basic radio repair

MARVIN TEPPER

**VOLUMES
1 and 2**

RIDER

Basic

Radio Repair

VOL. 1

MARVIN TEPPER
Electronic Services Division
Raytheon Company

Author of
FUNDAMENTALS OF RADIO TELEMETRY
BASIC RADIO

PREFACE

Knowledge of radio receiver and transmitter circuits is one part of the job. An equally important part is to be able to apply this knowledge to the maintenance and repair of defective receivers or transmitters.

These books are a logical extension of *Basic Radio,* and are presented in a manner calculated to best instill a common-sense approach to servicing. Too often the author has observed good knowledge of circuits being wasted by a complete lack of an approach, or a poor approach to circuit troubleshooting and repair.

The context of these books reflects an application of practical servicing procedures. The approach is to illustrate by a combination of words and pertinent artwork, as close an approximation as possible of repair techniques as they would actually be done on a workbench.

Starting as a single volume, it soon became apparent that there was more to say than could be covered in a single book. Rather than weaken its value the contents were expanded and placed in two volumes, allowing coverage of all phases of radio receiver and transmitter servicing.

The contents are carefully laid out. Beginning with an exhaustive discussion of the test equipment used in servicing, it goes into a complete discourse on significant aspects of different components. The next section thoroughly covers a most important subject, servicing procedures. No one servicing technique is favored—all are covered equally. The approach to superheterodyne receiver servicing was carefully set up to closely approximate the approach taken when actually serving a receiver. Servicing of each circuit is taken in the order most likely to be followed during actual receiver repairs. This also holds true for the chapters on portable, automobile, and FM receivers.

It was felt that to try and combine discussions of equivalent tube and transistor circuits side by side would be confusing. Accordingly a completely separate discussion is used on transistor receivers, allowing full concentration on servicing procedures peculiar to these receivers.

The final section, transmitter servicing, covers a neglected area. Previously very little has been written on this subject. The approach and coverage has been unstinting, covering all types of circuits, including FM and single sideband.
Those of you with extracurricular work activities will appreciate the long-enduring patience of my wife Celia, and my daughters Ruth and Shirley, who waited for me to compile and write these books, and then finally to rejoin the family.

<div align="right">MARVIN TEPPER</div>

Milton, Mass.
June 1963

Contents — Volume One

Volt-Ohm-Milliammeter

Later on in this book various techniques for rapid servicing of a defective radio will be discussed. One thing, however, is common to all these techniques — a method of measuring the values of resistance, voltage, and current. Individual meters, properly arranged with the correct values of multipliers or shunts, can be used to read those values. An assortment of individual meters would be a costly and clumsy method of servicing a radio receiver. The obvious answer is a combination of multipliers and shunts placed in a switching circuit with a single, basic meter movement. Those combination circuits are called multimeters, and in the case of the most commonly used type, they are called a Volt-Ohm-Milliameter, or VOM. The type of multimeter using vacuum tube circuits is called a Vacuum Tube Voltmeter, or VTVM. A VTVM is also capable of reading resistance by measuring a small value of voltage across the unknown resistor.

Volt-Ohm-Milliammeter

provides range
switching circuits

completely self contained
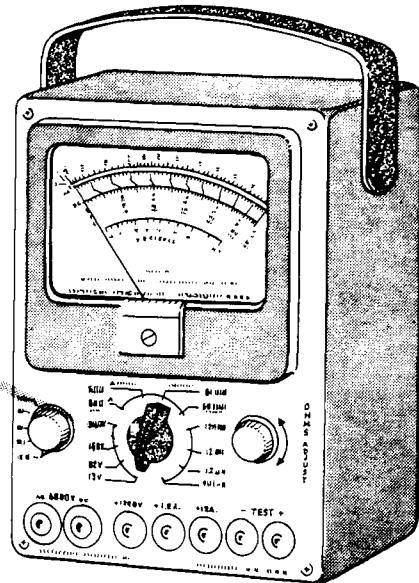
Discussing first the VOM, we find it to be one of the basic tools of servicing. It is convenient in that it is lightweight, portable, and completely self-contained, requiring no external source of power. It can measure voltage, resistance, and current. Switching circuits are required to provide the proper ranges for individual measurements. These circuits can be simplified and shown as individual circuits.

D-C Voltmeter Circuit

To simplify the discussion of the VOM, its individual circuits have been isolated and explained as though each were a single instrument using the same basic meter movement.

The basic d-c voltmeter circuit illustrated is a straightforward arrangement of multiplier resistors in series with the meter movement. The meter movement used in all circuits is a 50-microampere D'Arsonval type with a coil resistance of 2000 ohms. In order to read high voltages of 5000 volts, a separate jack terminal is provided on the bottom right-hand side of the meter panel. With the negative or common terminal on the bottom left-hand side, wide spacing between the input jacks is available, preventing possible arc-overs.

SIMPLIFIED D-C VOLTMETER CIRCUIT
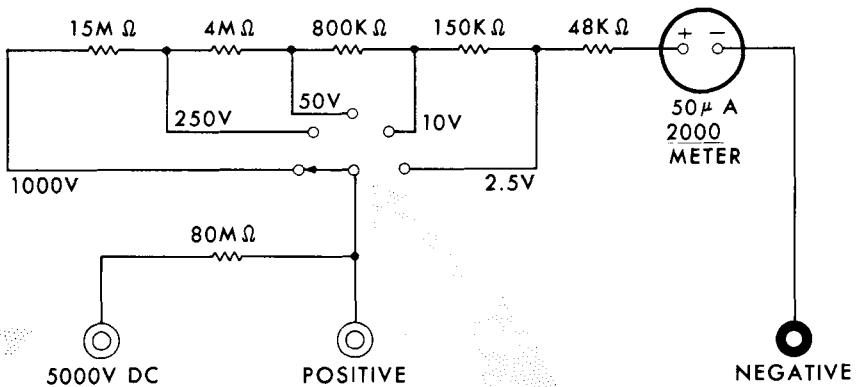
Courtesy of Simpson Electric Corporation

Although it is not noted on the switch positions, the meter will also read from 0 to 250 millivolts. The use of the meter to read this small a value requires *extreme care*. At this range it is easy to apply excessive voltage and damage the meter movement. To use the meter to read to 250 millivolts, it is set for a current reading of 100 microamperes. The 0-250 volt d-c scale is read directly in millivolts.

A-C Voltmeter Circuit

To read a-c volts a similar circuit to that of the d-c voltmeter is used with the addition of a rectifier circuit. Meter rectifier circuits are similar to other rectifier circuits previously discussed, but they have inherent problems that merit discussion. The most popular rectifier used is the copper oxide type. These consist of copper discs, each having a layer of copper oxide on one side. They are separated by lead washers and tightly clamped together. The symbol used for copper oxide rectifiers is the same as that used for crystal rectifiers — an arrow and bar, with the bar being the cathode. Copper oxide rectifiers are long-lived, but temperatures above 160°F will quickly shorten their life. The stray capacitance of the copper oxide rectifier restricts a-c measurements to the audio range of frequencies.

This rectifier circuit is a double section, half-wave rectifier circuit. During the first alternation, assume that point A is positive, and the electron flow is from point B, through the meter, through CR1 to point A. On the second alternation, the electron flow is from point A, through the low resistance of CR2 to point B. Diode CR2 prevents the possibility of any small reverse current flowing through CR1 and the meter. This small reverse current could cause the needle to deflect backwards. In addition the current flowing through CR2 removes the peak inverse voltage that would normally be applied between points A and B on the second alternation.
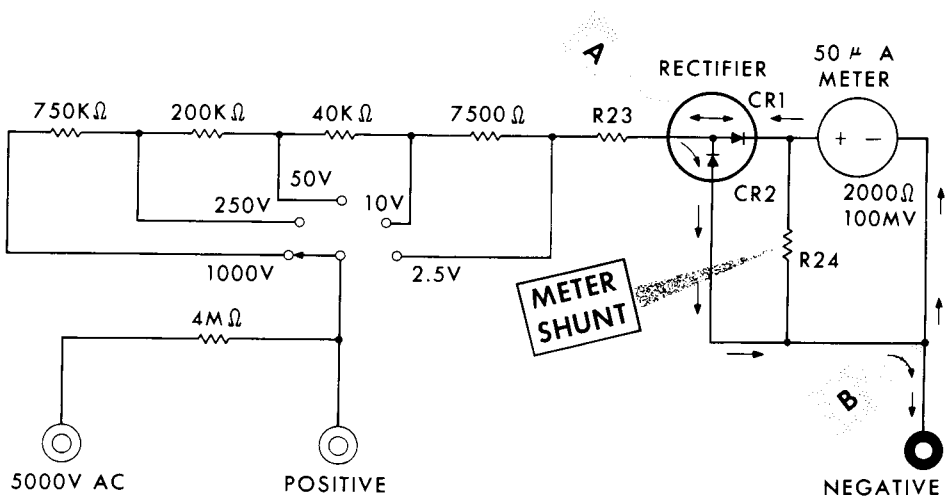
Simplified A-C Voltmeter Circuit

A-C Voltmeter Circuit (cont'd)
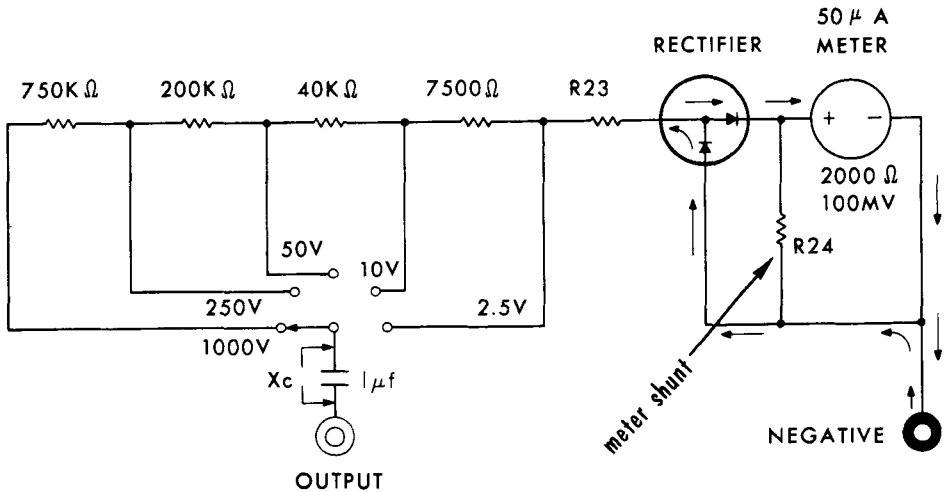
SIMPLIFIED OUTPUT METER CIRCUIT

Courtesy of Simpson Electric Corporation

The resistance of a copper oxide rectifier varies with the value of current flowing through it, causing the meter readings to be crowded together at the lower ranges. Because of the rectifier resistance, the meter needle does not deflect as far as it would if dc had been applied. Reduced values of multiplier resistors are used to overcome this problem.

To overcome the crowding, or nonlinearity of the meter readings at lower values, a shunt is placed across the meter. When using a shunt with a 200-microampere movement, a typical value will be one-fourth of the meter resistance. This causes four times as much current to flow through the shunt as will flow through the meter. Full scale deflection now requires 1000 microamperes or 1 milliampere. Of this 800 microamperes flows through the shunt, 200 microamperes through the meter. Since it now takes 1 milliampere for full-scale deflection the sensitivity of the a-c voltmeter circuit is 1000 ohms per volt.

Where the a-c signal component is combined with a d-c voltage, such as at the plate of an amplifier tube, the a-c component can be isolated and read by use of a blocking capacitor. This feature is useful in reading the output of the audio circuits of a receiver during alignment. A blocking capacitor and a separate function switch position permits the use of the a-c voltmeter circuit as an output meter.

Ohmmeter Circuit

The two basic types of ohmmeter circuits are the shunt type and series type. The shunt type, excellent for use in reading low values of resistance, has a decided disadvantage in that the battery is always in use, and if left on by accident it quickly runs down. In the series type circuit, the scale becomes crowded on the left-hand side of the scale. To relieve this crowding a shunt resistor is placed across the meter. Different ohmmeter ranges can be switched in by varying the values of the shunt resistor and current-limiting resistors, the zero-adjust rheostat remaining the same. Although separate scales for each range can be used, a more practical method is to calibrate the ohmmeter on the lowest scale. Multiplying the range by multiples of 10 permits using the same scale.
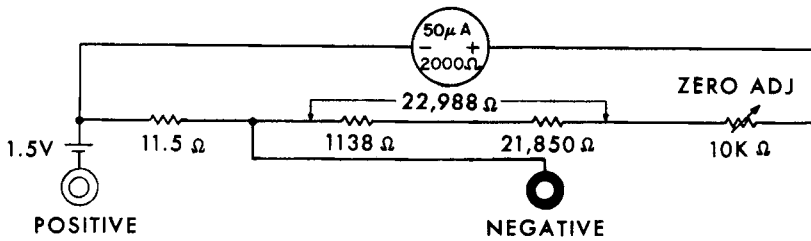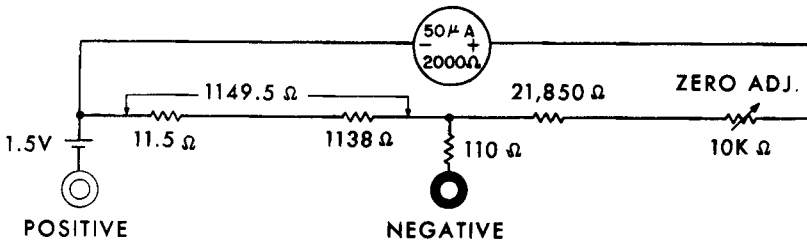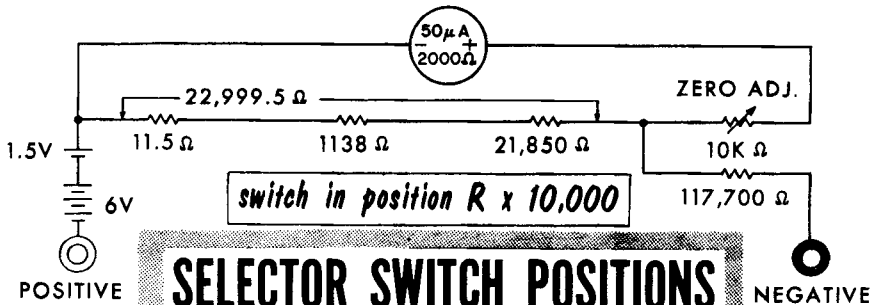
SELECTOR SWITCH POSITIONS
OF OHMMETER CIRCUIT

Current Meter Circuit

The simplified version of the current-reading microammeter circuit is shown. With 100 microamperes applied, the current will divide, half through the five shunt resistors that total 5000 ohms, the remaining 50 microamperes through the meter resistance of 2000 ohms, and the 3000-ohm series resistor. Thus, with 100 microamperes applied, the 50-microampere meter will read full scale.

50 μ A
2000 Ω
+ -

3000 Ω   4975 Ω   22.5 Ω   2 Ω   0.475 Ω   0.025 Ω

←————— 100 MICROAMPERES —————→

POSITIVE   NEGATIVE

SIMPLIFIED MICROAMMETER CIRCUIT

Courtesy of Simpson Electric Corporation
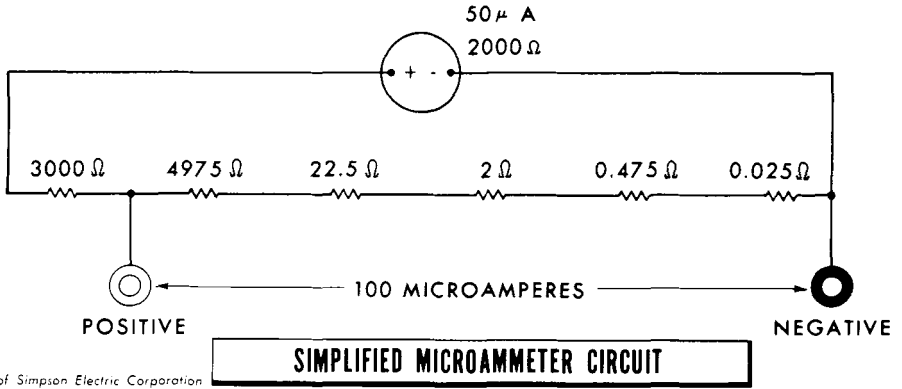
The combined milliammeter and ammeter circuit is shown. With the switch in the 10-milliampere position, the 3000-ohm resistor in series with the meter resistance of 2000 ohms (for a total of 5000 ohms) is shunted by a total resistance of 25 ohms. In the 100-milliampere position, the 22.5-ohm resistor is added to the 5000 ohms for a total of 5022.5 ohms. This is shunted by a total resistance of 2.5 ohms. In the 500-milliampere position, 24.5 ohms is added to the 5000 ohms for a total of 5024.5 ohms, and shunted by a total resistance of 0.5 ohms. In the 10-ampere position, 24.975 ohms is added to the 5000 ohms for a total of 5,024.975 ohms, and shunted by the 0.025-ohm resistor. In all ranges the current will divide so as to have full scale or 50-microamperes flow through the meter when 10, 100, 500 milliamperes, or 10 amperes are applied.

50 μ A   2000 Ω
+ -

3000 Ω   22.5 Ω   2 Ω   0.475 Ω   0.025 Ω

100MA

10MA   500MA

NEGATIVE   POSITIVE   +10A   -10A

SIMPLIFIED MILLIAMMETER AND AMMETER CIRCUIT

Courtesy of Simpson Electric Corporation
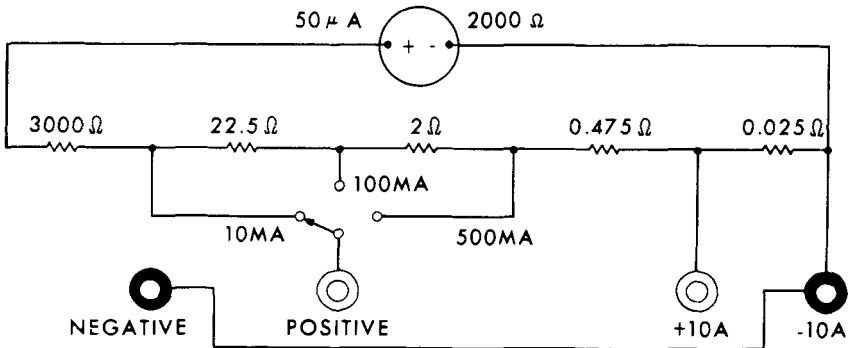
Multimeter Circuit

The complete schematic of the VOM is shown below. There are two selector switches — one to select the range to be measured, and the function switch which sets the circuits to read dc, ac, or output. The combination of selector switches and separate test jacks permit reading six voltage ranges, five current ranges, and three ohmmeter ranges. These ranges plus the function switch permit one meter to be used to read any value of a-c or d-c voltage, of d-c current, or of resistance that would normally require twenty separate meter circuits.
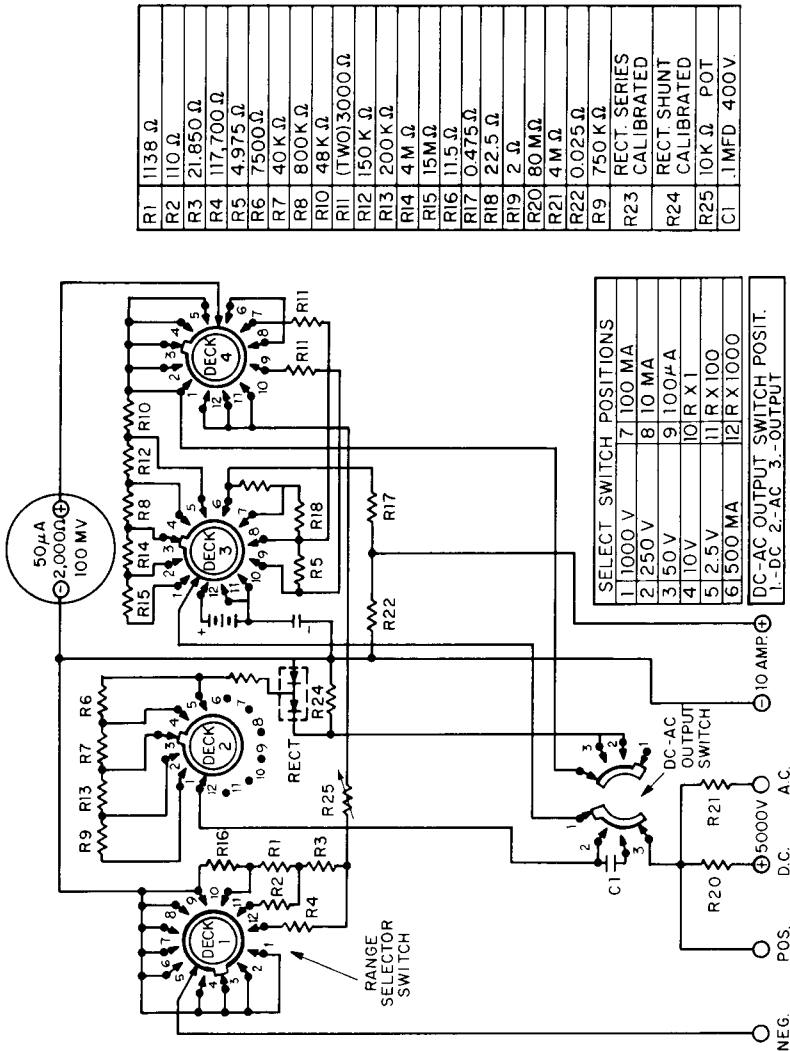
Ref	Value
R1	1138 Ω
R2	110 Ω
R3	21,850 Ω
R4	117,700 Ω
R5	4,975 Ω
R6	7500 Ω
R7	40 K
R8	800 K Ω
R10	48 K Ω
R11	(TWO) 3000 Ω
R12	150 K Ω
R13	200 K Ω
R14	4 M Ω
R15	15 M Ω
R16	11.5 Ω
R17	0.475 Ω
R18	22.5 Ω
R19	2 Ω
R20	80 M Ω
R21	4 M Ω
R22	0.025 Ω
R9	750 K Ω
R23	RECT. SERIES CALIBRATED
R24	RECT. SHUNT CALIBRATED
R25	10 K Ω POT
C1	.1 MFD 400 V

SELECT SWITCH POSITIONS			
1	1000 V	7	100 MA
2	250 V	8	10 MA
3	50 V	9	100 μA
4	10 V	10	R X 1
5	2.5 V	11	R X 100
6	500 MA	12	R X 1000

DC-AC OUTPUT SWITCH POSIT.
1.-DC 2.-AC 3.-OUTPUT

50 μA 2,000 Ω 100 MV

10 AMP.

5000 V A.C.

R21

R20 D.C.

POS.

NEG.

RANGE SELECTOR SWITCH

DC-AC OUTPUT SWITCH

Schematic Diagram of VOM

SUMMARY

All servicing techniques have one thing in common, a method of measuring values of resistance, voltage and current.

To replace a bulky assortment of individual meters, a combination of multipliers and shunts is used in a switching circuit with a single basic meter movement. This is called a Volt-Ohm-Milliammeter, or VOM.

The most popular type of meter movement is a 50-microampere D'Arsonval type movement with a coil resistance of 2000 ohms, providing a meter circuit sensitivity of 20,000 ohms per volt.

The d-c meter circuit reads a-c volts by adding a rectifier circuit.

A popular type meter rectifier is the copper oxide type. The rectifier is rugged and long-lived but sensitive to high temperatures. The stray capacity of the rectifier restricts accurate a-c voltage measurements to the range of audio frequencies.

The resistance of a copper oxide type rectifier does not vary directly with the value of current flowing through it. This nonlinearity causes crowding at the lower end of the scales.

A precaution taken to reduce crowding of the lower portion of the a-c voltage scales to place a shunt across the meter movement.

A shunt bypass, which increases the range of a meter, requires increased current for full scale deflection. The sensitivity of the voltmeter is therefore reduced.

The use of a blocking capacitor to isolate the d-c component of a varying voltage permits the use of the a-c voltmeter circuit as an output meter.

The shunt type ohmmeter circuit is excellent for reading low values of resistance, but has the disadvantage of high battery consumption.

In the series type ohmmeter circuits, the left-hand edge of the scale is crowded despite the use of shunting resistors.

All current reading ranges have shunts dividing the current so as to have 50 microamperes flow through the meter at a full scale value.

REVIEW QUESTIONS

1. Describe the metering functions available from a VOM.
2. What is the source of power that moves the meter needle of a VOM when measuring voltage or current?
3. In a comparison with a meter movement of 20,000 ohms per volt, a 1000 ohms per volt meter movement is *more/less* sensitive.
4. The circuit used to rectify a-c voltage for application to the d-c meter movement is a *half/full* wave rectifier circuit.
5. What are the two main drawbacks to the copper oxide rectifier?
6. How do we use the VOM to isolate and read the a-c signal component of a pulsating d-c voltage?
7. Describe the advantages and disadvantages of the shunt and series type ohmmeters.
8. What is the purpose of the battery in an ohmmeter circuit?
9. With 25 microamperes flowing through the meter movement of a 50 microampere meter, what would the reading be on the 0-1 milliampere scale?

Vacuum Tube Voltmeters: Basic VTVM

The standard multimeter just described is convenient and easy to use, but it has drawbacks, however, that limit its use. The main disadvantage is the possibility of its "loading" a circuit. There are many circuits of very high impedance with small values of current flowing. The standard 20,000-ohms-per-volt multimeter cannot be used in these circuits due to their relatively low impedance and high current drain. Also, to increase the range of a multimeter ohmmeter circuit requires an increased battery voltage. In addition the a-c voltmeter frequency range is limited. The use of a vacuum tube voltmeter, abbreviated VTVM, overcomes these difficulties.
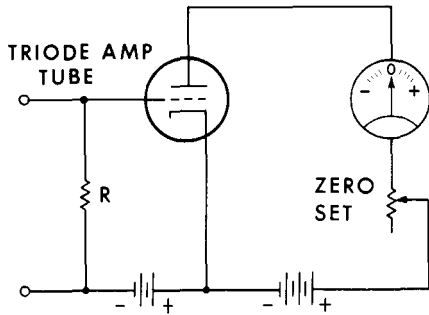
positive grid
voltage —
causes plate
current to rise,
positive meter
reading

negative grid
voltage —
causes plate
current to drop,
negative meter
reading

TRIODE AMP
TUBE

R

ZERO
SET

Basic VTVM Circuit

A basic VTVM using a triode amplifier tube is shown above. The meter coil winding is the plate load. By the proper choice of voltages and plate load, the tube can be set to operate on the linear portion of the dynamic transfer characteristic curve. With no signal there will be only the steady plate current flow set by the grid-bias voltage battery. The meter can be set to have a zero voltage reading in the center of the scale. Applying an unknown d-c voltage to the terminals will cause a voltage drop across resistor R. The polarity of this voltage drop will either add to or subtract from the bias voltage of the grid circuit. A positive grid voltage will cause an increase in plate current causing the meter pointer to rise. A negative grid voltage will cause a decrease in plate current causing the meter pointer to dip. Proper calibration of the meter could have it read in volts the value of plate current swing caused by the voltage under test.
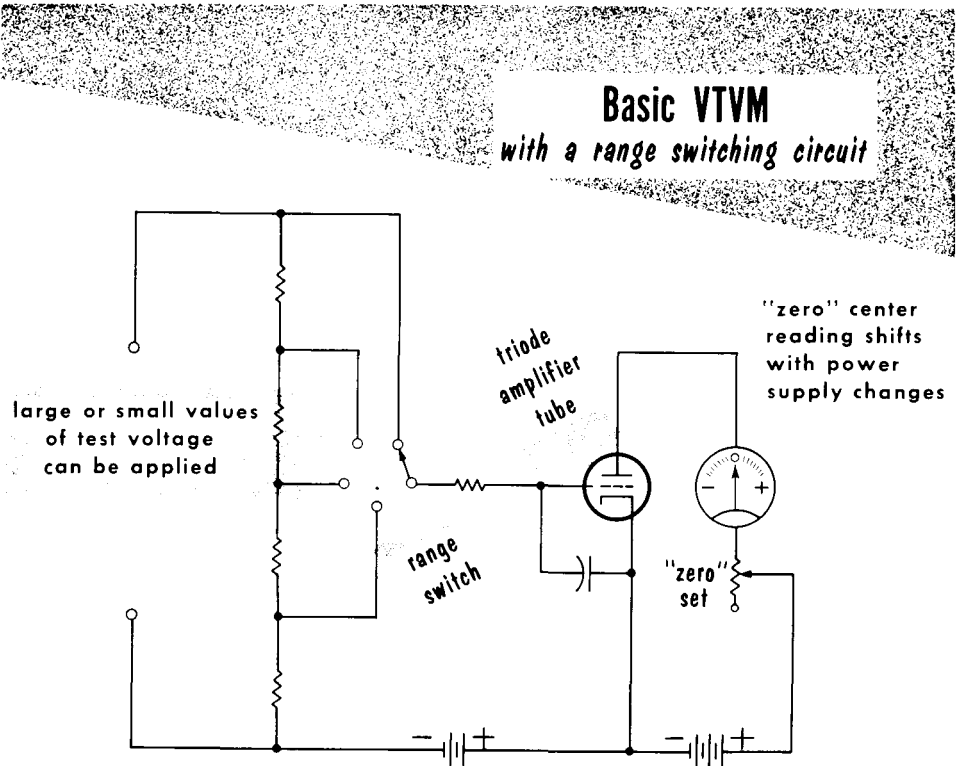
The fact that the grid resistor can be of high values, such as 10 to 15 megohms, means that the grid circuit will not load the circuit under test despite being placed directly across it. The possibility of contact potential due to the stray electrons striking the grid and returning to the cathode circuit is the limiting factor in the value of grid resistor.

