, grounded through L2 and R2, goes to ground or zero volts. The important point is that the forward bias measured between base and emitter is unusually good (0.8 volt); yet the transistor does not conduct. The reason, of course, is that a lead is open inside the transistor.

The emitter lead is not necessarily the only one that can open, although it seems to do so more than the others. If the base lead opens internally, the indications will be the same as seen for the emitter. If the collector lead opens, conduction is low, bias is normal, and the collector voltage goes to its source potential.

Review of Open Circuits

We have shown what happens to voltages when a lead opens in either the external circuit or the transistor itself. Now let's review these interesting situations.

Fig. 6-6 shows a summary of the most important voltage changes that took place with each defect. These changes will tip the troubleshooter off to the part of the circuit where the trouble probably lies.



(A) Open base circuit. (B) Open emitter circuit.

(C) Open collector circuit. (D) Open element within the transistor.

Fig. 6-6. Results of open conditions in a transistor circuit.

When the base circuit opened (Fig. 6-6A), the base element lost its connection to the voltage divider. This caused an error in the base voltage when measured to ground. Also, since the internal resistance between base and emitter is relatively low inside the transistor, the floating base element goes very close to the emitter voltage. This will show up when the voltages between elements are measured using the emitter as a reference. The base-to-emitter voltage will read zero. With no bias, the transistor cannot conduct, which will affect the emitter and collector voltages. There will be no voltage drops across the emitter and collector resistors.

The open emitter circuit (Fig. 6-6B) caused a similar set of conditions, except the base voltage to ground was fairly normal. The floating emitter lead, however, takes on the base voltage because of the low internal resistance inside the transistor. This causes the bias, when measured between base and emitter, to read zero, or even slightly reversed from normal in some instances. (The meter may actually go slightly *below* zero when it should be reading upscale.) This condition also causes the collector current to stop flowing.

The open collector circuit (Fig. 6-6C) caused the biggest change in collector voltage. In fact, the collector voltage changed so drastically that the internal resistance of the collector diode (collector-to-base) became very low. This caused a very low resistance all the way through the transistor, and the collector and emitter both went to the same voltage. When the collector voltage is measured with respect to the emitter voltage, this will show up as a zero difference. Such a condition is easy to spot because it is so far from normal. Usually, the collector-to-emitter voltage is the largest one between any two leads of the transistor. Another condition which will cause the emitter and collector to have the same voltage is a shorted transistor. This is a common trouble in power transistor output stages. It will be discussed in a later chapter.

The open lead inside the transistor (Fig. 6-6D) caused a larger-than-normal voltage between base and emitter, but a complete loss of collector current. These two conditions show that something is wrong, because a large bias should normally produce plenty of current. The lack of collector current will be evident by the lack of a voltage drop across the emitter and collector resistors.

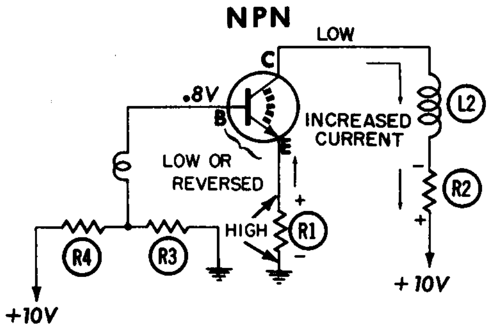
Several rules might be made from these observations:

1. If there is a loss of conduction, zero bias, and *wrong* base voltage, trouble is in the base circuit.
2. If there is "0" bias with *normal* base voltage, check for open emitter resistor (CAUTION: In many oscillator or converter circuits, it is normal for the bias to be zero or reversed).
3. If there is no difference between the collector and emitter voltages, the trouble may be an open in the collector circuit (or a complete short between emitter and collector; this usually happens to high-power transistors).
4. If a transistor has a better-than-normal bias voltage but no conduction, check for an open within the transistor.

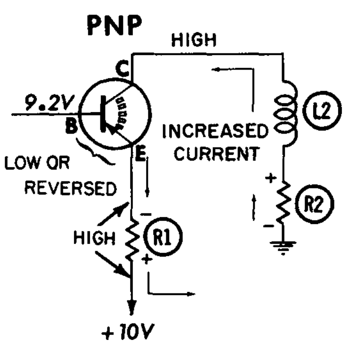
Most of these defects had one thing in common—they produced a *decrease* in collector current. The next question is, "What could cause an *increase* in collector current, and how will that defect change the voltages?"

Leaky Transistor

A transistor which develops a partial short between emitter and collector is commonly called a leaky transistor. It could be due to a partial breakdown in the transistor, or to excessive moisture or other contamination trapped inside.



(A) NPN circuit.



(B) PNP circuit.

Fig. 6-7. Effect of a leaky transistor on the circuit.

This is demonstrated in Fig. 6-7. The NPN transistor (Fig. 6-7A) has developed a partial short, causing the collector current to increase. The high collector current produces larger-than-normal voltage drops across the collector and emitter resistors, causing a decreased collector and an increased emitter voltage. The base, which is tied to its voltage divider, remains fairly constant. This means the emitter voltage may rise above the base voltage, causing a reversed bias between base and emitter. The transistor should be cut off; however, collector current continues to flow through the leakage path between emitter and collector.

A signal fed into the stage will be lost because of the wrong bias polarity between base and emitter, and because the collector current cannot be controlled. The increased collector current, without proper bias, leads us to suspect a leaky transistor.

In the PNP circuit (Fig. 6-7B) a similar defect has occurred. The partial short between emitter and collector causes increased current and the resulting increase in voltage drops across R1 and R2. This makes the collector voltages more positive and causes the emitter voltage to go down. In fact, the emitter voltage may even swing less positive than the base voltage and put a reversed bias between base and emitter. The wrong bias polarity, in conjunction with the increased collector current, causes us to be suspicious of the transistor.

High leakage is probably the most common defect in small transistors. Large power transistors usually go ahead and completely short, once they start to become leaky. Small transistors, on the other hand, very rarely develop a complete short.

Leaky transistors will not always produce a reversed bias voltage. Mild cases of leakage may cause only a reduction in the normal bias between base and emitter and in the stage gain.

Short in Base Circuit

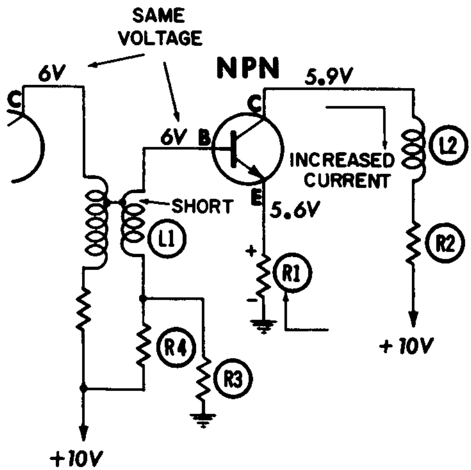
Transformers have been known to short between primary and secondary. Although not a common defect, it has occurred several times in transistor radios. When it does happen, an unusual set of voltages is produced.

In Fig. 6-8 for example, the transformer in the base circuit has shorted. The base voltage of this stage and the collector voltage of the preceding one go to the same voltage, since they are shorted together. In our NPN circuit (Fig. 6-8A), this caused the base voltage to go very high. As a result, the transistor conducts very heavily. When the collector current goes up, so does the emitter voltage; meanwhile, the collector voltage drops way down from normal. In some circuits the emitter resistor may open because of the increased current through it. In most low-power circuits, this will not happen. The signal, of course, will be lost.

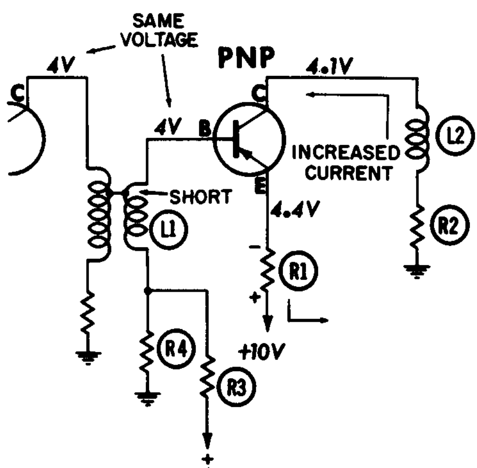
The PNP transistor with shorted base transformer (Fig. 6-8B) will also conduct very heavily if its base voltage is lowered. *Reducing* the base voltage on a PNP transistor is like *increasing* the base voltage on an NPN transistor—the forward bias and conduction will increase. This makes all the elements go closer to the same voltage. In this respect, it somewhat resembles the open in the collector circuit discussed previously. With an open collector circuit, however, the base voltage remained fairly near normal, whereas now it is far from normal, indicating trouble in the base circuit.

Table 6-1 lists some of the typical circuit defects and what effect they have on the voltages.

The second column in Table 6-1 shows the effect of each trouble on the transistor current flow (conduction). Note that



(A) In an NPN circuit.



(B) In a PNP circuit.

Fig. 6-8. Results of a short between the primary and secondary winding of a coupling transformer.

all problems except open capacitors or detuned coils upset the collector current. This change in conduction is a tip-off that something is wrong in the DC circuit (transistor, coils, resistors, or connections).

TABLE 6-1.

Common Defects and Their Effects on Voltages

Defect	*Transistor Current*	*Bias (B to E)*	*Other Indications*
Open Base Circuit	0	0	Base voltage not normal
Open Emitter Circuit	0*	0	
Open Collector Circuit	Low	Normal	Voltage between C & E is 0
Open Transistor	0†	High†	
Leaky Transistor	High	Low or Reversed	
Detuned IF Coil	Normal	Normal	All DC voltages OK
Open Capacitor	Normal	Normal	All DC voltages OK

* If emitter resistor is open there will be a voltage across it, but voltage across collector resistor will be zero.

† When base or emitter is open internally. See text for open collector.

The second column shows what happens to the voltage measured directly between base and emitter (bias). To see the bias, it is always best to measure directly between those two elements, not from element to ground. This allows you to use a lower meter range and to see the voltage more clearly. The bias measurement tells us whether the transistor is being "told" to conduct. In the first check (conduction), we learned whether the transistor was conducting. Now, we are finding out if it is being "told" to conduct, because transistor conduction depends on normal bias.

This gives us a new, more complete set of rules which will be invaluable in troubleshooting transistor amplifiers:

RULE 1—A transistor which is *not conducting* and *not* being "told" to conduct is not at fault, so look for trouble in the base or emitter circuit. (Examples: See open base circuit or open emitter circuit in Table 6-1.)

RULE 2—A transistor which is *not conducting* but *is* being strongly "told" to conduct, is probably defective. (Example: See open transistor. Check for open emitter diode.)

RULE 3—A transistor which is *conducting too heavily* and has *low or reversed bias* is probably leaky. (Example: See leaky transistor.)

RULE 4—A transistor which has *lower than normal conduction* and *normal bias* should have voltage between emitter and collector checked. If zero, collector circuit is open (see open collector circuit). If E to C voltage is normal or slightly high, the collector diode of the transistor may be open (see chapter on Transistor Testing).

RULE 5—A transistor stage which has *all normal DC conduction* but doesn't amplify properly, probably has an open capacitor or detuned coil.

Open Capacitors and Defective IF's

Open capacitors and detuned coils generally have no affect on the DC voltages, as discussed in the last chapter. Hence, once the trouble has been isolated to a stage, and if the voltages all check normal, it would be well to suspect a detuned coil or open capacitor. IF coils which change the radio volume when tapped or heated, or those which do not peak properly, should be replaced. Likewise, if the volume is increased when a capacitor is bridged with a good capacitor, the bridged capacitor should be replaced.

Shorted Capacitors

The effect of a shorted capacitor depends on its location in the circuit. Leaky or shorted "A" line electrolytics usually decrease all stage voltages and greatly increase the battery current drain. They also may cause motorboating or fluttering and a slight dip in "A" voltage with each flutter.

Electrolytic coupling capacitors, which couple the signal from one stage to another, can usually be spotted easily if they short. Since they are usually connected into the base circuit of a stage, the base voltage will be thrown way off when they short. Also, the voltage across the capacitor will measure zero, or much less than it should.

Other bypass capacitors, such as emitter and collector bypasses, seldom short. Most shorted capacitors are confined to the electrolytic type. However, a shorted capacitor in the emitter or collector circuit would be very easy to spot because of the voltage reading there.

SAMPLE DEFECTS IN ACTUAL CIRCUITS

Now it is time to apply all of this information to an actual radio circuit. The ones we will discuss are taken from a typical transistor radio containing both NPN and PNP circuits.

NPN Stage Defects

Trouble examples in the NPN stages will be discussed first. These stages were shown in Fig. 5-9.

Trouble: Shorted 1st IF base capacitor C2 (10 mfd).
Result: Base and emitter voltages drop to zero, and the 2N253 transistor *stops conducting*. This causes the

collector voltage to rise. The stage is very weak or is dead because there is *no bias.*

Trouble: Open emitter resistor R5 (100 ohms).

Result: The stage is dead because *no current* can flow. The emitter voltage rises to the base voltage or slightly above, resulting in *no forward bias* between the base and emitter. The collector voltage rises because the collector current has stopped.

Trouble: Open printed wiring between the 2N253 collector and the 7.5-ohm IF coil winding in L4.

Result: Collector *current stops flowing.* The emitter voltage therefore drops to an unreadable value near zero. The collector voltage drops to the same value as the emitter voltage, and there is *no difference between collector and emitter.* The base voltage remains near normal. The stage is dead.

Trouble: "Leaky" 2N254 transistor in the second IF stage.

Result: The *collector current goes up,* and the emitter voltage rises accordingly. The emitter voltage may rise above the base voltage, since the latter stays fairly constant. The collector voltage drops only slightly because the resistors in series with the collector are small (7.5 ohms in coil L5 and 220 ohms in resistor R18). The collector voltage will decrease by about 0.2 volt for each 1 milliampere of increased current. The stage will be either weak or dead, depending on how leaky the transistor becomes.

Trouble: Open capacitor across primary of IF coil L5.

Result: Very weak second IF stage, with *no change in voltages.* The slug in IF coil L5 *will not peak* the IF. Also, if this is an intermittent open capacitor, the radio will probably kick in when the IF can is moved or tapped, or when its lugs are heated with a small iron.

Trouble: Open secondary lead in IF coil L4, between the 2N254 base connection and voltage divider R7-R8.

Result: The 2N254 base voltage reads zero, the collector current decreases, and the emitter voltage reads zero. The collector voltage increases only slightly, not enough to be noticeable (about 0.1 volt). Because of the *loss of bias,* the signal is lost.

PNP Stage Defects

The next group of troubles refers to the PNP circuits, which were shown in Fig. 5-15.

Trouble: Open connection at the 1.2-ohm oscillator feedback coil, causing the collector circuit of the 2N252 converter to open.

Result: The collector voltage rises to assume the emitter voltage, which also rises. *Conduction is low* and *zero voltage* is read between collector and emitter. The base voltage also rises a little because of the increased base current (but it would still be considered within normal limits). The stage is dead, and the oscillator fails to oscillate.

Trouble: Open 7.2-ohm oscillator-coil winding.

Result: The oscillator does not oscillate and cannot be heard in a nearby receiver. The voltages on the 2N252 converter *read normal*, except when the following test is made: When a voltmeter is set on the lowest DC scale and connected across the base and emitter leads, the 0.2-volt bias will not change as the variable capacitor is tuned across the band. The radio stage will pass noise signals easily, but no station signals will be heard.

Trouble: Open base lead inside the 2N252 converter transistor.

Result: The base voltage (at the transistor socket or solder terminal) will be fairly normal. The emitter voltage will be high (probably above 8 volts) because of *loss of conduction* through emitter resistor R4. This makes a *very high forward bias* voltage when measured between base and emitter. The collector voltage stays at zero. The stage is dead for all signals, and the oscillator does not oscillate.

Trouble: 1,000-ohm resistor R14 in the 2N403 driver stage has a poor solder joint, making it effectively open.

Result: The base voltage reads about 7 volts. The floating emitter in the transistor "assumes" about the same voltage through the relatively low internal resistance of the emitter diodes, resulting in a *loss of bias*. With no *collector current* flowing through the 440-ohm transformer winding, the collector voltage goes to zero or ground. Audio signal is lost.

Trouble: Shorted emitter bypass C4 (40 mfd) in the driver stage.

Result: The 2N403 emitter voltage drops to zero, the *transistor cuts off*, and the *collector voltage* therefore drops to *zero* also. The shorted capacitor causes about nine more milliamperes of current to be drawn through resistors R14 and R18 and, as a result, an additional voltage drop of about two volts across R18. Since R18 is in the "A" line, the 8.3 volts on this line is reduced to roughly 6.3 volts. This makes the voltages in some of the other stages appear low, and also points out the advantage of properly isolating the trouble in the beginning. The big tipoff here is that the *battery current* will read 16 or 17 milliamperes, instead of the normal 7 or 8 for this radio. This would lead us to suspect a shorted electrolytic in the very beginning, and the inability of the stage to pass an audio signal would steer us to the audio section.

AM-FM Stage Defects

The same principles apply when checking AM-FM circuits; for example (refer to Fig. 4-1):

Trouble: Intermittent RF transistor in the FM tuner.

Result: In most cases, transistors which cause a radio to *cut out intermittently* have a bad connection on one of the leads internally, usually the emitter. This would cause the conduction to stop, and zero voltage across emitter resistor R3. Also, bias would be higher than normal. Since only the FM signals are affected when this happens (AM is normal), this leads you to suspect the FM tuner section of the radio.

Special Note: Transistors which exhibit this type of defect are often sensitive to a small amount of heat. The heat from a portable hair dryer (about 140°F) is safe, but *do not use a soldering iron.*

Trouble: Open IF transformer (either AM or FM) in one of the dual purpose stages.