Basic VTVM (cont'd)

To enable the basic VTVM circuit to be used with large or small values of test voltages, a range switching circuit is incorporated in the grid circuit. The circuit acts as a voltage divider with the switch choosing the proper voltage value applied to the grid circuit causing sufficient deflection of the meter pointer. In this circuit the test voltage is always applied to the total resistance. No matter what switch range is chosen, the VTVM offers a constant high-value impedance to the circuit under test.

The basic triode VTVM, although an improvement over the VOM, has some drawbacks. Any change in the power supply causes the zero center reading to shift, requiring constant readjustment. As the tube ages, the value of plate current varies, requiring further readjustment. The main feature of the basic VTVM is its simplicity.

Basic VTVM
with a range switching circuit

"zero" center reading shifts with power supply changes

large or small values of test voltage can be applied

triode amplifier tube

range switch

"zero" set

The capacitor from grid to cathode acts as a bypass for any a-c voltage that may be combined with the d-c voltage under test. Any a-c variations in plate current will average out and cause no change in the meter reading. However, if the a-c component were large enough, it could change the bias voltage so that the tube would amplify on a nonlinear portion of the dynamic transfer characteristic curve.

Bridge Type VTVM

meter reads "zero" with R1, R2, R3, and R4 equal

A

R1   R2

C ← AMMETER → D

R3

R4

B

+
−
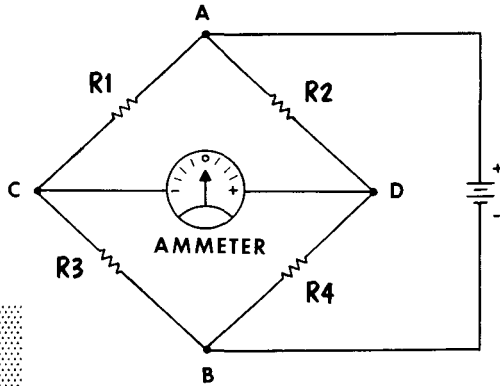
Basic Bridge Circuit

An improved VTVM circuit makes use of a bridge circuit. The basic bridge circuit is shown. With R1, R2, R3 and R4 having equal values, the voltage drops across R1 and R3 will be identical with that across R2 and R4. Thus, points C and D will be at the same potential. With no difference in potential there is no current flow between points C and D, as indicated by a zero reading on the current meter. The bridge is thus *balanced*. When either pair of resistors, R1 and R3, or R2 and R4, are of unequal values, the unequal voltage drop across them will cause a difference of potential between points C and D. This difference of potential will cause current to flow; the value of current and its direction, will be indicated by the meter. The bridge is now *unbalanced*.

*variable
resistance
matches tube's
plate resistance
to balance circuit*

R1   R2

AMMETER

R3   R4

INPUT

+
−
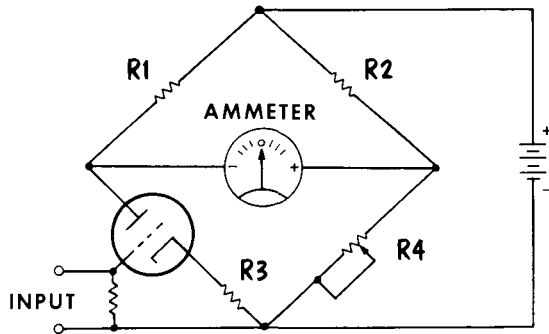
Bridge Circuit
employing the plate resistance of a tube

Replacing R3 with a vacuum tube circuit, and making R4 adjustable to match the tube's plate resistance can balance the bridge again. Applying d-c voltage to the input terminals will vary the tube's plate current thus varying its plate resistance. This unbalances the bridge as indicated by the meter reading. Proper callibration will have the meter read in proportion to the d-c voltages applied to the input terminals.

Bridge Type VTVM (cont'd)

An improved version of the bridge type VTVM is shown below. The use of two tubes reduces the effects of changes in power supply voltage. When the power supply voltage increases or decreases, the plate current through V1 and V2 will increase or decrease together, keeping the bridge balanced. Plate current for both tubes flows through R6. Making R6 a high resistance causes it to be the determining factor in current flow for both tubes, removing tube variations from determining plate current flow.
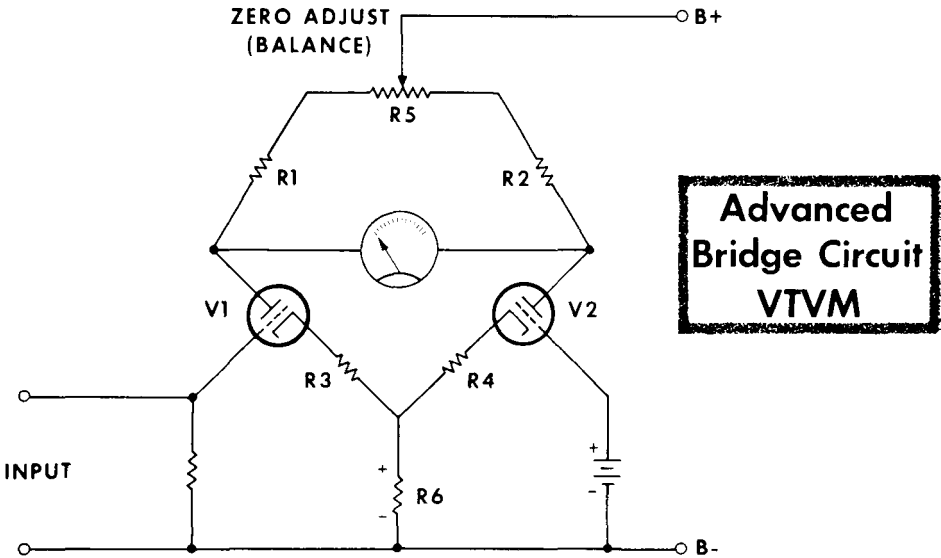
Applying a positive d-c voltage to the input terminals increases the plate current of V1. The increased current flowing through R6 will cause a higher voltage drop, with the resulting change in bias causing the cathode of V2 to go in a more positive direction. Making the cathode of V2 more positive is the equivalent of making its grid more negative. This in turn reduces the plate current of V2. Looking upon the tubes as resistors in a bridge circuit, increased plate current in V1 means lower plate resistance. Decreased plate current in V2 means higher plate resistance. The result is to have an unbalanced bridge, in the same direction, caused by both tubes, resulting in a larger flow of current through the meter. This *push-pull* action increases the sensitivity and permits reading small values of voltage. By setting the "zero" on the left-hand edge of the meter scale, a more sensitive meter movement may be used — typical being 1 milliampere or 200 microamperes full scale. When a negative voltage is applied, the meter pointer will move backwards; to overcome this a switch can be placed at the meter leads reversing the polarity of the meter. To balance the bridge with no input applied, R5 is adjusted to have the meter read "zero", or balanced.

Differential Amplifier VTVM

Another type VTVM uses a differential amplifier circuit. The circuit operates in this manner: applying a negative signal to the grid of V1 lowers its plate current. The plate current of V2 remains the same. The reduced plate current through V1 causes a lower voltage drop across cathode resistor R1. This places the cathode of V1 at a lower potential than that of V2. Current will flow from the cathode of V1 to the cathode of V2, deflecting the meter. The circuit is designed so that current flow will be of small value — a 0-1ma meter movement being used for full-scale deflection.
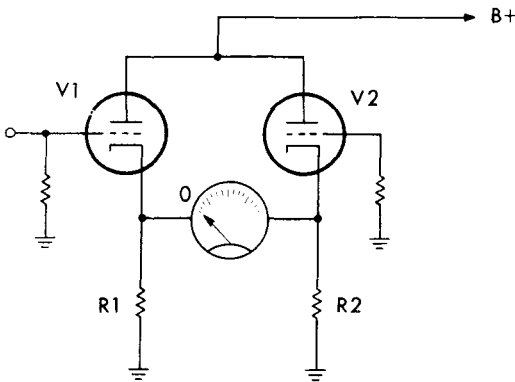
Basic Differential Amplifier VTVM

To limit the meter current to 1 ma, a variable resistor labeled "Meter Calibrate," is placed in series with the meter. To balance the circuit with no input applied, a potentiometer is placed so as to add more or less resistance in series with each cathode resistor.
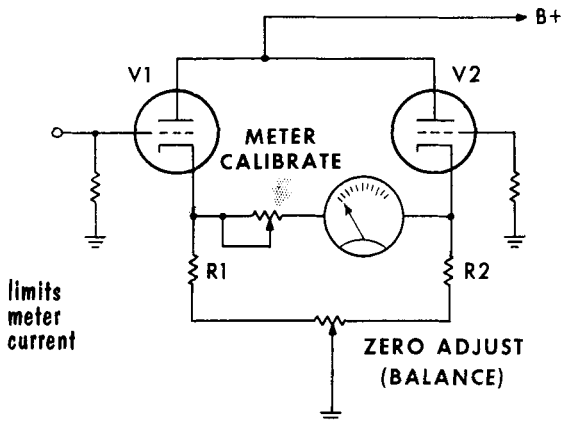
Advanced Differential Amplifier VTVM

VTVM As A D-C Voltmeter

A typical, commercial, differential amplifier-type VTVM used to read d-c voltages is shown in the figure. Note that the voltage divider string of resistors totaling 10 megohms, plus the five-megohm resistor in the probe, is always parallel to the input circuit under test. Thus, the meter presents a constant impedance of 15 megohms no matter what voltage range the switch is set to read. Placing the 5-megohm resistor in the proble isolates the test signal from the meter. Shielding the probe lead keeps it from picking up induced voltages from outside circuits.

To reverse the polarity of the meter, a polarity reversing switch is placed in the cathode circuits of the differential amplifier. This permits use of a single probe — there is no necessity of reversing test leads to match polarities. Placed in series with each side of the switch is a calibration control used to adjust the circuit against a known potential, usually a 1.5-volt cell.
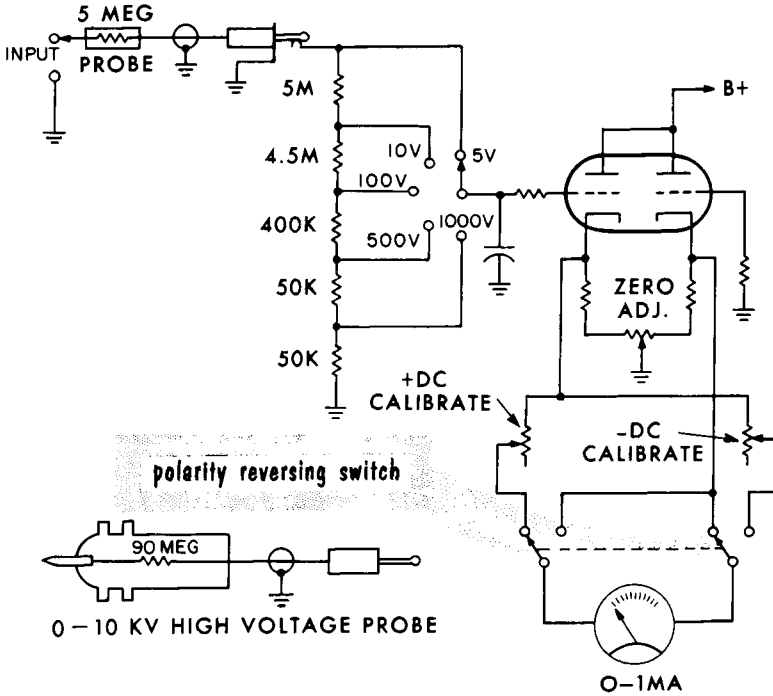

VTVM D-C Voltmeter Circuit

A special probe is available to read high voltage such as are found in transmitter power supplies. The probe is constructed with flanges for a very high leakage path to prevent shock. Using a 90-megohm resistance in the probe provides a range of 0-10,000 volts, which is read on the 0-1000 volt scale.

VTVM As An A-C Voltmeter

To read ac with the bridge or differential-type, amplifier VTVM circuit, the a-c voltage under test is rectified then fed to the d-c voltmeter portion of the VTVM. The use of a single diode tube to rectify the signal brings about a problem. With no applied input, the few electrons breaking away from the space charge about the cathode will go on to the plate and develop an IR drop across the rectifier load resistor; this is *contact* potential. The value of this contact potential may be as high as one volt. To overcome this another diode is connected as shown. With no applied signal, the polarity of the contact potential of diode V1 is developed across R1 as shown by its arrow. The contact potential of diode V2 flows through R1 in the opposite direction. Adjusting R2 to the proper value, the contact potential of diode V2 can be made equal and opposite that of diode V1. As a result of these bucking currents, no voltage is passed on to the VTVM circuit when no a-c input is applied. Control R2 is known as "a-c balance" or "a-c zero adjust".

VTVM A-C VOLTMETER INPUT CIRCUIT
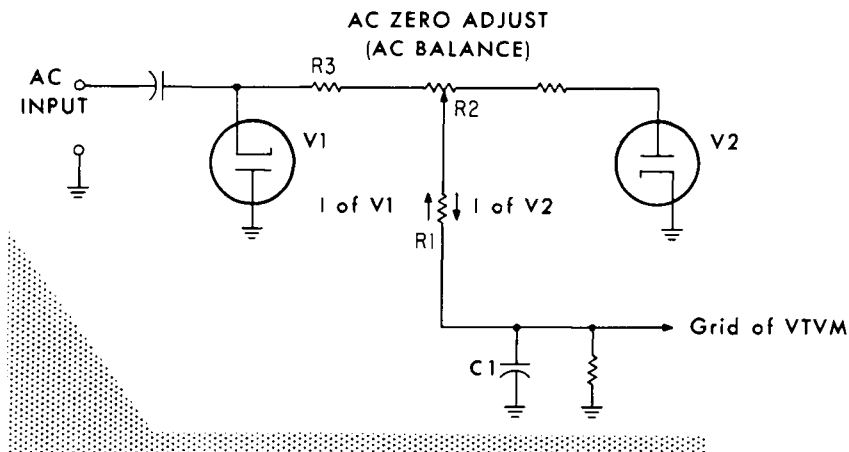
With diodes V1 and V2 connected as shown, the negative alternations of the input signal will be removed. The positive alternations are passed on and filtered by the resistance of R1, R2, and R3, and capacitor C1. The stray capacity presented by the circuit is such that a-c voltage readings are accurate only with the audio-frequency range. For use above audio frequencies, a special probe is available. The special probe uses crystal diode rectifiers and extends the frequency range to as high as 100 mc.

When the special rectifier probe is used, it is plugged directly into the d-c volts input jack.

VTVM As An Ohmmeter

To use either the bridge or differential amplifier VTVM as an ohmmeter, a battery and a resistor of known value are placed across the input terminals. With the input terminals shorted, the negative battery terminal is placed at the other end of the known value resistor, placing the full battery voltage across the resistor. At the same time, with the input terminals shorted, the VTVM dc-voltage-measuring circuits are adjusted to read "zero" input.

adjusting VTVM ohmmeter
for "zero" setting

using VTVM ohmmeter
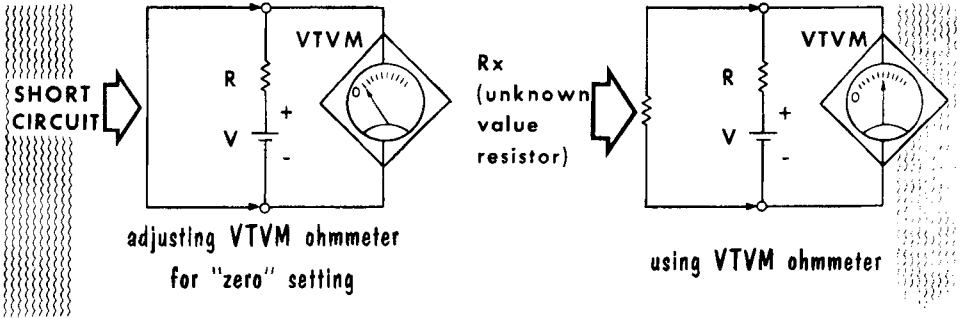
Placing an unknown value resistor across the input terminals causes the battery voltage to divide between the unknown value resistor and the known value resistor. The VTVM dc-voltage-measuring circuits will measure the voltage drop across the unknown value resistor. The value of battery voltage across the unknown value resistor is determined by its resistance as compared to that of the known value resistor. The voltage across the unknown value resistor may be shown in ohms if the dial scale of the VTVM is calibrated in ohms.

Assume a larger value of unknown resistance is placed across the input terminals. This will result in an increased voltage drop across the unknown value resistor, and a reduced voltage drop across the known value resistor. The VTVM will indicate this by a higher reading on the scale. As a result we find the ohmmeter scales of a VTVM are read from left to right.
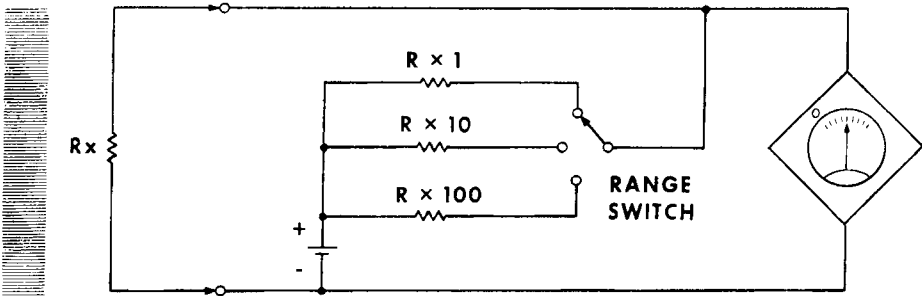
adding ranges to the ohmmeter

VTVM Circuit

Illustrated below is the complete schematic diagram of a VTVM. The function switch also acts as a polarity reversing switch, allowing a common ground lead and a single test lead. The test lead used to measure d-c voltages contains a 15-megohm isolation resistor in the probe, and uses a shielded lead. The voltage used for the ohmmeter section is a standard 1.5-volt flashlight cell.
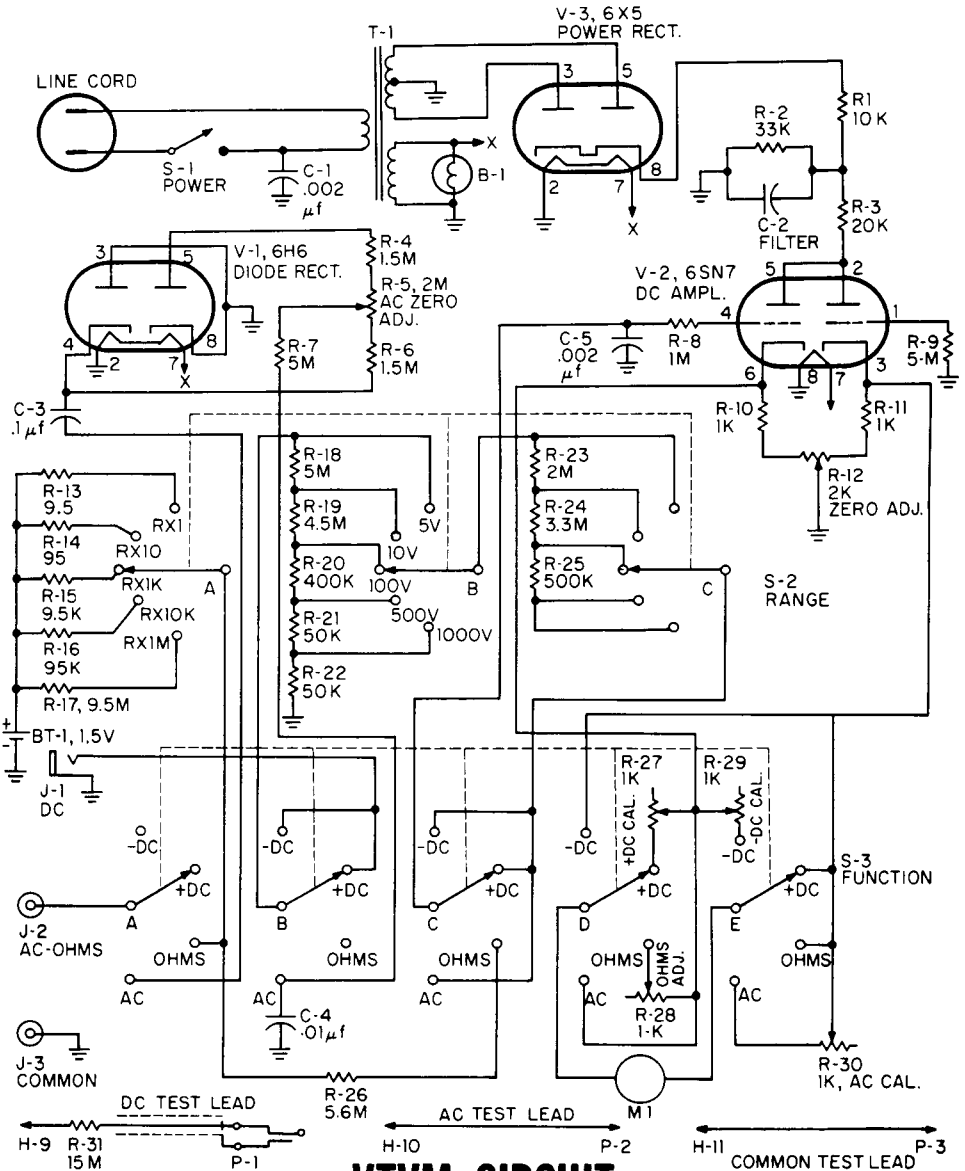
VTVM CIRCUIT

Courtesy of Electronic Instrument Corporation, Inc.

The basic VTVM uses a triode amplifier in which the plate load is the coil
of the meter movement. With the tube operating on the linear portion
of its characteristic curve, application of a d-c voltage to the grid will
cause a corresponding change in plate current flow through the meter
coil.

The high input impedence of the grid circuit, as high as 10 to 15 megohms,
means that the VTVM will not load the circuit under test.

To enable the VTVM to be used to read large or small values of voltage, a
range switching circuit is incorporated in the grid circuit.

The basic triode VTVM disadvantages include tube ageing, and power
supply fluctuations, both causing constant circuit readjustments.

The differential amplifier type VTVM uses two tubes with a meter con-
nected between the cathodes of each. Any change in the cathode
voltage of one tube in respect to the cathode voltage of the other will
create a difference in potential indicated by the meter movement.

In most commercial VTVM's, a series resistor is placed in the d-c voltage
probe to isolate the circuit under test from the meter circuit.

In reading a-c voltages with a VTVM, a single rectifier diode develops an
undesired contact potential. To overcome this a second diode is con-
nected in opposite polarity to have its contact potential buck out that
of the first diode.

To use a VTVM as an ohmmeter, a battery and known-value resistor are
placed across the d-c terminals. Placing an unknown value resistor
across the known-value resistor and battery causes a division of the
battery voltage. The voltage across the unknown resistor is read by
calibrating the voltage scale in ohms.

REVIEW QUESTIONS

1.   What are the disadvantages of a VOM as compared to a VTVM?
2.   What is the limiting factor of the grid circuit resistor in a basic triode
     type VTVM?
3.   In the range switching circuit of the basic VTVM, does the impedance
     offered to the circuit under test vary as the range switch is varied?
4.   What is the main feature of the basic VTVM?
5.   Describe the push-pull action of the two tubes used in a bridge type
     VTVM.
6.   Why does the d-c voltage probe of a commercial VTVM use shielded
     wire?
7.   Describe the special physical construction of the high voltage probe
     and the reason for this special construction.
8.   Describe how two diodes are used to buck out contact potential in the
     a-c measuring circuit of a VTVM.
9.   Describe how to use the crystal rectifier probe for high frequency a-c
     signal measurements.
10. Describe why you short the ohmmeter terminals of a VTVM to zero
     the meter scale.

R-F Signal Generator

A signal generator is essentially a substitute radio station. It can be used to generate radio frequencies in the broadcast band and higher frequency bands to provide test signals for a radio receiver. In addition, it will provide the frequencies needed for correct alignment of i-f circuits, and the audio frequencies required for testing of audio circuits.

The basic requirement of an r-f signal generator is a variable frequency oscillator capable of producing the desired frequencies. These frequencies may vary from a value of 150 kc to 34 mc. For higher frequencies harmonics are used, with the third harmonic supplying a signal as high as 102 mc.

An r-f signal by itself is insufficient. To be a substitute radio station, the r-f signal must also be available in a modulated form. An additional part of a signal generator is the audio oscillator providing a low frequency audio signal of 400 or 1000 cycles. This audio signal is used separately, or to modulate the r-f signal.

BASIC...

...R-F Oscillator   **...A-F Oscillator**

VARIES THE FREQUENCY OF OSCILLATION

B+

B+

COLPITTS TYPE OSCILLATOR

AUDIO OUTPUT

R-F OUTPUT

HARTLEY TYPE OSCILLATOR
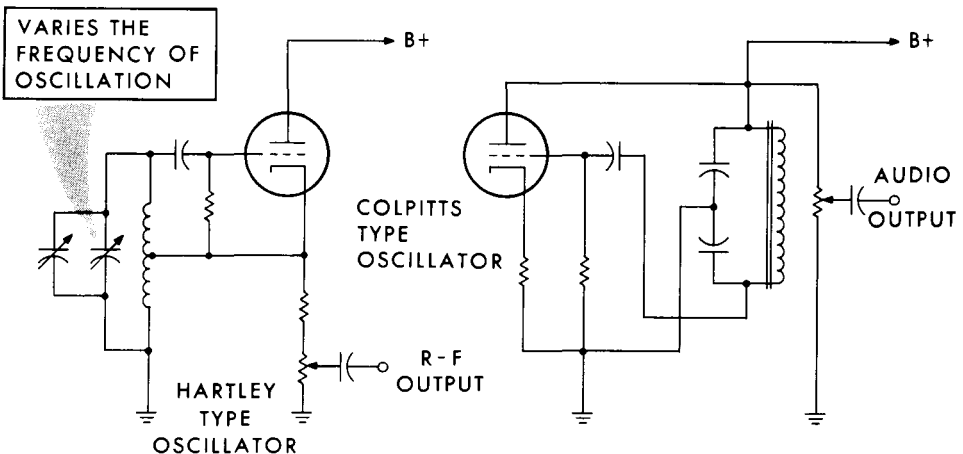
The signal levels in the tuned circuits ahead of the detector vary from microvolts in the antenna circuit to millivolts in the output i-f amplifier circuit. The output signal level required of a signal generator is small, the average value at the output jack is 0.1 volt. This value is equivalent to 100 millivolts or 100,000 microvolts. When applying the output of a signal generator to a receiver, keep in mind that only a small value is required as a substitute signal.

R-F Signal Generator (cont'd)

The schematic diagram of a commercial, r-f signal generator is illustrated in the figure. Switch SW1 is used to change the coils, enabling the r-f oscillator to cover a fr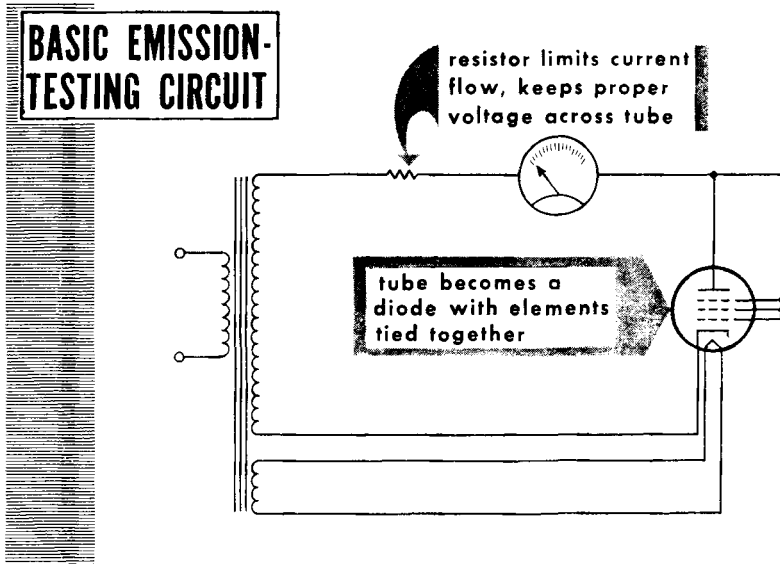equency range of 150 kc to 34 mc. With the harmonic output frequencies, the generator provides frequencies usable to 102 mc. Switch SW3 is used to switch the audio oscillator tank circuit in or out, causing the audio oscillator to be on or off. With the audio oscillator off, the output at the r-f output jack is a continuous wave (CW) signal. With the audio oscillator switched on, the 400-cycle output of the audio oscillator is available as a separate signal at the audio output jack. Capacitor C is common to both plate circuits; it offers a low reactance to the r-f frequencies, bypassing them. At the audio frequencies the reactance of C is high, causing the plate current to vary at an audio rate. With the plates of both oscillators being tied together, the common plate current varying at an audio rate will modulate the r-f signal. With the audio oscillator switched on, the signal at the r-f output jack will be modulated by the audio frequency.
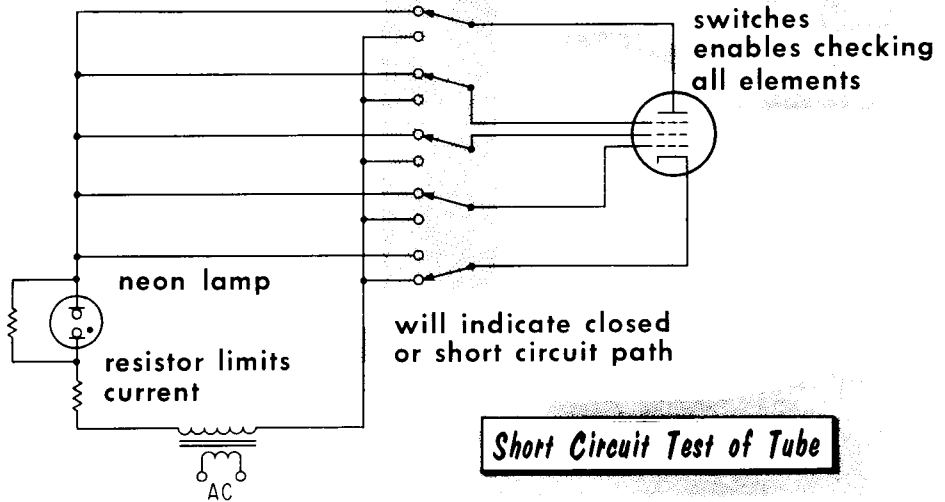

R-F SIGNAL GENERATOR
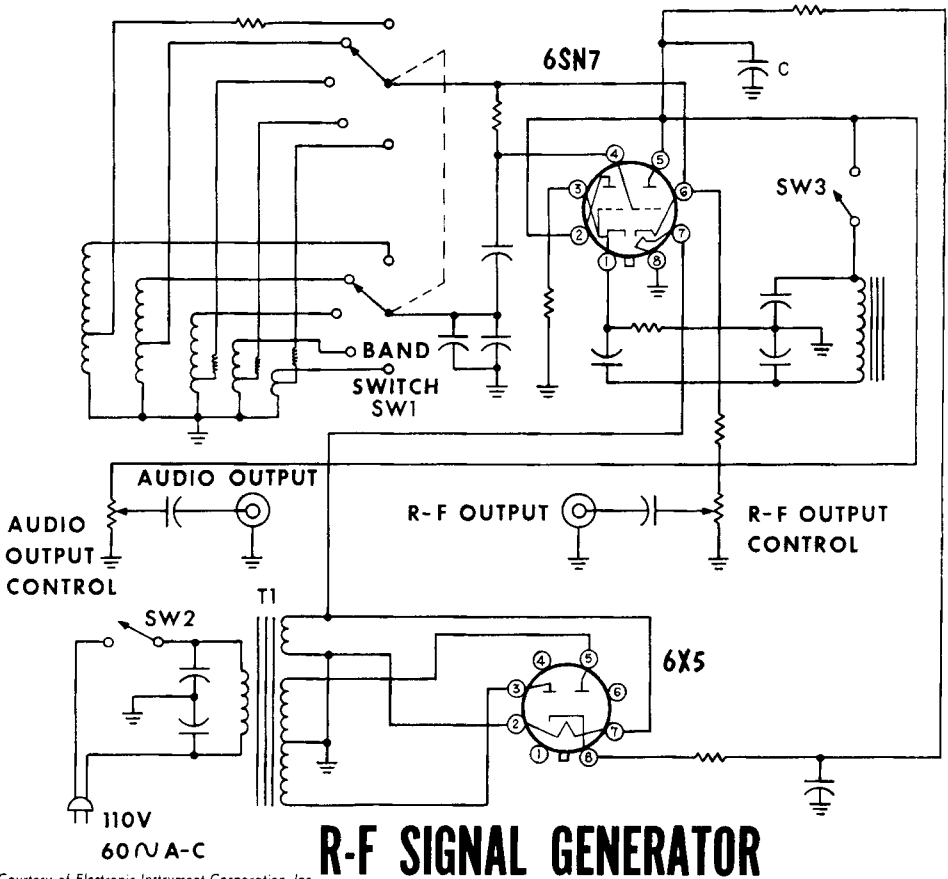
Tube Testers

The need for testing tubes is obvious; faulty tubes comprise as high as 70% of the reasons for receiver defects. Testing a tube in a tester is no substitute for testing the tube in the actual circuit designed for it. Replacing the tube to be tested by a good tube of the same type is a quick and effective method of determining whether the tube or circuit is at fault. With the multitude of different types of tubes, it would be difficult to keep replacements for all. This, plus the fact that service shops require testers to please their customers, places the tube tester in an important category.

The two most popular circuits used in tube testers are the simpler *emission* test and the more complex *dynamic mutual conductance* test. In addition, both types of testers will combine their tube test with a test for short circuits between tube elements.

BASIC EMISSION-
TESTING CIRCUIT

resistor limits current
flow, keeps proper
voltage across tube

tube becomes a
diode with elements
tied together

A tube in which the cathode emission has fallen off will cause reduced plate-current flow, reducing the output of the tube. To test a tube's emission, all elements aside from the cathode are tied together, and a voltage is then applied between the cathode and the other elements. The resulting value of plate current will determine whether or not there is sufficient cathode emission. The basic emission-testing circuit is shown above. With all of the tube's elements, other than the cathode, tied together, the tube becomes a diode. Applying ac to the tube will cause it to act as a half-wave rectifier. The measured amount of current that will flow during the alternation, applying a positive voltage to the plate, will be an indication of the tube's emission. A resistor is placed in series with the tube to limit the current flow and keep the proper voltages across the tube.

Tube Testers (cont'd)

switches
enables checking
all elements

neon lamp

resistor limits
current

will indicate closed
or short circuit path

Short Circuit Test of Tube

AC

To test for short circuits between the tube elements, an a-c voltage is applied across any two of the tube elements. In series with the voltage is a neon lamp. When any two elements are shorted there will be a complete path, and the neon lamp will indicate a closed or short circuit path. To enable checking between all elements, individual switches are used. A resistor is placed in series with the neon lamp to limit the current. Another resistor is shunted across the neon lamp to prevent the lamp lighting from a small charging current that may pass through the tube interelectrode capacities.

BASIC TRANSCONDUCTANCE TEST CIRCUIT

PLATE CURRENT
METER CALIBRATED
IN MICROMHOS

AC SIGNAL
VOLTAGE

DC BIAS
VOLTAGE

PLATE
SUPPLY
VOLTAGE
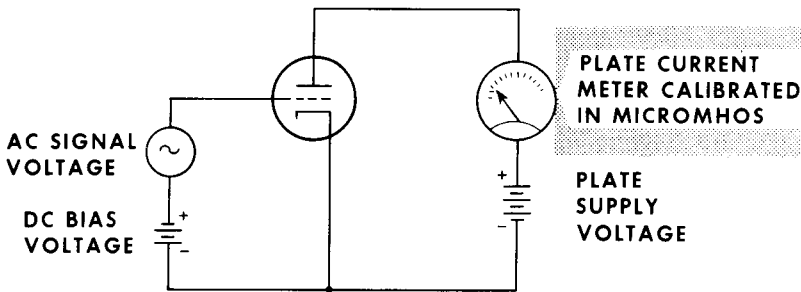
A mutual conductance test places a tube in a basic circuit as shown. The same tube voltage used by the tube manufacturer to establish the tube's ratings will be applied. Mutual conductance is the ratio of change in plate current to the change in grid voltage. The grid signal voltage can be changed by a known small amount such as 1 volt. Reading the plate current change will indicate whether the tubes transconductance is the same as that given by the tube manufacturer.

Tube Tester Circuit

A commercial, emission-type tube-checker circuit is illustrated below. The complex switching circuits are necessary to place the proper voltage to any pin of any tube socket, and to tie together all elements, other than the cathode, in order to test emission.
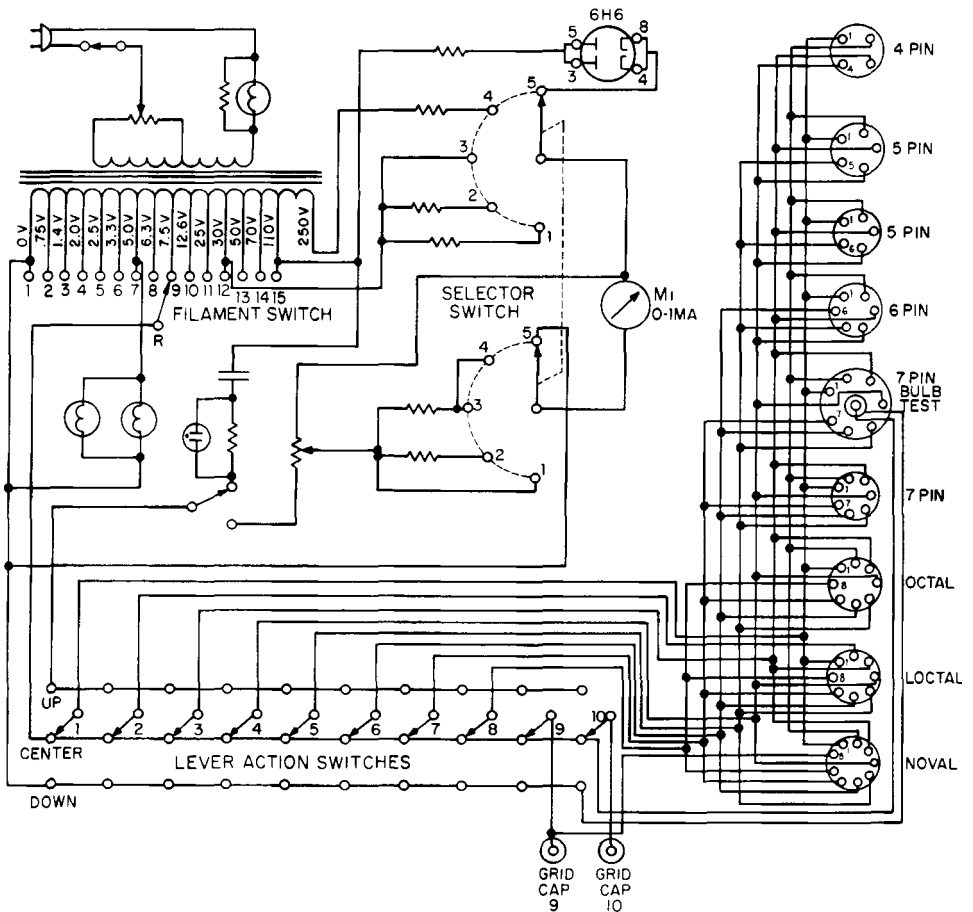
EMISSION TYPE TUBE TESTER CIRCUIT

A signal generator is essentially a substitute radio station used to generate radio frequencies in the broadcast band and higher frequencies.

The basis of an r-f signal generator is a variable frequency oscillator.

Harmonics of the fundamental frequencies are used to obtain the higher frequencies.

In addition to the r-f signal, a modulating audio frequency of 400 or 1000 cycles must also be available. The audio frequency can be used independently as a substitute audio signal or to modulate the r-f signal generator output.

With faulty tubes causing an estimated 70% of receiver troubles, tube testing becomes important.

The best test of a tube is to replace it with a known good tube of the same type. However, with the large number of tube types available, this would be difficult.

The two most popular type tube tester circuits are the *emission* type and *dynamic mutual conductance* type.

In addition to the test for emission or conductance, all tube testers must check for internal short circuits between the tube elements.

To test a tube for emission all elements aside from the cathode and heater are tied together and a voltage applied between the elements and the cathode. The resulting plate current flow indicates the value of cathode emission.

To test a tube for mutual conductance it is placed in a basic amplifier circuit. The grid signal voltage is changed by only a small amount; the resulting plate current change indicates whether the tube's mutual conductance is the same as that given by the manufacturer.

To test for short circuits between elements, a neon lamp in series with an a-c voltage is placed across the tube elements. A short circuit will cause the neon indicator to glow.

REVIEW QUESTIONS

1.   The r-f signal generator is used to align what tuned radio circuits?

2.   Describe one method used to have the audio oscillator modulate the r-f signal of the signal generator.

3.   What is the purpose of the blocking capacitor at the audio and r-f signal output jacks?

4.   What is the basic method of changing bands of frequencies in the r-f signal generator?

5.   What is a good precaution to follow when applying the output of the signal generator to a receiver?

6.   With both an emission and dynamic mutual conductance tester available, which would be preferable?

7.   In testing a tube for emission, it is connected as a diode. Why?

8.   With only one neon lamp short circuit indicator, how are the multiple elements of a tube tested for individual short circuits?

9.   The plate current meter calibrations read in a mutual conductance tube tester are calibrated in what values?

Cathode Ray Oscilloscope—Cathode Ray Tube

The Cathode Ray Oscilloscope is an invaluable servicing tool used to display a-c voltage waveforms. Taking the a-c voltage present at any point, it will convert this voltage to a visual display of the voltage waveform on a Cathode Ray Tube (CRT) that is most often five inches in diameter. This large, visual waveform display allows constant observation as to whether the voltage present is of the proper amplitude, has the correct waveform, and whether it is remaining constant or is varying.

The heart of the oscilloscope is the Cathode Ray Tube. In the basic tube the electrons emitted from the cathode are attracted by the high positive potential of the anode. The anode is circular in shape with a small hole in the center. The high potential of the anode causes the electrons to accelerate to a high speed. Most of the electrons will strike the anode, however, a sufficient number will go through the hole as a beam, and continue on to the front or faceplate of the tube.
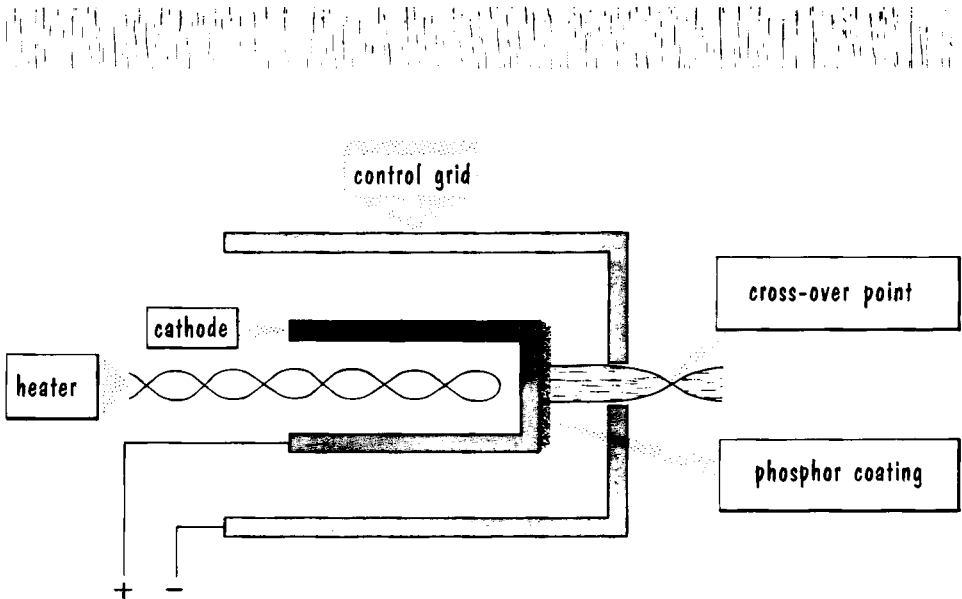
CATHODE   ANODE

ELECTRON
BEAM

SPOT
OF
LIGHT

B-   B++

FACEPLATE
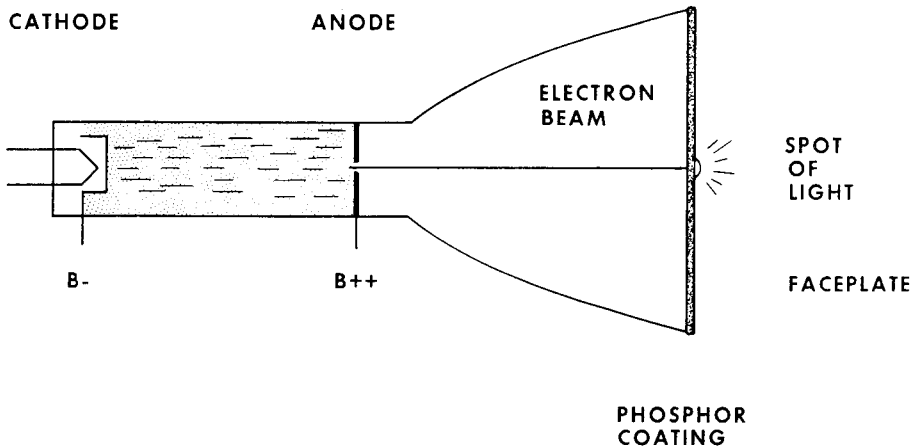
PHOSPHOR
COATING

BASIC CATHODE RAY TUBE

The face of the tube is coated with a phosphor that converts the energy of the electron beam to a spot of light. The property of the phosphor emitting light when struck by an electron beam is called *fluorescence*. The type of phosphor used determines the type of glow emitted by the face of the tube. For use in oscilloscopes, the color is usually green, although other colors are available for special purposes. After the beam of electrons is removed, the spot of light will remain on the face of the tube for a short time. This is called its *persistence*. For rapidly-changing waveforms a short-to-medium-persistence phosphor is required.

## Cathode Ray Oscilloscope—Cathode Ray Tube (cont'd)

A cylindrical cathode is slipped over a noninductively wound heater to provide the large numbers of electrons required to form a beam. The flat end of the cathode sleeve is liberally coated with an oxide for copious electron emission. The control grid is a larger cylindrical sleeve, similar to the cathode, containing a small hole at the end. The grid completely encloses the cathode permitting the value of grid bias to provide control over the electron flow as in a conventional tube. This controls the number of electrons striking the face of the tube, which in turn controls the intensity of the light.

control grid

cathode

heater

cross-over point

phosphor coating

+ —

## Construction of Cathode and Control Grid

In addition to controlling electron flow, the shape and placement of the grid allows focusing of the electron beam. Due to the difference in potential between the control grid and cathode, an electrostatic field is developed. The lines of force of this field act to converge the scattered electrons, causing the majority of electrons to pass through the hole in the end of the grid and converge or focus at a crossover point. This is called electrostatic focusing, and is analagous to an optical lens focusing light rays.

Cathode Ray Oscilloscope—Cathode Ray Tube (cont'd)

Accelerating Anodes
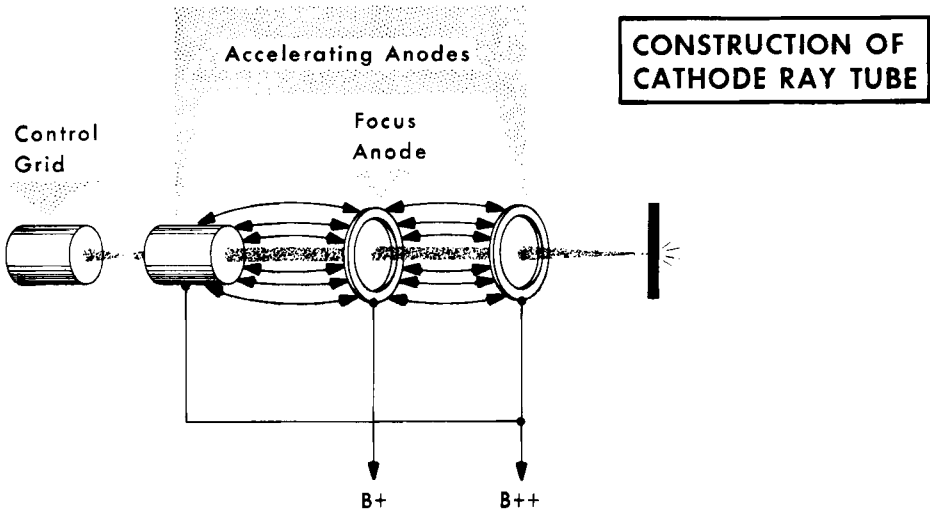
CONSTRUCTION OF CATHODE RAY TUBE

Control Grid

Focus Anode

B+   B++

To accelerate and focus the beam for a bright sharp spot the beam is passed through a split accelerating anode and a focus anode. The accelerating anode is placed at a very high potential, a typical value being 2000 volts. (This is a good place to remind you to observe safety rules when working with these voltages.) The high potential of the accelerating anode accelerates the electrons in the beam to the high velocity required to have the phosphor glow when struck by the speeding electrons. The focus anode being at a lower potential provides the desired electrostatic field between it and the accelerating anode on either side. Varying the focus anode voltage varies the shape of the electrostatic field, resulting in the electron beam converging and crossing over at slightly different points close to the tube's face plate. With the correct setting the beam will converge directly on the phosphor coating to provide a sharp clear spot of light. Incorrectly set, the crossover point will be before or after the phosphor coated faceplate, resulting in a large, blurry blob of light.

incorrect crossover points result in blurred spot

FOCUSING

correct crossover point results in a sharp spot
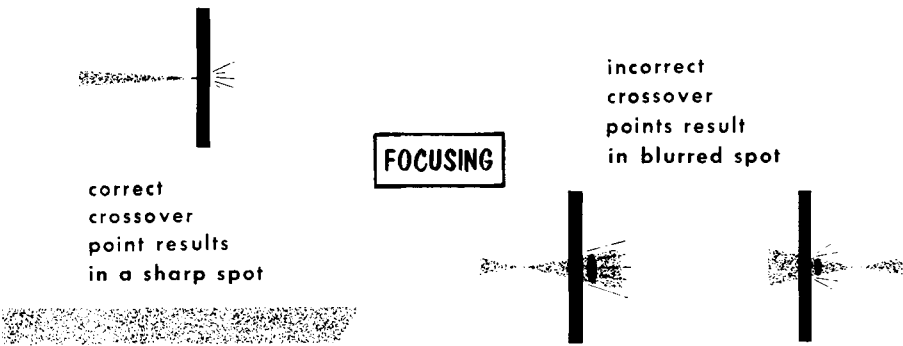
Cathode Ray Oscilloscope—Control Voltages

Control voltages are applied to the deflection plates to move or deflect the beam. Going back to one of the basic principles of electricity—like charges repel, unlikes attract—we use a negative charge to repel, and a positive charge to attract the electron beam.

The action of the deflection plates is identical for both vertical and horizontal deflection. Taking first the action of the vertical deflection plates: With one of the vertical deflection plates at ground potential, a negative potential is applied to the opposite plate. As the electron beam goes by the deflection plates, the negative, electrostatically charged plate will repel the beam, deflecting it towards the bottom of the faceplate. Changing the charge and placing a positive electrostatic charge on the deflection plate will cause the beam to be attracted towards the deflection plate. This deflects the beam towards the top of the faceplate. Varying the voltage of the vertical deflection plates from a negative value, through zero to a positive value will draw a vertical line on the faceplate of the cathode ray tube. The action of the horizontal deflection plates is identical.
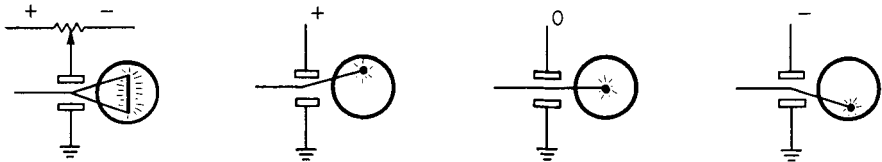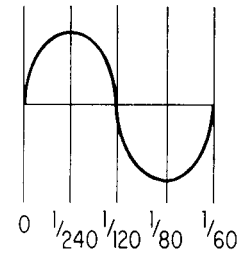

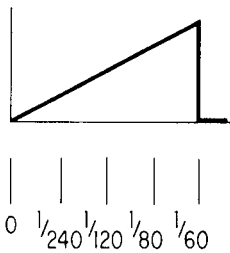**Vertical Deflection**
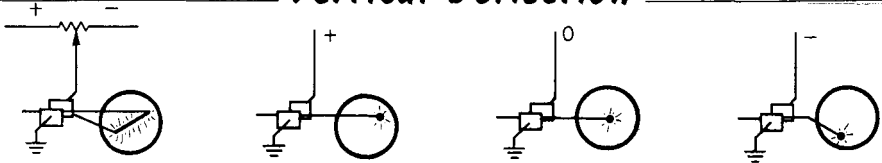
Horizontal Deflection
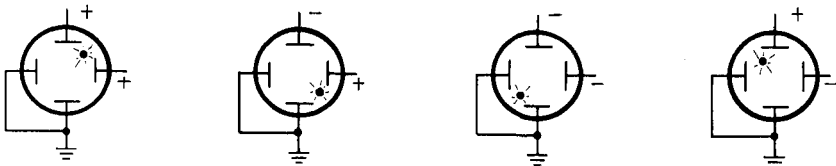
Combined Vertical and Horizontal Deflection

ACTION OF DEFLECTION PLATES

Cathode Ray Oscilloscope—Signal Display

T in Seconds
60-Cycle Sine Wave

T in Seconds
Sawtooth Voltage

The main task of an oscilloscope is to display a-c waveforms. For simplicity, a sine wave (see illustration) will be used for purposes of explanation; however, in practice the most complex waveform may be displayed. A sine wave is most often drawn as shown above, in a vertical manner. To have it reproduced or traced in this manner on the face of the cathode ray tube, we apply the sine wave to the vertical deflection plates. This is not enough, however, as a moments thought will remind us that it will merely "pull-and-push" the beam in a vertical manner, resulting in a straight vertical line on the face of the tube. To have it draw the sine wave horizontally, from left to right, and vertically, from top to bottom, we must


SINE WAVE REPRODUCTION
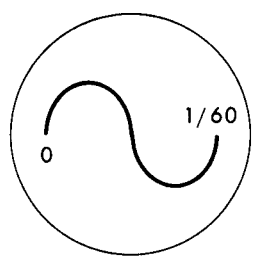
"pull" the beam both left to right and up and down (looking at the front of the tube) in the same length of time it takes the sine wave to complete one cycle. To do this we apply a voltage to the horizontal deflection plates that, starting at zero, increases to maximum in a steady (linear) increase with time. This pulls the beam horizontally across the face of the tube at the same time the sine wave signal applied to the vertical plates goes through one cycle.

The electron beam must then immediately return to its starting point. If not the beam will draw or trace another copy of the sine wave as it returns to the starting point. This is called a *retrace*. To have the beam instantly return to the starting point, the voltage applied to the horizontal deflection plates goes from maximum to minimum in the shortest possible time. The resulting shape of the voltage applied to the horizontal deflection circuit appears as a tooth in a handsaw, and, accordingly, is called a *sawtooth* voltage.

Cathode Ray Oscilloscope—Sawtooth Oscillator

To develop a sawtooth voltage, we take advantage of the charge and discharge of a resistor-capacitor combination (discussed in Volume 2 of *Basic Radio*). In the charging curve of a capacitor, see illustration, the initial portion of the curve is linear. The sawtooth oscillator circuit is used to charge a capacitor, then discharge it to form a sawtooth waveshape.