Result: Since the AM and FM-IF transformers are connected in series, if *either* one opens the radio will be *dead on both bands.* After checking the audio system and finding it normal, conduction is checked in each of the dual purpose IF stages. The open coil will cause the conduction reading to be either low or zero, depending on which side of the coil is open. If a primary winding is open, one of the transistors will have an open collector circuit. (Low conduction, normal bias, and no voltage between emitter and collector.) If a secondary winding is open, an open base circuit for one of the transistors will result (zero conduction, no bias).

CHAPTER 7

Testing Transistors

There are many types of transistor tests. Transistor testing actually begins with stage isolation and voltage checks, because a high percentage of defective transistors will cause one or more faulty voltages in the stage.

By defective transistor we mean one far enough from its normal ratings to cause the customer to complain. Since this is a practical manual we are not concerned with borderline cases —where a transistor has lost a db or two of its gain, but the effect in the receiver cannot be heard. To find such defects requires laboratory-type equipment, and they are not of interest to the average service technician anyway. Thus, the use of a common ohmmeter for transistor testing will be stressed in this chapter.

Transistor tests can be either dynamic or static—that is, made under actual operating conditions, where AC signals are fed in and the results measured; or strictly DC tests, which measure the ability of the transistor to respond to a simple battery current.

One form of AC signal test is substitution, where the suspected transistor is replaced in an effort to determine if the new transistor does a better job. In this test the station signal is the test signal: if it shows an improvement in the speaker, the original transistor is assumed to be defective. There are several disadvantages to the substitution test, especially if the transistor is soldered into the circuit and hard to reach. There is also the increasingly difficult problem of having each type of transistor available in the shop, plus the "detuning" action that a new transistor might have on a tuned circuit because of the difference in internal impedance. This detuning action on an IF transformer is not usually too serious if, for example, only one transistor is changed. But when substitution is being tried in several stages in the receiver, the tendency is to leave the new transistor in the radio and put the old one back in stock. If this is done in two or three stages before the defect is found, several circuits may be detuned, resulting in substandard sensitivity and performance.

So, if the substitution method is to be used, there is a great advantage in isolating the trouble to the *proper stage* first. Voltages should also be measured in the suspected stage or stages to make certain the trouble is not due to another defective component or to a poor connection.

Another form of dynamic, or AC, test is to remove the transistor from the receiver and place it in a dynamic tester. This type of tester usually contains a transistor amplifier or oscillator circuit into which a prescribed amount of signal input is fed. The transistor is then plugged into the tester and its characteristics noted by the output produced. This type of test, of course, is most accurate if the circuit in the tester is the same as the one in the receiver. Also, for a more accurate test the input signal used with the tester should be nearly the same as the signal fed to the transistor in the radio. Because this tester is usually quite expensive, it is generally used only with design work in the laboratory.

DC TESTS

Testing transistors by simple DC tests is the more popular method. Although not always perfect, the DC test does catch a high percentage of the defects occurring in transistors after they reach the field.

DC testing can be done in several ways. There are fairly inexpensive testers on the market. One of the first ones, introduced several years ago, tested only small, low-power transistors, principally the RF and IF types. Later, provisions were added for testing power transistors. Most DC testers read leakage and DC gain. They consist of a current meter, plus some resistors and self-contained batteries. The transistor usually must be removed from the circuit before it can be tested.

Almost every electronics technician owns one piece of equipment which contains a current meter and some resistors and self-contained batteries. In fact, it is usually the first piece of test equipment purchased for all-around shop use. We are referring, of course, to the popular VOM (volt-ohm-milliammeter) which has several voltage, current, and resistance ranges. The ohmmeter is actually a battery and ammeter in series, with several values of resistors for selecting the various multiplier ranges. Here, then, is an excellent DC transistor tester, provided it is used properly and its limitations are understood.

So those who have said to themselves, "I can't test transistors because I don't have a tester," may have had one staring them in the face and didn't know it. Most modern VOM's or VTVM's (vacuum-tube voltmeters) can be used for making several DC checks of the transistor.

This does not mean regular transistor testers are not recommended; on the contrary, they are usually quite convenient. But since instructions are furnished with these instruments, it would serve little purpose to cover their operation in detail here. On the other hand, little has been written about transistor testing by ohmmeter. Moreover, existing shop equipment should be employed whenever possible.

TESTING TRANSISTORS WITH AN OHMMETER

Several tests can be made with an ohmmeter. The one used in our tests had 1.5 volts at the ohmmeter leads (measured with a separate voltmeter).

Possible tests include one for open leads, a check of both diodes, and a leakage, gain, and transistor identification test. The last test simply tells whether the transistor is a PNP or an NPN unit.

Since they are all DC tests, the gain checks will have very little meaning for RF and IF transistors, which operate at the higher frequencies. The audio gain test, however, *will* give an

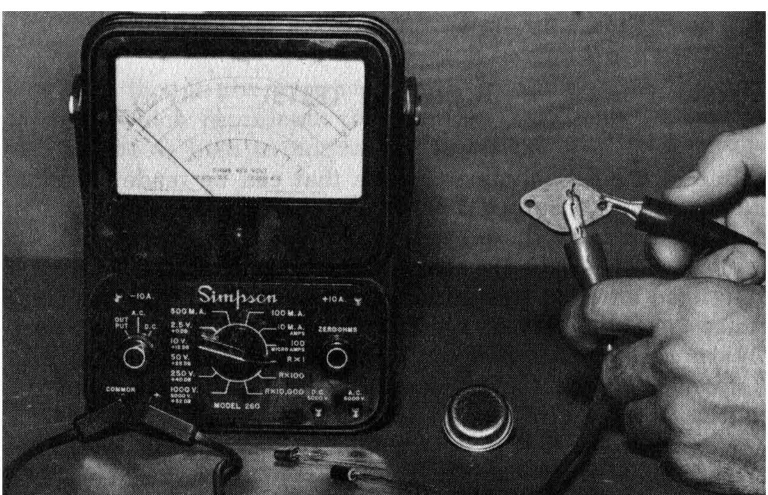


Fig. 7-1. Checking a transistor with an ohmmeter.

indication of the amplifying ability of audio transistors, because these operate at lower frequencies, which are closer to the DC end of the spectrum.

Most tests must be performed with the transistor removed from the circuit, as shown in Fig. 7-1, except when checking for open internal leads.

Ohmmeters used to gather data for this book were VTVM's containing a 1.5-volt battery, or VOM's in the 20,000-ohms-per-volt class. Older VOM's rated at less than 20,000-ohms-per-volt may not be satisfactory.

Most VOM's have an R × 10,000 range, usually their highest ohms range. Depending on the make of the meter, from 7.5 to 30 volts can be switched into the circuit on the R × 10,000 range. Needless to say, voltages above its maximum voltage rating could immediately damage the transistor. Therefore, this range should not be used.

On the lowest ohms range, such as the R × 1, it is current, not voltage, that must be considered. Most ohmmeters are capable of sending out 100 milliamperes of current on that range. To check, simply turn the ohmmeter to the R × 1 range and connect a separate milliammeter across the ohmmeter leads. The current will probably read 100 mils. This means a transistor with a very low diode resistance might draw close to 100 mils when being checked on the ohmmeter. Therefore, the R × 1 scale should not be used for checking RF and IF transistors. This scale is reserved for audio power and sometimes for audio driver transistors, as will be discussed later.

Except for these precautions, the ohmmeter is a very safe instrument for most transistor devices.

IN-CIRCUIT TESTS

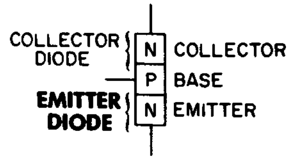
Checking for Open Leads

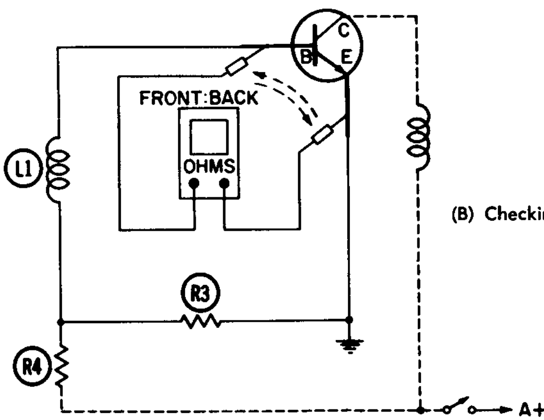
One of the few ohmmeter tests that can be made with the transistor still mounted in the circuit is for an open lead in the transistor.

If the voltages at its elements indicate that the transistor may have an open lead, the radio is turned off and the ohmmeter is used. We know that NPN and PNP junction transistors contain two diodes, as shown in Fig. 7-2A. The base element in the center is common to both the emitter and the collector diodes.

We also know that if the ohmmeter leads are placed across a diode in one direction, a relatively low resistance will be read, whereas in the other direction the resistance will be higher. This is true if the diode is functioning properly and one of the leads is not open internally. However, will this check still work with the transistor mounted in the circuit? The answer is yes, it will still work in most circuits, although the front-to-back ratio (the difference between the low and the high reading) will not be as great. The low reading, obtained when the ohmmeter biases the diode forward, should still be

(A) Basic transistor construction.





(B) Checking the emitter diode.

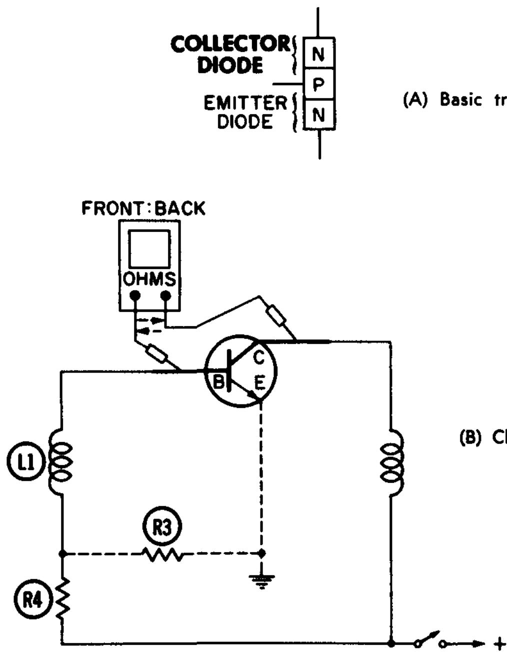
Fig. 7-2. An in-circuit test for an open emitter.

low even though the transistor is in the circuit. But the high reading, which represents the reverse (back) bias, probably will not be as high as normal because of the resistors in the circuit.

This can be clearly seen from Fig. 7-2B. The ohmmeter is measuring the resistance of the emitter diode, but note that L1 and R3 are also connected across the ohmmeter. Depending on their values, the high reading will be reduced from what it would be if the transistor had been removed. However, if the proper scale is used, the resistance should change somewhat when the ohmmeter leads are reversed. The R $\times$ 100 scale is suitable for most small transistors, and the R $\times$ 1 scale, for large power transistors.

Let's assume the transistor in Fig. 7-2B is good and is mounted in an IF stage. On the R $\times$ 100 range, the ohmmeter probably will read 300 to 500 ohms in one direction and over

2,000 ohms in the reverse direction, depending on the value of R3. The exact readings are not important, as long as they are fairly low in one direction, and are higher when the ohmmeter is reversed. For a germanium transistor the low reading should be under 500 ohms; for a silicon transistor, it should be under 1,000 ohms. The high reading in most circuits should



(A) Basic transistor construction.

(B) Checking the collector diode.

Fig. 7-3. An in-circuit test for an open collector.

be *at least* twice the low reading. Had the base or emitter lead in Fig. 7-2 been open in the transistor, the reading would probably be above 2,000 ohms in both directions (assuming R3 is at least 2,000 ohms). Failure to get a fairly low reading (less than 1,000 ohms) in one direction would lead us to suspect an open lead.

In Fig. 7-3 the same check is being made on the collector diode. The meter is placed between base and collector, and the reading is noted. Then the meter leads are reversed and again connected between the base and collector. There will be a noticeable change in resistance if the transistor leads are not open and the proper ohmmeter range is used. All but high-power transistors are generally checked on the R $\times$ 100 scale, as before. As in checking for an open emitter, the low reading for a germanium transistor will be under 500 ohms and the high reading at least twice the low reading. For a silicon transistor, the low reading should be under 1,000 ohms.

There are exceptions when this test will not work with the transistor mounted in the circuit. In some portable-radio output stages, for example, the emitter diode may show a low reading in *both* directions of the ohmmeter leads. Also, power transistors in audio-radio output stages will show very low resistances because of the shunting effect of circuit resistors, even on the R × 1 scale. However, as long as these exceptions are kept in mind, there should be no confusion. The fact that both readings are not *high* usually indicates the transistor leads are not open.

Checking for Leakage and Shorts

Ohmmeter tests for emitter-to-collector leakage cannot be made with the transistor mounted in the circuit because all transistors will appear leaky or partially shorted. They can be checked for complete shorts; however, there are very few "zero ohm" shorts except when a power transistor fails. In checking for a complete short, the same scales are used—R × 100 on small transistors and R × 1 on power transistors. When connected into an output stage, power transistors will normally read very low in resistance. Even on the R × 1 scale, it will be as low as 2 to 5 ohms in some circuits. A complete short, of course, will produce zero ohms in both directions of the ohmmeter leads.

One might ask, "How can I check for partial shorts between the emitter and collector without removing the transistor from the circuit?" The best method is to read the voltages and to thoroughly understand what produces them. (See Chapters 5 and 6.) Leaky transistors will probably draw excessive collector current, and this will affect the emitter and collector voltages. If the voltage readings are taken before the transistors are removed, much time can be saved.

OUT-OF-CIRCUIT TESTS

Checking a Transistor Diode

Checking for diode action with the transistor removed from the circuit is quite simple. It is performed in the same manner as before, except that no circuit resistances are involved. Therefore, a much higher front-to-back ratio is obtained.

The back, or reverse, reading is generally very high when read on the recommended range of the ohmmeter. The front, or forward, resistance reading is generally about the same as when the reading was taken in the circuit.

Selecting the Proper Range

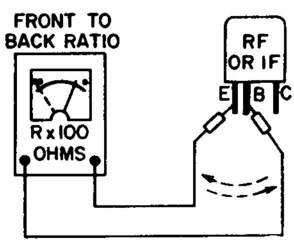
To perform this test, first set the ohmmeter on the proper range. For small, low-power transistors like those in RF, IF, or converter stages, the R × 100 range is recommended. (If the ohmmeter does not have an R × 100 scale, R × 1,000 can be used for out-of-circuit checks. On in-circuit tests, the R × 1,000 range makes the resistance read too low.)

For small audio transistors, such as the driver or output transistors in portable radios and the driver transistor in automobile radios, the R × 100 scale is also recommended for the diode check.

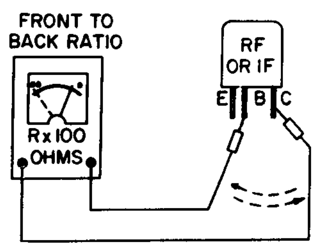
Large power transistors like those in the output stage of automobile radios or hi-fi amplifiers can be checked on the R × 10 or R × 100 scale, but never on a higher one. Higher scales make the diode appear shorted. Remember that we are now assuming the transistor being checked has been removed from the circuit. Power transistors must also be allowed to cool to room temperature before being checked.

Here is a summary of the recommended ohmmeter ranges for checking transistor diodes which have been removed from the circuit:

Low-power RF and IF types—R × 100
(or R × 1,000 if R × 100 is not available.)
Small audio driver types—Same as above
Large power transistors—R × 10 or R × 100.



(A) Between the base and emitter.



(B Between the base and collector.

Fig. 7-4. Checking the front-to-back resistance ratio of a transistor.

Performing the Diode Test

After removing the transistor from the circuit and selecting the proper scale, connect the ohmmeter leads between the base and emitter, as shown in Fig. 7-4A. Observe the reading, and then reverse the meter leads, placing them across the same two transistor leads. Again observe the reading. One reading should be rather high and the other fairly low, indicating a good front-to-back ratio.

The same test is then performed on the other diode section by placing the leads between the base and collector, as shown in Fig. 7-4B. The base lead, of course, is common to both diodes, so it is used during both tests. In Fig. 7-4A the emitter diode of a small RF or IF transistor is being checked, and in Fig. 7-4B the collector. Note that the R × 100 scale is used. Note also that the highest reading on both diodes is completely at the high-resistance end of the scale. This is quite typical for small transistors, which should have a very high reading on each diode in the reverse direction. In fact, don't be surprised if the meter needle doesn't budge from the high-resistance end of the scale—it does not mean the diode is open. However, when the ohmmeter polarity is again reversed, the resistance should be much lower. If a low reading cannot be obtained in one direction of the ohmmeter leads, then it is safe to assume one of the transistor leads is open.

Small transistors, including RF, IF, and audio driver types, usually show a very high reverse diode reading and a forward reading of less than 1,000 ohms (less than 500 ohms for germanium).

Large power transistors usually have a reverse reading of 5,000 ohms or higher and a forward reading of less than 100 ohms for each diode.

A summary of these normal transistor diode readings is shown in Table 7-1.

Ohmmeter Battery Polarity and Voltage

The common, or ground, lead of some ohmmeters does not always have negative voltage on it. The ground may actually be positive and the probe lead negative because of the way the internal battery is connected when the meter is switched to read ohms. However, this makes no difference in our tests because we are simply checking for a resistance *change* when the lead polarity is reversed. This is mentioned at this point merely because some technicians may purposely connect their meter in the forward direction across a diode—*plus* lead to P-type and *ground* lead to N-type material—and expect to get

TABLE 7-1.

Normal Transistor Diode Readings

Transistor Type	*Scale Used*	*Forward Ohms*	*Reverse Ohms*
RF, IF, Audio Driver (Silicon)	R × 100	Below 1,000	Very High*
RF, IF, Audio Driver (Germanium)	R × 100	Below 500	Very High*
Large Power Unit	R × 10 or R × 100	Below 100	Over 5,000

* It is not necessary to read the actual value of ohms. The highest range of VOM's is not used because from 7.5 to 30 volts may appear across the leads on that range.

a low reading. The reading will depend on the meter design and whether the *plus* lead actually *is* positive.

Those interested in finding out which way their ohmmeter is designed can simply connect it to a separate voltmeter, the two common and two probe leads being connected together as

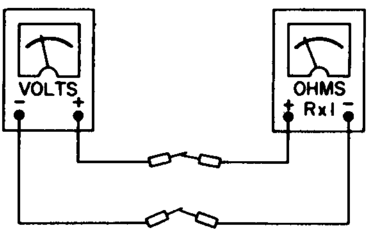


Fig. 7-5. Checking the ohmmeter lead polarity.

shown in Fig. 7-5. If the voltmeter reads upscale, the positive lead is actually positive and the common lead is negative. If the voltmeter reads below zero, however, the ohmmeter is of the opposite polarity. (This would be a good time to find out if your ohmmeter has the conventional 1.5 volts when switched to the R × 1 range.)

Checking the Emitter-to-Collector Leakage

The resistance between emitter and collector is often referred to as the leakage resistance.

The leakage test is made with the transistor disconnected from the circuit and the ohmmeter connected between emitter and collector; the base lead is not used and is therefore left open. Because the base lead isn't connected to anything, this is sometimes called an open-base test—a confusing term because it sounds as if the transistor is being checked for an open lead, which isn't true. Open leads are found by checking the transistor diodes, as discussed previously.

The amount of resistance between emitter and collector depends on the following:

(1) *Transistor Type*—In this book we are concerned only with junction transistors. However, there are many different processes used to build junction transistors, making the leakage resistances vary tremendously.
(2) *Gain*—Has less effect on the leakage reading than the transistor type. However, it does have some effect, which is one reason a definite leakage value cannot be assigned to each transistor.
(3) *Amount of Contamination*—The more a transistor is contaminated by moisture or other unwanted impurities, the poorer the showing on the leakage test, compared to other transistors of the same type and gain.
(4) *Condition of Base Area Between Emitter and Collector*—If subjected to too much current, the transistor may have a broken-down area between the emitter and collector. The leakage test will therefore be very poor because the transistor will appear totally or partially shorted.
(5) *Transistor Temperature*—The hotter the transistor, the lower its resistance between emitter and collector. Therefore, the leakage test should be performed only at room temperature, when the transistor is cool to the touch.
(6) *Type of Ohmmeter*—Our checks were taken with ohmmeters employing a 1.5-volt battery.

Selecting the Ohmmeter Range

When checking the transistor for leakage, be sure to use the proper range.

Since power transistors normally have the lowest resistance, the R × 1 scale must be used with them. Even then, the transistor may appear to be almost shorted unless it is disconnected from the circuit and cooled to room temperature.

With RF and IF types, the R × 100 or R × 1,000 scale can be used. Audio driver and other small transistors are checked on the R × 10 or R × 100 range.

In summary:

Low-power RF-IF types—R × 100 or R × 1,000
Audio driver types—R × 10 or R × 100
Large power transistors—R × 1

Performing the Leakage Test

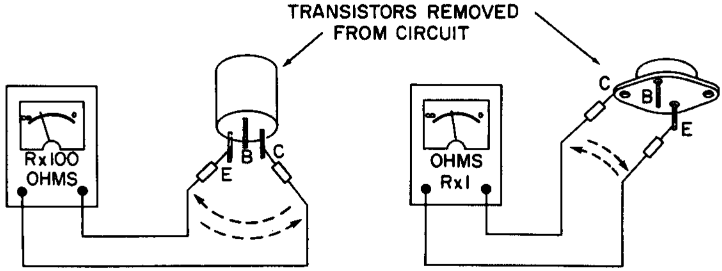
The leakage test is a very simple one. After removing the transistor from the circuit and letting it cool, place the ohmmeter between the emitter and collector, as shown in Fig. 7-6. (The base lead is left open and is not used during the test.)

Note the reading; then reverse the ohmmeter leads and read the leakage resistance again. We are not interested in finding the front-to-back ratio. In fact, the resistance does not have to change at all. The important thing is that the resistance must not be "0," because that would indicate a shorted transistor *provided* the proper ohmmeter range was used. The mistake most often made is to measure a power transistor on some range other than R × 1. This will make a good unit *appear* to be shorted.

If the transistor is not shorted, the next most important consideration is whether the reading is fairly steady or not. This is more important than the actual value of resistance. For normal units, the leakage resistance will hold fairly steady and will not "drift" quickly after the meter is connected. A very slow, steady drift which covers a period of several minutes is not to be concerned about, since it is probably due to temperature changes within the transistor.

Typical Leakage Readings

In the foregoing tests it is assumed that the transistor is removed from the circuit. In the circuit, you can check for a dead short between emitter and collector, but that is all. Out of the circuit, small transistors measure anywhere from 100 ohms to almost infinity, depending on the particular transistor. Some of them measure so high on the R × 100 range that they appear to be "open," but don't worry about this. Assuming that the transistor has passed the "diode" checks, it cannot be open.



(A) RF-IF type.
(Over 100 ohms.)

(B) High-power audio type.
(Over 10 ohms.)

Fig. 7-6. Testing a transistor for leakage.

Typical power transistors will measure anywhere from 10 ohms to 500 ohms between emitter and collector, on the R × 1 range.

Summary of Leakage Tests

When the resistance between emitter and collector is "0," or when it changes or "drifts" quickly after the ohmmeter is applied, the transistor is considered to be defective.

The limits are difficult to set because so many things influence the readings. But by using the "guide-lines" given here, the troubleshooter can quickly confirm what he already suspects from the conduction, bias, and other voltage readings.

Power transistors generally measure lower leakage resistances than small transistors and must be measured on the R × 1 range.

CHECKING TRANSISTOR GAIN

DC gain tests, such as with an ohmmeter, mean very little for RF and IF transistors. For audio units, however, a fairly good estimate of their amplifying ability can easily be made. We will begin, therefore, with the audio gain test.

Even this test is not used too often. Experience has shown that transistors which suffer gain breakdowns will almost always have a bad diode or suffer from a leakage defect; so they will be caught during previous tests. Very seldom does a transistor have a noticeable gain problem without one of the other defects, assuming it at one time worked normally.

Our simple gain test will mean little if the transistor is leaky or has bad diodes. Hence, these tests should always be made first.

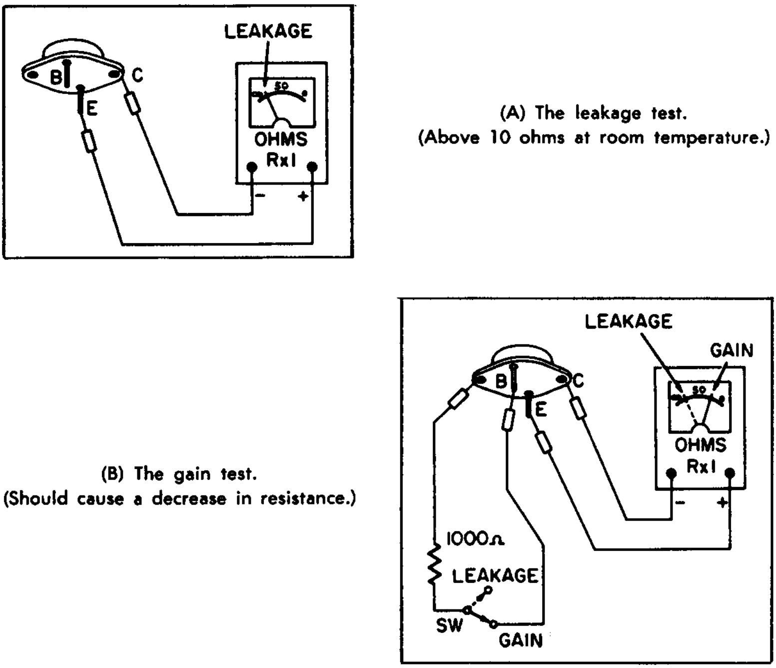
For gain checks, it is important to know the voltage and polarity on the ohmmeter leads. As stated before, the common lead is actually connected to the *positive* side of the internal battery in some ohmmeters.

Audio Gain Test

To check the gain of a PNP power transistor, set the ohmmeter on the R × 1 scale. Connect the lead which has the negative voltage on it to the collector, and the positive lead to the emitter (Fig. 7-7A). (This is the polarity used on a PNP transistor when in the circuit.) The amount of leakage should be well over 10 ohms, as described in the leakage test instructions.

Now connect a 1,000-ohm resistor in series with a switch, between the base lead and the collector or case of the transistor, as shown in Fig. 7-7B.

When the switch is closed, the resistor brings a small negative bias to the base lead from the ohmmeter battery, causing the transistor to conduct more heavily. As a result, the resistance decreases between the emitter and collector. This



(A) The leakage test.
(Above 10 ohms at room temperature.)

(B) The gain test.
(Should cause a decrease in resistance.)

Fig. 7-7. Testing the gain of an audio transistor.

decrease, which is read on the ohmmeter, means more current is being conducted. In general, the lower the resistance reading after the 1,000-ohm resistor is switched into the circuit, the higher the transistor gain. Typical resistance readings for power transistors are from 5 to 40 ohms.

One major precaution when performing the test in Fig. 7-7B —if the ohmmeter does not show a lower resistance after the 1,000-ohm resistor has been connected, reverse the ohmmeter leads and try again. Reversing the leads will prevent any confusion due to the wrong ohmmeter lead polarity. (The wrong polarity will not put the proper bias on the transistor base.)

Although, a transistor which measures 7 to 15 ohms probably has a higher gain than one which reads 30 ohms, it will not necessarily work any better in the circuit. A circuit designed for a lower-gain transistor may be unstable, and may even oscillate or motorboat if an extremely high-gain unit is substituted.

Small audio driver transistors may be checked for DC gain in a similar manner. However, they should have a maximum power rating of at least 75 milliwatts; otherwise, the transistor may be damaged. Also, the ohmmeter being used should not have more than 1.5 volts at the leads.

Audio transistors which read over 50 ohms on the gain test are usually very low-gain units, but this does not mean they will not work in certain circuits. Transistors in power supplies or switching circuits, for example, are often purposely produced with very low gain.

Two different audio transistors which measure very close to the same resistance during the leakage test (and also during the gain test) are usually pretty well matched. If both transistors measure within 20% of each other, the match is very good, and 30% is usually passable.

RF-IF Gain Test

As stated previously, the RF-IF gain test means very little and therefore is seldom used. RF and IF transistors often perform in a completely different manner in the circuit than they did during the DC gain test.

The R × 100 scale is used, and the transistor is first checked for leakage and a good diode ratio. Then the same procedure described for the audio gain test is used, except the meter is left on the R × 100 range, and the 1,000-ohm resistor is replaced with a 10,000-ohm resistor.

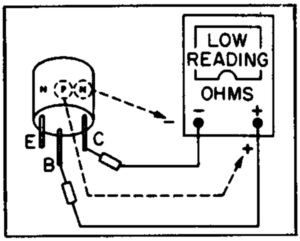
If the transistor is a PNP type, connect the negative lead to the collector and the positive lead to the emitter. Then connect the 10,000-ohm resistor between the base and collector. The resistance on the ohmmeter should immediately decrease. If it doesn't, reverse the ohmmeter leads, which may have been of the wrong polarity. NPN units require a positive voltage on the collector and a negative one on the emitter.

The resistance read on the ohmmeter will almost always be less than 5,000 ohms—typical values being from 500 to 4,000 ohms. Although the low values mean a high DC gain, the signal-amplifying ability will not necessarily be high.

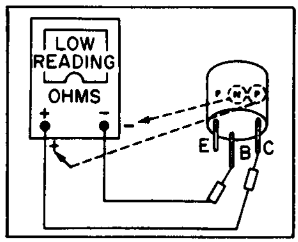
IDENTIFYING TRANSISTOR TYPES

If the polarity of the ohmmeter battery is known, the transistor can be identified as an NPN or PNP unit. Place one lead of the meter on the collector and the other on the base (Fig. 7-8A), using the same range as for checking the front-to-back ration of a diode. Then reverse the ohmmeter leads and check the collector diode again, noting which lead polarity gave the lower reading.

The lowest resistance will be obtained when the ohmmeter lead polarity matches the internal polarity of the transistor. In other words, when the *N*egative voltage is placed on the *N* material and the *P*ositive voltage on the *P* material, a low



(A) Connections indicating NPN type.



(B) Connections indicating PNP type.

Fig. 7-8. Method of determining the transistor type.

reading will be obtained. So, for an NPN transistor (Fig. 7-8A), the low reading will be obtained when the negative lead is on the collector and the positive lead is on the base. For a PNP transistor (Fig. 7-8B), just the opposite is true.

The same check could be made on the emitter diode, between the base and emitter.

Another way of stating this makes it easy to remember: When either diode is biased forward, the polarity connected to the base lead is the middle letter in the transistor type, such as NPN or PNP. So, a glance at the meter leads will tell which type the transistor is.

But remember that some meters are actually *plus* on the common lead and *minus* on the positive lead because of the internal battery connections. One example of this "reversed" polarity is the Triplett Model 630.

SUMMARY OF OHMMETER TESTS

Several transistor tests can be made with an ohmmeter. These are not foolproof tests, but they will help to confirm what is already suspected by the conduction and bias voltage checks.

Transistors can be checked for:

1. Open leads
2. Shorts
3. Low-frequency gain
4. Polarity type (NPN or PNP)
5. Construction type (germanium or silicon)

Important points to remember when using the ohmmeter to check transistors are:

1. *Ohmmeter Range* (small units)—Use the R × 100 range for most tests on small transistors.
2. *Ohmmeter Range* (large units)—Use the R × 1 range for most tests on power transistors.
3. *Temperature*—Power transistors will appear shorted if checked when hot. Allow to cool to room temperature.
4. *Transistor Diodes*—When checking between the base and one of the other elements, a low reading should be obtained with one direction of the meter leads (below 500 ohms for germanium units; below 1000 ohms for silicon units). Also, the ratio between the low reading and the high reading should be at least 2:1.
5. *Transistor Leakage*—The resistance between the emitter and collector is called the "leakage" resistance. This resistance varies considerably because of the different manufacturing processes; no definite limits can be given. Watch for complete shorts and a quick drift toward a short as the meter is applied.

CHAPTER 8

Troubleshooting AM Automobile Radios

Transistors are ideally suited for auto radios. The low-voltage DC power supply (car battery) is already present, and because transistor radios draw less current than tube sets, the drain on the battery is kept to a minimum.

Transistors did not replace tubes in these radios all at once. Instead, it was a gradual process. The part-tube, part-transistor radios were called "hybrid" sets. The power output tube was first replaced by a power transistor, and millions of these 4-tube, 1 transistor radios were produced in the late 1950's and early 1960's. Actually, three engineering achievements teamed together to provide a perfect blend between tubes and transistors: (1) the development of the transistor itself, (2) the change from a 6-volt to a 12-volt automobile ignition system, and (3) the design of a vacuum tube which required only 12-volts on the plate for efficient operation.

With these developments, it was possible to eliminate the high voltage power supply and its troublesome and bulky components—rectifier tube, vibrator, and power transformer. The cost saving permitted the use of a power transistor, even though transistors were much more expensive than tubes at that time. Then, in 1962, more efficient and moderately priced RF transistors were available, so most auto radios became all-transistor sets. By 1963, practically no tube models were being produced. Troubleshooting the transistor car radio follows the same principles learned previously. The problem is first localized to one section of the radio, then certain voltages are read to pinpoint the defect.

SCHEMATIC FAMILIARIZATION

A typical auto radio diagram is shown in Fig. 8-1. For study purposes, some of the bypass capacitors have been eliminated, but a complete auto radio schematic will be shown later.

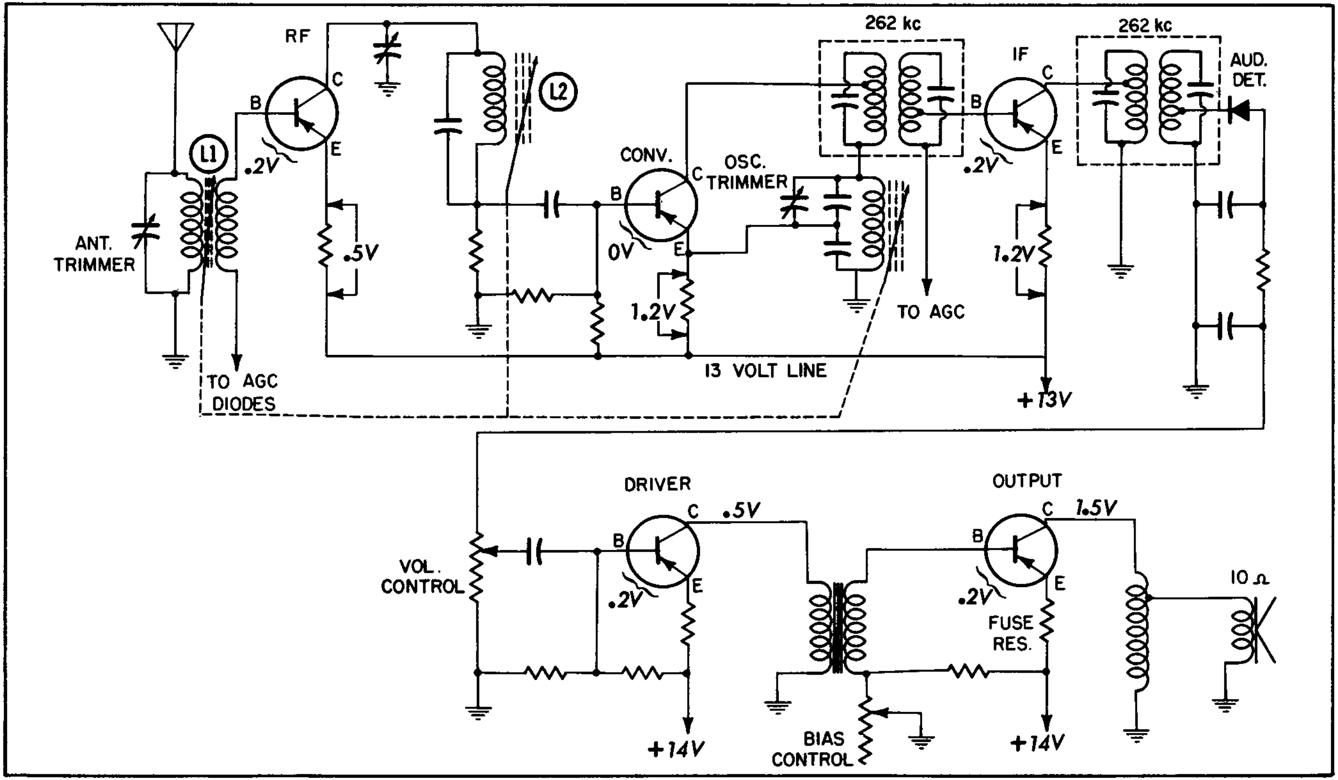


Fig. 8-1. Simplified schematic of a five-transistor auto radio.