The neon gas-filled tube exhibits a high resistance with a low voltage across it. When the voltage across the tube reaches the correct value (approximately 90 volts for a type NE-2), the high voltage pulls electrons from the gas atoms. The atoms that lost an electron become positive ions. The freed electrons will rush to the positive electrode and the positive ions to the

DEVELOPMENT OF A SAWTOOTH VOLTAGE

Basic RC Oscillator
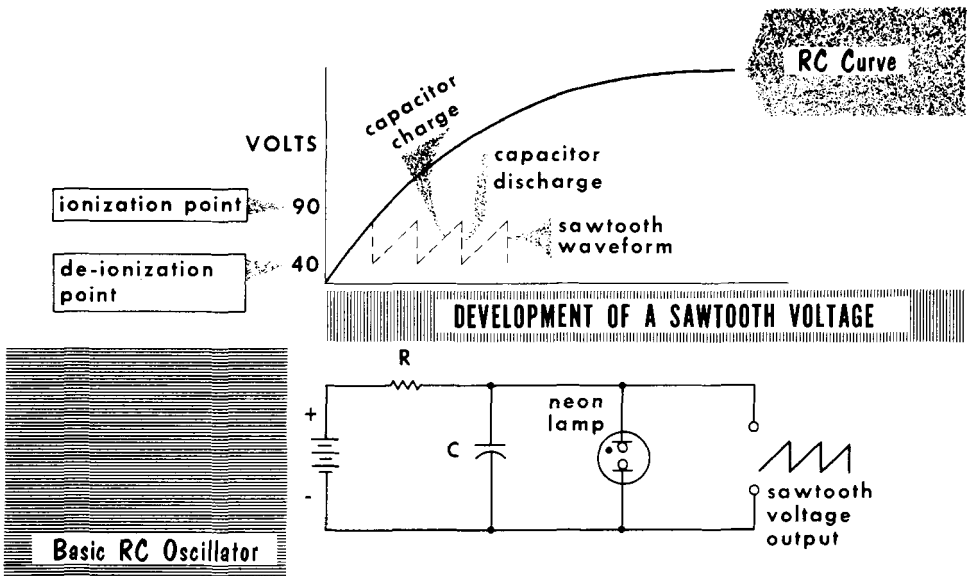
negative electrode. This results in *ionization* of the tube and a correspondingly heavy current flow. In its ionized condition the tube represents a virtual short circuit. The tube will remain this way until voltage across it drops to about 40 volts (for a type NE-2), when the tube will *de-ionize* — return to its normal state — and again exhibit a high resistance.

The neon tube is placed parallel to the charging capacitor in the circuit. The charging voltage across the capacitor builds up to 90 volts, and the neon tube ionizes. The ionized tube presents a short circuit across the capacitor. The capacitor discharges through the tube — almost instantaneously. The voltage across the capacitor starts to drop to zero; however, at 40 volts the tube de-ionizes to present an open circuit. With the short circuit removed, the capacitor again starts to charge to repeat the cycle.

The frequency of the oscillator can be changed by changing the value of R or C, changing the time required for the capacitor to charge to the ionization voltage.

Cathode Ray Oscilloscope—Sawtooth Oscillator (cont'd)

The neon tube is not very stable, and the required ionizing voltage varies between tubes. A gas-filled triode tube, a thyratron, is an improvement over the neon tube. The action of the thyratron is the same as the neon tube with these important exceptions: a cathode is used as a source of electrons. The gas employed, mercury or argon, is more reliable than neon. The firing point is under control by the addition of a grid. The thyratron oscillator circuit provides methods for changing its frequency, changing the R in the RC circuit, changing the C in the RC circuit, changing the applied B+ voltage, and changing the grid bias voltage.
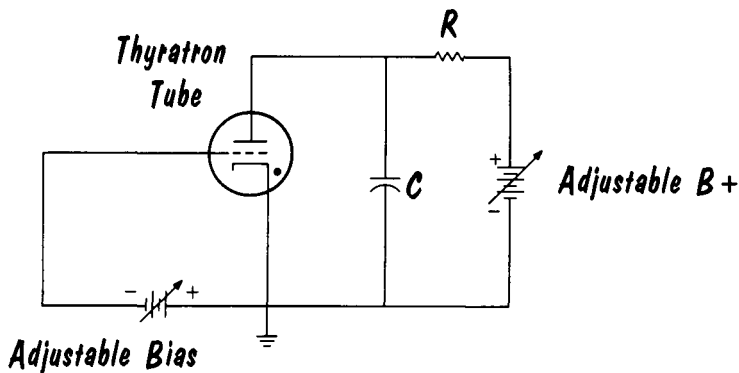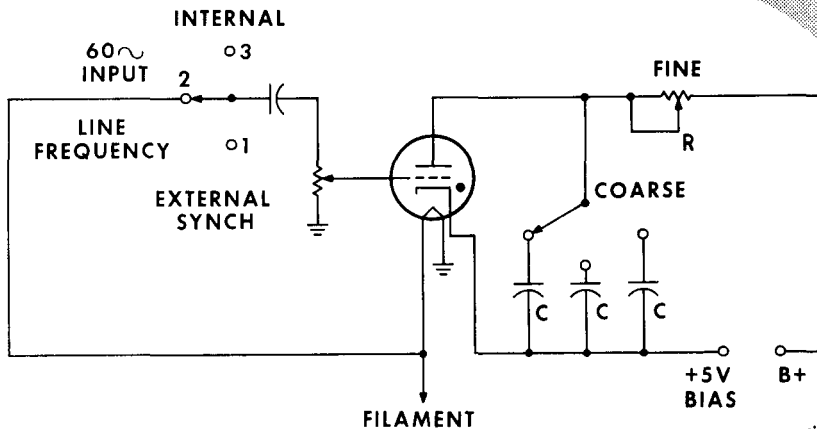

Basic Thyratron RC Oscillator

The ionization of the thyratron can be controlled by applying the signal voltage to the grid. This permits the sawtooth oscillator to act as a sweep circuit which sweeps the beam across the face of the tube in step with the signal under observation. This is called *synchronization*. Applying the signal under observation to the grid of the thyratron causes it to act as a trigger, keeping the thyratron in step with the signal. When the signal voltage on the grid goes sufficiently positive, the thyratron will ionize. This will place the horizontal-deflection-plate sawtooth signal in step with the 60-cycle sine wave or other signal under observation. A small fixed value of external bias is used in the cathode circuit.

Cathode Ray Oscilloscope—Sawtooth Oscillator (cont'd)

Provisions are made for varying the time constant set by the values of R and C of the oscillator circuit. Switching circuits are used to change the value of the capacitor in the circuit, and a potentiometer is used to

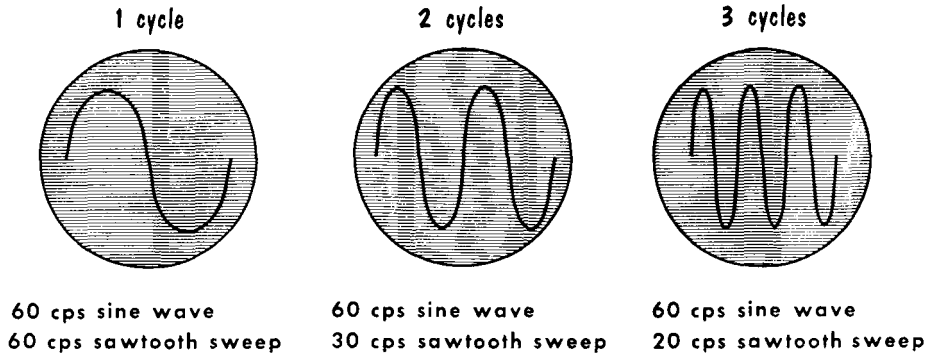THYRATRON RC OSCILLATOR *with Frequency Control*

vary the resistance. The switch that changes the capacitor is called the *Coarse* or *Range* switch because it sets the C of the RC circuit roughly to the desired range of frequencies. The potentiometer is called the *Fine*, *Fine Frequency*, or *Frequency Vernier* since it sets the R of the RC circuit close to the desired frequency.

Note the three positions of the switching circuit in the grid of the thyratron oscillator. In position 1, the switch is set for *External Synchronization.* This enables the firing of the thyratron to be synchronized with an external signal voltage. In position 2, the switch is set for *Line Frequency*. This is a 6.3-volt, a-c sine-wave voltage from the filament circuit. Whenever a 60-cycle signal, or multiple of 60 cycles is used, it will synch readily at the grid of the thyratron. In position 3, the switch is set for *Internal*. This takes a portion of the signal under observation and applies it to the grid of the thyratron tube, synchronizing the oscillator with the signal.

Cathode Ray Oscilloscope—Sweep Display

As discussed previously, the time value necessary to charge the capacitor is equal to five time constants. One time constant is $t = R \times C$. The larger the values of R and C, the longer it takes to reach the ionization voltage of the thyratron. Therefore, for low frequencies we use larger values of R and C, and, conversely, we use smaller values of R and C for higher frequencies. The most popular method to control the frequency of the sawtooth voltage is to switch to different values of capacitors as a rough, or *coarse* adjustment, and use a variable resistance as a *fine* adjustment.

RELATION OF INPUT FREQUENCY TO SWEEP FREQUENCY

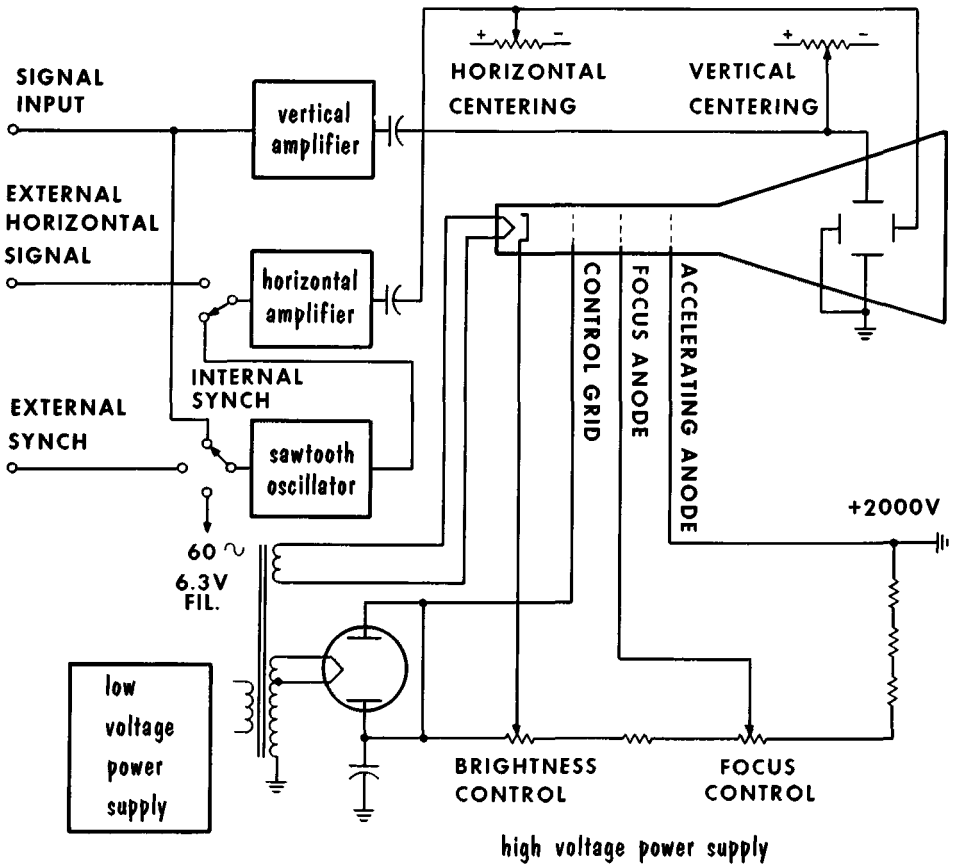| 1 cycle	2 cycles	3 cycles
60 cps sine wave	60 cps sine wave	60 cps sine wave
60 cps sawtooth sweep	30 cps sawtooth sweep	20 cps sawtooth sweep

In actual practice the input signal or sawtooth sweep voltage is not sufficient to deflect the beam completely across the face of the CRT. To overcome this obstacle, amplifiers are used between the signal input and the deflection plates. The vertical amplifier, and, to a lesser degree, the horizontal amplifier must meet special requirements. They must respond to a wide band of frequencies, and have high gain to provide sufficient signal voltage to drive the beam completely across the face of the tube. The gain of the vertical amplifier will determine the sensitivity of the instrument. The higher the gain, the weaker the signal input required to provide sufficient sweep across the face of the tube.

Often the signal to be observed is not sufficient to couple directly to the deflection plates. However, it is large enough to overload and cause distortion. To prevent this an attenuator may be placed at the input of the amplifier. The attenuator is a carefully designed voltage divider with compensating circuits that prevent loss of high frequencies. Using a switch, it is possible to tap-off a sufficient portion of the signal across the divider and feed it to the amplifier, providing sufficient signal without overloading. Attenuator switches are usually calibrated in units of 10, 100, 1000, etc.

Cathode Ray Oscilloscope Diagram

The combined block and schematic diagram of a basic Cathode Ray Oscilloscope illustrates the high voltage power supply. Note, that it is a negative-output power supply with the positive end at ground. Tieing the heater to the cathode places the heater at the same potential as the cathode. If this had not been done the heater would be at a difference in potential to the cathode of almost 2000 volts, and would cause an arc-over between the cathode and heater. A variable bias voltage is applied to the deflection plates to center the beam on the face of the tube.

SIGNAL
INPUT

EXTERNAL
HORIZONTAL
SIGNAL

EXTERNAL
SYNCH

vertical
amplifier

horizontal
amplifier

INTERNAL
SYNCH

sawtooth
oscillator

60 ∿
6.3V
FIL.

low
voltage
power
supply

HORIZONTAL
CENTERING

VERTICAL
CENTERING

CONTROL GRID

FOCUS ANODE

ACCELERATING ANODE

+2000V

BRIGHTNESS
CONTROL

FOCUS
CONTROL

high voltage power supply

Basic Cathode Ray Oscilloscope

Cathode Ray Oscilloscope Controls

Vertical and Horizontal Centering: Locates the beam or trace in the correct position on the face of the C. R. T.

Focus: Varies the voltage of the focus anode to vary the diameter of the spot on the face of the CRT for sharpness and clarity

Intensity: Varies the grid bias voltage to vary the brilliance of the spot on the face of the C. R. T.

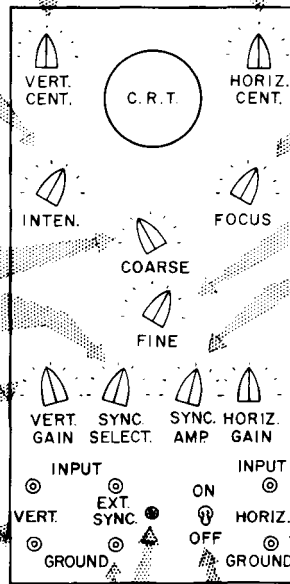**Fine:** Varies the resistor value of the RC network to set the desired frequency of the sweep oscillator

Coarse: Changes the capaciter used in the RC network to roughly set the desired frequency of the sweep oscillator.

Sync Amplitude: Controls the value of signal used to lock the RC oscillator in step with the observed signal

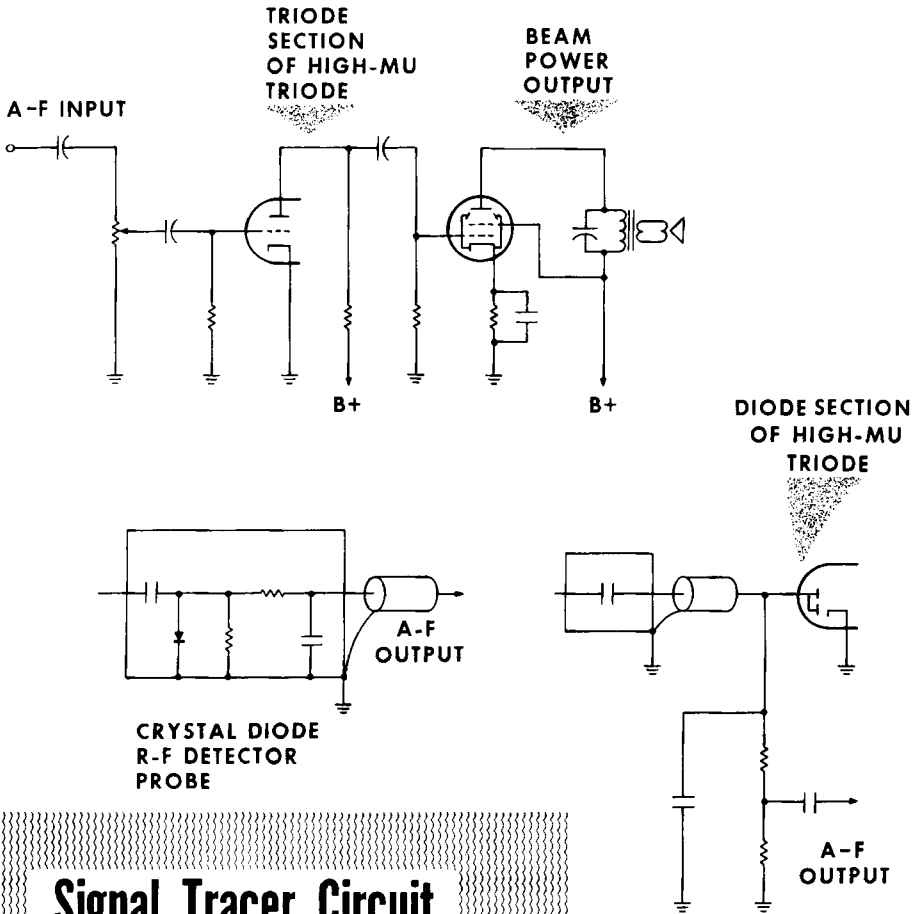**Sync Selector:** Determines what signal will be used to synchronize the RC oscillator.

Horizontal Gain: Controls the gain of the horizontal amplifier used to provide sufficient signal voltage to the horizontal deflection plates to sweep the beam across the face of the CRT

Vertical Gain: Controls the gain of the vertical amplifier used to provide sufficient signal voltage to the vertical deflection plates to sweep the beam across the face of the C. R. T.

Horizontal Input For external sawtooth, or other timing signal.

Vertical Input: For signal under observation.

External Sync Input: For use with an external synchronizing signal.

Power Indicator

Power Switch

Panel labels:

VERT. CENT.   C.R.T.   HORIZ. CENT.

INTEN.   FOCUS

COARSE

FINE

VERT. GAIN   SYNC. SELECT.   SYNC. AMP.   HORIZ. GAIN

INPUT   EXT. SYNC.   ON   INPUT

VERT.   HORIZ.

GROUND   OFF   GROUND

Signal Tracer

A signal tracer allows testing for the presence or absence of a signal in a receiver circuit with the receiver operating. The use of a built-in detector permits tracing the signal from the antenna through the r-f and i-f stages to the detector circuits. After the detector the tracer is used as an audio amplifier to follow the signal through the a-f stages to the speakers.

TRIODE
SECTION
OF HIGH-MU   BEAM
TRIODE   POWER
                  OUTPUT
A-F INPUT

B+   B+   DIODE SECTION
                                  OF HIGH-MU
                                  TRIODE

A-F
OUTPUT

CRYSTAL DIODE
R-F DETECTOR
PROBE

A-F
OUTPUT

Signal Tracer Circuit

The signal tracer consists of an audio amplifier with two probes. The audio-signal tracer probe contains only a blocking capacitor used to couple a-f signals to the audio amplifier. For tracing r-f and or i-f signals, a detector is used ahead of the input to the signal tracer's audio amplifier. The detector can be mounted directly in the probe as shown, or it can be the diode portion of a duo-diode high-mu triode.
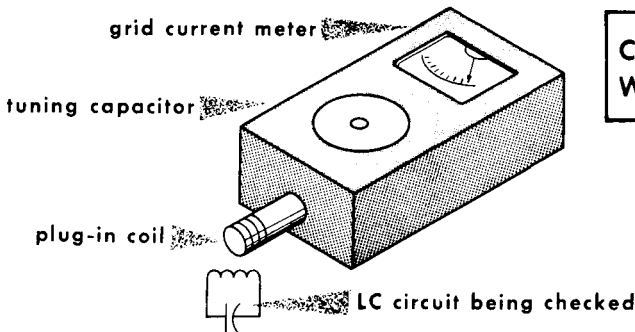
Grid-Dip Meter

The grid-dip meter, also called a grid-dip oscillator, will indicate the reso-
nant frequency of an LC circuit. The grid-dip meter is a tuned oscillator
with a current-reading meter placed in the grid circuit. The oscillator-
tuning-circuit coil is a plug-in type that mounts on the outside of the
instrument case. The grid-dip meter coil is placed close to the tuned circuit
being checked. The grid-dip meter is then tuned through the frequency
region of the tuned circuit being checked. When the grid-dip meter oscil-
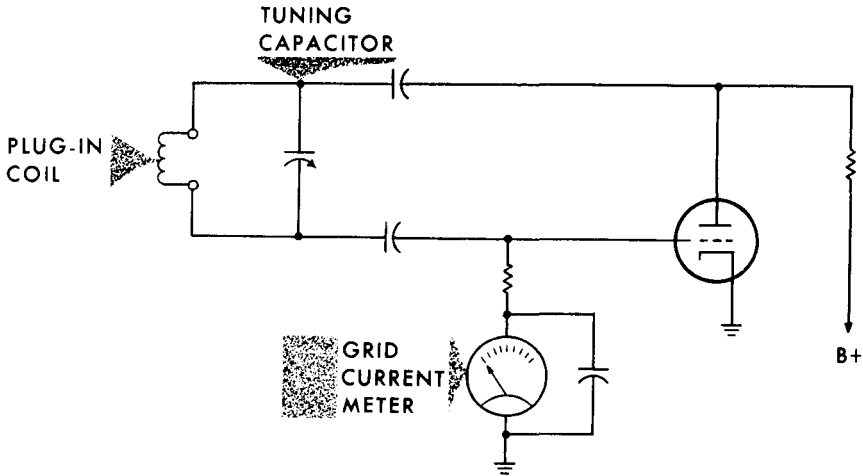
Basic Grid-Dip Meter Circuit

lator frequency is identical to that of the tuned circuit being checked,
some of the energy of the oscillator will be absorbed by the circuit being
checked. This loss of energy is indicated by a reduction (dip) in the grid-
circuit-current indicating meter, hence the name *grid-dip meter*. Calibrat-
ing the tuning capacitor dial in several bands of frequencies to match the
various plug-in coils, allows a wide frequency coverage.


Checking Frequency
With Grid-Dip Meter

The Cathode Ray Oscilloscope is used to display a-c voltage waveforms. It
allows observation of the voltage for amplitude, waveform, and
whether it is constant or varying.

The heart of the oscilloscope is the cathode ray tube (CRT). The face of
the tube is coated with phosphor chemicals that convert the energy of
an electron beam to a spot of light.

To accelerate and focus the beam of electrons, they are passed through an
accelerating anode and a focus anode. The accelerating anode is at a
high potential, as much as 2000 volts. The high voltage requires ob-
servation of safety rules.

The focus anode is at a lower potential than the accelerating anode, creat-
ing an electrostatic field between them. Varying the focus anode
voltage varies the field to provide focusing action.

Control voltages are applied to the deflection plates to deflect the electron
beam.

A combination of voltages on the vertical and horizontal deflection plates
will allow the electron beam to draw any desired pattern on the face
of the cathode ray tube.

To pull the electron beam steadily (linearly) across the face of the tube
and then have it instantly return to the starting point, requires a
sawtooth voltage applied to the horizontal deflection plates.

To develop a sawtooth voltage oscillator, we use the charge and discharge
of a resistor-capacitor combination in addition to a neon tube.

The frequency of the sawtooth voltage oscillator can be varied by changing
the value of R or C.

An improvement over the neon tube is a thyratron, which uses a cathode,
a control grid (another method for changing frequency), and a more
reliable gas.

Applying the signal under observation to the grid of the thyratron causes
the signal to act as a trigger and provide synchronization of the oscil-
lator and signal.

When the frequency of the sawtooth oscillator is the same as the signal
under observation, one cycle of the signal will be displayed.

REVIEW QUESTIONS

1.   What determines the color of the spot of light on the face of a CRT?
2.   What is meant by persistence of a cathode ray tube?
3.   Briefly describe electrostatic focusing.
4.   What will be the results of applying a sine wave signal to the vertical
      deflection plates?
5.   Describe a *retrace*.
6.   What portion of an RC curve is used in a sawtooth oscillator?
7.   Briefly describe ionization of a neon tube.
8.   Two controls are used to change the frequency of a sawtooth oscil-
      lator: *Coarse* or *Range*, and *Fine Frequency* or *Frequency Vernier*.
      Briefly describe the action of each control.
9.   What is mean by *external* synchronization?
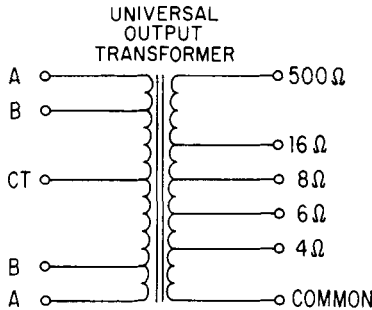
Components

There are essentially only four types of components: tubes (and transistors) resistors, capacitors, and inductors. The variations are numerous — a transformer, oscillator coil, or antenna loop all come under the heading of inductors. The theory of operation of components is presumed to be understood, and, therefore, testing of components will not be a complex discussion. Replacement of defective component parts requires some thought. There are two types of replacement parts: *exact replacement* — where the parts are usually obtained from the manufacturer or the manufacturer's local distributor — and *general replacement* — where the parts are usually obtained from mail-order-catalog supply houses, or local parts jobbers.

ELLIPTICAL
SPEAKER

6"

2"

TAP

TAPPED
CONTROL
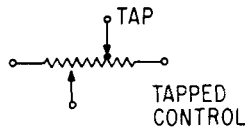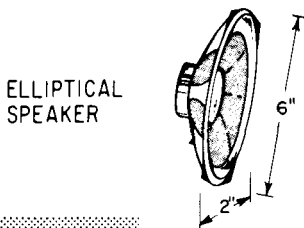
Special Components That Require Exact Replacements

PRIMARY USED
FROM A TO A
OR B TO B FOR
SINGLE OUTPUT
PLATE IMPEDANCE

FROM CT TO EITHER
AA OR BB FOR
PUSH-PULL OUTPUT
PLATE IMPEDANCE

UNIVERSAL
OUTPUT
TRANSFORMER

A

B

CT

B

A

500 Ω

16 Ω
8 Ω
6 Ω
4 Ω

COMMON

SECONDARY
FOR VARIOUS
VOICE COIL
OUTPUTS OR
FOR PUBLIC
ADDRESS
SYSTEM
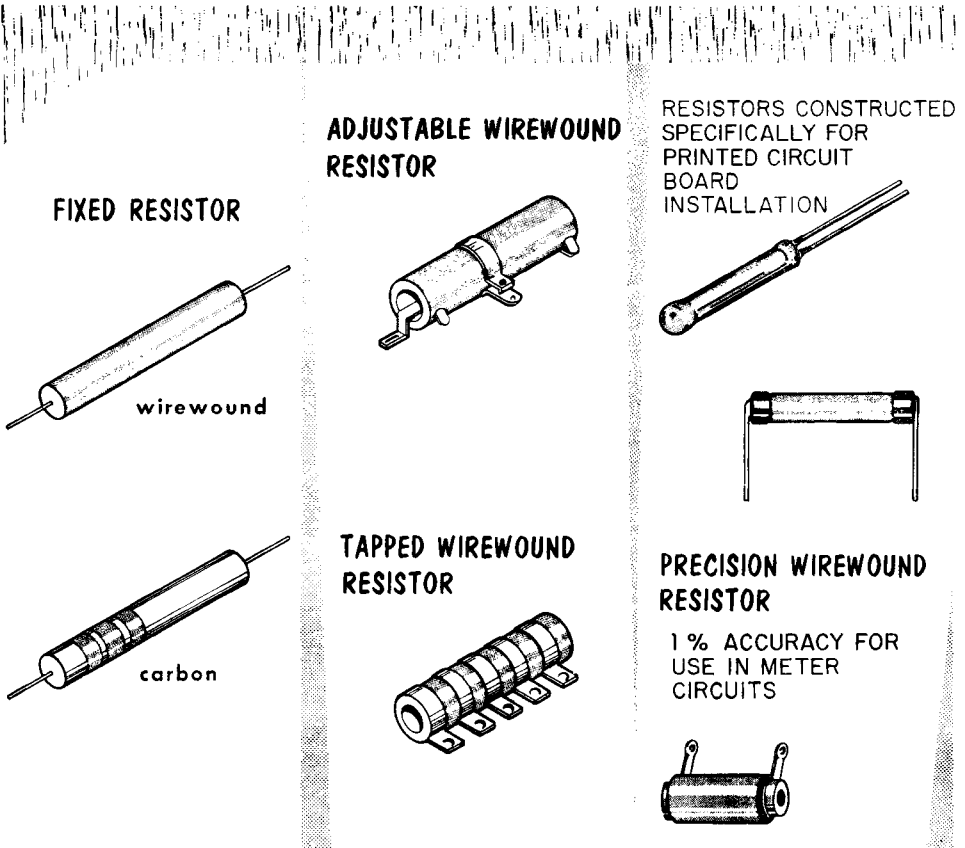
An Example of a

Universal Component

Exact replacement parts include special shaped speakers used to support a dial, volume controls with special taps, replacement cabinets, etc. General replacement parts include tubes, capacitors, resistors, etc. Also available as general replacement parts are specially designed components that are essentially "universal". A typical example is an output transformer with multiple taps to match different output tube combinations.