What do you notice about this schematic? First of all, it is *very* similar to the first transistor radio schematic studied (see Chapter 3). One additional stage—the RF stage—has been added, but otherwise, the auto radio contains the same number and type of stages.

There is one other difference in the way the car radio is tuned. Notice the three dotted lines and arrows shown with coils L1, L2, and L3. They represent tuning cores, or slugs, which are located inside each coil. The slugs are all mounted on a common bar, which moves as the radio is tuned. This changes the inductance of the coils and tunes the auto radio. Formerly, tuning was done by variable capacitors (as in home and portable radios) but, due to vibrations experienced in automobiles, the more stable inductive tuning has been practically universally adopted in auto radios. Small trimmer (or padder) capacitors are connected across each coil for alignment purposes.

Again, the radio should be mentally divided into blocks (Fig. 8-2) for troubleshooting purposes. Each block represents

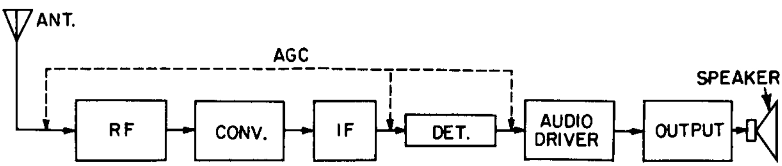


Fig. 8-2. Block diagram of the receiver in Fig. 8-1.

a transistor or diode and its associated components (resistors, coils, and capacitors).

What else can we determine about this radio by a quick glance at its schematic?

1. That the radio uses all PNP transistors.
2. That all transistors are of the germanium type (germanium amplifiers require .2 volt bias, silicon amplifiers .6 volt, except converters).
3. That the IF frequency is 262 kc.
4. That the audio stages are transformer coupled.
5. That the radio requires an 8 to 10-ohm speaker.
6. That the radio operates on a car battery voltage of 12 volts (14 volts with generator running).
7. That the RF and IF stages are controlled by AGC (automatic gain control).
8. We can also see how to check the conduction (current flow) of each transistor.

Since Step 8 is the most important test available to the troubleshooter (along with bias), it will be stressed as we get into pinpointing the troubles. But first, let's turn this radio on and see if we can localize the trouble with our listening checks and expert personal observation.

TRACKING DOWN THE TROUBLES

Naturally, we want to find out as much as we can from the owner as to how the radio acted and what he doesn't like about it. Unfortunately, this is quite difficult in many cases, especially when the radio is sent by the car dealer, and the owner is not personally contacted. This makes it ever so important to use all of our senses and keen observations as we tackle the auto radio.

Testing Procedure in the Car

In some cases, the radio will still be in the car when first seen. Let's assume this is the case for our first example. It must first be determined whether the fuse, antenna, speaker, or radio is at fault.

First turn the radio on and listen for a slight "thump" in the speaker as power is applied. . . .

If no thump occurred, see if the radio picks up stations. . . .

If no stations are heard, check the antenna before removing the radio to check all stages between antenna and output stage. Fig. 8-3 shows how to make continuity and leakage tests of the antenna.

Best ways to check:

Fuse—by ohmmeter or substitution.

Speaker—by substitution; or place ohmmeter on R × 1 range and tap on and off the case (collector) of output transistor. The radio is turned off and negative lead of ohmmeter grounded during this test. A scratching noise should be produced by the battery in the ohmmeter, indicating speaker is "alive" and plugged into radio.

Antenna—By substitution (plugging in good antenna and holding it out the window); by an ohmmeter, or an antenna tester.

Special Note About Antennas: If the antenna is not mounted tightly on the fender, or lead-in is not screwed tightly on to the base of antenna, the shield on the antenna lead will not be grounded well. This can result in *motor noise pick-up*, or turn signal *flasher noise* in the speaker of the radio.

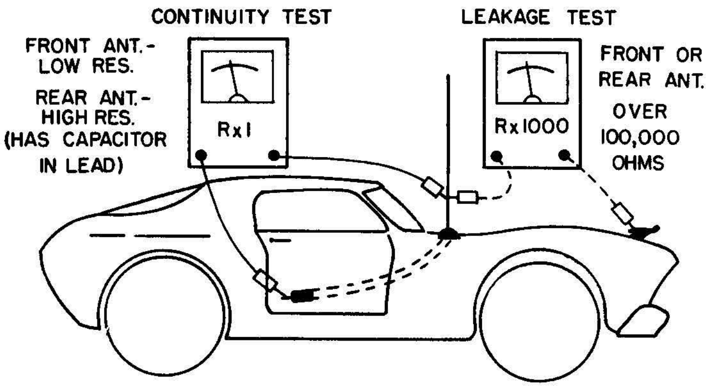
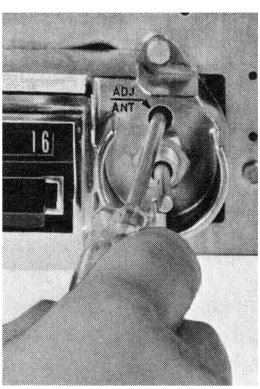


Fig. 8-3. Ohmmeter tests for an auto radio antenna.

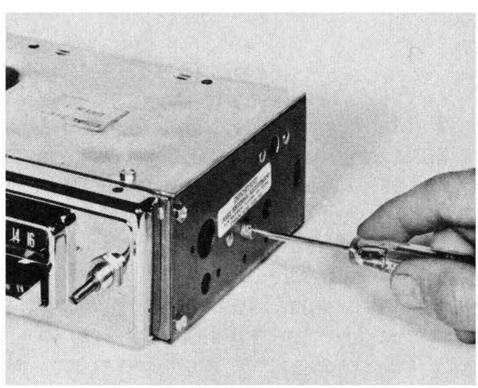
Also, if the antenna is not matched to the radio, station fading, mixing, and excessive whistles will be heard. An antenna trimmer capacitor is accessible on the outside of all auto radios for this purpose (Fig. 8-4). It should be peaked for maximum volume while tuned to a weak station or noise near 1400 kc. This adjustment is much more critical on transistor than tube radios.

Isolating Troubles in the Radio

Assuming that the trouble is in the radio, we must quickly determine what section it is in, and then track it down to the exact stage and component. When the chassis is removed, first take time to look it over carefully. Become familiar with the location of the various stages. Fig. 8-5 shows a typical all-transistor auto radio and the location of the transistors. A sche-



(A) Behind tuning knob.



(B) At side of chassis.

Fig. 8-4. Location of antenna trimmers.

matic of this same unit is given in Fig. 8-6. By looking over the circuit and coordinating it with the chassis layout, you will know where to look for the various sections and have a mental block diagram of the unit.

Important points to remember when checking an auto radio on the bench are:

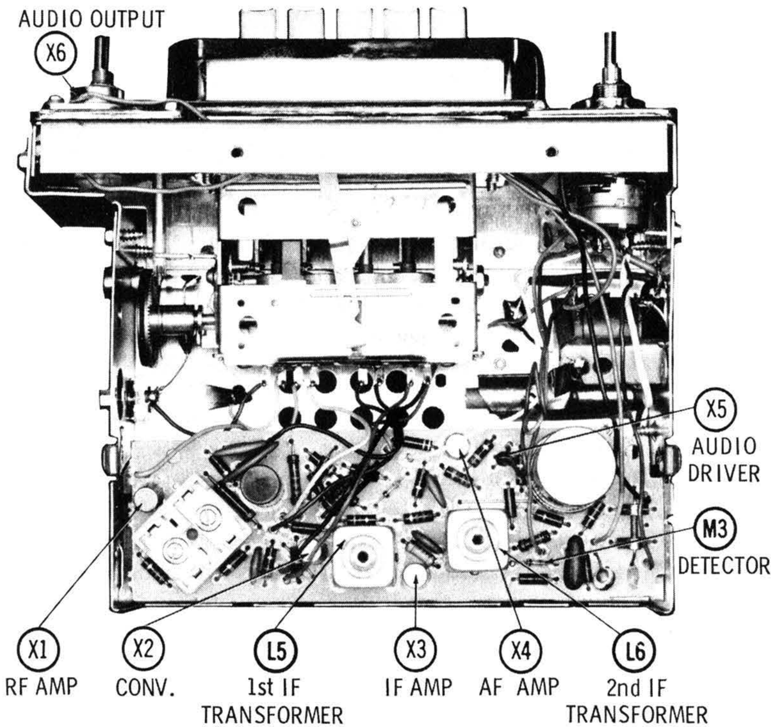


Fig. 8-5. Top view of a typical auto radio.

1. Make sure the polarity of the supply voltage is correct.
2. Make sure the speaker is connected properly.
3. Make sure the rated input voltage is used while measuring voltages; but vary the input above and below that voltage before releasing radio to owner (car voltages do not remain constant).
4. Make sure radio is tapped and vibrated all over to test for intermittents (cars are in constant motion, causing all components to be jarred). Sometimes heat supplied by a hair dryer while the voltage is increased and the chassis tapped (Fig. 8-7) will cause intermittents to show up.

Checking the Audio System

The audio system is checked first. If it is working properly, it will produce the normal thump when turned on, the output transistor will have normal collector voltage, and a good noise will be heard when injected at the volume control. If radio fails any of these tests, proceed as follows.

Troubleshooting the Output Stage

As the radio is turned on, the surge of output current in most models causes the speaker cone to move and a slight thump is produced. This is not true in push-pull output circuits, where the idling current is small.

The lack of thump in radios which normally have it can be caused by (1) the speaker not being connected, (2) an open fuse resistor, (3) a defective power transistor, (4) a short in the insulator between output transistor and its heat sink, or (5) any defect which prevents the output transistor from conducting current.

Fig. 8-8 shows how to make certain that the speaker, output transformer, and transistor insulator are all right. Set the ohmmeter on the R $\times$ 1 range and clip one lead to chassis. Tap or rub the other lead on the case (collector) of the output transistor. If a popping or scratching sound is heard, you can free your mind of everything between collector and speaker.

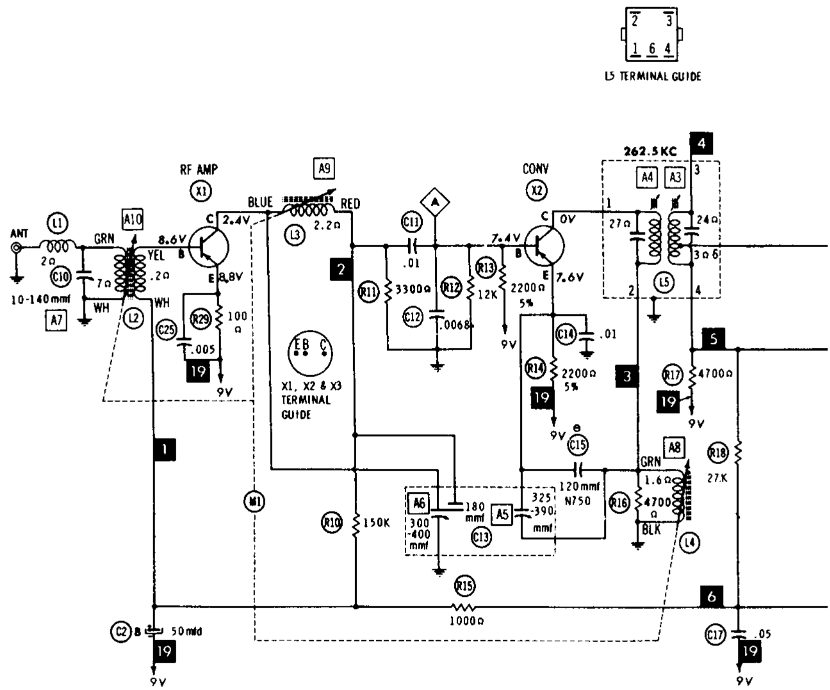
Things which can prevent the pop are: (1) open speaker, (2) shorted interlock switch (used on older models), (3) shorted transistor insulator, (4) shorted collector bypass capacitor (if present), and (5) shorted output transformer.

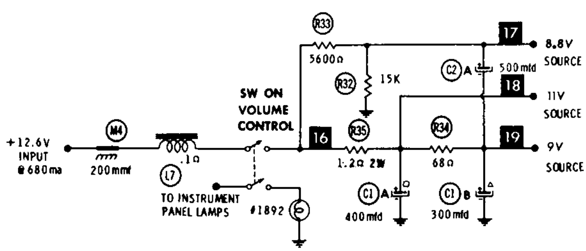
Let's assume that a radio produces no thump when turned on, but the above ohmmeter test causes a noise. The trouble must be somewhere *before* the collector circuit, such as an open fuse resistor (emitter circuit), or shorted transistor *and* open fuse resistor (Fig. 8-9). In both cases, the collector voltage of the DS-501 is zero, because no current can flow through output transformer L3. However, in Fig. 8-9A the emitter voltage is 12 volts and in Fig. 8-9B, it has zero voltage.

Adjusting the Transistor Bias

Assume now that the trouble turns out to be a shorted power transistor (emitter to collector short), and an open fuse resistor (Fig. 8-9B). These are the most common problems in power output stages.

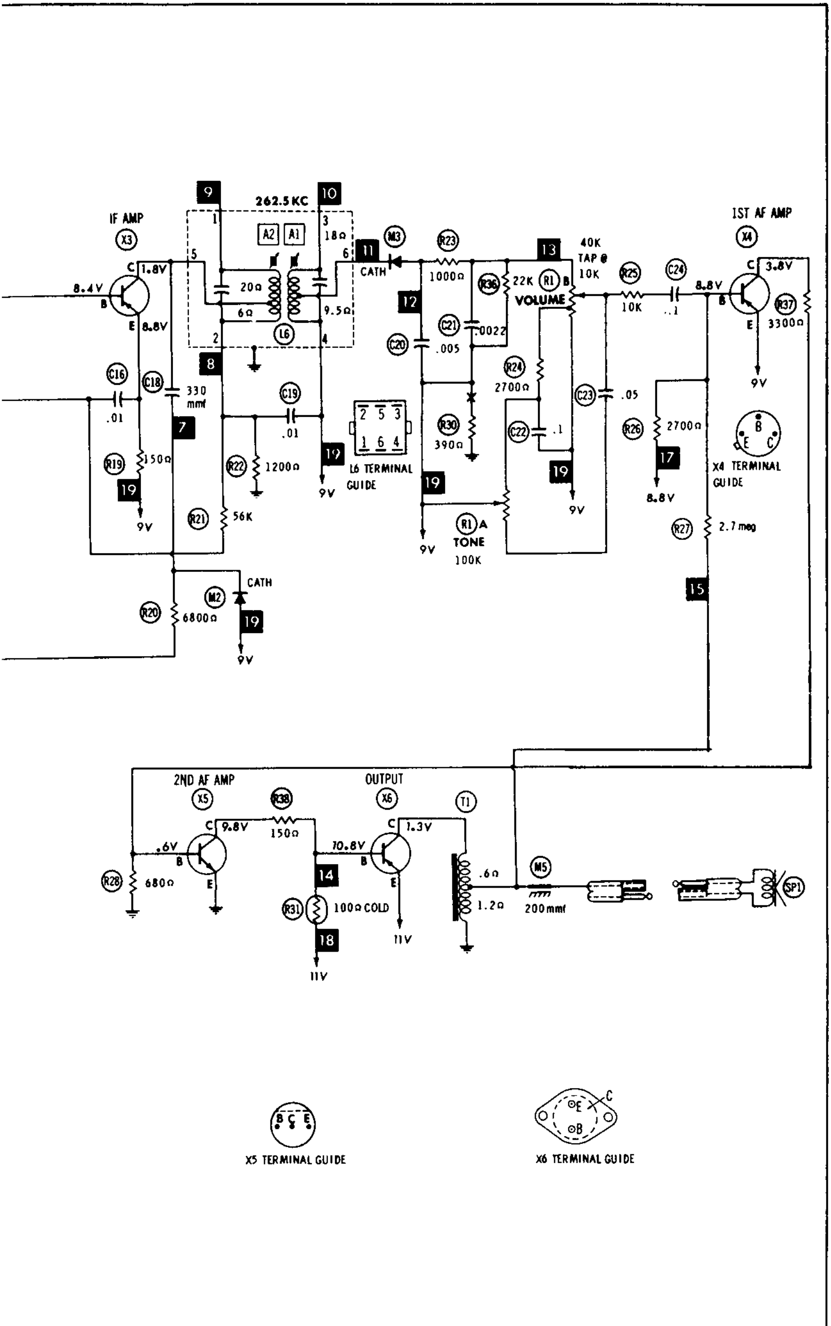
After replacing the parts, the collector voltage of the output transistor should be checked. If it doesn't read what the schematic specifies, the transistor bias control, R4, must be adjusted





1. Voltage measurements taken with vacuum tube voltmeter.
2. All controls set for normal operation, no signal applied.
3. Measured values are from socket pin or terminal to common ground.
4. All terminals viewed from bottom unless otherwise designated.
5. Numbers assigned to terminals may not be found on the unit.
6. Supply voltage maintained at rated value for voltage readings.
7. Resistance measurements not given because of the wide variation in internal resistance of transistor.

Fig. 8-6. Schematic of the



auto radio pictured in Fig. 8-5.

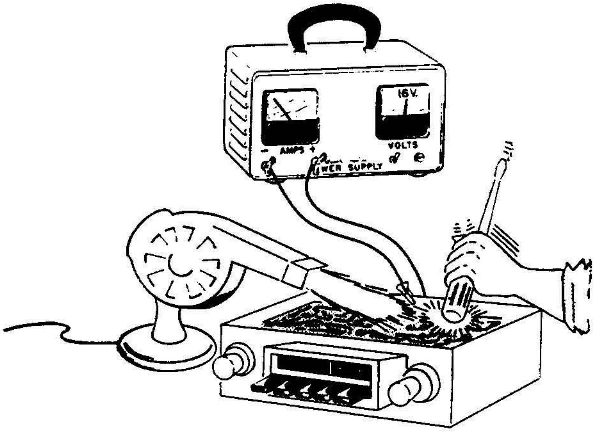


Fig. 8-7. Tapping the chassis, applying heat from hair dryer, and increasing input voltage to help locate intermittents.

until proper collector voltage is obtained. This sets the transistor at the proper operating point for minimum distortion. It must be adjusted with the speaker connected, and the rated supply voltage applied to the radio (see schematic of individual radio).

A word of caution: If the bias control cannot bring the collector voltage down to the value listed on the schematic, check the bias resistors. The shorted transistor often causes R3 to increase in value, so that the new transistor can't be set properly. If this happens, R3 must be changed to prevent a repeat failure. Also, always replace the fuse resistor with the exact

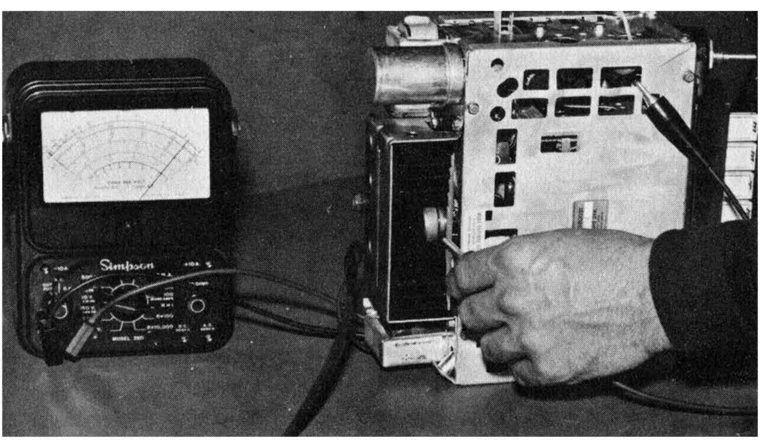
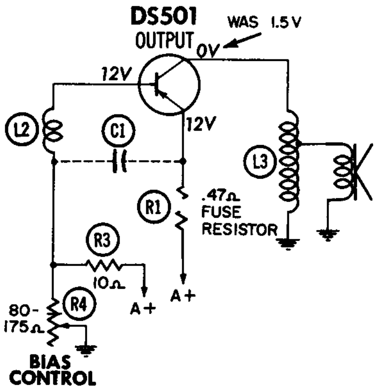
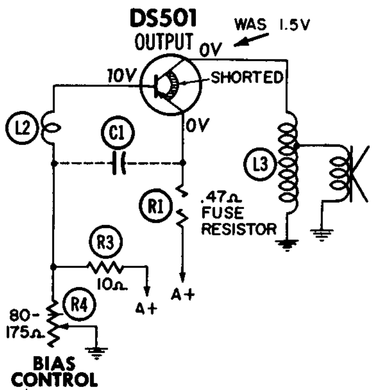


Fig. 8-8. Checking speaker and output transformer (and connections) by tapping ohmmeter (R $\times$ 1 range) on case of output transistor.



(A) Normal transistor with open fuse resistor.



(B) Shorted transistor with open fuse resistor.

Fig. 8-9. The most frequent output stage troubles.

manufacturer's replacement. *Do not substitute*, as damage to components and even fire can result. Fuse resistors are not only fusable resistors, but they also provide temperature compensation—the value varies with temperature to prevent transistor "run-away."

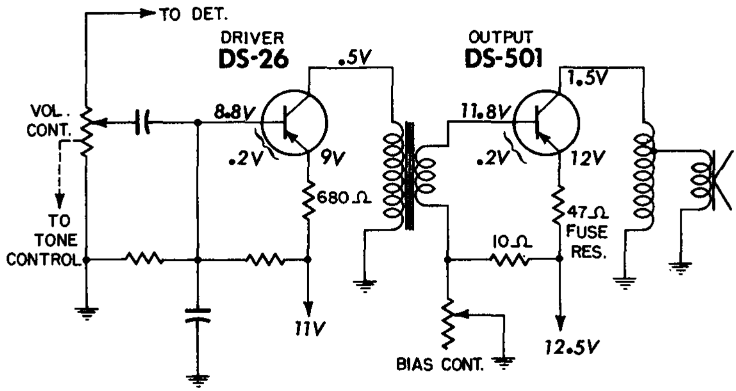
Troubleshooting the Driver Stage

Now let's assume that a "thump" *was* produced when the radio was first turned on, but no signal is heard when injected at the volume control by a noise generator. This tells us that the trouble probably lies in the audio driver stage. Before checking the driver, however, make a quick check of the output stage collector voltage, just to be sure that all is well there. If all right, proceed as follows.

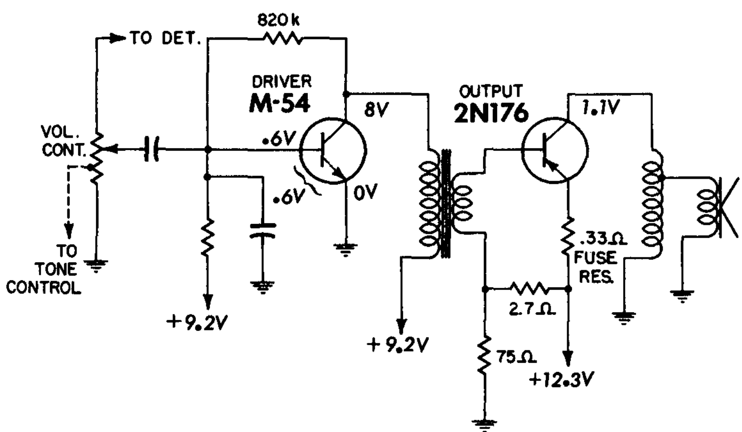
Fig. 8-10 shows two popular drivers—NPN and PNP. In the PNP circuit (Fig. 8-10A), transistor conduction or idling current can be checked two ways. The quickest is to measure collector voltage to ground. If .5 volt is found, conduction is probably normal. The other method is to measure voltage across the 680-ohm emitter resistor. If about 1.0 volt is found, conduction is normal. This can be used as a confirming test or a "double check" of conduction.

If conduction is *normal*, chances are all DC components (transistor, resistors, and transformer winding) are good, and the trouble is probably an open capacitor.

If conduction is *low*, measure the bias to determine if the trouble is in transistor or circuit. (Low conduction with *good* bias usually means transistor trouble; low conduction with *zero* bias usually means base or emitter circuit trouble.)



(A) With PNP driver.



(B) With NPN driver.

Fig. 8-10. Two popular audio systems.

If the conduction is *high*, measure the bias to determine if trouble is in transistor or circuit. (High conduction with *good* bias usually means circuit trouble; high conduction with *low* or *reversed* bias usually means the transistor is leaky or shorted.)

The NPN driver in Fig. 8-10B is checked in the same manner, with two minor differences: (1) Conduction can only be checked by measuring from collector to the 9.2 volt line, since there is no emitter resistor, and (2) the normal bias is .6 volt instead of .2 volt, because the transistor is a silicon unit.

It is important to notice that the same basic rules that we learned for other transistor radios are used for auto radios. First, a general idea of the trouble area is obtained, then transistor conduction and biases are checked. This quickly gets you down to one part of a circuit, where individual components can easily be checked.

Direct-Coupled Audio Systems

In recent years, direct coupling from one audio stage to another has become popular. This eliminates the need for interstage transformers but makes troubleshooting a little more difficult, because the conduction of each stage in the system is dependent on the other stages.

Fig. 8-11 shows a typical schematic. Driver AF-1 is a PNP transistor, and AF-2 is an NPN unit. This is typical of Ford circuits. General Motors radios use NPN transistors in both driver stages.

The conduction of transistor AF-1 through R4 produces .6 volt across that resistor. Since R4 is connected between the base and emitter of AF-2, this provides the proper bias for AF-2. The conduction of AF-2 through R6 produces .2 volt, which is the bias for the 2N1227 output transistor. Thus, each transistor is dependent on the previous one for its bias and conduction. While this has some disadvantages in troubleshooting, it also has a definite advantage. The DC condition of all audio stages can be checked by measuring one voltage—the output transistor collector voltage. Normal conduction there means that the two drivers are also conducting properly.

What if the conduction is *not* normal? Check the conduction and bias of each stage, beginning with AF-1, to see where the trouble is located. Shorted or open transistors can easily be located. Silicon drivers seldom fail, but when they do, they almost always go completely open or shorted between two elements.

If noise is produced by a direct-coupled circuit (high hiss or squeal), bridge each electrolytic capacitor in the audio

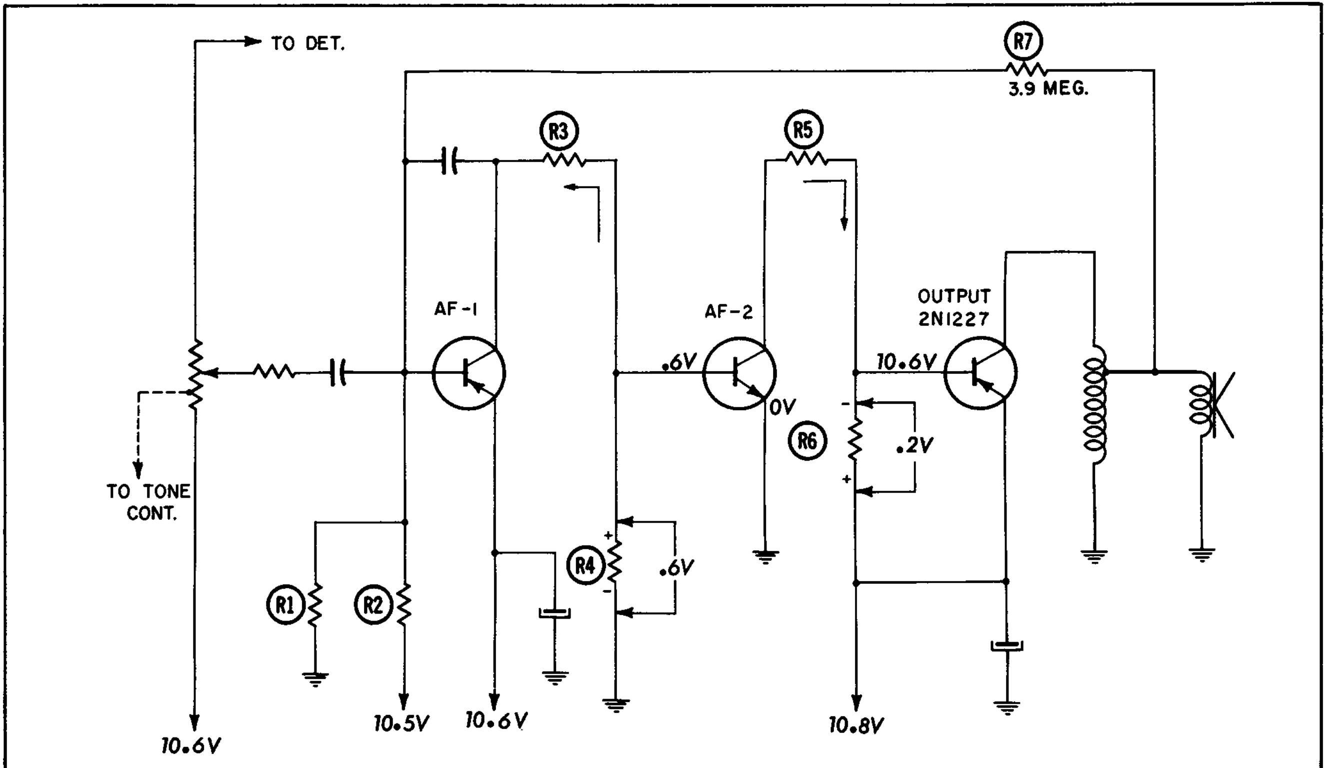


Fig. 8-11. A typical direct-coupled audio circuit.

system and power supply with a good capacitor of the same value. If this doesn't locate the defective part and AF-1 is a PNP transistor, replace AF-2 (NPN unit).

Checking the "Front End"

If the audio system is working properly, turn the volume control up and see if the radio has the normal "background" hiss. Since most of the noise is produced in the RF stage, this test will tell you how much of front end is working. If the IF or converter stages are malfunctioning, there will probably be no hiss level at all. If the RF stage is not operating properly, there may be a small hiss level present.

A typical auto radio front end is shown in Fig. 8-12. The most important check to determine the condition of each stage is the emitter voltage drop (conduction). Some manufacturers are even showing the voltage across each emitter resistor on their schematics. If conduction of one of the stages is not near normal, check the bias to see if the transistor is being "told" to conduct.

As in previous transistor amplifiers, normal DC conduction eliminates the transistor, resistors, coil windings, and connections to each of those parts. This checks practically all components in that stage except the capacitors and tuned circuits which, of course, do not affect the DC conduction of the stage. The best way to illustrate how this knowledge will help you locate troubles is to take some examples and show how the troubles were found.

Locating Troubles Which Affect Conduction

Assume that the audio stages were found to be performing perfectly and that turning the volume control up produces no hiss level—the front end is completely dead. Conduction of the IF stage is checked by measuring the voltage drop across R3. This voltage measures zero (instead of 1.2 volts). No signal is produced when a noise generator is touched to the IF base. The bias measures .9 volt (instead of .2 volt). Thus, the bias is high, but the transistor isn't drawing current. By using an ohmmeter on the R × 100 range, we find that the emitter diode (between B and E) reads 2000 ohms in one direction, and higher when the ohmmeter polarity is reversed.

Conclusion—The IF transistor is open.

Let's take another example. The radio is very weak. Conduction of the RF transistor (measured across R1) is 1.5 volts (instead of .5 volt). Bias is very low (near 0). Thus, the transistor is being told *not* to conduct, but it is conducting heavier than normal. A new transistor is tried, and the radio is normal.

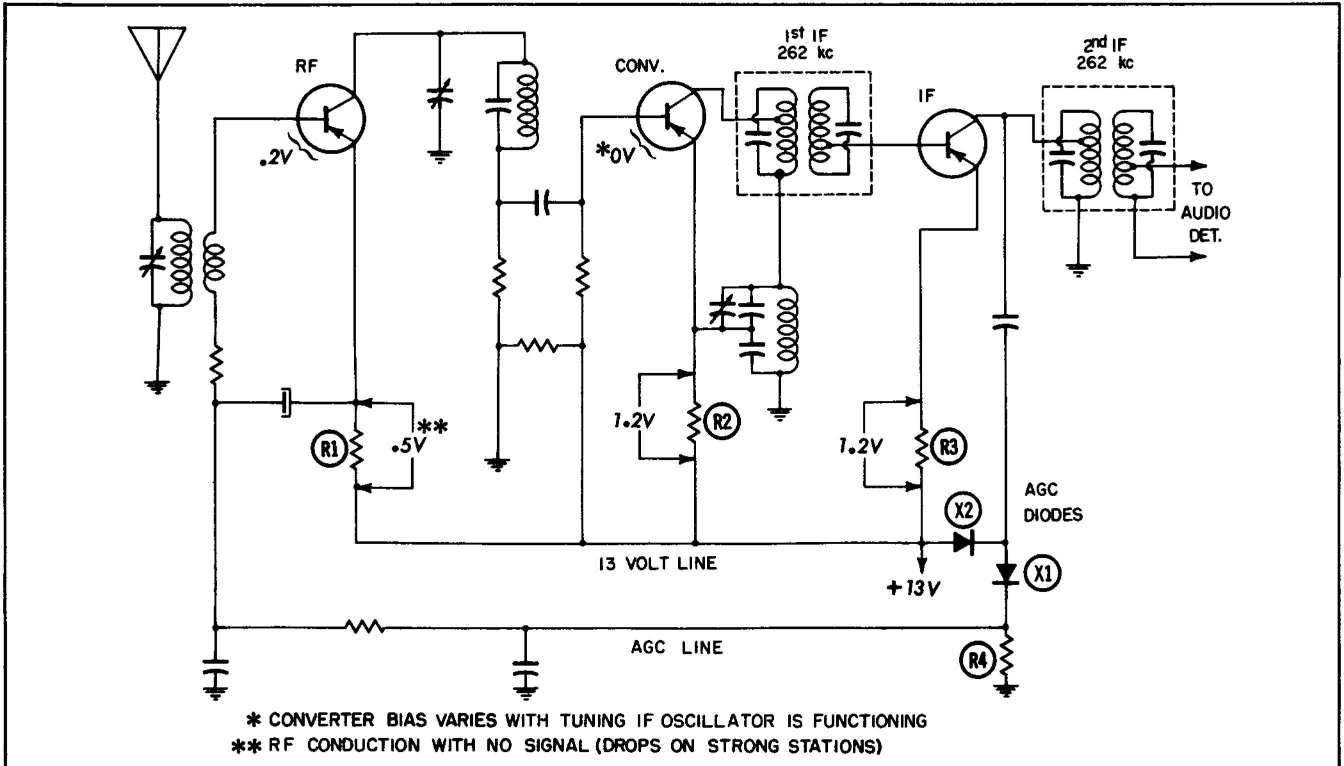


Fig. 8-12. Typical auto radio "front end."