Any component under suspicion can be tested, as will be explained; however, when in doubt a known good component can be substituted. Substitution of parts indiscriminately is not the sign of a good technician. Substitution should only be done when either the test is inconclusive or no method of testing is available. An example might be a questionable capacitor and no capacitor checker available. When changing a component with multiple leads, make a penciled sketch of where each wire goes. Do not depend upon memory alone; this can be disastrous.

Resistors

To check a resistor that is wired in a circuit, one end must be unsoldered or *lifted*. This removes the possibility of a false reading due to a parallel circuit shunting the resistor.

Resistors by themselves cause very little trouble. Occasionally the resistor will change value over a period of time due to heat. When a resistor is charred, burnt to the point where it breaks in half, mere replacement will

FIXED RESISTOR

wirewound

carbon

ADJUSTABLE WIREWOUND RESISTOR

TAPPED WIREWOUND RESISTOR

RESISTORS CONSTRUCTED SPECIFICALLY FOR PRINTED CIRCUIT BOARD INSTALLATION

PRECISION WIREWOUND RESISTOR

1% ACCURACY FOR USE IN METER CIRCUITS

not cure the trouble. A resistor itself will not burn up; it chars because too much current flowed through it. Before replacing a burnt out resistor be sure to correct the difficulty that caused the excess current to flow through it.
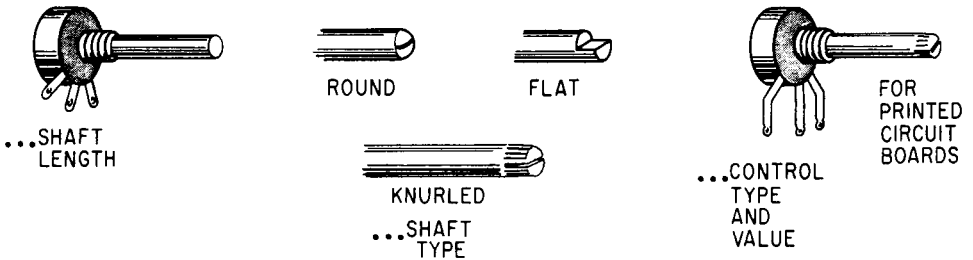
In replacing a resistor use an equal or increased wattage rating. The tolerance of a resistor should also be matched.

When a resistor is charred beyond recognition and no schematic is available to indicate the correct replacement value, similar circuits in the receiver or another receiver can be checked for a typical value.
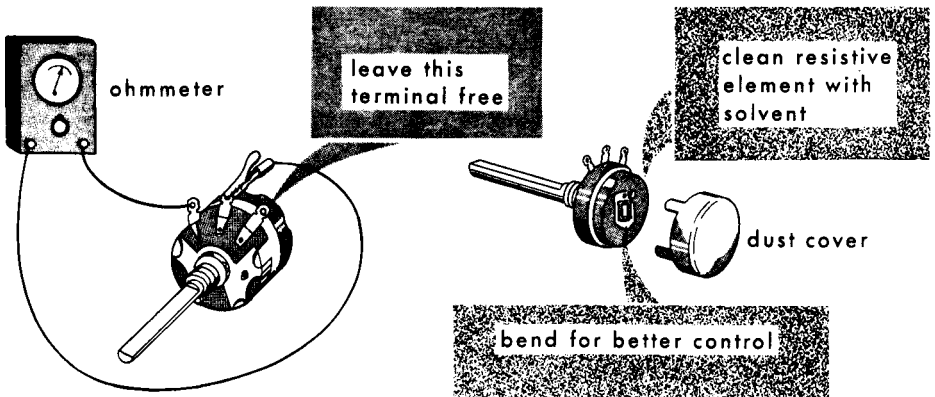
Controls

Controls are checked with an ohmmeter for continuity and correct value. One end should be free to prevent shunting by parallel circuits. In checking a volume control one lead of the ohmmeter is placed at the free end and the other ohmmeter lead at the wiper arm connection. The shaft is then rotated to make sure the wiper arm is making contact along the full length of the control.

When replacing a control, make sure you have the correct...

...SHAFT
LENGTH

ROUND   FLAT

KNURLED

...SHAFT
TYPE

...CONTROL
TYPE
AND
VALUE

FOR
PRINTED
CIRCUIT
BOARDS

When replacing a control, the shaft has to be matched in both length and shape. Too short a shaft and the knob will not go on; too long and the knob projects, sticks out too far. Using the wrong shaft will result in a knob that will not fit the shaft. Many controls have the "on-off" switch mounted as an integral part of the control. A defective switch usually means replacing both switch and control.

When no replacement is readily available, a temporary repair can be made to a noisy control that has an intermittent wiper arm. The control is removed and disassembled, the resistance element cleaned with a solvent, and the contact arm bent slightly to insure better contact. A small coating of conducting lubricant is then placed on the resistance element, and the control reassembled.

ohmmeter

leave this
terminal free

clean resistive
element with
solvent

dust cover

bend for better control

Tubes and Transistors

In testing tubes a quick and obvious check is for an open filament. An open filament in a parallel heater circuit will show itself in a cold tube. If the tube is made of glass, a visual check can be made for an operating filament. Portable-radio 1.25-volt tubes will not show any filament light — they cannot be checked by visual means. In a series string of filaments, an ohmmeter can be placed across the heater-tube base pins of the individual tubes as they are removed from the socket.
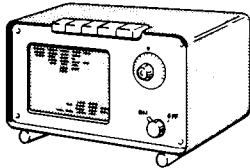
When a tube is suspected of an intermittent short circuit, it can be tapped gently with a pencil eraser. A complete test of a tube can be made on a tube tester or a known good tube can be substituted for the questionable tube.
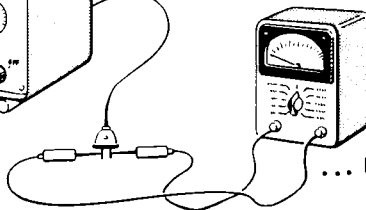
Suspected Tube is Checked For...
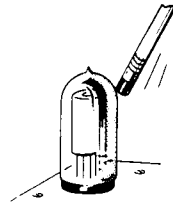
TAP TUBE WITH ERASER END OF PENCIL

... INTERMITTENT SHORT CIRCUITS

SWITCH ON

... FILAMENT CONTINUITY

When substituting a glass tube for a metal tube, check the operation of the receiver to be sure it does not need a metal shield. Some tubes are interchangeable with other similar type tubes. Books listing such tubes are published and are available at most parts jobbers.
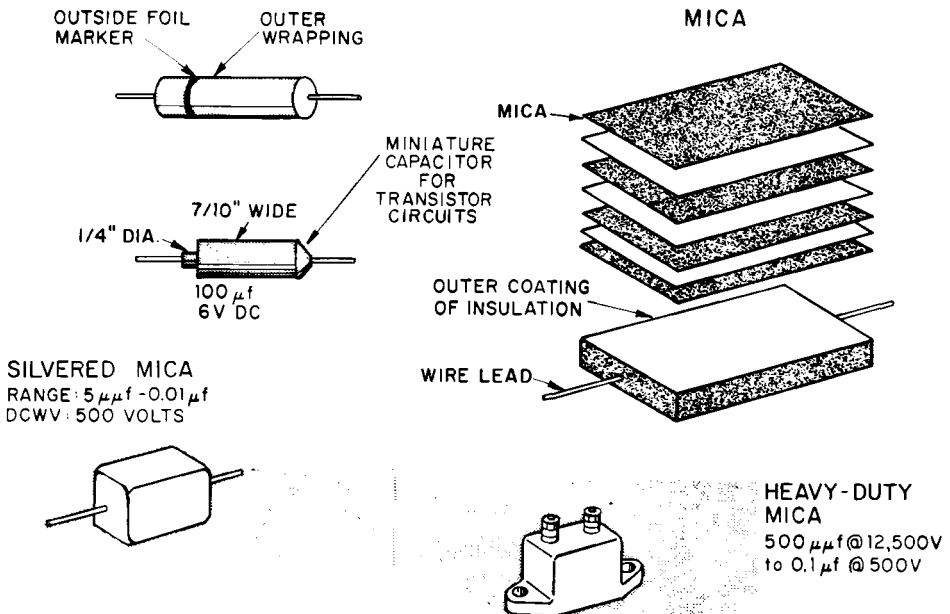
After servicing a radio, a good idea is to test all the tubes in the receiver and label them: good, weak, etc. This proves to the customer that your work is thorough and may lead to additional tube sales.

In transistor radios, transistors should not be checked except as a last resort, particularly when they are wired directly in the circuit. When a transistor is questioned it should be checked with a transistor checker. If the transistor is defective, the circuit should be checked to insure that the transistor was not ruined by excessive current due to a circuit defect. If this were the case, the replacement transistor would also be ruined.

Capacitors

Paper and mica capacitors can be checked while still wired in circuits with capacitor checkers designed for in-circuit testing. To test the capacitors with an ohmmeter for leakage or a short circuit, one end of the capacitor must be unsoldered. This prevents any parallel circuit shunting the capacitor. Often a short circuit will not be indicated with only the low voltage of an ohmmeter applied to a capacitor. It requires the application of full working voltage before the capacitor breaks down. To give the capacitor a proper test for this type of failure, a capacitor checker should be used.

When replacing a capacitor it is best to substitute one with the same rating. If this cannot be done a slightly higher rating will suffice in most cases.

OUTSIDE FOIL   OUTER   MICA
MARKER   WRAPPING

MICA

MINIATURE
CAPACITOR
FOR
TRANSISTOR
7/10" WIDE   CIRCUITS

1/4" DIA.

100 μf
6V DC   OUTER COATING
                                   OF INSULATION

SILVERED MICA   WIRE LEAD
RANGE: 5 μμf - 0.01 μf
DCWV: 500 VOLTS

HEAVY-DUTY
MICA
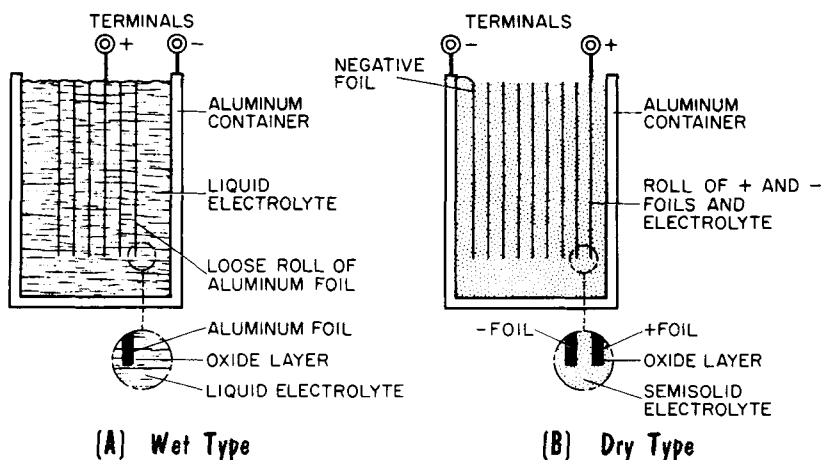500 μμf @ 12,500V
to 0.1 μf @ 500V

CAPACITORS

The voltage rating of a capacitor is important. The replacement capacitor should always be equal to, or higher, in voltage rating than the capacitor it replaced. A good practice is to use a 600-volt-rating replacement capacitor at all times, unless size and lack of room forces the use of one with a smaller voltage rating. When replacing a buffer capacitor in an auto-radio power supply, be sure to replace it with a duplicate. When replacing capacitors with an outside foil marking, place the marking to the ground side of the circuit.

Electrolytic Capacitors

A safe habit is shorting the leads of an electrolytic capacitor; they can store a charge for a long period of time. To check an electrolytic capacitor be sure at least one lead is free of any circuit wiring to prevent a false reading due to a shunt circuit. An ohmmeter can be used for a check of an electrolytic capacitor.

Be careful to observe the polarity of the ohmmeter leads and the electrolytic capacitor. When the leads are placed across the capacitor, the ohmmeter will read a low resistance value, followed by an increasing resistance reading, and ending at a higher resistance value, with a typical reading being approximately one-half to one megohm. Electrolytic capacitors show

electrolytic capacitor construction

TERMINALS
◎+ ◎−

TERMINALS
◎− ◎+

NEGATIVE FOIL

ALUMINUM CONTAINER

ALUMINUM CONTAINER

LIQUID ELECTROLYTE

ROLL OF + AND − FOILS AND ELECTROLYTE

LOOSE ROLL OF ALUMINUM FOIL

ALUMINUM FOIL

OXIDE LAYER

LIQUID ELECTROLYTE

−FOIL

+FOIL

OXIDE LAYER

SEMISOLID ELECTROLYTE

(A) Wet Type

(B) Dry Type

some leakage, but it should be high — 100,000 ohms or more. The best method of testing an electrolytic is with a capacitor checker where the full working voltage can be applied.

When replacing an electrolytic capacitor, one having a small value can be replaced by one having a higher value. If the electrolytic capacitor is the input filter the increase in value should not be too much, as it may draw too high a value of charging current and damage the rectifier.

The working voltage of the replacement capacitor should be as high or higher than the original unit. When possible the type of mechanical mounting used should be matched. When one section of a multisection electrolytic capacitor becomes defective, it is best to replace the entire capacitor; however, if necessary, the defective section can be replaced with an individual capacitor. When testing electrolytic capacitors in transistor radios, special precautions must be taken. An ohmmeter with low battery voltage should be used since the working voltage ratings of many of the capacitors are as low as 6 volts, with some as low as 1 volt.

Power Transformers

The reason for a defective power transformer is most often a short circuit elsewhere in the receiver, causing excess current to flow through the transformer windings. After the short circuit is removed, the transformer will have to be tested for damage. To check the continuity of the windings an ohmmeter is used. To check the transformer output voltages, the rectifier and other tubes are removed, and the output voltage values are checked with an a-c voltmeter.

Probe

Alligator Clip

Voltmeter
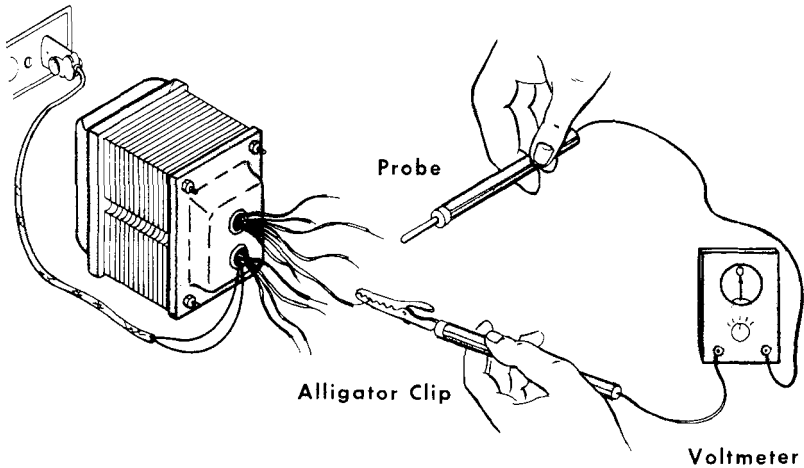
measuring VOLTAGES of a power transformer

A power transformer that has had an excessive current drain through the windings for sufficient time to have the insulating pitch melt has an unmistakable odor. When this has happened the transformer should be replaced by a duplicate. If a general replacement transformer is used, be sure there is sufficient room to mount it. If the exact ratings of the transformer being replaced are not known, they can be easily calculated. The filament current of each tube is added to provide the total filament drain, plus a 50% safety margin. To figure the B+ current drain, the typical ratings of each tube can be obtained from the tube manual. Note the typical value of plate current listed for each tube. After totaling the typical-value plate currents, be sure to add the 50% safety margin.

To change an auto-radio power transformer, it is best to use a duplicate. If this cannot be done and a general replacement part is used, check the directions carefully, as a new value buffer capacitor will probably be required.

Output and I-F Transformers

Typical Output Transformer

An ohmmeter is used to
check for an open winding

Defective transformers can be replaced
by general replacements
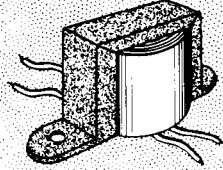
Occasionally the output stage will draw excessive current through the output transformer, opening the primary winding. An open winding can easily be checked for continuity with an ohmmeter. General replacements are often used to replace a defective output transformer, which are available with multiple taps to match any desired impedances.

For receivers having good fidelity, or in high-fidelity amplifiers, it is important that a transformer of equal or better quality is used as a replacement. An inferior output transformer will reduce the quality of the audio reproduction.
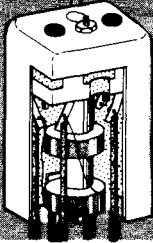
Typical I-F Transformer

I-f transformers of special type
or frequency require replacement
by a duplicate

Intermediate-frequency transformers with open windings are due mostly to the wire lead from the windings breaking off at either the soldering lug, or where it enters the main winding. An open winding can be checked by an ohmmeter continuity measurement. When the wire breaks off at the lug it can be repaired by cleaning the end of the wire and resoldering it to the lug.

A defective i-f transformer of a special type, or special frequency, requires replacement by a duplicate. A general replacement i-f transformer is suitable in most cases. If the i-f transformer is an input, interstage, or output transformer it should be replaced with a similar unit. When wiring the replacement transformer the leads should be placed in the same positions as the original leads. Care should be used to keep the leads short, particularly the plate and grid leads.

Coils

Oscillator coils will open when the fine wire used breaks off either at the connecting lug or at the winding. An open winding can be checked for continuity with an ohmmeter. A defective oscillator coil should be replaced with a duplicate. When using a general-replacement oscillator coil, it will be difficult during realignment to have the oscillator stage track the r-f stage along the entire tuning dial.

OSCILLATOR COIL

Pentagrid
Converter

+B

OSCILLATOR
COIL

check for breaks
at lug connections

check for breaks
at beginning of
windings
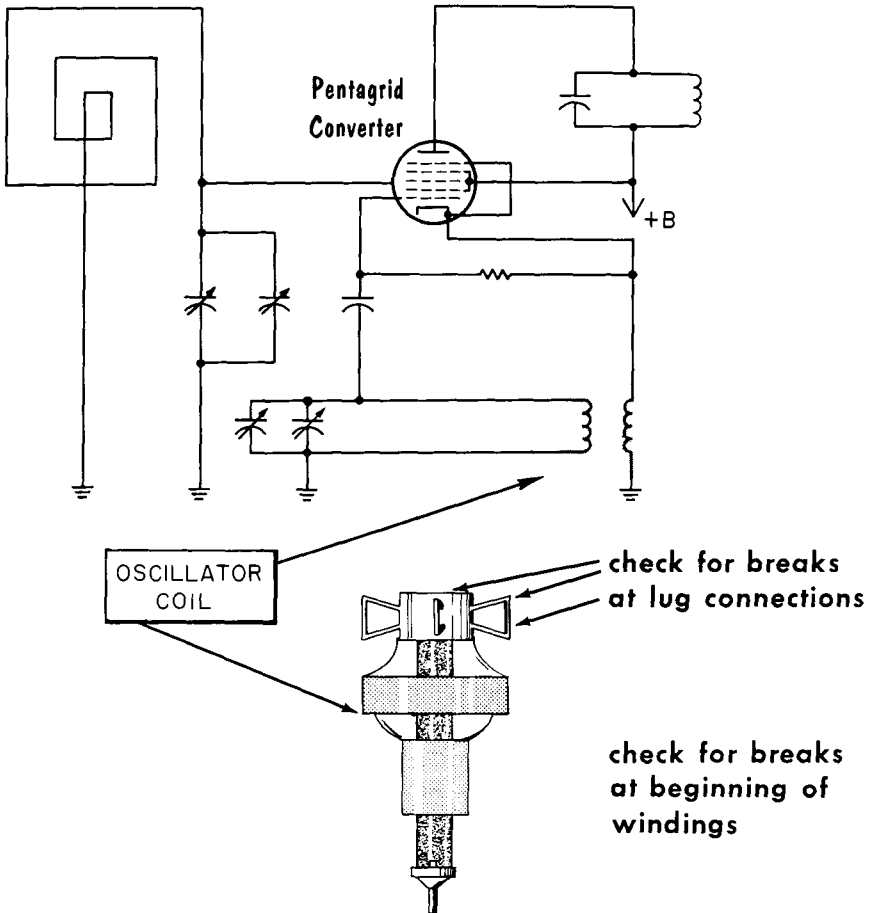
Loop Antennas

Defective loop antennas with open windings can be repaired or replaced with ferrite-core antennas.

When replacing the loop antenna be sure to mount the ferri-loopstick rigidly and free and clear of the chassis, or any metallic object, such as an i-f transformer. A minimum spacing should be one inch.

Loop Antennas

Symbol

Primary

Primary

Secondary

Secondary

"Ferrite" Powdered-Iron Core
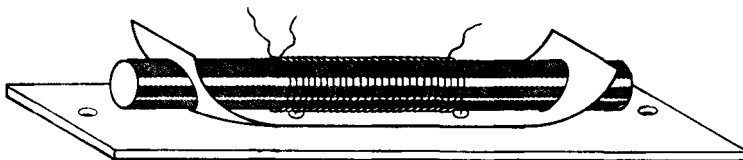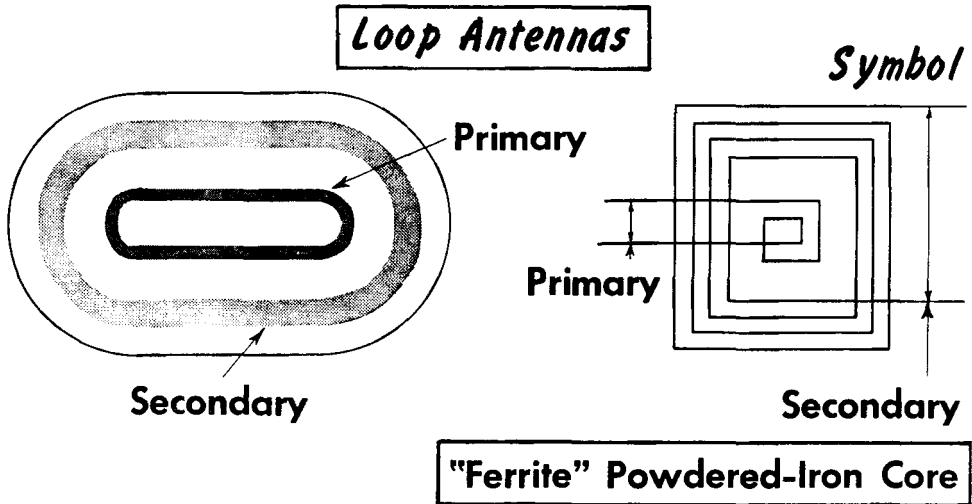
Ferri-Loopstick Antenna

The Q of a loop antenna can sometimes be changed by pinching together the wires. In some extreme cases, a complete removal of one turn may do the trick. This may be necessary because the antenna has been damaged by an inexperienced technician, or the customer tried repairing the radio himself. A loopstick, on the other hand, can be adjusted by turning the iron core. Tuning the antenna is recommended only as a last resort. Ordinarily, it should not be tampered with.

On older sets in particular, the loop antenna is mounted on the back cover. Care should be taken when removing the cover so that the wire is not pulled from the winding.

Loudspeakers

Defective PM loudspeakers with no output will have either an open or *frozen* voice coil winding. An EM speaker with a field coil winding can be checked by carefully bringing a screw driver close to the magnetic field from the front of the speaker (near the voice coil). If there is no magnetic attraction, either the field coil is open or there is no current flowing through the field coil winding. An open voice coil or open field coil is checked by testing for continuity with an ohmmeter.

A speaker cone that is rattling may require recementing of the gasket ring at the outer rim. Rattling can also be caused by a torn speaker cone. Speaker distortion may be due to a warped voice coil rubbing the pole piece. To

To Check For Warped Voice Coil...
gently press side of cone
to move rubbing pole piece

SOURCES OF SPEAKER-CAUSED DISTORTION

Torn Cone

Loose Gasket Ring
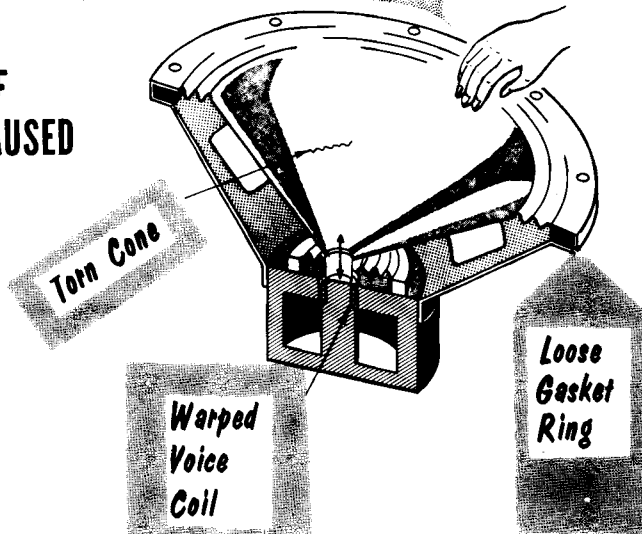
Warped Voice Coil

check for a warped voice coil turn the receiver on and *gently* press one side of the speaker cone to try and move the rubbing voice coil away from the pole piece. If the voice coil winding is open or warped, the speaker cone and voice coil can be replaced. Centering a voice coil on the pole piece requires some skill. The time taken to do this in the shop may prove to be more costly than the purchase price of a replacement speaker.

A defective speaker with an open field coil may be difficult to replace. If no mounting or space problems are encountered, the speaker may be replaced with a PM type speaker and a separate choke used in place of the field winding. When replacing a defective speaker in a high fidelity receiver or amplifier, it is important that a speaker of equal quality or better is used. An inferior speaker will reduce the reproduction quality.

There are essentially only 4 types of components: tubes (and transistors), resistors, capacitors, and inductors.

There are two types of replacement parts: *exact* and *general* replacements.

To check a resistor wired in a circuit, one end may have to be unsoldered.

In replacing a resistor use an equal or increased wattage rating.

In testing tubes a quick and obvious check is for an open filament.

A tube suspected of containing an intermittent short circuit can be checked by tapping it gently with the eraser at the end of a lead pencil.

When substituting a glass tube for a metal tube, check the receiver operation to be sure a metal tube shield is not required.

A transistor is best checked in a transistor checker.

To test a capacitor with an ohmmeter for leakage or a short circuit, one end of the capacitor must be unsoldered or "lifted."

When replacing a capacitor it is best to replace it with the exact value and with an equal or higher voltage rating.

Watch the polarity when checking an electrolytic capacitor with an ohmmeter.

Special precautions must be taken when testing electrolytic capacitors in transistor receivers. An ohmmeter with low battery voltage must be used because of the low working voltage ratings of the capacitors.

When changing an auto-radio power transformer it is best to use an exact replacement.

General replacement output transformers usually replace a defective output transformer.

A general replacement i-f transformer is suitable for most replacements.

Most often oscillator coils open where the fine wire breaks at the connecting lug or at the beginning of the winding.

Speaker-cone rattle is often caused by a loose gasket ring at the outer rim or by a torn cone. Distortion is usually due to a warped voice coil.

REVIEW QUESTIONS

1. Describe the difference between exact and general replacement parts.
2. What is a good precaution to take when changing a multiple lead component?
3. What steps must be taken before replacing a charred resistor?
4. A visual test can be made of the filaments of glass tubes other than those used for portable receivers. Explain why.
5. After servicing a radio receiver, what would be a good idea regarding the receiver's tubes?
6. Why is it possible for an ohmmeter check to be inconclusive when testing a capacitor for a short circuit?
7. Describe how to figure the ratings required for a replacement power transformer when the ratings are not available.
8. What precautions must be taken when replacing an output transformer in a high-fidelity audio system?
9. When replacing an i-f transformer, what precaution must be taken with the circuit wiring?

Servicing Procedures

To service a radio with the least expenditure of time, which is another way of saying to make the most money, involves three variables. First, there are the techniques which enable a serviceman to quickly and efficiently go about his business. Second, there are the various methods by which he uses his technique, each being useful in its particular place. The third variable is localization of the defect and its repair.