Conclusion—The RF transistor was leaky. A word of caution, however. Note that the base circuit of the RF stage is connected to the AGC (automatic gain control) system to control its gain. An open AGC diode can also cause high conduction of the RF transistor. In that case, however, conduction will be high, but bias will be normal or slightly high because AGC diodes X1 and X2 form one leg of the voltage divider for the RF base circuit (R4 completes the divider circuit).

Locating Troubles Which Don't Affect Conduction

Let's assume that a radio is received which cuts out. The audio system checks good. All conductions are normal in the RF, converter, and IF stages. The circuit board and all components are tapped. When the 2nd IF coil is wiggled from side to side, the radio cuts out, but the IF conduction stays normal (1.2 volts). Since conduction stays normal, the trouble is probably an open capacitor or detuned coil.

Conclusion—The IF coil is suspected and changed—the radio is then O.K. The mica capacitor inside the IF can was cracked, causing the coil to detune.

Another radio cuts out intermittently, and sometimes stations "drift" toward the left end of the dial. This indicates oscillator (converter stage) trouble, but all conductions and voltages check normal. When tapping components, it is found that the oscillator trimmer adjustment screw is very sensitive, sometimes causing the radio to cut out.

Conclusion—The oscillator trimmer is defective. Replacing and aligning it cures the trouble. (This was the most common defect in 1963 GM car radios. The trimmer was redesigned with silver contacts internally, to prevent the capacity from shifting value.)

Short-Cut Test of "Front End"

There is a short cut test of the front end, similar to the direct-coupled audio test. You will recall that because all audio stages are coupled together in some radios, the conduction check on the output stage checks the DC circuits in the entire audio system.

In one way, the front end stages of most auto radios are also "tied together"—by the AGC system. The AGC samples the output of the IF stage, rectifies the signals present there, and feeds a DC voltage back to the base of the RF transistor. The DC voltage reduces the forward bias on the RF stage, causing it to conduct less and reducing its gain. The stronger the station, the stronger the AGC voltage. This cuts off the RF stage to prevent the radio from "blocking" or distorting on strong stations.

If all three stages in the front end are working properly, the output at the IF will be good. This will cause a reduced forward bias on the RF transistor and reduced conduction *only* when tuned to strong stations. So, by measuring conduction of the RF stage while tuning through strong stations, a check of the whole front end is made. If the conduction goes to almost zero, the entire system is functioning. Chances are the conduction as well as tuned circuits in all stages are functioning, with possible exception of the 2nd IF coil secondary which this method does not check.

TROUBLESHOOTING SUMMARY

The most important aid in troubleshooting is to use a *systematic* procedure. Follow a set procedure on every radio. The hunt and poke method is time-wasting and strictly taboo.

Conduction checks are recommended before signal injection because the latter will sometimes shock intermittent troubles back into operation. Where conduction checks do not reveal the trouble, use a noise generator to isolate the defective stage. Fig. 8-13 shows what to expect when the noise generator is

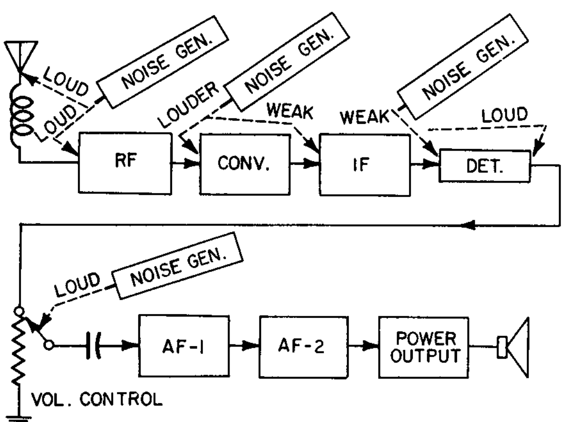


Fig. 8-13. Noise generator checks.

used at the various points in the circuit. Merely touch the noise generator to the various points on the printed circuit board (Fig. 8-14) and listen to the output. The results expected at each point are summarized in Table 8-1. The volume control should be turned all the way up when making tests.

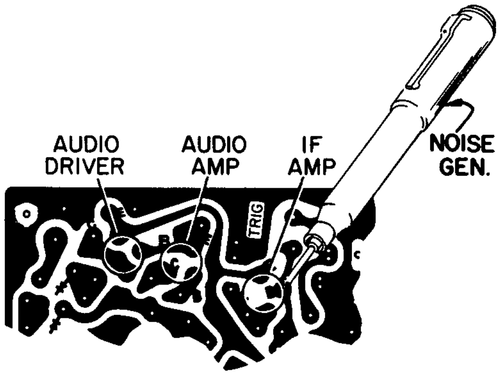


Fig. 8-14. Touching noise generator to printed board.

TABLE 8-1.

Noise Generator Tests

Test Point	*Results Expected*	*Checks*
Volume Control	Loud Signal	Audio System
Audio Detector (Audio Side)	Loud Signal	Volume Control
Audio Detector (IF Side)	Weak Signal	Detector Diode
IF Base	Weak Signal	IF Stage
Converter Base	Louder Signal	Converter Stage
RF Base	About Same as Above	RF Stage
Antenna Socket	About Same as Above	Antenna Circuit

Basic Procedure

The following procedure, taken in the order given will quickly lead you to the cause of any trouble in auto radios.

1. TURN RADIO ON, OBSERVING SPEAKER CONE MOVEMENT. If no speaker action, check speaker connections. Ohmmeter (on R × 1) should produce scratching noise at collector of output transistor.
2. TRY ALL CONTROLS. Volume, tone, manual, push-buttons.
3. REMOVE TOP COVER AND LOOK RADIO OVER CAREFULLY.
4. MEASURE COLLECTOR VOLTAGE OF OUTPUT TRANSISTOR. This checks audio amplifier, driver, and power output stages (except capacitors) in direct-coupled systems.

5. MEASURE CONDUCTION OF RF TRANSISTOR: WHEN TUNING THROUGH STRONG STATION FREQUENCIES, VOLTAGE SHOULD DIP TO A LOW VALUE. This checks RF, Converter, and IF Stages, and the AGC diodes. If no dip is obtained, measure current flow of each stage.
6. INJECT SIGNAL (Table 8-1).

CHAPTER 9

Troubleshooting AM-FM Automobile Radios

FM is not ideally suited for automobiles, but it is becoming very popular because of the excellent programming, fidelity, and noise-free reception. It does offer considerable relief from the overcrowded AM band, but the range is definitely limited.

The FM band (88-108 mc) is actually between Channel 6 and 7 TV channels. Proof of this can be easily seen in areas which have a channel-6 TV station. The audio can be heard just below 88 mc on many FM receivers.

Broadcasts in this frequency range are "line of sight"—the receiving antenna must "see" the transmitting antenna. In homes where the antenna is on the roof, it is possible to obtain range from high powered stations of 100 miles or more. In automobiles, a different situation exists where the antenna is virtually half a rabbit ears operating close to the ground. The range from a typical 50,000-watt station is 25 miles (Fig. 9-1). Beyond this distance, flutter can be expected. Lower-power stations exhibit flutter at less distance.

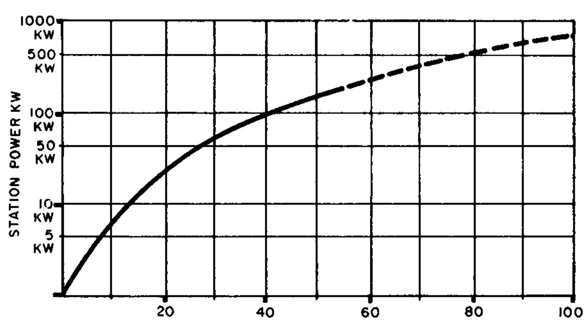


Fig. 9-1. Range versus FM station power for average condition in flat terrain.

The length of the car antenna is very important when listening to FM. To obtain maximum signal pick-up, it should be extended to exactly 30 inches above the fender. This 30-inch length is 1/4 wavelength at the center of the FM band. This matches the antenna to the radio, since the AM antenna trimmer is switched out of the circuit and has no effect on FM signals. Failure to use the proper antenna height increases the flutter effect.

Other causes of flutter are terrain (hills, etc.) and buildings (Fig. 9-2). Not only do they block the signal as the car moves

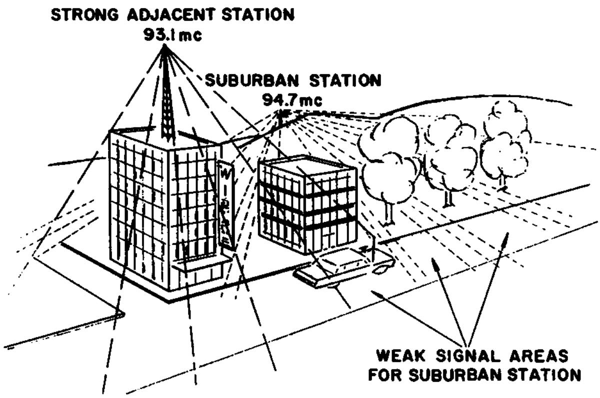


Fig. 9-2. How low antenna height, buildings, etc. limit FM range.

by, but they cause multipath reception. That is, signals from the station are reflected by the buildings and arrive at the car antenna a fraction of a second later than the direct signal. If the two arrive in phase (depending on the position of the car), they add, but when the car moves and they arrive out of phase, they cancel each other. This is flutter—a momentary drop out, or loss, of signal.

SCHEMATIC FAMILIARIZATION

AM-FM auto radio circuits are very similar to the household AM-FM radios described earlier. For this reason, the circuits should look familiar and will only be discussed briefly.

Fig. 9-3 shows a simplified AM-FM auto radio schematic. At the top of the schematic are three tuner stages—the FM-RF amplifier, FM oscillator, and FM mixer. Power is switched to the tuner when the band switch is in the FM position, and, at the same time, the antenna is connected to the FM-RF input. The station signal is amplified and sent to the FM mixer, where it meets the signal generated by the FM oscillator. The difference of those two signals is 10.7 mc.

The 10.7 mc IF signal is coupled to the 1st FM-IF stage, which is a dual purpose amplifier (it doubles as the AM-RF amplifier). After amplification by two other dual purpose stages and the 4th FM-IF, it is sent to the FM detector and three direct coupled audio amplifiers: AF-1, AF-2, and the power output stage.

The individual stages and their functions are:

FM-RF Amplifier	Amplifies the FM signals.
FM Oscillator	Generates a signal 10.7 mc higher than the station signal.
FM Mixer	Produces the 10.7-mc IF signal.
1st FM-IF AM-RF Amplifier	Amplifies the 10.7-mc signal. Amplifies the AM signals.
AM Oscillator	Generates a signal 262 kc higher than the AM station signal.
2nd FM-IF Amplifier AM Mixer	Amplifies the 10.7-mc signal. Changes the AM signals to IF (262 kc) (assisted by AM osc.)
3rd FM-IF Amplifier AM-IF Amplifier	Amplifies the 10.7-mc signal. Amplifies the 262-kc signal.
4th FM-IF	Amplifies the 10.7-mc signal.
FM Detector	Changes the FM signal to audio.
AM Detector	Separates the audio from the 262-kc signal.
AF-1	Amplifies the audio.
AF-2	Further amplifies the audio.
Output	Builds sufficient audio power to drive the speaker.

The block diagram in Fig. 9-4 shows the path the signal takes through each stage. Keeping the block diagram in mind is most helpful in troubleshooting.

TROUBLESHOOTING THE RADIO

All that has been learned in previous chapters can be applied to this radio. All of the tools for localizing the trouble to one section of the radio and measuring conduction and bias of transistors in that section should be used in troubleshooting AM-FM auto radios.

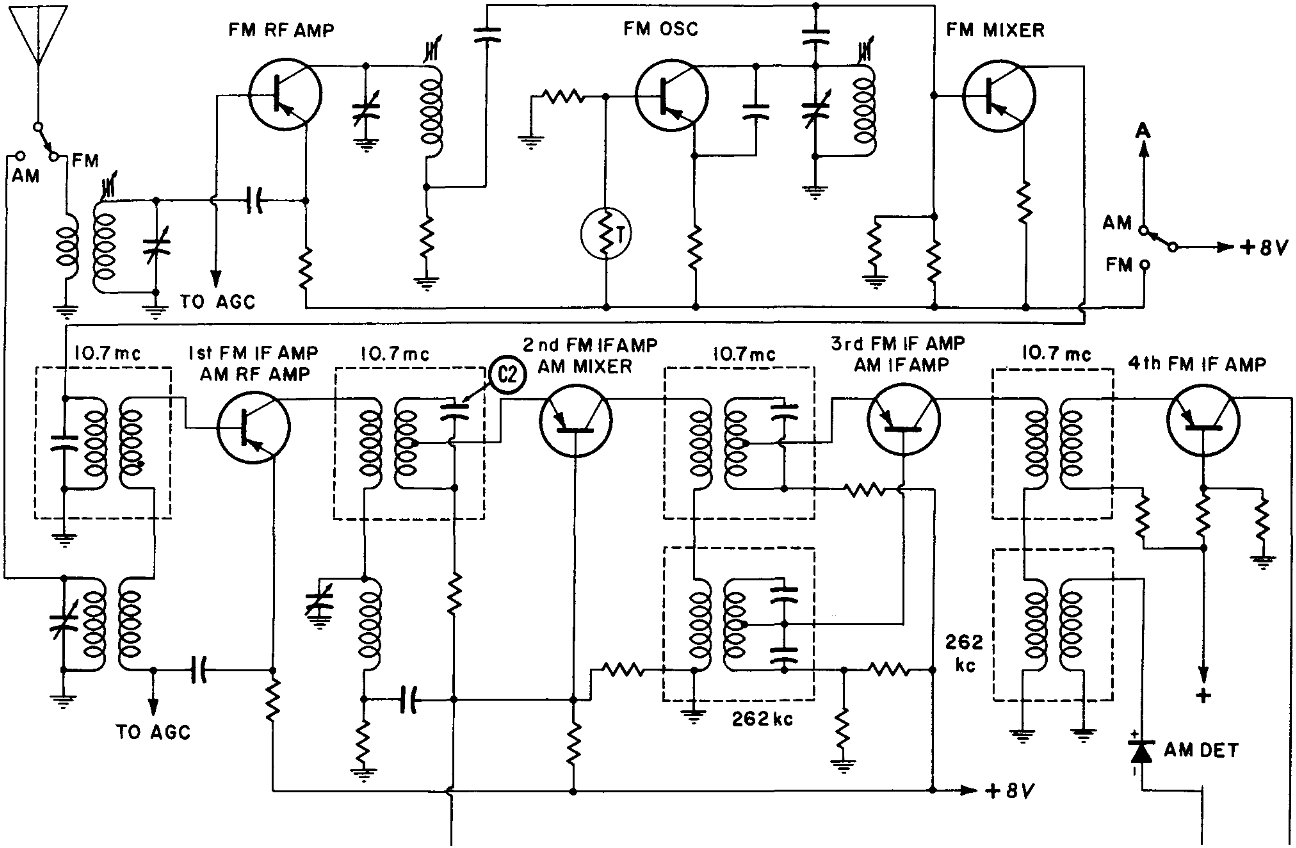
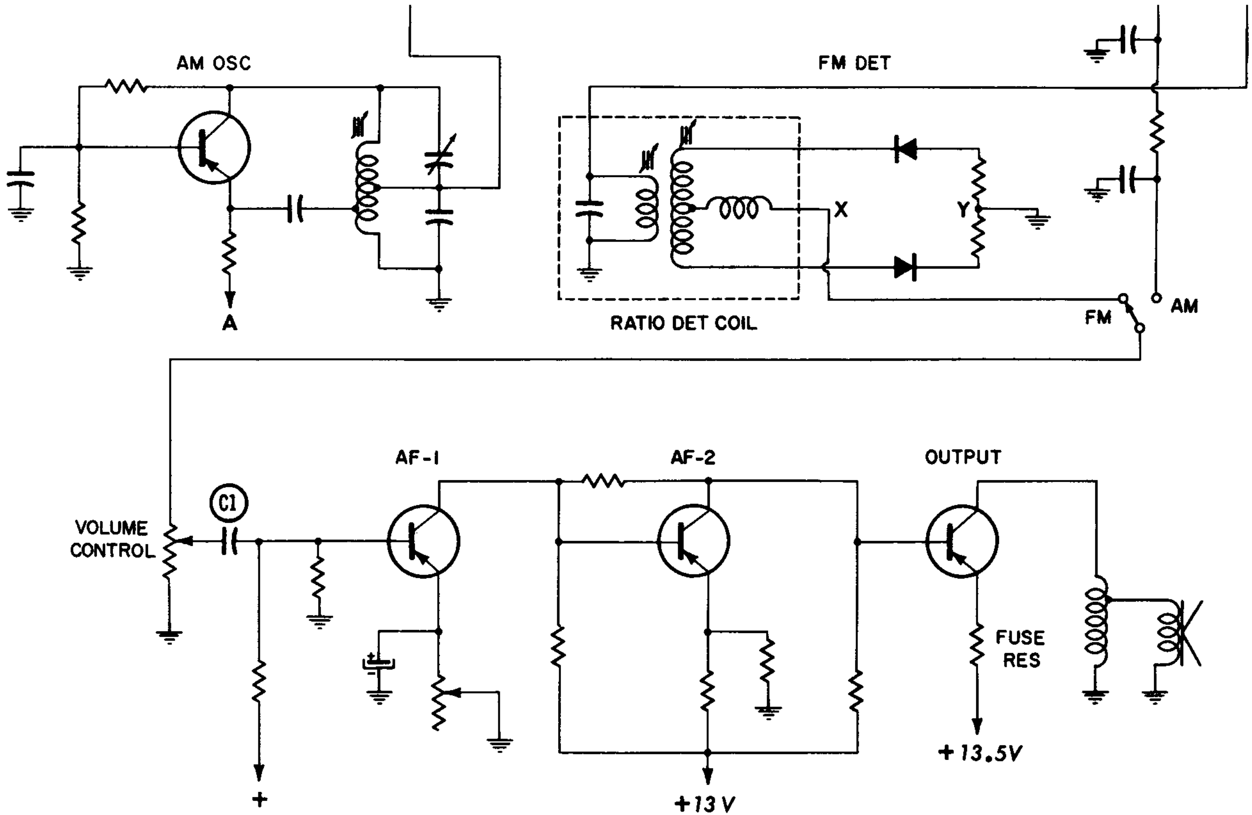


Fig. 9-3. Simplified schematic



of an AM-FM auto radio.