DO NOT Trust Your Memory
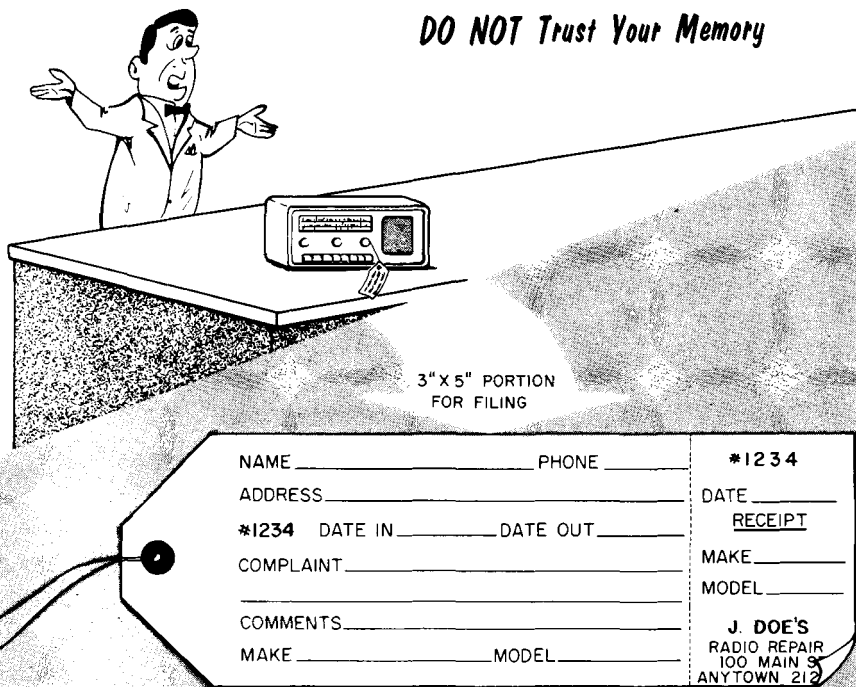
When a receiver is delivered for servicing it is a good idea to use the customer's complaints as a guide in locating the difficulties. This requires some care, as it can lead to misunderstanding since many people are not as articulate as desired. An example is the complaint "the set doesn't work." This does not necessarily mean that the receiver is completely inoperative, or *dead*; it may mean that it is working, but so poorly as to have the customer consider it useless.

The first question to ask a customer is: "WHAT IS THE COMPLAINT?" never ask, WHAT IS WRONG? Obviously if they knew what was wrong, they would not need a serviceman. There are other leading questions that can be asked: *How long has it been like this? How often does it happen? Does it happen any special time?* Do not ask too many questions—the cusmer should not get the feeling he is being interrogated. Be sure to note the customer's complaints on a service tag; do not trust your memory.

Servicing Techniques

An important aspect of technique is to *reason* the difficulties. All too often the beginner is prone to guess—changing a component that looks bad—or worse yet, surmising that this just might be the difficulty. Logic will tell the serviceman to pause and reason what could cause this effect. Knowledge of the circuitry enables the serviceman to reason the nature of the difficulty, and perhaps its exact cause.

An example might be a 60-cycle hum in an ac-dc receiver. Usually this is a result of inoperative or ineffective filter capacitors. Most servicemen would quickly bridge the filtered capacitors with a good capacitor to reduce

USE YOUR SENSES...

Broken Lead

Wax From Leaking Capacitor

Smoke From Overheated (Charred) Resistors

Hum From Defective Filter Capacitor

Static Caused by Arcing
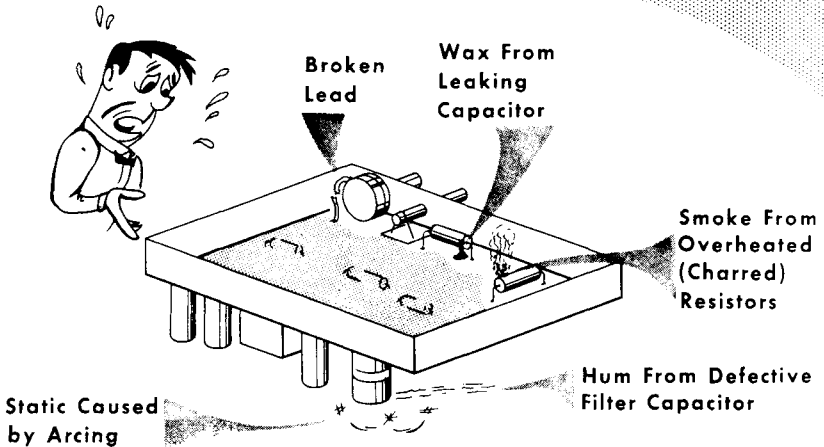
OBSERVE by SIGHT, SOUND, and SMELL

the hum. Should this test fail the serviceman must then ask himself where else can 60-cycle hum be developed in the receiver. A moment's thought would remind him that it could be a cathode-to-heater short in a tube.

The subject of calm reasoning and logic versus guess work can not be over-emphasized. Many servicemen find that from past experience they can readily learn the common types of troubles and often make quick repairs. When the unusual trouble comes along that is not similar to the routine repairs, then *reasoning* separates the men from the boys.
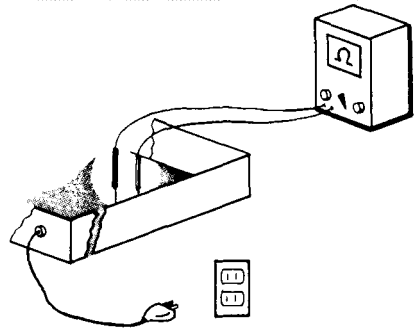
Servicing Methods

There are different methods of approaching the job of servicing a receiver. Each method has its devotee—some will insist this is the only way, and others will disagree. The four most popular methods of servicing are: servicing by voltage readings, by resistance readings, by signal injection, and by signal tracing. Each method has its merits. The individual serviceman may use methods that may consist of one of the four methods or a combination of any of them.
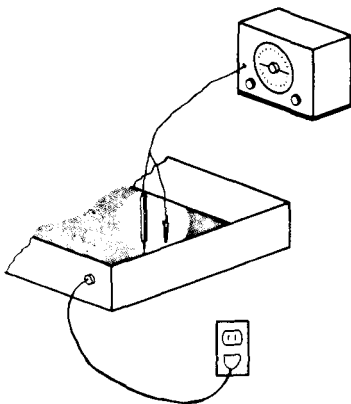
POPULAR SERVICING METHODS
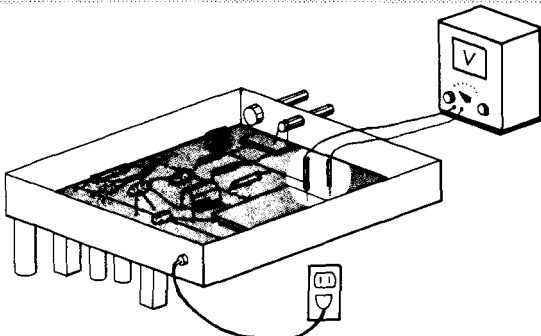
voltage readings   *resistance readings*

signal substitution   *signal tracing*
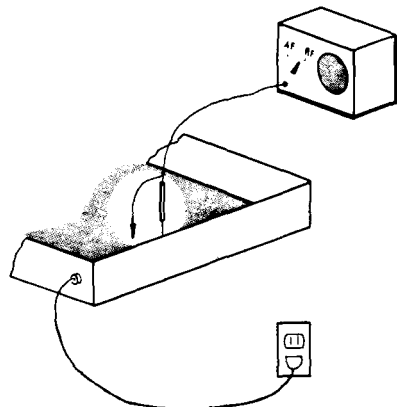
THESE METHODS CAN BE USED INDIVIDUALLY OR COMBINED

Voltage Readings

may be floating
common in
ac-dc receivers

B +
B -
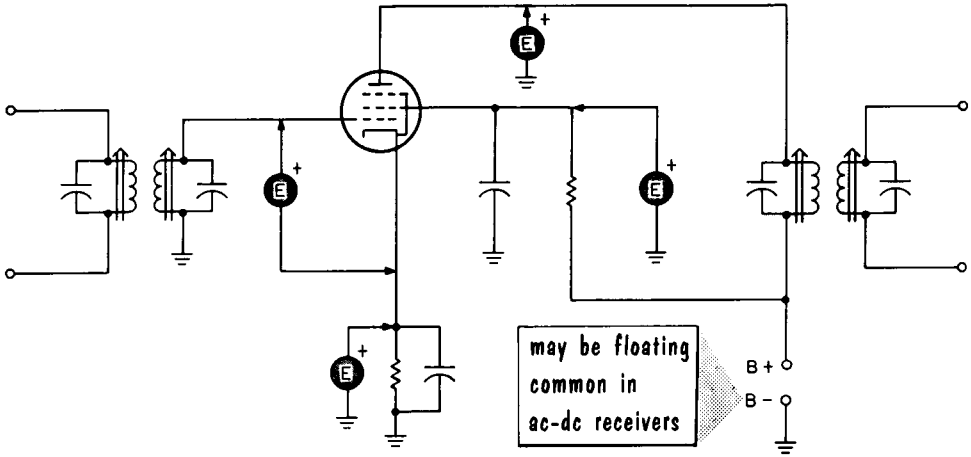
VOLTAGE READING POINTS

A good first step in servicing is to take voltage readings. With low or no voltages the circuits will not operate correctly or not at all. A quick step is taken by checking power supply voltages since these voltages are common to the entire receiver. The values of the measured voltage may vary from those listed on the schematic diagram. Changes in the line voltage can effect the voltage, and low emission of the rectifier tube can reduce the power supply voltage. The voltages measured may vary ±20%, usually minus, of the required voltage. A circuit that should have 250 volts applied may have only 200 to 300 volts. When a reading is low by almost the full 20%, it should be corrected even though it may not be the cause of the trouble in the receiver.

Typical voltage readings that can be taken, are shown in the circuit above. In practice, the plate-to-cathode voltage can be approximated by taking a reading from plate to ground. The cathode voltage (in most cases) will be insignificant.

In checking voltages in ac-dc receivers, the chassis is usually *not* common B—; common is *floating*. In checking voltages in any receiver it is a good policy to determine whether the chassis is common or not. If any doubt exists a safe point to place the negative probe is the negative terminal of the power-supply filter capacitor.

Resistance Readings

An important precaution when taking ohmmeter readings is to be sure the receiver is turned off and the a-c plug removed from the line. In battery sets be sure to remove the battery. Resistance tests quickly check for open or short circuits, or changes in component values.

In the typical i-f amplifier circuit below are shown the ohmmeter check points. The plate circuit is checked by a value reading and continuity of the plate load. The screen circuit is checked by reading the value and continuity of the screen dropping resistor. The screen bypass capacitor is checked for a short circuit. The cathode circuit is checked by a simultaneous reading of both the cathode resistor and bypass capacitor. If the cathode capacitor is not shorted, the only reading in the cathode circuit should be that of the cathode resistor. The grid circuit is checked for continuity.

The B+ line is checked for a short circuit by taking an ohmmeter reading between B+ and B−. The reading should normally be high, in the order of 100,000 ohms or more; a low value reading of hundreds of ohms or less indicates a short circuit in the B+ line.
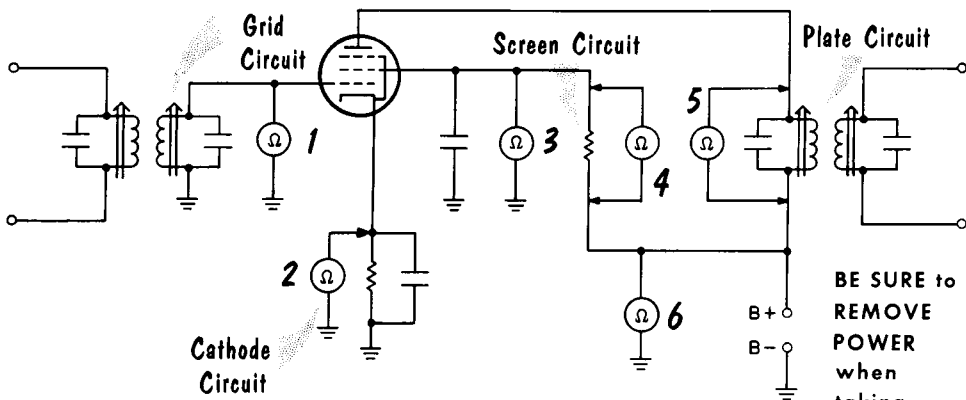
TEST POINT	TESTS FOR	TEST POINT	TESTS FOR
1	open coil shorted capacitor	4	open resistor
2	open resistor shorted capacitor	5	open coil shorted capacitor
3	shorted capacitor	6	short in B+ line

NOTE: Resistance readings will also indicate changed values

RESISTANCE READING POINTS

Signal Injection

A dynamic method of servicing is by means of signal injection. A signal from a signal generator is used as a substitute. An audio signal is first injected in the audio power output stage of the receiver, and then worked towards the detector. Care must be taken not to overload the receiver. This will check the audio circuits to the detector. From the detector to the converter a modulated i-f signal is used and a modulated r-f signal is used from the converter to the antenna.
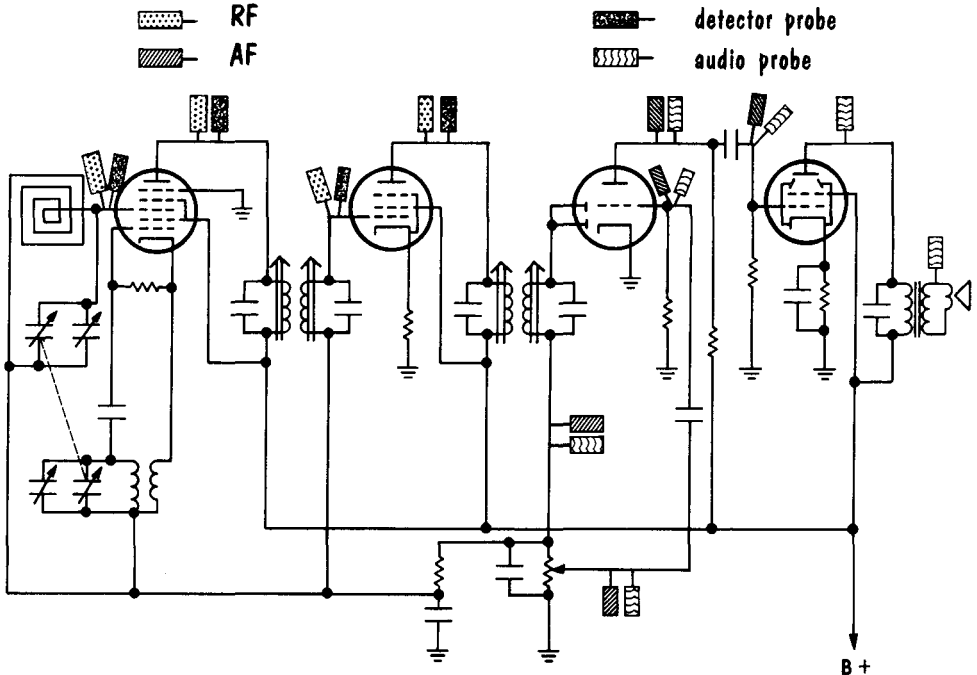
Signal Tracing

Another dynamic method of servicing that has gained many adherents is signal tracing. A signal tracer, as the name implies, will trace the signal from input to output—the opposite direction of signal injection. From the antenna to the detector a special detector probe is used to trace the signal path. From the detector to the loudspeaker an audio pickup probe traces the signal path.

Signal tracing has an advantage in that it does not load the circuit and requires no special precaution in its use.

Isolation of Trouble

When a set is brought in for repairs the customer's complaint should be noted, and must be confirmed by the serviceman. This is especially important since the complaint can be misleading.

Prior to any troubleshooting a visual and audible test should be made. If the set has a cathode-ray tuning indicator (magic eye), a visual test can be made before the set is removed from the cabinet. With the set turned on, the indicator tube should turn green; if not it means there is no B+. If the indicator tube turns green, the tuning shadow should be checked. If the shadow remains open at the widest angle while tuning through the dial, it indicates a defect in circuits ahead of the detector. When the indicator tube shadow opens and closes while tuning through the dial but no output is heard, it indicates a defect in circuits after the detector.
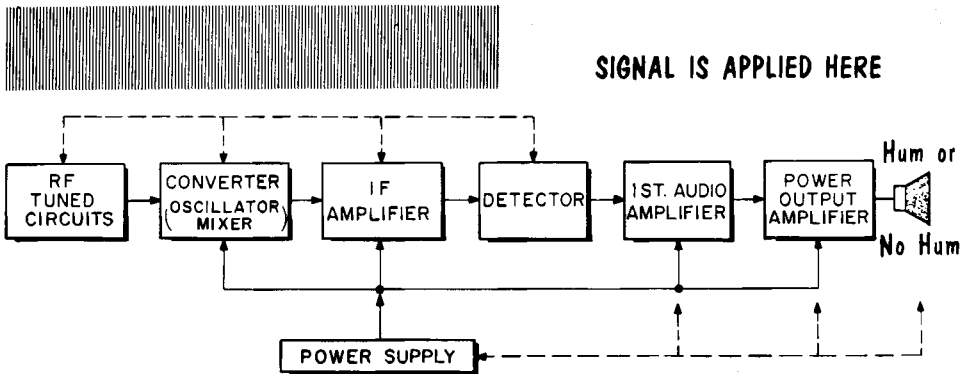
Whether the receiver has a tuning indicator or not, a visual test must be made for obvious defects such as charred resistors, open filaments, a completely dead filament string in series-wired filament circuits, etc. In addition to the visual test a simple audible test should be made — listening to the receiver for hum, excessive noise, a noisy or intermittent volume control, etc. Since tubes are responsible for a large percentage of the defects, they should be tested before taking the next steps.
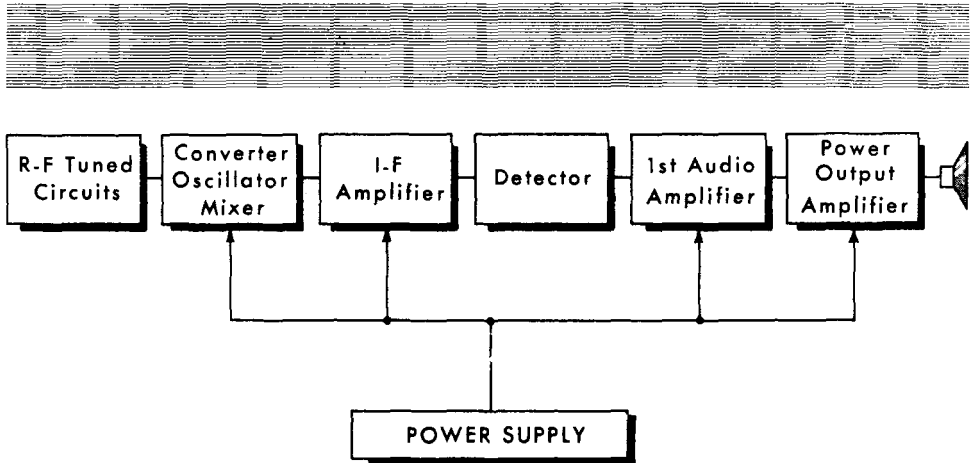
TYPICAL RECEIVER STAGES

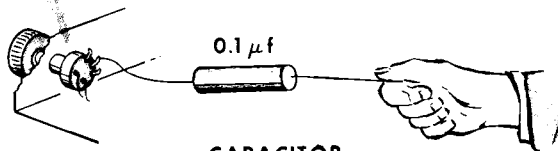## Isolation of Trouble (cont'd)

SIGNAL IS APPLIED HERE

```
┌────────┐   ┌──────────┐   ┌─────────┐   ┌────────┐   ┌──────────┐   ┌─────────┐
│   RF   │   │CONVERTER │   │   I F   │   │        │   │ 1ST. AUDIO│  │  POWER  │   Hum or
│ TUNED  │   │OSCILLATOR│   │AMPLIFIER│   │DETECTOR│   │ AMPLIFIER │  │ OUTPUT  │
│CIRCUITS│   │  MIXER   │   │         │   │        │   │           │  │AMPLIFIER│   No Hum
└────────┘   └──────────┘   └─────────┘   └────────┘   └──────────┘   └─────────┘
```

```
              ┌──────────────┐
              │ POWER SUPPLY │
              └──────────────┘
```

If there is no hum, trouble is here

VOLUME
CONTROL

0.1 μf

CAPACITOR
FOR SAFETY

Isolation Technique

A quick and effective method is to place a finger on the center tap or arm of the volume control of the receiver while it is on. There is no operating voltage at this point. If desired as a safety precaution, a coupling capacitor such as a 0.01-mfd capacitor can be held in the hand with the other end applied to the volume control arm or center tap. This applies enough induced 60-cycle signal to the grid of the first audio amplifier to produce a clear, audible 60-cycle hum in the speaker. If the hum is loud and distinct, two important portions of the receiver are quickly checked out: the power supply and the audio section. The defective stage, therefore, is the detector or a stage ahead of it. If no hum is heard in the speaker, it means that the audio circuits or the power supply is defective. In the latter case the power supply should be checked first since it is common to the entire receiver.

If the trouble is in or before the detector stage, a signal tracer can be applied from the r-f tuning circuit at the antenna toward the detector until the defective stage is reached. If the trouble is in the circuit after the detector, the power supply having been checked out, the signal tracer can be used with an audio probe to follow the signal from the detector load (volume control) towards the loudspeaker to locate the defective stage.

Isolation of Trouble (cont'd)

Signal injection could also be used in a similar manner. If the troubles are before the detector stage, a modulated i-f signal can be applied to the detector to check it out. The injected signal can then be moved back to the grid of the i-f amplifier tube. To check the converter or mixer tube a modulated r-f signal of the same frequency to which the receiver is tuned can be injected to the r-f grid of the converter or mixer tube. If an r-f amplifier stage is used the same r-f signal can be moved to the grid of the r-f amplifer tube. When the trouble is after the detector, the audio output of the signal generator can be applied to the power output stage and then worked back to the detector load to determine the inoperative stage.

FIRST Isolate the Defective Stage...

B+   AVC   B+
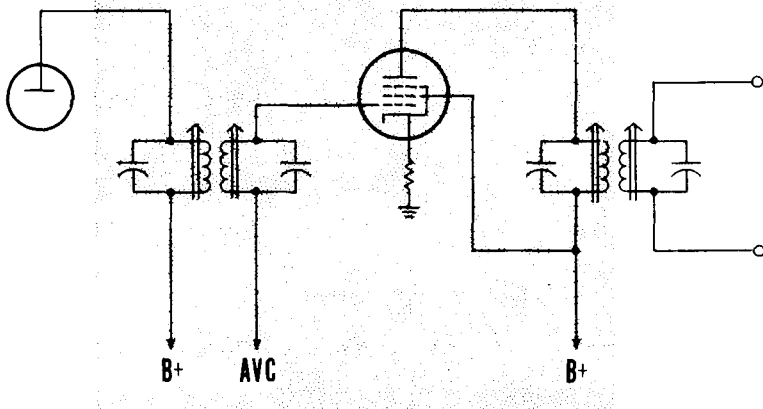
TYPICAL I-F AMPLIFIER STAGE

After locating the defective stage the next step is to isolate the defective circuit. Using as an example a typical i-f amplifier stage, see figure, it will be assumed that this is the defective stage. The next step is to determine the defective circuit within the stage. Using a signal tracer—if the signal is present at the grid but not at the plate, the difficulties are either in the tube or plate circuit. The plate circuit includes the cathode circuit, and the screen grid circuit or plate circuit. If the signal is present in the plate of the preceding stage but not at the grid of the i-f amplifier stage, the grid circuit is checked. The grid circuit includes the secondary of the i-f transformer, the AVC circuit, and the cathode circuit. Common to both circuits are the filament circuits.

Isolation of Trouble (cont'd)

The same procedure is used for signal injection. If the i-f signal injected at the grid is not heard at the loudspeaker, the plate circuit is checked. If the plate circuit checks out, the grid circuit has to be checked to find the cause of failure.

After the defect is isolated in the circuit, the next step is to isolate the defective part or parts. The voltages on all the tube elements are noted, including the filament voltage and the AVC voltage, if necessary. If the voltage readings are correct and the tube is good, the next step is to take resistance readings. In taking resistance readings of the i-f transformer, the resistance of the windings should be carefully noted. A shorted capacitor will give a zero reading while the correct reading should be a few ohms.

If all resistance readings check out the last resort is part substitution. This extreme measure is taken when all the other methods fail. An example would be a ferrite-core i-f transformer in which the core has cracked. All measurements would indicate a good transformer; the only way to find this difficulty would be to substitute another i-f transformer.

GRID CIRCUIT   PLATE CIRCUIT

B+   AVC   B+
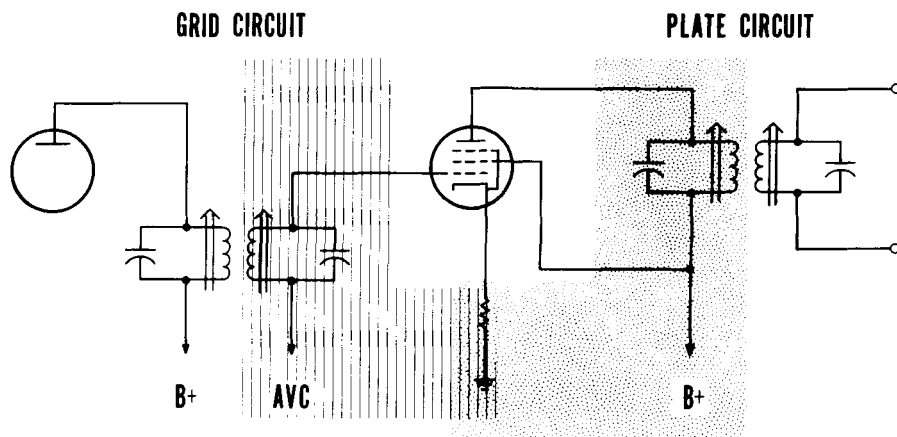
...THEN Isolate the Defective Circuit

After the defective part or parts are replaced, the set should be checked for proper operation. Quite often, in addition to the defect that caused the set to cease operating, or to operate so that it could not be used, there are other minor defects that should be remedied. These include such things as open pilot lights, alignment and dial tracking, cleaning the dial, chassis and cabinet, high hum level due to inefficient filters, etc.

Use the customer's complaints as a guide in locating receiver difficulties. Note the complaints on a service tag; don't trust to memory.

An obvious first step in servicing a receiver is a sharp visual inspection.

An important servicing technique is to reason the difficulties. Knowing the circuit operation helps in reasoning the nature of the difficulty.

The four most popular methods of receiver servicing are by voltage readings, resistance readings, signal injection, and signal tracing.

A good first step is taking voltage readings. Checking power supply voltages is a quick step since these voltages are common to the entire receiver.

For absolute tube circuit voltages the readings should be taken with the negative lead of the voltmeter at the cathode of the tube. In actual practice the negative probe of the meter is usually clamped to a common point.

An important precaution when taking ohmmeter readings is to be sure the receiver is turned off and the a-c plug removed from the outlet.

Prior to troubleshooting a receiver, a visual check should be made for charred resistors, open tube filaments, leaking capacitors, etc.

If visual and audible checks have not located the difficulty, three steps should be taken: isolate the defective stage, isolate the defective circuit, and isolate the defective part or parts.

A quick method of isolating the stage is to place a finger on the center tap of the volume control. A resulting 60-cycle hum indicates the power supply and audio section are checked out and the defect is in or ahead of the detector. No hum will indicate either a defective power supply or defective audio amplifier circuit.

Signal tracing or injection can be used to isolate the defective stage.

After locating the defective stage, use signal tracing or injection to locate the defective circuit or portion of the circuit.
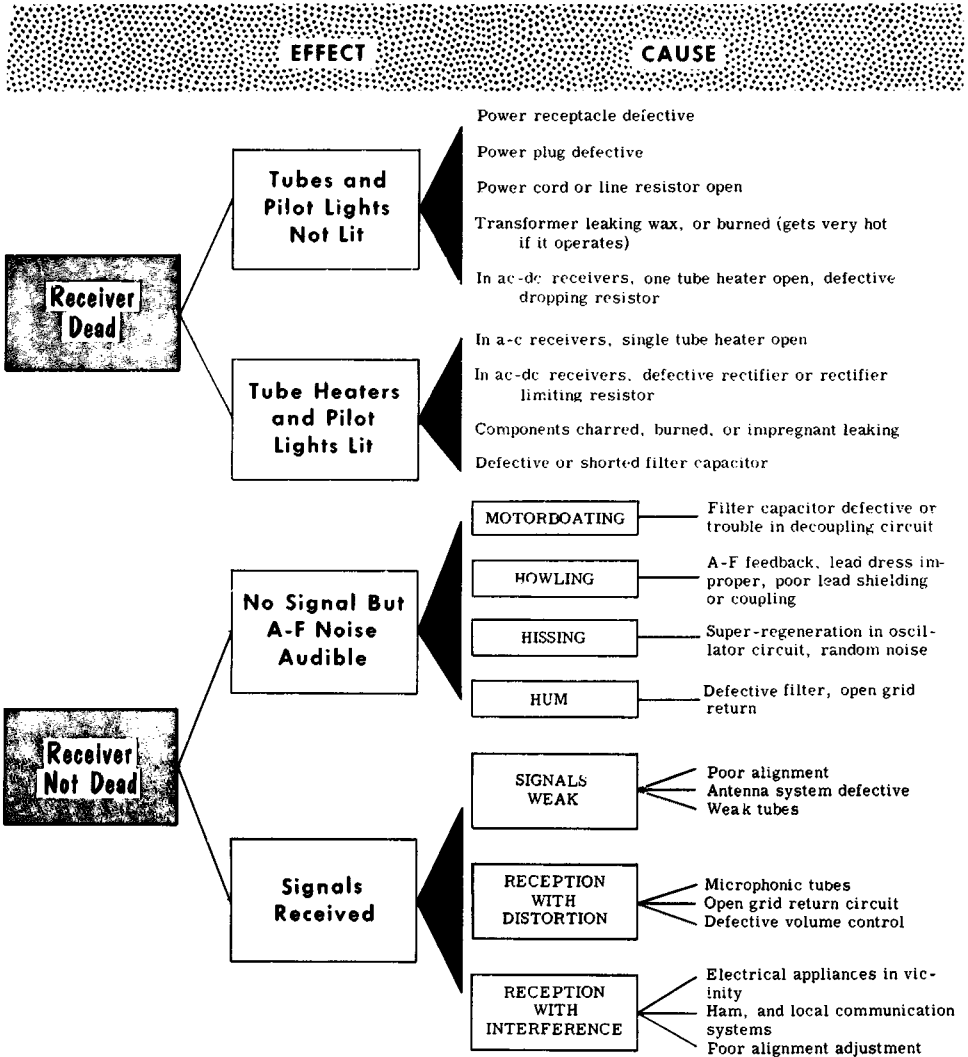
To isolate the defective component, voltage and/or resistance readings are taken. If all readings check good a last resort is part substitution.