If the radio is in the car, the trouble should first be isolated to the radio or one of its supporting components before it is removed.

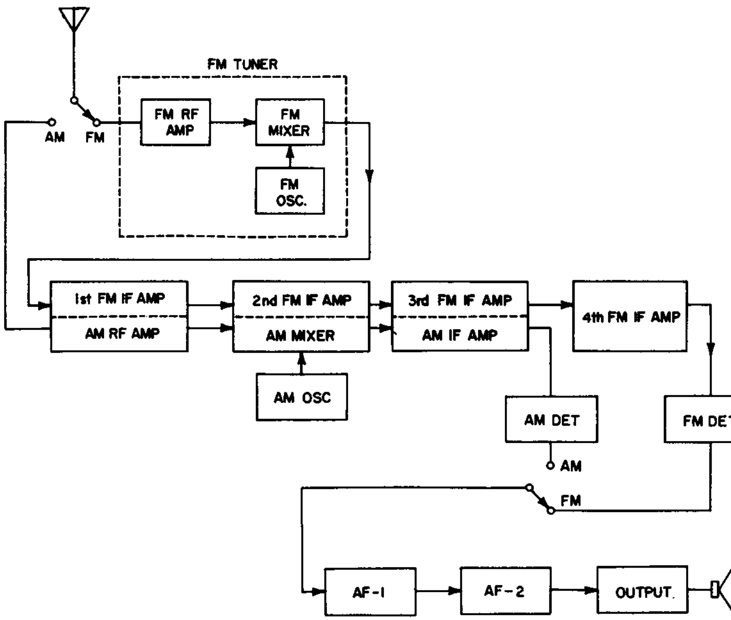


Fig. 9-4. Block diagram of a typical AM-FM auto radio.

Checking the Radio in the Car

The antenna, fuse, and speaker can be checked in the same manner as the straight AM auto radio discussed in the previous chapter was checked.

Important Points to Remember:

1. The antenna height should be adjusted for 30 inches. Reason: To minimize flutter on FM.
2. The antenna trimmer should be adjusted for maximum volume while listening to a weak AM station or noise near 1400 kc. Reason: To minimize fading, station mixing, and whistles on AM.
3. No "thump" when power is applied indicates an open fuse, defective speaker, or defective audio system.
4. Owners who have FM in their home and complain of FM flutter when operating their car radio may not understand the normal range limitations of automobile installations. Take a test ride and compare with other FM car radios.

Checking the Radio on the Bench

The following are important points to remember when checking any AM-FM auto radio on the bench:

1. Use the "thump" test to check the audio system.
2. Listen to the radio on both AM and FM.
   If the FM only is dead, trouble is probably in one of the stages which operates during FM only (FM tuner, 4th FM-IF amplifier, or FM detector).
   If AM only is dead, the trouble is probably in one of the stages which operates during AM only (AM oscillator or AM detector).
   If AM *and* FM are dead, the trouble is probably in one of the dual-IF stages or the audio system.
3. Noise generators work on AM only. If set is dead on both bands, troubleshoot on AM.
4. Conduction checks are made with no signal entering the radio (antenna disconnected). To check conduction, measure the voltage across emitter resistor; except, in output stage use collector voltage to ground.
5. Normal transistor bias is .2 volt for PNP germanium units and .6 volt for NPN silicon uints (except oscillators, which vary with tuning).

Locating Troubles Which Affect Conduction

Let's take some typical troubles and see how they make the radio react and how we track them down.

Note how the indications lead you right to the trouble, provided the basic tools of troubleshooting are employed.

If the fuse resistor in the output stage is open:

1. The radio will be dead on both AM and FM.
2. There will be no thump as the radio is turned on.
3. There will be no noise whatever as the volume control is rotated.
4. There will be no voltage at the output collector (conduction test).
5. There will be little, if any, bias on the output transistor (pointing to trouble in base or emitter circuit).
6. The resistance of fuse resistor will measure very high in one direction of ohmmeter ($R \times 1$).*

---

* If the ohmmeter leads are reversed, the reading will be low due to the low resistance of the transistor diode. This shows the importance of always taking two readings in transistor circuits.

If the AM oscillator transistor is open:

1. The radio will be OK on FM; dead on AM.
2. It will have the normal "turn-on thump."
3. When switched to AM, a noise generator will work all the way back to the AM antenna.
4. No whistle (oscillator signal) will be heard in a nearby radio when this radio is tuned.
5. There will be no voltage across the AM oscillator emitter resistor (conduction test).
6. The bias of AM oscillator will be 1.1 volt (high).
7. The emitter diode resistance will be high in both directions of meter (R × 100 range).

If the 3rd FM-IF amplifier (AM-IF amplifier) transistor is leaky:

1. The radio will be weak on AM and FM.
2. It will have the normal "turn-on thump," and the output collector voltage will be normal.
3. The voltage across *all* IF emitter resistors will be normal, except the AM-IF amplifier stage, which is above normal.
4. The bias on the AM-IF amplifier will be low or reversed (depending on how leaky the transistor is).

Locating Troubles Which Don't Affect Conduction

If the audio coupling capacitor C1 is open:

1. The radio will be dead on AM and FM.
2. It will have the normal "turn-on thump."
3. The collector voltage of the output stage (conduction) will be normal.
4. There will be no volume control noise.
5. No output will be obtained when the noise generator is placed at the volume control.
6. A loud output will be obtained when the noise generator is placed at the AF-1 base.

If one of the diodes in the FM detector is open:

1. The radio will be distorted on FM; AM OK
2. It will have the normal "turn-on thump."
3. The collector voltage of the output stage (conduction) will be normal.
4. All conductions and biases will be normal.

5. The voltage between points X and Y will not be zero, as it should be in a balanced detector.*

If the 10.7-mc IF capacitor C2 is open:

1. The radio will be dead or *very* weak on FM; AM OK
2. All audio checks will be good.
3. With volume control turned up, there will be no "FM hiss."
4. All transistor conductions, biases, and other voltages will be normal.
5. An FM signal injected at the 1st FM-IF amplifier collector will be dead or *very* weak.
6. An FM signal injected at the 2nd IF amplifier collector will be loud.
7. The IF coil connected across C2 cannot be aligned.

From the foregoing, it can be seen that an FM signal generator comes in handy when troubleshooting AM-FM radios, especially when FM reception is weak. Also, it is sometimes necessary to make a good, sharp alignment of the FM auto radio to minimize flutter. The radio needs all of the sensitivity it can get to help overcome the poor reception conditions in the car.

ALIGNING AM-FM RADIOS

Since alignment of individual models is described in service manuals and other books, it will only be discussed very briefly here. There are some things peculiar to AM-FM auto radios which should be mentioned.

Fig. 9-5 shows the usual hook-up for alignment. The FM signal generator should be crystal controlled (such as the Heath Model FMO-1 or equivalent) and is generally connected at the antenna of the radio. The output meter is connected to one side of the ratio detector output.

Difficulties often encountered are:

1. The IF peaks are not sharp.
   Solution—keep the signal level of the FM generator low (so that the output meter in Fig. 9-5 reads about .5 volt).
2. When attempting to align the tuner, the FM generator output cannot be attenuated, resulting in broad peaks or no peaks at all.

---

*Other faults in the FM detector circuit will cause an unbalanced condition and distortion; for example, an open or detuned ratio detector coil.

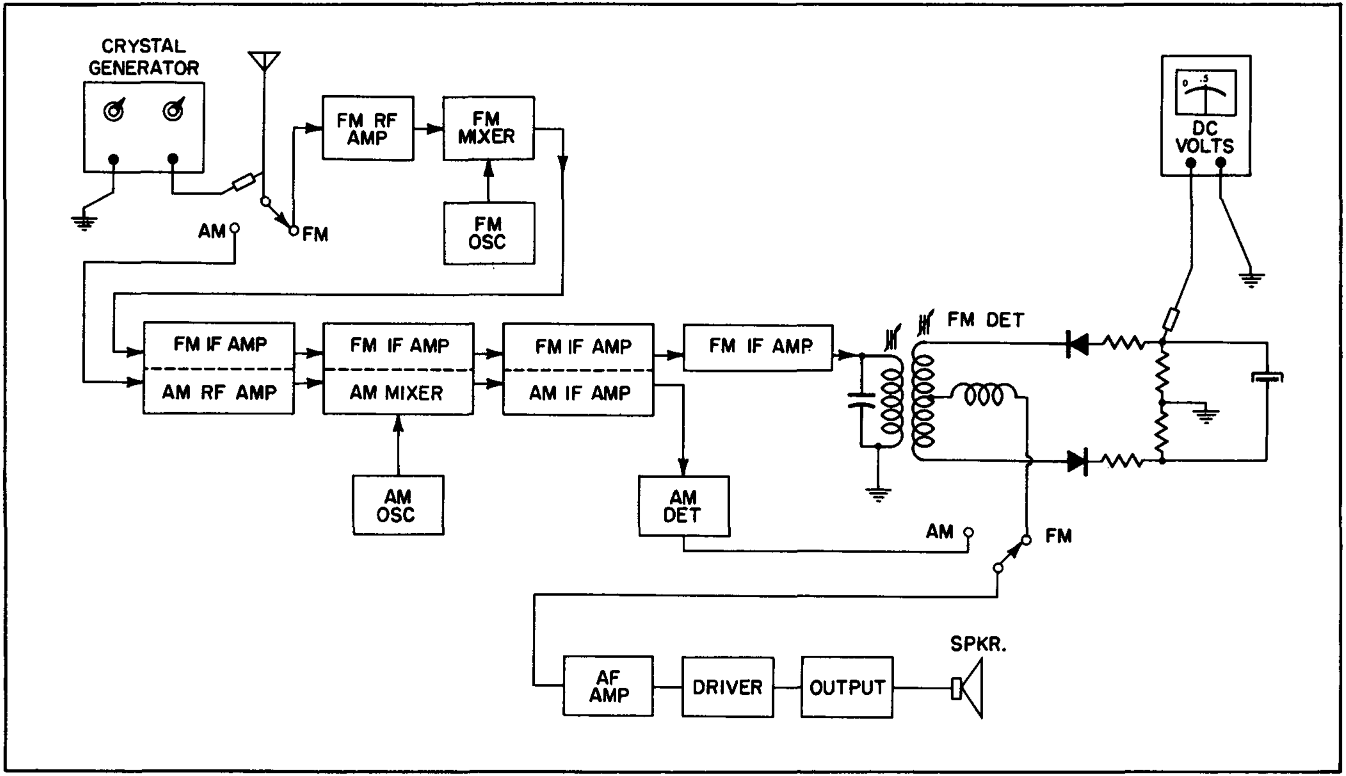


Fig. 9-5. Alignment setup for FM auto radios.

Solution—change one of the generator crystals to 9 mc. and use its harmonics (90 mc, 99 mc, 108 mc) for tuner alignment. A generator with two crystals (9 mc for tuner alignment and 10.7 mc for IF alignment) makes an excellent instrument.

CHAPTER 10

Case Histories of Actual Troubles

Now it is time for a practice session, where all you have learned can be applied to solving actual problems. All case histories were written from actual experience; they were not simply "armchaired" from theory.

The experiences are described step by step, beginning with the customer complaint and ending with the method of repair. The troubles described will not necessarily be those most often encountered; instead, they are ones which can cause the most difficulty.

The following troubles are described to demonstrate the testing procedures in this book, and to assist you with some of the more ellusive troubles encountered in transistor radios.

CASE HISTORY NO. 1—THE DEAD PORTABLE

Type of Radio: Transistor AM portable
Transistors: 6
Stages: Converter, 1st IF, 2nd IF, driver, push-pull output
Customer Complaint: "The radio doesn't play."

Test Procedure:

1. The radio was turned on and the batteries checked.
   Result—Normal voltage and current drain.
   Meaning—The batteries are good, and the electrolytics are not shorted.
2. The radio was observed closely.
   Result—It was completely dead, except for a slight pop as it was turned on and off. There were no obvious loose connections or broken conductors.

Meaning—The speaker was probably all right, and the circuit board apparently was not broken.

3. The volume control was turned to its maximum position, and the audio system was checked by the body click test. That is, with one hand on the chassis and the other holding a metal probe, the probe was used to tap the base lead of the driver transistor. The body resistance thus prevented the transistor from being grounded directly.

   Result—A click was heard.

   Meaning—The audio system was functioning.

4. The same procedure was applied to the 1st IF base lead and the converter collector lead.

   Result—Nothing was heard at either point.

   Meaning—The trouble was in one of the IF stages, since no signal could be sent through them.

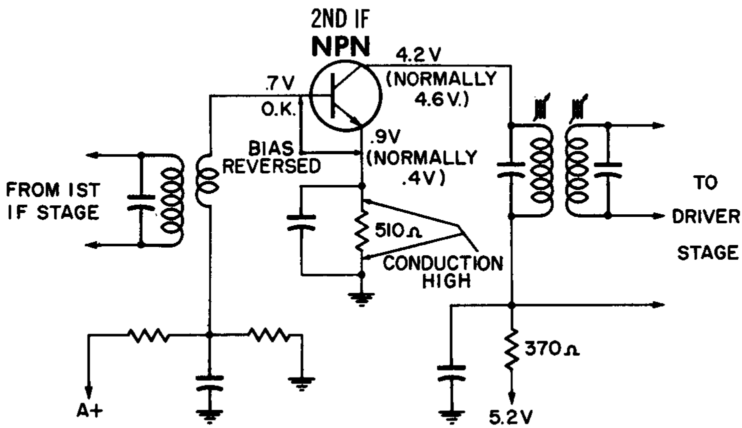


Fig. 10-1. Abnormal voltages in this stage are caused by a leaky transistor.

5. Voltages were read on the IF transistors.

   Result—The 1st IF stage measured all right, but the 2nd IF transistor had incorrect conduction and bias voltages (see Fig. 10-1).

   Meaning—The transistor was drawing a lot of collector current, but the bias voltage was reversed from normal. This meant the transistor must be partially shorted between emitter and collector.

6. The transistor was removed from the radio and checked.

   Result—The leakage resistance between emitter and collector (with base floating) dived rapidly toward zero.

   Meaning—The transistor was very leaky.

Conclusion

When some very simple procedures were followed, this case was solved in a few minutes. Systematic stage isolation plus voltage readings paid off.

A minimum of test equipment was used—the eyes and ears, a small probe, and an ohmmeter.

CASE HISTORY NO. 2—THE DROPPED RADIO

Type of Radio: Transistor AM portable
Transistors: 6
Stages: Converter, 1st IF, 2nd IF, driver, push-pull output
Customer Complaint: "The radio is dead—it was dropped."

Test Procedure:

1. The radio was turned on and given a listening test.
   Result—Nothing was heard.
   Meaning—Not conclusive.
2. The batteries were checked.
   Result—Battery voltage normal; battery current normal or slightly below.
   Meaning—The batteries were good, and no filters were shorted.
3. The radio was given a good visual check. The printed side of the board was pointed downward and soldered to the front plate. The transistors were on top, however, and easily accessible.
   Result—No cracks or other obvious faults were noted.
   Meaning—Not conclusive.
4. The base lead of the audio driver transistor was given the click test.
   Result—No click was heard.
   Meaning—The audio system was not working.
5. Voltage readings were taken on the audio transistors.
   Result—All driver transistor voltages read about the same (see Fig. 10-2). The collector voltage was very high.
   Meaning—The collector lead may be open, allowing the collector to assume the emitter potential.
6. The radio was given another careful visual check in the area of the driver transistor.
   Result—A small crack was observed which extended through to the copper conductor, between the driver collector lead and the collector transformer.
   Meaning—The collector circuit was open.

Conclusion

Close visual observation is very valuable; but when the defect cannot be seen, routine isolation and voltage checks should be made.

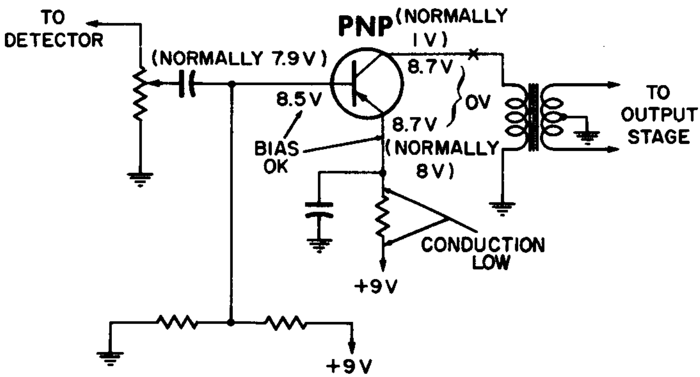


Fig. 10-2. Improper voltages resulting from an open in the collector circuit.

CASE HISTORY NO. 3—INTERMITTENT AND WEAK OUTPUT

Type of Radio: Transistor AM portable
Transistors: 9
Stages: RF, oscillator, mixer, 1st IF, 2nd IF, AGC, audio driver, and push-pull output.
Customer Complaint: "The radio fades at times."

Test Procedure:

1. The radio was turned on.
   Result—Normal reception.
   Meaning—Not conclusive.
2. The radio was jarred to see if it would fade.
   Result—The signal suddenly became weaker.
   Meaning—The radio was intermittently weak.
3. The battery voltage and current were checked.
   Result—Normal voltage and current.
   Meaning—The batteries weren't weak or making poor connection; the electrolytics weren't shorted.
4. The circuit board was tapped at various spots, and so were the components.
   Result—The radio seemed to be sensitive to jarring around the IF section.
   Meaning—The IF section should be checked.