REVIEW QUESTIONS

1.   What is the prime objective for servicing a receiver in the shortest possible time?

2.   In addition to a visual inspection, what other testing senses are available? Describe how you would use them.

3.   Do the four methods of servicing have to be used independently, or may they be combined?

4.   How low can the voltage readings be before we should correct them, even if they are not the source of the trouble?

5.   In servicing by signal injection, what precaution should be taken?

6.   What are the advantages of servicing by signal tracing?

7.   When a tuning eye indicator tube is available, describe what functions can be checked by the indicator tube.

8.   What are some of the minor defects that may require remedying after a receiver has been restored to operation?
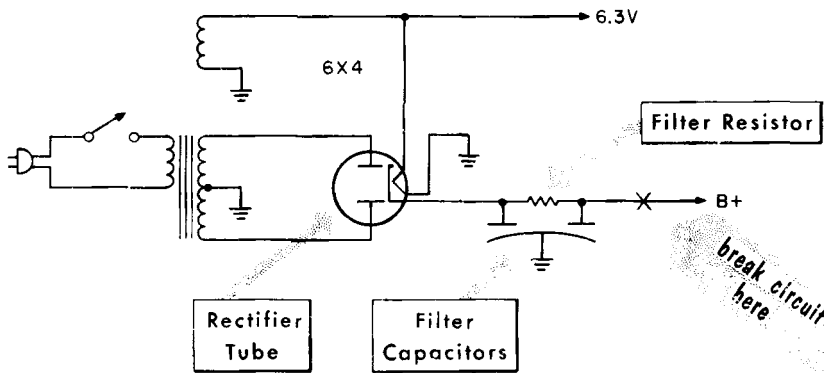
Servicing Superheterodyne Receivers

The preceding discussions were of a general nature; no specific stages were discussed except as examples. Knowing the methods of isolating and eliminating the defect in general is not in itself sufficient; additional discussion of typical stages is also required. Each stage can be serviced methodically with the least wasted time by following the reasoning of cause and effect. An example might be a power supply with low output voltage, resulting in

EFFECT	CAUSE

Receiver Dead

Tubes and Pilot Lights Not Lit
- Power receptacle defective
- Power plug defective
- Power cord or line resistor open
- Transformer leaking wax, or burned (gets very hot if it operates)
- In ac-dc receivers, one tube heater open, defective dropping resistor

Tube Heaters and Pilot Lights Lit
- In a-c receivers, single tube heater open
- In ac-dc receivers, defective rectifier or rectifier limiting resistor
- Components charred, burned, or impregnant leaking
- Defective or shorted filter capacitor

Receiver Not Dead

No Signal But A-F Noise Audible
- MOTORBOATING — Filter capacitor defective or trouble in decoupling circuit
- HOWLING — A-F feedback, lead dress improper, poor lead shielding or coupling
- HISSING — Super-regeneration in oscillator circuit, random noise
- HUM — Defective filter, open grid return

Signals Received
- SIGNALS WEAK — Poor alignment / Antenna system defective / Weak tubes
- RECEPTION WITH DISTORTION — Microphonic tubes / Open grid return circuit / Defective volume control
- RECEPTION WITH INTERFERENCE — Electrical appliances in vicinity / Ham, and local communication systems / Poor alignment adjustment

a check for only the possible causes for this effect, and not the entire power supply. All the stages discussed will be vacuum tube operated, and a discussion of transistor-operated, radio receiver circuits will be found in a later chapter.

A-C Power Supply

Rectifier Tube — 6X4 — 6.3V

Filter Resistor

B+

break circuit here

Rectifier Tube

Filter Capacitors

Basic A-C Power Supply

A typical transformer-operated a-c power supply is illustrated above. With no B+ output, a check is made of the a-c voltage to the primary winding. If this voltage is not present, the line cord, line plug, and switch are tested. If the line voltage is present at the primary, test for high voltage ac to the rectifier plates. If the high voltage is not present, the primary and secondary windings should be tested for an open circuit. With high voltage ac at the plates of the rectifier, verify the center tap of the secondary winding by testing the a-c winding from the common to either rectifier plate. If there is no reading the difficulty can be the opening of the center tap lead to common.

If the previous checks are positive and there is still no a-c output, the trouble is either a defective rectifier tube, no filament voltage to the rectifier, a shorted input filter capacitor, or open filter resistor. A shorted output filter capacitor could remove B-- from the output, but would permit a reading of voltage at the input filter capacitor.

To determine the cause of low B+ voltage, the circuit should be opened at the point indicated to remove the load at the output filter. If after doing this the B-- voltage rises to normal, it indicates a short circuit in some other stage. If the B-- voltage remains low. it indicates the difficulty is in the power supply, and the following tests can be made. Check the electrolytic capacitors for excessive leakage. Take an ohmmeter reading of the filter resistor for an increase in value. Replace the tube to check for low emission and verify that the correct a-c voltage is being applied to the rectifier plates.

AC-DC Power Supply

A typical ac-dc power supply is shown. With an a-c line input, the circuit becomes a simple half-wave rectifier; with a d-c input, the anode of the diode must be connected to the positive side of the line. The diode then acts merely as a conductor, permitting the dc to be applied directly to the circuits. The higher B-- voltage at the input to the filter can be applied to circuits that do not require a completely ripple-free voltage. The rectifier you may encounter in actual practice may be a vacuum tube or a selenium or silicon diode rectifier.

The output voltage of an ac-dc power supply is dependent upon the line voltage. Assuming an a-c line voltage of 115 volts, the average output voltage under load will be from 125 to 135 volts. When used with a d-c line,

AC-DC Power Supply
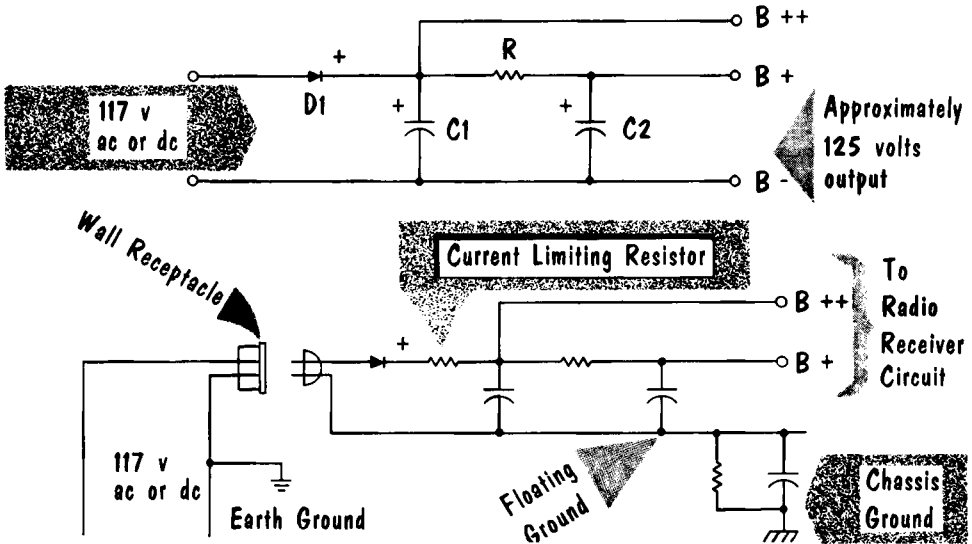
the receiver B+ will be the value of the d-c line voltage. In most receivers using an ac-dc power supply, the common line is floating, and returned to the chassis through a capacitor and high value resistor. With no B+ output voltage check if ac is being applied to the anode (plate), and if dc is at the cathode of the rectifier. If a-c voltage is present at the plate, but no d-c voltage is at the cathode, the rectifier should be checked. If the rectifier checks good, test for short-circuited filter capacitors or an open filter resistor.

With low B- the load to the power supply should be lifted at both filters. If the output voltage stays low, the following tests should be made: check the electrolytic capacitors for excessive leakage; take an ohmmeter reading of the filter resistor for an increase in value; and replace the rectifier to check for low emission

AC-DC Power Supply (cont'd)

A typical half-wave rectifier circuit with tube layout is shown. An open filament in the series filament circuit is perhaps the most common difficulty. The surge of line current through the tubes when they are cold will often open a filament, particularly in the higher voltage filaments of the rectifier
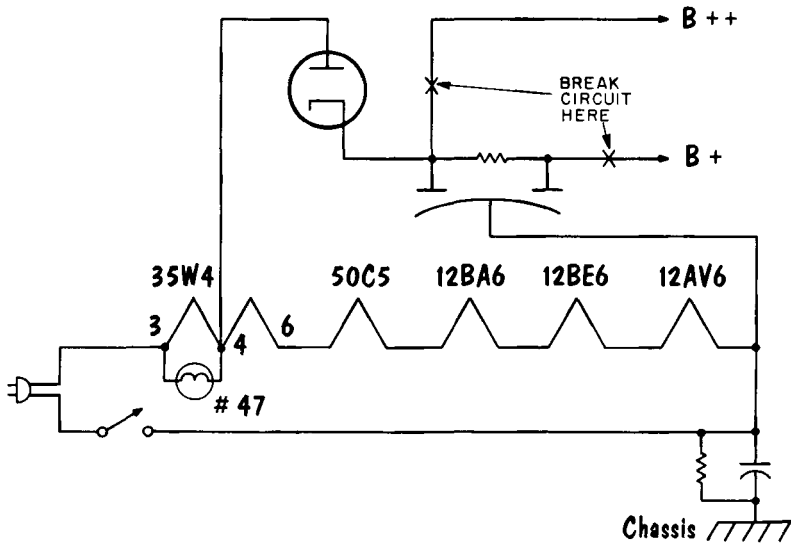
HALF-WAVE RECTIFIER CIRCUIT

and power output tubes. To check for an open filament, the ohmmeter probes are placed across the line cord plug with the switch turned on.

If an open circuit is indicated, the individual tubes can be removed one at a time for a continuity test of the filaments. The first tube tested should be the rectifier. Often the pilot light will have opened and not been replaced, causing the current that should have been flowing through the pilot light to flow through the portion of the filament that develops the pilot-light voltage drop. In time the excess current causes the filament to open between pins 3 and 4. Another possibility is that a short circuit in the receiver will cause excessive current flow through the rectifier tube and this portion of the filament. The next probable open filament is the power output tube due to its high filament voltage. Following the power output tube the tubes can be tested in any order. On occasion the difficulty may be an open line cord, defective a-c line cord plug, or an open switch.

Audio Power Output Stage

A typical, one tube (single ended), audio power output stage is illustrated. One of the more common ailments of this stage is distortion caused by a leaky coupling capacitor placing a positive voltage on the grid. A gassy (soft) tube will also cause distortion. The power output tube in ac-dc receivers is prone to develop a heater-to-cathode leakage, possibly due to the high filament voltage used. This leakage places 60 cycles in the plate circuit causing an annoying 60-cycle hum similar to that caused by defective filter capacitors.

A test speaker is often available in the shop to substitute for a questionable speaker or to save the trouble of having to remove the speaker from a cabinet. A good quality substitute speaker should be used since it may have to check out high-power output receivers as well as small receivers.

Output Tube

PM Speaker

Output Transformer

Cathode Bias Network

B+
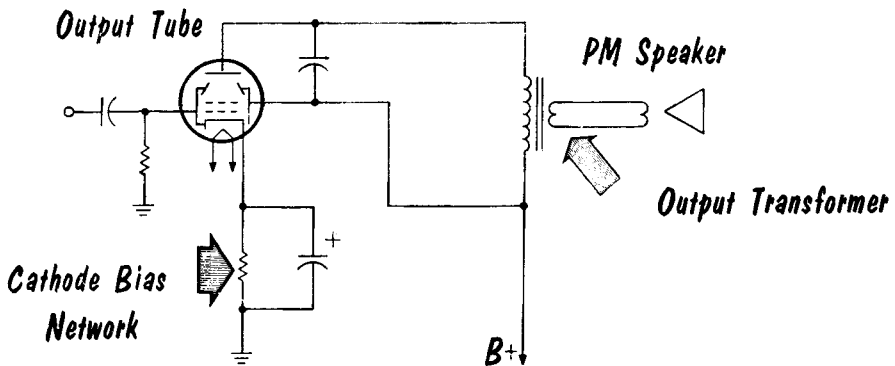
Typical Audio Power Output Stage

With no audio output the first step is to check the plate, screen, and cathode voltages. If all voltages are correct, listen carefully to the speaker. If there is some hum or a slight bit of noise, it indicates the speaker is operating and the troubles are probably before the speaker. If there is no hum or noise then the speaker should be tested. If the speaker checks good then the output transformer should be checked for an open secondary winding. An open primary winding would have been disclosed in a check of the plate voltage, and would cause high screen grid current. After the output transformer is replaced, check the tube carefully to be sure it has not been damaged.

Audio Power Output Stage (cont'd)

The majority of receivers use a capacitor across the primary of the output transformer. In some receivers the capacitor is placed from plate to ground. Should this capacitor short circuit, it would draw excessive current through the primary of the output transformer, probably damaging it. If the capacitor is defective it should be replaced with a 600-working-volts-rating capacitor.

A defective tube could also cause the loss of an audio output signal. An open cathode-bias resistor would have been disclosed in the check of voltages. An open grid-return resistor would block the tube and cut off any output signal. An open coupling capacitor is another possibility in testing for a lack of audio output signal.

Do not overlook any radio-phonograph switch that has inadvertently been placed in the phonograph position, cutting off the radio signal.

A disorted output signal can be caused by a warped voice coil, causing it to rub against the pole piece. Other causes of distortion could be a leaky or
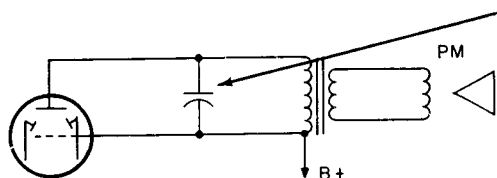
capacitor in
most receivers
is placed
across primary
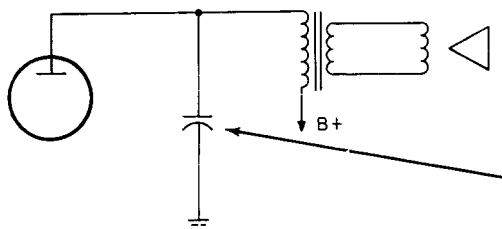
some capacitors may
be connected from
plate to ground
a shorted capacitor
may permanently
damage transformer

open tone-control capacitor, a gassy (soft) tube, a shorted coupling capacitor. A 60-cycle hum is often caused by a cathode-to-heater leakage in the tube.

Low output can be caused by a tube with low emission. Another cause could be an open, cathode bypass capacitor causing degeneration. Degeneration will aid the fidelity of the signal at the expense of the amplitude. Low B+ would have been disclosed with the check of plate and screen voltages. On rare occasions shorted turns in the output transformer could also cause a reduced output signal.

Push-Pull Power Output Stage
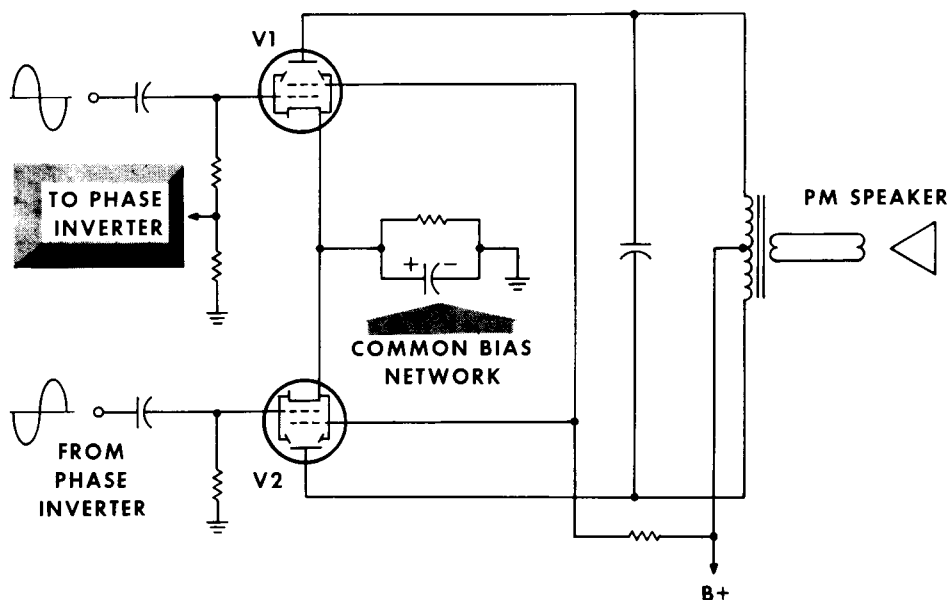
Push-Pull Audio Power Output Stage

A typical push-pull power-output audio amplifier is shown. The problems of a push-pull audio amplifier are similar to those of a single-ended amplifier with the addition of the special problems brought on by push-pull operation. The more common difficulties are leaky coupling capacitors, defective tubes, and speakers.

As in the single-ended amplifier with no audio output, the first step is to check out the plate, screen, and cathode voltages. With all voltages correct, listen carefully to the speaker—any audible hum or noise means that the speaker is operating and the troubles are before the speaker. If no hum or noise can be heard, the speaker voice coil should be tested for an open circuit. If the speaker voice coil tests good, then the output transformer should be tested for an open secondary winding. Should the capacitor across the primary short out, it would remove the plate load, and there would be no output. An open coupling capacitor to tube V1 would result in no signal to V1, and the phase inverter. In turn V2 would also have no signal input. An open cathode bias resistor would have shown up in checking the cathode voltage.

Push-pull audio circuits are in more common use in radio-phonograph combination receivers. It is important that the radio-phonograph switch be examined to be sure that it has not been set to the phonograph position, cutting off the radio signal.

Push-Pull Power Output Stage (cont'd)

Distortion in the output signal can be caused by a warped voice coil. Other causes of distortion could be that the capacitor across the output transformer primary is leaky or open. A gassy tube, a shorted coupling capacitor, a cathode resistor that has increased in value, or a shorted, cathode bypass capacitor can also cause distortion. A 60-cycle hum could be introduced by heater-to-cathode leakage in a tube.

If one output tube becomes defective, the other tube will still provide an output. With only one tube operating the reduced plate current would result in reduced cathode bias. The improper value of bias could cause distortion. Any difficulty causing a difference in gain between the phase inverter amplifier and the first audio amplifier could supply unequal values of signal to V1 and V2, causing distortion. Waveforms for Class A operation (plate current present during entire cycle of input for each tube) are shown in the illustration.

Low-value audio output could be caused by one tube or both tubes having low emission. An open cathode bypass capacitor could cause degeneration and reduce the output. Reduced values of plate or screen voltage would have been disclosed with the voltage check. Ocassionally, shorted turns in the output transformer could also cause a reduced output signal. An open circuit in one-half of the primary would have shown up in a check of the plate voltages. A defective tube with no output would result in low output since the other tube will still operate and provide a reduced output signal.

WAVEFORMS IN CLASS A OPERATION

Audio Amplifiers

A typical audio amplifier stage is shown. The tube used is usually the high-mu triode section of a duo-diode, high-mu triode tube. The cathode is at ground since it is common to both the detector stage and the first audio-amplifier stage. The low value of input signal received from the detector output requires a high-mu triode. A high-value, grid-return resistor of 5 to

Weak Output

Check B+, Plate Resistor,
Coupling Capacitor

Plate Voltage

Typical values: ac/dc — 50 volts
ac — 125 volts

To Grid of Power
Output Stage
Tube V1

**Volume
Control**

Plate Resistor
(usually high
value — typical:
250-470K)

B+

Coupling
Capacitor
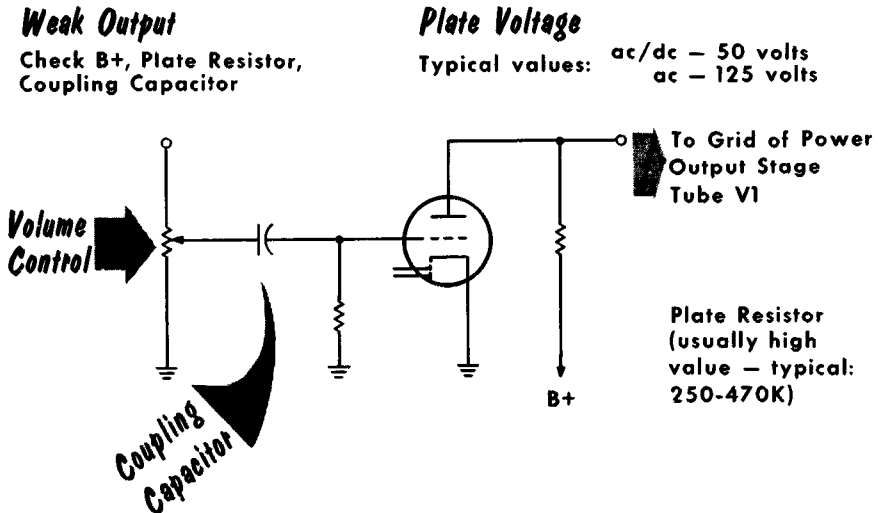
Audio Amplifier

10 megohms is used to develop contact bias. The high impedance grid input circuit makes it "hot" and prone to hum pick-up. This is especially true in radio-phonograph combinations where a long phonograph pick-up lead may be used. To keep hum to a minimum, shielded cable is used for the phonograph lead.

If there is no audio output of the first audio amplifier stage, the plate voltage should be checked. An open plate-load resistor would show up in this check. If the plate voltage and plate-load resistor check out, a good tube should be substituted. An open grid resistor could block the tube, resulting in no output. The same result would occur with an open coupling capacitor to the grid. A defective wiping-arm contact on the volume control potentiometer could remove the input signal to the amplifier. An open potentiometer (a defect in the detector circuit), would also result in no signal to the amplifier tube.

Phase Inverters

A typical phase-inverter stage is shown below. To achieve an equal but opposite signal an exact duplicate of the first audio-amplifier stage is most often used. The input signal is taken from a signal voltage divider in the grid of V1, one-half of the push-pull power-output stage. The problems in the phase-inverter stage are identical with those of the first audio-amplifier stage. The only difference is the possible loss of the input signal due to an open grid resistor in the grid circuit of V1.

To have the push-pull amplifier work effectively, the outputs from the audio amplifier and the phase inverter should both be approximately equal. If the value of the grid resistor of V1 should change, it may result in one output
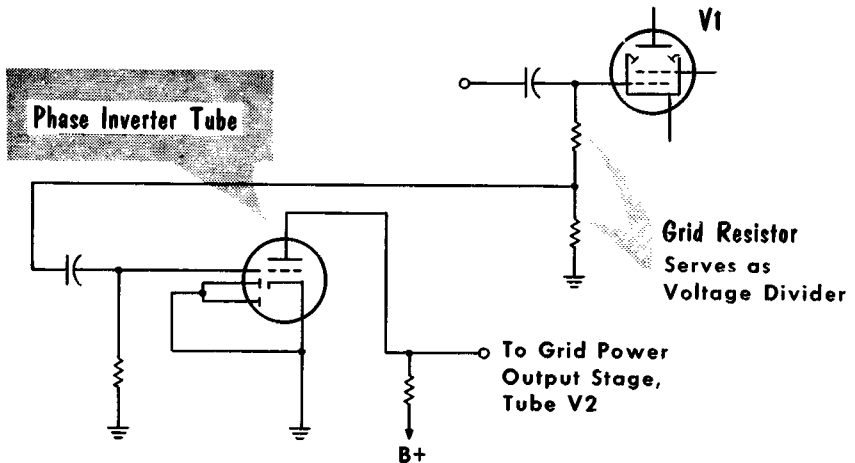
PHASE INVERTER CIRCUIT

being greater than the other; an undesirable effect. However, this change would be over the entire resistor, hence the voltage divider ratio would remain the same, and not affect the output. The resistor tap may not necessarily equal half the total value of the grid resistance since the gain of the tubes may not be equal; the difference in gain is compensated by the voltage divider network. A good test would be to check the outputs of the audio amplifier and phase inverter; they should be approximately equal. However, because the gain of the tubes may not be equal, a slight difference in the outputs can be expected and tolerated. If there is a large difference, then the tubes are likely suspects.

Detector Stage

The detector circuit shown below operates with signal voltages and currents, making it relatively trouble-free. The tube used is usually the diode portion of a duo-diode, high-mu triode tube. Perhaps the most prevalent trouble is due to misalignment. To check for misalignment the intermediate frequency should be injected with a signal generator at the grid of the

Crack in ferrite core could cause reduction in Q of tuned circuit.

Detector Diode

Reduced output can be caused by misalignment or an open filter capacitor (C1 or C2). An open C1 or C2 might cause oscillation by feeding back high i-f ripple through AVC line.

C1

R1

R3

AVC

C3   C2   R2   To First Audio Amplifier
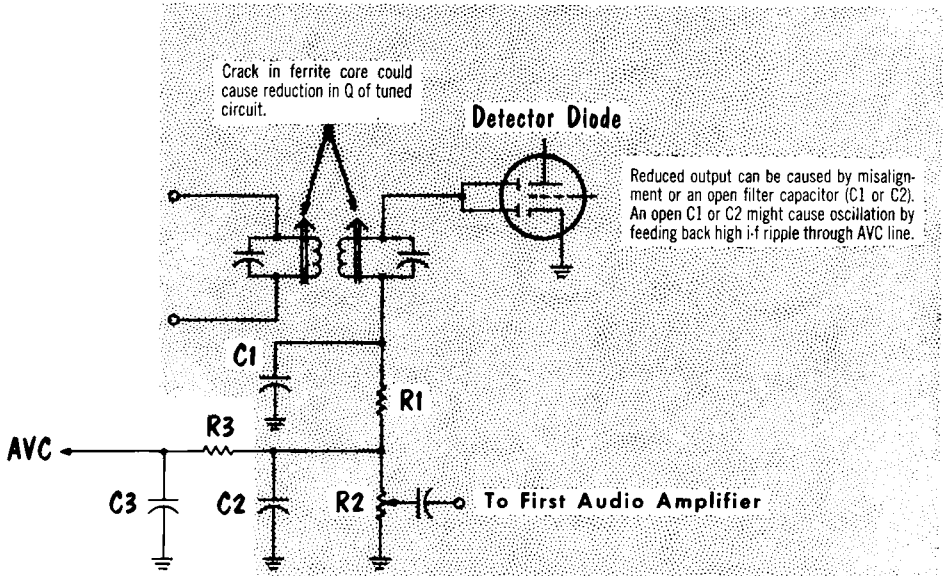
Detector Circuit

preceding i-f amplifier stage. The output frequency of the signal generator should then be varied above and below the intermediate frequency until an output signal is heard. If the output is above or below the correct frequency, the stage should be realigned.

In many detector circuits the filtering provided by R1 and C1 is omitted, with R2 and C2 providing all the filtering. The volume control is the only component of the circuit to receive any wear, and ocassionally it will open.

With the receiver tuned to a local station, there should be a voltage developed across the detector load. This signal can be checked with a VTVM, a cathode ray oscilloscope, or signal tracer. Loss of output voltage could be caused by misalignment as previously discussed, or an open secondary winding of the i-f transformer. The detector load, R2, or filter resistor, R1, could open to cause the loss of signal. The possibility of a defective tube must also be checked, keeping in mind that the tube may operate correctly as an audio amplifier and still be defective as a diode detector. A broken ferrite core or a shorted trimmer in the i-f transformer could also cause a signal loss.

AVC Circuit

Atmospheric conditions may cause fading of signals coming from certain stations. The resulting output of the receiver may, at one moment, be loud enough to blast the listener from his seat, while it may fade during the next moment to the point of becoming inaudible. With AVC this is prevented. The most frequently encountered AVC circuit is incorporated in the diode detector stage. Resistor R2 is the AVC load resistor and also the diode load.