5. A close observation was made of that area.
   Result—Nothing was found.
   Meaning—No loose connections were visible.
6. The radio was jarred again until its output became very weak. Gain checks were then made.
   Result—The IF section was very weak.
   Meaning—Further check should be made in that section.
7. Voltage were read in the IF stages.
   Result—All were normal.
   Meaning—DC conduction was normal.
8. A pencil soldering iron was applied to the IF transformer terminals.
   Result—The last IF was very sensitive to heat, and the sensitivity became normal when the radio was touched.
   Meaning—The transformer was intermittent.

Conclusion

An intermittent open capacitor in the base of an IF transformer does not usually cause the development of an incorrect voltage. This goes back to the rule that if all voltages are normal, the defect is probably an open capacitor or a detuned circuit. In this instance we had both because the capacitor was part of a tuned circuit. So, when it opened, it detuned the transformer. The result was an extremely weak radio, but no incorrect voltages!

CASE HISTORY NO. 4—THE HIGH-DRAIN PORTABLE

Type of Radio: Transistor AM portable
Transistors: 6
Stages: Converter, 1st IF, 2nd IF, audio driver, push-pull output.
Customer Complaint: "The radio is dead."

Test Procedure:

1. The radio was turned on.
   Result—It was dead.
   Meaning—Not conclusive.
2. The battery voltage was checked with the radio turned on.
   Result—It was 1.2 volts (instead of 9).
   Meaning—It was much too low.
3. The battery current was checked.
   Result—It was 60 milliamperes (instead of 6).
   Meaning—There was a short on the "A+" line.

4. The printed circuit was closely observed for a solder short.
   Result—Nothing unusual was noted.
   Meaning—No apparent short in the circuit.
5. The electrolytic was checked with an ohmmeter on the R×1 scale.
   Result—It was 40 ohms.
   Meaning—It was much too low.
6. The electrolytic was disconnected and checked again.
   Result—It was still about 40 ohms.
   Meaning—The capacitor was defective.

Conclusion

Much time was saved by checking the battery voltage and current first.

CASE HISTORY NO. 5—CASE OF THE UNUSUAL SHORT

Type of Radio: Transistor AM portable.
Transistors: 9
Stages: RF, oscillator, mixer, 1st IF, 2nd IF, AGC, audio driver, push-pull output
Customer Complaint: "Dead radio."

Test Procedure:

1. The radio was turned on.
   Result—It was completely dead—not even a "hiss."
   Meaning—Not conclusive.
2. The battery voltage and current were checked.
   Result—Both were within normal limits.
   Meaning—Batteries O.K.; electrolytic not shorted.
3. Stage gains were checked with a noise generator.
   Result—At the base of the audio driver—good signal. At the base of the 1st IF—no signal. At the base of the mixer—extremely weak signal.
   Meaning—The trouble is in the IF section, because a good signal normally is heard at the 1st IF base.
4. Voltages were checked in the IF stages.
   Result—The 2nd IF voltages were normal, but the 1st IF voltages were not (see Fig. 10-3).
   Meaning—There was a defect in the 1st IF base circuit, because the base voltage was much too high.
5. On a hunch, we checked the collector voltage of the preceding stage.
   Result—The mixer collector and the 1st IF base voltages (Fig. 10-3) checked the same.

Meaning—1st IF transformer T1 was shorted between the primary and secondary.

Conclusion

An ohmmeter confirmed the defect. The base voltage was much too high because of the shorted transformer, and thus

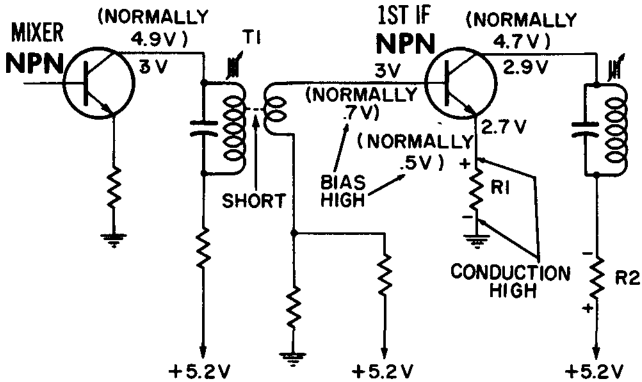


Fig. 10-3. Voltages caused by a short between the primary and secondary windings of the 1st IF transformer.

caused the 1st transistor to conduct much too heavily. As a result, the collector voltage dropped, and the emitter voltage rose because of the voltages produced by the current flow through R1 and R2.

By isolating the trouble to the IF section and then properly analyzing the voltages, we rapidly found the cause. (We also could have isolated the trouble by click testing.)

CASE HISTORY NO. 6—AM-FM WITH NO AM

Type of Radio: AM-FM table model
Transistors: 11
Stages: FM RF, FM mixer, FM osc., AM osc., 3 dual-purpose FM IF amps, audio amplifier, audio driver, push-pull output.
Customer Complaint: "Dead on AM, O.K. on FM."

Test Procedure:

1. The radio was turned on.
   Result—AM dead, FM O.K.
   Meaning—The audio system is working, and so is FM tuner. Trouble must be in one of the dual stages or AM oscillator.

2. On a hunch, another radio was placed next to the defective one, and tuned to a station near 1600 kc. The defective radio was "Rocked" between 1000 kc and 1400 kc.

   Result—The oscillator "beat" signal, or "birdie" was not heard.

   Meaning—The AM oscillator was probably not working. (Further checks revealed that the bias on the oscillator was high, and did not change when the radio was tuned. A new AM oscillator transistor was tried and set returned to normal.)

Conclusion

By careful inspection and listening to both bands, it is easy to isolate most troubles rapidly in AM-FM radios.

CASE HISTORY NO. 7—THE FADER FIXED FAST

Type of Radio: AM auto radio
Transistors: 6
Stages: RF, converter, IF, AF amp, driver, output.
Customer Complaint: "Radio fades when I get out of town or near buildings."

Test Procedure:

1. The radio was still in the car. It seemed weak on out of town stations; locals O.K.

   Meaning—The antenna trimmer could be off "Peak."
2. The radio was tuned to a very weak station near 1400 kc. The trimmer was rocked back and forth until the station was loudest.

   Result—The sensitivity improved tremendously.

Conclusion

On a weak or fading auto radio complaint, always check the antenna trimmer before removing the radio from the car. (If AM-FM radios, make sure antenna height is 30 inches above fender for best FM reception). The antenna trimmer is *only* adjusted on AM; it is not in the circuit on FM.

Index

A

AGC, 36-38
Alignment, AM-FM auto radio, 175-177
AM-FM, auto radio, 167-177
  receiver, circuits, 80-87
    comparison with AM, 79-80
    test points, 82-87
  stage defects, 128
Antenna, checking of, 150
  trimmer, 151
Audio, direct coupled, 159-161
Audio gain test, 141-143
Audio system, checking of, 153-161
Auto, testing radio in, 150-151
  antenna, checking of, 150
Auto radio
  alignment of, 175-177
  AM, 147-166
  AM-FM, 167-177
  checking in car, 172
  checking on bench, 173-175
Automatic gain control; *see* AGC

B

Base lead, open, 118
Base-to-emitter bias, loss of, 114-116
Base voltage, wrong, cause of, 112-114
Basic transistor-circuit limitations, 21-26
Battery
  current measurement, 46, 47
  eliminator, use of, 47
  voltage check, 45, 46
    importance of, 79
  weak, effect of, 79
Bench check, auto radio, 173-175
Bias
  adjustment of, 153, 156-157
  battery elimination, 26-32
  effect on transistor current, 22-25
  loss of, 114-116
  variable, 36-38

C

Capacitor
  open, 125
  shorted, 125
Case histories of actual receiver troubles, 179-186
Circuit board, component-location method, 58-59
Circuit components and their functions, 21-39
Click test, 67-72
  performance of, 71
  test point for, 70
  using body resistance to protect transistor, 67, 68
Collector lead, open, 118
Common defects and their effects on voltages, 124
Comparison of tube and transistor elements, 91-92
Conduction, transistor
  factors affecting, 7
  test, 108-109
Crystal impurities, 8
Crystal material, 8

D

DC tests, 130-131
DC transistor testers, use of, 130
Defective IF, 125
Defective NPN stage, 125-126
Defective PNP stage, 126-128
Defective stage isolation, 41-78
Defective voltages and their meanings, 111-128
Degeneration, 34-35
Detection, AM-FM, 85-87
Diode
  action of, 8-16
    caused by connecting ohmmeter across, 10-11
    current carriers, 9-16
    in transistor, 8-16
  adding current carriers to, 8-9
  construction, 8
    material used for, 8

Diode (cont'd)
nonconducting, 9-10
test, performance of, 137
use of, 8
Direct-coupled audio stage, 159-161
Direct current test; *see* DC test
Driver stage, troubleshooting of, 157, 159
Dynamic test, transistor, 130

E

Eliminating the bias battery, 26-32
biasing by voltage driver, 27-31
Eliminator, battery, use of, 47
Emitter lead, open, 118
Emitter-to-collector leakage, 138-141
Emitter-to-collector voltage, loss of, 116-118
Errors, voltage, cause of, 111-125

F

Familiarization, schematic, 43-45
FM tuner section, 80, 83-84
Forward biasing the NPN transistor, 13-14
Front end, checking of, 161-164
Fuse, checking of, 150

G

Gain, transistor, checking of, 141-143
Gain test
audio, 141-143
RF-IF, 143
Generator, noise
advantages of, 67
summary, 66-67
test points, 59, 63-64, 65-66
Generator, signal
setting controls, 55-58
test points, 52-55

H

Heat sink, 26

I

Identifying transistor
elements, 16
leads, 58
type, 143-144
Idling current, transistor, 17
IF amplifier, defective, 125
dual purpose, 84-85
In-circuit transistor tests, 132-135
checking for leakage and shorts, 135
checking for open leads, 132-135
Injection, simplified signal, 67-72
click test, 67-72
Input and output transformers, 32-35
Isolating
defective stage, 41-78
Isolation by
noise test, 59-67
noise-generator summary, 66-67
test point for noise generator, 59, 63-64, 65-66
personal observation, 48-50
signal injection, 50-59
locating test points, 58-59
setting generator test points, 52-55
signal-generator test points, 52-55
signal tracer, 72-78
summary, 76-78
test points, 74-76
Isolation of troubles, 87-90

L

Leads, transistor, identification of, 58
Leakage and shorts test, transistor, 135, 140-141
Leakage test, 140-141
Leaky transistor, 121-122
Listening checks, 48-50, 87-88
Local oscillator, checking operation of, 69-70
Locating
components on circuit board, 58-59
test points, 58-59
Loss of
bias, 114-116
emitter-to-collector voltage, 116-118

M

Maximum current ratings, transistor, 18-19
Measuring battery current, 46, 47
Mosquito noise generator, 59, 63

N

Network, voltage-divider, 27-31
Noise generator
  advantages of, 67
  Mosquito, 59-63
  small, use of, 59
  summary, 66-67
  test points, 59, 63-64, 65-66
  use of, 164-165
Noise test, isolation by, 59-67
Nonconducting diode, 9-10
Normal transistor diode readings, 125
Normal voltages, transistor, 91-109
NPN stage defects, 125-126
NPN transistor, 11-14, 81, 88; *also see* Transistor, NPN
  adding forward bias, 13-14
  basic circuit of, 93
  circuit, positive ground, 100
  schematic symbol for, 12

O

Ohmmeter
  lead polarity, checking of, 137-138
  testing transistors with, 131-132
Ohm's law, application of, 95, 105
Open
  capacitors, 126
  circuits, review of, 119-120
  leads, testing for, 132-135
Oscillator
  checking operation of, 69-70
  feedback, 38-39
  frequency, FM, 83-84
Out-of-circuit transistor tests, 135-141
Output and input transformers, 32-35
Output stage, 153

P

Personal observation
  audible check, 48-50
  visual checks, 50
PNP stage defects, 126-128
PNP transistor, 14-16, 94; *also see* Transistor, PNP
  circuit, positive ground, 106
  comparison with NPN type, 14
  forward bias, 15
Points, test, location of, 58-59
Polarity of ohmmeter leads, checking of, 137-138
Power supply, 45-47
  load and no-load voltages, 45-46
  voltage and current measurements, 45-46, 47
Power transistors, special test for, 144-145

R

Radio troubles, actual case histories, 179-186
Range, 167-168
Receiver, transistor
  block diagram of, 43
  schematic of, 42
Receiver power supply, 45-47
Recommended ohmmeter ranges for testing transistors, 136
Resistance polarity rule, 93, 95
Resistor, stabilizing, 22-26
RF-IF gain test, 143
Rules, troubleshooting, 124-125

S

Schematic familiarization, 43-45
  AM-FM, 80-87
  auto radio, 147-150
Setting signal-generator controls, 55-58
Shock injection; *see* Click test
Shorted capacitors, 125
Signal degeneration, 34-35
Signal generator, 89-90
  controls, setting of, 55-58
  settings when audio section is being tested, 56
  test points, 52-55
Signal injection
  AM-FM receiver, 89-91
  isolation method, 50-59
    locating test points, 58-59
    setting signal-generator controls, 55-58
    signal-generator test points, 52-55
  simplified, 67-72
    click test, 67-72
  test points, locating, 57, 58-59
Signal tracer
  isolation method, 72-78
    summary, 76-78
    test points, 74-76.
  major test points for, 75
  summary, 76-78

Signal tracer (cont'd)
test points, 74-76
Signal-tracing test-point sequence, 77
Simplified signal injection, 67-72
click test, 67-72
Speaker, checking of, 150
Special test for power transistors, 133-134
Stabilizing resistors, 22-26
Stage defects
AM-FM, 128
NPN, 125-126
PNP, 126-128
Stage isolation methods, 47-78
noise test, 59-67
test points for generator, 59, 63-64, 65-66
personal observation, 48-50
listening checks, 48-50
visual checks, 50
signal injection, 50-59
locating test points, 58-59
setting generator controls, 55-58
signal-generator test points, 52-55
signal tracer, 72-78
summary, 76-78
test points, 74-76
simplified signal injection, 67-72
click test, 67-72
Stages, AM-FM receiver, 80-82
Static test, transistor, 129-130
Summary
noise generator, 66-67
signal generator, 76-78
Supply, power, checking of, 45-47

T

Temperature, effect on transistor current, 22-25
Temperature, transistor, 139
Test points
AM-FM receiver, 82-87
locating of, 58-59
noise generator, 59, 63-64, 65-66
signal generator, 52-55
signal injection, 57
signal tracer, 74-76
Test, types of
direct current; *see* DC tests
in-circuit, 132-135
for leakage and shorts, 135
for open leads, 132-135
Test, types of (cont'd)
out of circuit, 135-141
checking the transistor diodes, 135
selecting the proper ohmmeter range, 136
Testing transistors, 129-145
Testing procedure, in car, 150-151
Thermistor, 26
Tracer, signal, isolation method, 72-78
signal-tracer summary, 76-78
signal-tracer test points, 74-76
Transformer coupling, comparison with resistance coupling, 33-35
Transformers, input and output, 32-35
Transistor
advantages of, 7-8
basic circuit limitations, 21-26
basic function of, 7-16
bias, adjusting of, 153, 156-157
checking emitter-to-collector leakage, 138-141
circuit components, 21-39
circuits, sample defects in, 125-128
conduction, factors affecting, 7
current stabilization of, 21-26
diode action, 8-16
effect of operating temperature and bias on current, 22-25
element, comparison with vacuum tube, 91-92
element identification, 16
example of, 17
gain, checking of, 141-143
heat sink, 26
identification of type, 143-144
idling current, 17
lead identification, 58
leakage-test, 140-141
leaky, 121-122
normal voltages, 91-109
NPN, 11-14
adding forward bias, 13-14
schematic symbol, 12
NPN circuit, 92-102
actual radio voltages, 100-102
effect of collector resistor, 95-96
effect of collector transformer, 97-98
effect of emitter resistor, 93-95
estimating collector current, 96-97

Transistor (cont'd)
NPN circuit
voltages between elements, 98-99
open lead, 118
oscillator, 38-39
circuit, 38
operation, 38-39
PNP, 14-16
comparison with NPN type, 14
forward biasing, 15
PNP circuit, 102-109
actual radio voltages, 106-109
effect of coupling transformer, 104
effect of emitter and collector resistor, 103-104
estimating collector current, 104-105
voltages between elements, 105
rating chart, interpreting of, 18-19
receiver
block diagram of, 43
current drain, 47
schematic, 42
typical IF section, 101
short in base circuit, 122-125
stabilizing resistor, 22-26
in collector lead, 25-26
in emitter lead, 23-25
substitution, 129-130
temperature, 139
testing of, 129-145
audio gain, 141-143
dynamic and static, 129-130
in circuit, 132-135
leakage and shorts, 135
open leads, 132-135
out of circuit, 135-141
RF and IF, 143
special, for power transistors, 144-145
substitution, 129-130
with an ohmmeter, 131-132
voltage, effect of defects on
leaky transistor, 111-112

Transistor (cont'd)
voltage
open capacitor and defective IF, 125
open lead within transistor, 118
short in base circuit, 122-124
shorted capacitors, 125
theory of, 7-19
tube-element comparison, 91-92
types, 16-19
understanding, 7-19
importance of, 7
voltage and current ratings, 18-19
Trouble, isolation of, 87-90, 150-164
Troubleshooting, AM-FM auto radio, 169-175
driver stage, 157, 159
rules, 124-125
Tuned circuits, AM-FM, 84-85
Tuner, FM, 80, 83-84
Typical transistors, 7

U

Understanding the transistor, 7-19

V

Variable bias, 36-38
Visual checks, 50
Voltage, battery, checking of, 45, 46
Voltage checks, 108
Voltage-divider network, 27-31
Voltage errors, causes of, 111-125
Voltage measurements, meter used for, 112
Voltages
defective, and their meanings, 111-128
effects of defects on, 124
expected, when lead is open in transistor, 118
importance of checking, 111

Z

Zero bias, causes of, 120