AVC Circuit
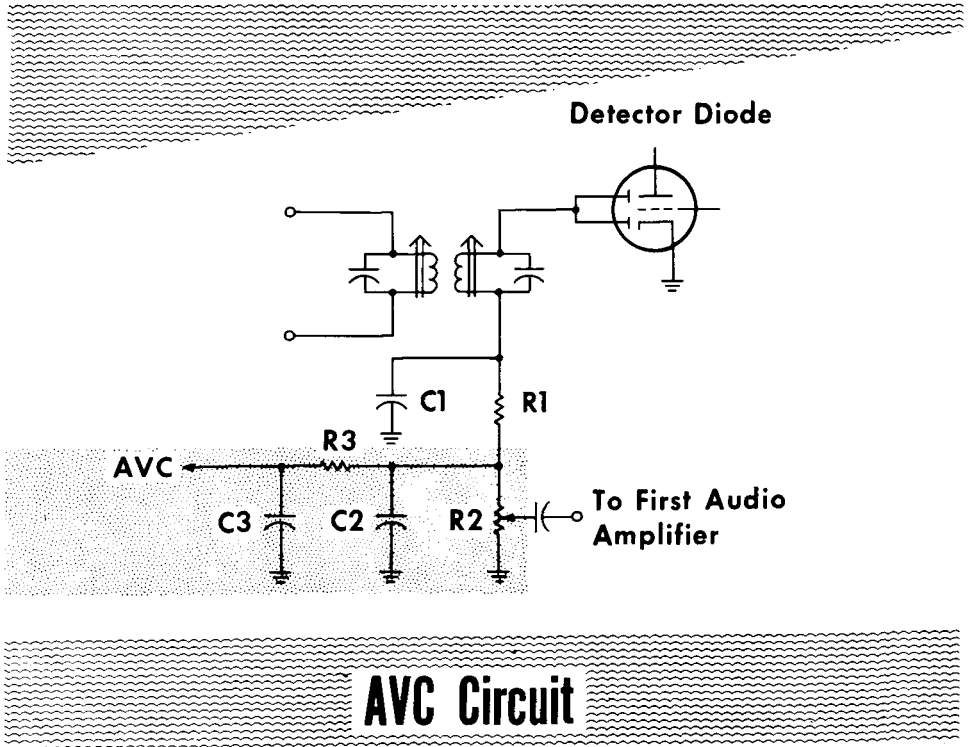
The AVC bias voltage is developed through the additional filtering of R3 and C3. With the low currents and voltages developed, these components give very little trouble. To check the AVC voltage a VTVM should be used to prevent loading the circuit. Should the filter capacitor become leaky or open, it would reduce the AVC bias voltage. The reduced bias will cause the set to act as though there is no AVC. For weak stations the volume will have to be turned up and for strong stations the volume will have to be reduced. On strong local stations the reduced bias will cause the tube to overload and distort.

Should filter resistor R3 open there would be no output since the grid return of the i-f and r-f stage is through AVC line. With no grid return the i-f and r-f amplifier tubes would block and pass no signal. The open grid circuit may also cause 60-cycle-hum pickup.

I-F Amplifier Stage

A typical i-f amplifier stage as used in ac-dc receivers is shown in the figure. The cathode bias resistor is a precaution — with no signal there will be no AVC bias developed, the grid will be at zero potential, and the tube will draw heavy plate current. The cathode bias resistor provides a small amount of bias to limit the plate current flow under no-signal conditions.

As in the detector stage a common difficulty is misalignment. To check this the intermediate frequency should be injected with a signal generator at the r-f grid of the converter tube. The output frequency of the signal generator should be varied above and below the intermediate frequency until an output signal is heard. If the output is above or below the correct frequency, the stage should be realigned.

AC-DC Receiver I-F Amplifier Circuit

I-F AMPLIFIER

AVC BIAS

B+
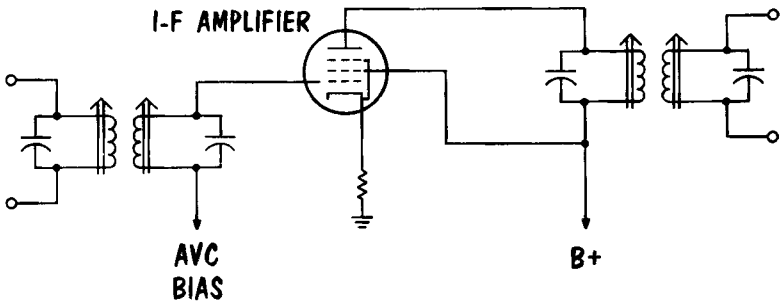
With no output from the i-f amplifier stage, the plate, screen, and cathode voltages (where a cathode resistor is used) should be checked. An open primary winding in the output i-f transformer would show up on the check of the plate voltage. An open cathode resistor would also cause the loss of a signal. A defective tube should be checked by inserting a substitute. To check for an open secondary winding of the input i-f transformer, check for presence of the bias voltage between grid and cathode or check with an ohmmeter continuity test. Another possibility for loss of signal is a shorted, i-f transformer trimmer capacitor, or a broken ferrite core.

I-F Amplifier Stage (cont'd)

Receivers with transformer-operated power supplies will most often have the i-f amplifier-tube screen-grid operate at a lower voltage than the plate. For this a voltage-dropping resistor is placed in series with the screen grid and a bypass capacitor is placed at the screen grid. The screen resistor can open or the screen bypass capacitor can short, removing the screen voltage.

A-C Receiver I-F Amplifier Circuit

I-F AMPLIFIER

AVC
BIAS

B+

When the bypass capacitor has shorted, be sure to check the screen resistor — it may have changed value due to the excess current flow through it caused by the shorted capacitor.

A reduced output signal can be a result of the cathode bias resistor changing value. Another reason could be a crack in the ferrite core causing a reduction in the Q of the i-f transformer tuned circuit. A low emission tube can also cause a reduction in the signal output. Reduced screen voltage because of an increase in the value of the screen grid resistor will have shown up in the voltage check. In receivers using transformer-operated power supplies with a screen dropping resistor and screen bypass capacitor, an open bypass capacitor would cause the screen resistor to act as a screen load. A signal will be developed at the screen grid that might cause feedback and oscillations.

Converter Stage

The converter stage is a multi-purpose stage that serves many functions. The r-f tuned circuits select the desired signal, the oscillator portion provides a locally-generated signal, and the tube mixes the two signals and develops the intermediate frequency in the plate circuit. The oscillator grid-leak bias is developed by R1 and C1; this is a convenient check point. The voltage at the oscillator grid should be approximately minus 5 volts or more if the oscillator is operating. No grid-bias voltage is a sign that the oscillator is inoperative. The AVC filter capacitor, C2, acts as the a-c signal ground-return path for both the oscillator and r-f tuned circuits.

An aged pentagrid converter tube can get fussy — it may not oscillate over the entire range. When tested with a tube tester it may still check satisfactory. The proper test for such a tube to replace it with a good tube. Another common difficulty with the pentagrid converter is cathode-to-heater leakage causing 60-cycle hum.

OPEN LOOP would cause high hum level due to 60-cycle pickup of the floating r-f grid

PENTAGRID CONVERTER

SHORTED CAPACITOR would remove signal

B +

R1

C1

AVC BIAS

C2
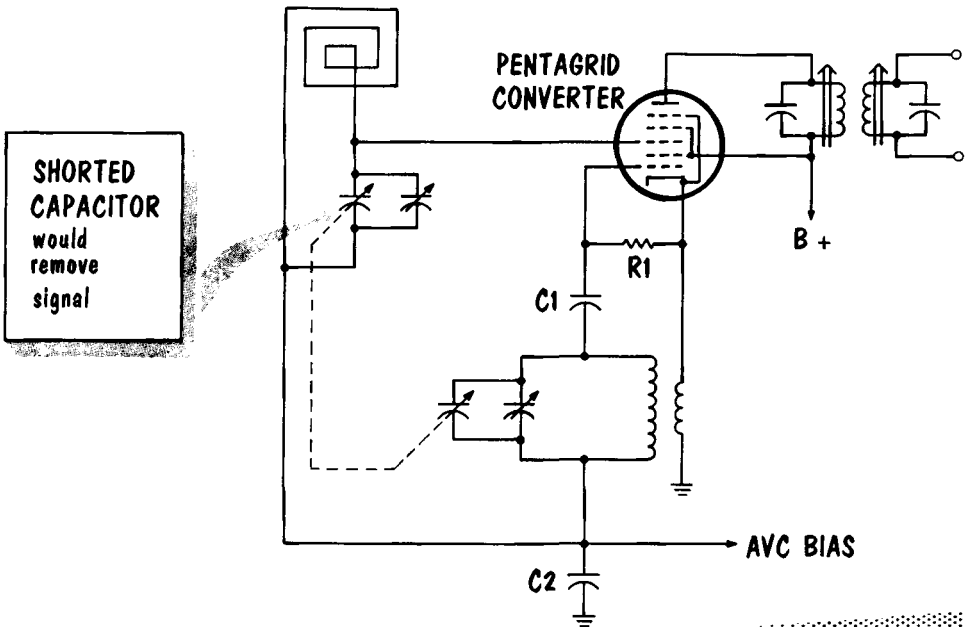
CONVERTER STAGE

Converter Stage (cont'd)

In many receivers a voltage-dropping resistor reduces the screen grid voltage. A bypass capacitor is used at the screen grid to prevent the voltage-dropping resistor from acting as a screen load.

B+
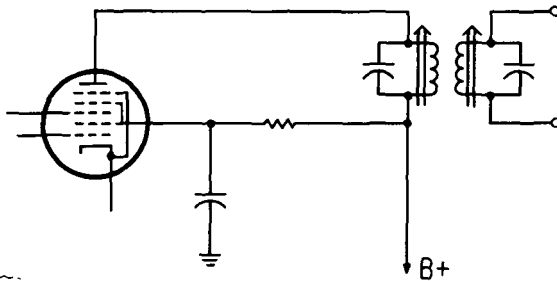
ALTERNATE SCREEN GRID CIRCUIT
used in a-c operated receivers

With no output signal the first step is to check the plate, screen, and oscillator-grid voltages. An open primary winding in the i-f transformer will show up in the plate voltage check. Another difficulty that could be caused by the i-f transformer is a shorted trimmer capicitor or a broken ferrite core. As mentioned previously, when the tube is suspect it should be replaced with a good tube. A check of the screen voltage would disclose an open screen-voltage-dropping resistor or a shorted screen-bypass capacitor.

When the voltage check indicates plate and screen voltages are present in the proper values but there is no voltage at the oscillator grid, it indicates that no oscillations are taking place. The first thing to test is the tube by replacing it with a good tube. The oscillator coil primary and secondary should be checked with an ohmmeter for continuity. Should the oscillator coil be defective, it is best to replace it with a direct substitute. This will prevent any difficulty in having the r-f and oscillator circuits track each other during the alignment procedure.

Another possibility for lack of oscillation could be a short circuit in the oscillator tuning capacitor or in its associated trimmer capacitor. On rare occasions resistor R1 will open or capacitor C1 will open or short. Should the AVC filter capacitor, C2, open, the a-c signal ground-return path would be a high impedance, and could also cause the oscillator to cease functioning.

R-F Amplifier Stage

Very little trouble is encountered in r-f amplifier stages. Ocassionally a loop antenna will open or the tuning capacitor will short circuit. A small amount of cathode bias is developed as a precaution. With no signal there will be no AVC bias developed, the control grid will be at zero potential, and the tube will draw heavy plate current. The small amount of cathode bias limits the plate current flow under no-signal conditions.

Because of the added number of stages and the possibility of feedback between the stages, an additional decoupling filter, R1 and C1, is used in the AVC circuit.

Should capacitor C1 of the AVC decoupling filter short, there would be no bias at the control grid of the amplifier tube. With no bias the tube would operate at full gain, and, on strong local signals, the tube would overload
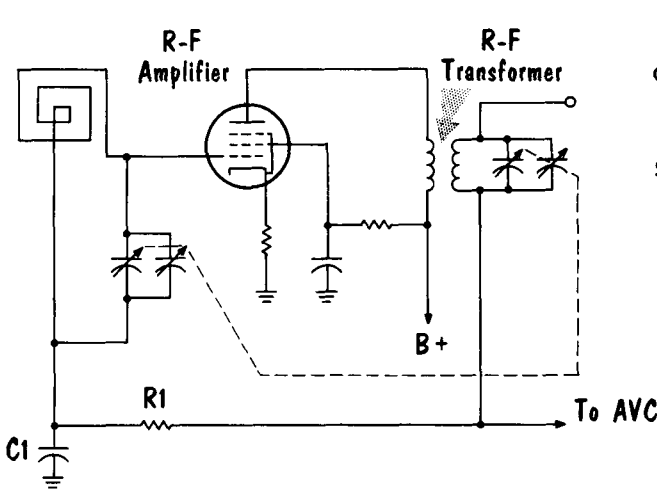
R-F Amplifier Circuit

and cause distortion. An open antenna loop would leave the control grid floating to pick up a 60-cycle hum. Should resistor R1 open, the grid return path would be open, and the grid would be floating and pick up a 60-cycle hum.

Reduced output of the r-f amplifier stage could be due to a reduced value of B+ voltage, or a low emission tube. Should the cathode bias resistor increase in value it will reduce the output signal. An open screen bypass capacitor would cause the screen resistor to act as a screen load. A signal will be developed at the screen grid that might cause feedback and oscillation. An increase in the value of the screen dropping resistor would reduce the screen voltage in turn reducing the gain of the stage.

Alignment of Superheterodynes

There are many tuned circuits, operating at different frequencies, in a superheterodyne receiver A major point in maintenance and proper operation is that they all be tuned to the proper frequencies; this is known as alignment.

There are three tuned circuits or sets of tuned circuits that must be adjusted — the i-f amplifier, the local oscillator, and the tuned r-f amplifier. These circuits should be adjusted in the order given. To align the i-f amplifier circuits, the local oscillator and AVC circuit must be made inoperative.

R-F Alignment

I-F Alignment

Oscillator Alignment

C1

From Detector
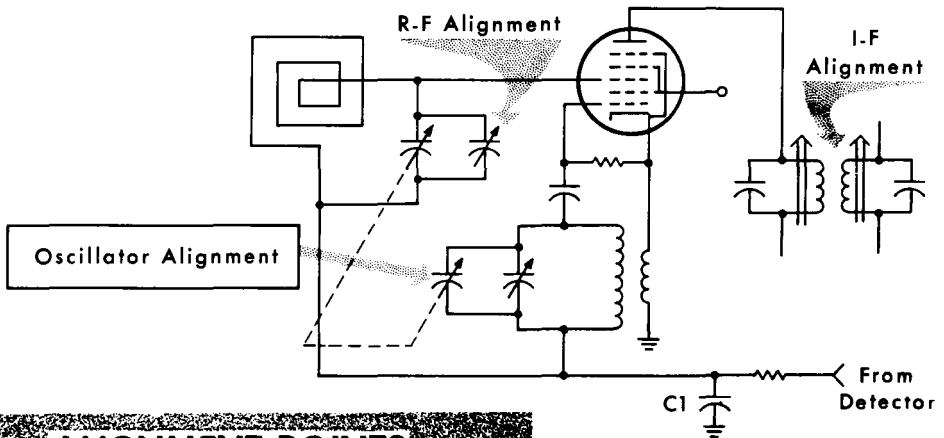
ALIGNMENT POINTS

The simplest method to disable the oscillator is to place a small length of solder across the oscillator stator plates, then turn the rotor plates all the way out till they rest firmly against the lengh of solder, which will short the oscillator variable capacitor and disable the oscillator.

To disable the AVC the bias across the AVC filter capacitor, C1, should be shorted to common. With the local oscillator and AVC bias voltage disabled, the modulated output of the r-f signal generator is coupled through a 0.01 mfd capacitor to the r-f grid of the converter. This is easily accessible at the r-f section of the variable tuning capacitor — the lug on the side of the variable tuning capacitor is connected to the stator plates. The stator plates are directly connected to the r-f grid of the converter tube.

The output frequency of the r-f signal generator is carefully set to the correct value of the intermediate frequency as noted by markings on the transformer or printed on the schematic diagram of the receiver. It is important that this value be correct, otherwise the circuit will not tune and may inadvertently be seriously detuned. The modulation signal should then be heard in the speaker output. Although the variations in output can be heard by ear, an output meter is more reliable since it will register small inaudible variations. The output meter, an a-c voltmeter, is placed across the speaker voice coil.

Alignment of Superheterodynes (cont'd)

600 kc — 1400 kc
(modulated)   signal generator

R-F

First, align the...   →   then, the...

455 kc
(modulated)

I-F

and finally, the...

adjust for
maximum
response

| R-F AMPLIFIER | CONVERTER | I-F AMPLIFIER | I-F AMPLIFIER | AUDIO SECTION |

— i-f transformers —

adjust

OSCILLATOR
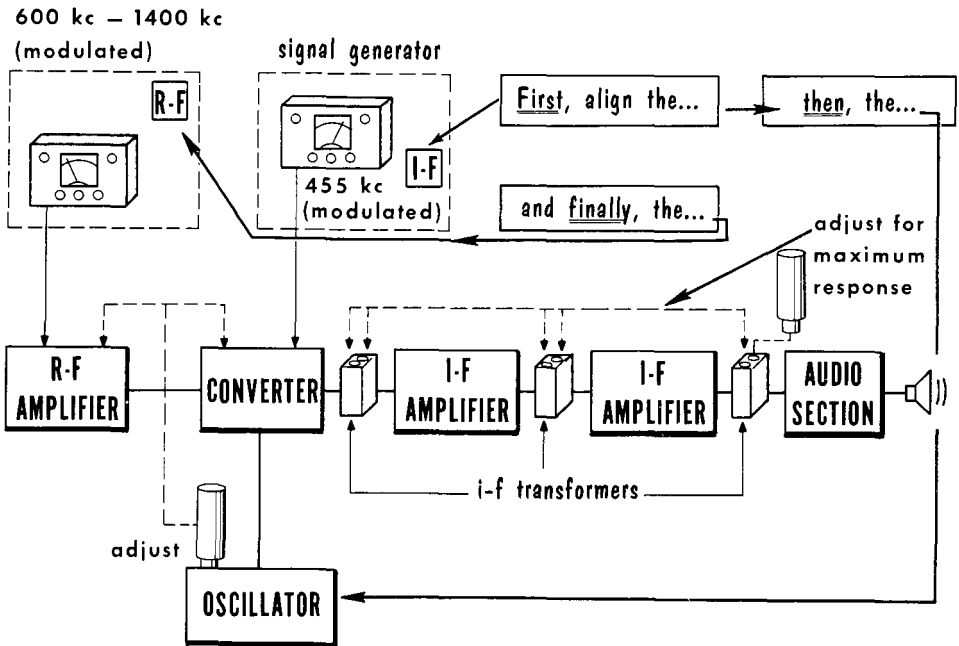
Alignment Involves the Adjustment Of All
Tuned Circuits For Optimum Sensitivity and Selectivity

With the receiver volume control turned up to full gain, the output of the r-f signal generator is set for a reasonable meter indication. Using an insulated alignment tool, the output i-f transformer primary and secondary circuits are tuned for maximum gain as indicated on the output meter. The next step is to align the input i-f transformer primary and secondary circuits. If two stages of i-f amplification are being used, the interstage i-f transformer is followed by the input i-f transformer. Should the output greatly increase during alignment, the output of the r-f signal generator should be reduced. When all the i-f transformers are aligned, it is good policy to provide a final check by repeating the procedure.

Should the i-f transformers have been tampered with, the preceding procedure will be slightly changed: The output of the signal generator is coupled to the grid of the i-f amplifier, and the output i-f transformer primary and secondary circuits are aligned. The output of the r-f signal generator is then coupled to the r-f grid of the converter tube, and the input i-f transformer is aligned. After the i-f transformers have been aligned, the procedure should be repeated.

Alignment of Superheterodynes (cont'd)

To align the oscillator the small length of solder used to short the oscillator tuning capacitor must be removed. The next step is very important: Check the dial pointer to be sure it is set properly. To do this set the variable tuning capacitor all the way in for maximum capacity. This should set the dial pointer at the extreme low end of the calibration. Then turn the variable tuning capacitor all the way out for minimum capacity. This should set the dial pointer to the extreme high end of the calibration. If the dial pointer is off it should carefully be reset before proceeding. Some receivers have the dial markings on a glass or clear plastic plate mounted on the cabinet. This may necessitate sliding the receivers in and out of the cabinet to check the pointer. Some receivers have markings on the background plate used to set the pointer with the receiver out of the cabinet.

With the pointer accurately set, the next step is to remove the r-f signal generator output from the r-f grid of the converter tube, and couple a signal to the antenna coil. The signal is coupled to the antenna binding post through a 200-mmfd coupling capacitor. When a loop antenna is used, merely placing the output lead of the r-f signal generator on or near the loop without making a direct electrical connection will induce sufficient signal voltage in the loop antenna. Set the modulated output of the r-f signal generator to a frequency of 1400 kc, and set the dial pointer to 1400 kc. If the oscillator is correctly set, it should beat with the r-f signal, and produce a signal at the value of the i-f tuned circuits. Adjust the trimmer of the oscillator section of the variable tuning capacitor for maximum output.

If plates are fully meshed, the dial should point to low end of the band. In this case, something is wrong
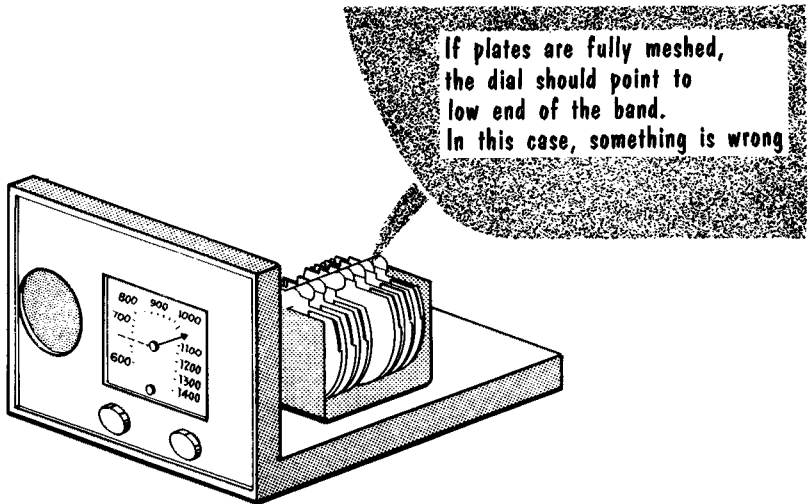
Alignment of Superheterodynes (cont'd)

Quite often the r-f signal generator being used may not be accurate. To check both the oscillator setting and the r-f signal generator, a station at a known frequency should be tuned in. If the oscillator trimmer and dial pointer are correctly set, the station should be at the correct position on the pointer. At times the oscillator frequency is so far off that the i-f beat frequency comes in at some other point on the dial, perhaps 1450 kc, while at the correct frequency of 1400 kc, no signal is heard. When this happens the dial pointer can be set to a slightly lower frequency, say 1440 kc, where the beat can still be heard. At this frequency the trimmer should be set for maximum. The dial is then slowly moved down step by step 1430 kc, 1420 kc, etc., until it is finally at the correct position of 1400 kc.

Location of PADDER CAPACITOR

Trimmer

Padder

recheck after padder is set
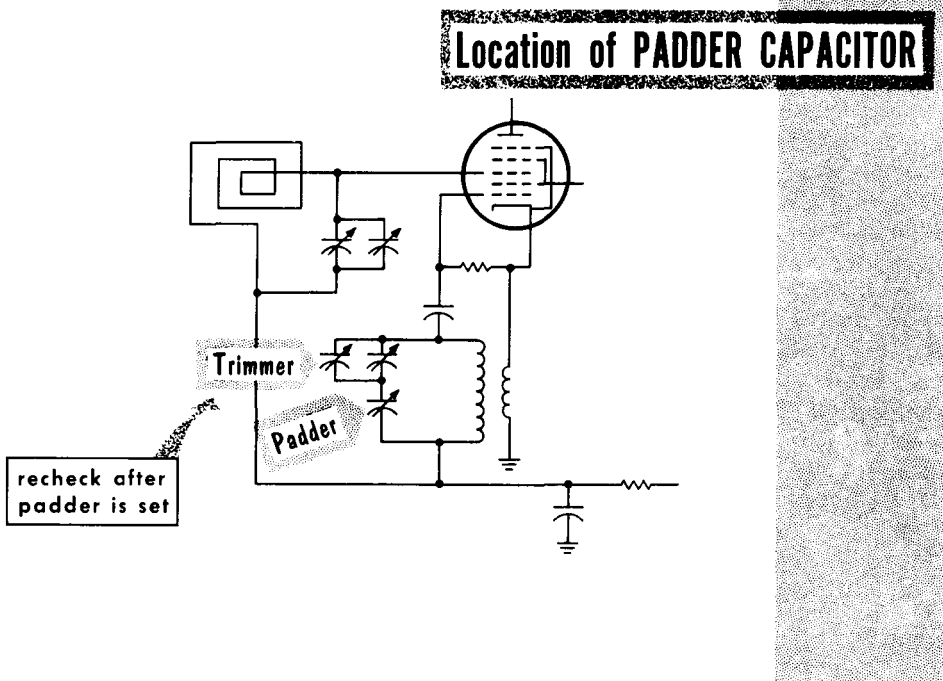
When the oscillator circuit contains a padder capacitor, the padder capacitor is adjusted at a low frequency, say 600 kc. The modulated output of the r-f signal generator is set to 600 kc, and the padder capacitor adjusted for maximum output. While adjusting the padder, the variable tuning capacitor is gently rocked back and forth to be sure that the padder is set at the proper point on the dial. After the padder is set it is good practice to recheck the trimmer at 1400 kc. With the output of the r-f signal generator set at 1400 kc and the receiver tuned to 1400 kc, the trimmer of the r-f section of the variable tuning capacitor is adjusted for maximum output.

In a typical a-c power supply with no B-plus output, first test for a-c voltages of the power transformer's primary and secondary. Also test the rectifier tube, filter capacitors, and filter resistor.

In an ac-dc power supply, the most common difficulty is an open filament in the series filament circuit. In testing for an open filament, the first tube tested should be the rectifier, the next tube the power output amplifier, and the remaining tubes in any order.

With an a-c line voltage of 115 volts, the average output voltage of an ac-dc power supply under load is from 125 to 135 volts.

In an audio power output stage, a leaky grid coupling capacitor, a gassy tube, or heater-to-cathode leakage are common difficulties.

When replacing a defective capacitor from the plate of the output tube to ground, use a replacement with a 600 working volts rating.

If one tube of a push-pull amplifier becomes defective, the remaining tube will still provide an output, though it may be reduced and distorted.

The detector circuit operates with signal voltages and currents—it is relatively trouble-free with the major problem being output i-f transformer misalignment.

A common trouble in the i-f amplifier stage is misalignment.

In converter stages, a tube with reduced emission may test satisfactorily though the tube may not oscillate over the entire tuning range, or it may oscillate intermittently. Another cause of a loss, or intermittent oscillation, is shorted plates in the tuning capacitor.

R-f amplifier stages are relatively trouble-free, with an open loop antenna or shorted tuning capacitor being the major problems.

In aligning the tuned circuits of the i-f amplifier, local oscillator, and r-f amplifier should be adjusted in that order.

During alignment of the i-f amplifier tuned circuits, the local oscillator and AVC circuits are made inoperative.

REVIEW QUESTIONS

1. In testing power supply electrolytic capacitors for excessive leakage, what would be a typically correct reading on the ohmmeter?
2. In an ac-dc receiver, what is the method of checking at one time the entire series string of tubes?
3. What important fact must be kept in mind when using a substitute speaker to test high-fidelity audio amplifier circuits?
4. Explain the necessity for reading the AVC voltage with a VTVM.
5. What is the purpose of the small value cathode bias resistor often found in i-f amplifier stages?
6. Explain the necessity of an additional AVC bias decoupling filter at the grid of the r-f amplifier stage.
7. Describe a simple method of disabling the local oscillator for alignment of the i-f circuits.
8. What is the important reason for using an output meter for alignment?
9. At what frequency do we adjust the padder capacitor? The trimmer capacitor?

Servicing Portable Receivers

With the exception of the power supply, the stages used in a portable superheterodyne radio are identical to those in a table or console model radio. To service a portable receiver the same steps are used to isolate the troublesome stage and defective component. In using test probes the probe may slip and short together two tube-socket lugs, burning out a tube. For example, the probe placed on pin #2 of a type 1R5 tube may slip and short the pin to pin #1, the filament connection, resulting in applied plate voltage to the filament. Applying tape, or in any manner covering the probe, and leaving uncovered approximately $\frac{1}{8}$-inch of the extreme tip to make electrical contact, is a precaution against shorting.

AC
DC

BATTERY

TYPICAL
THREE-WAY
PORTABLE
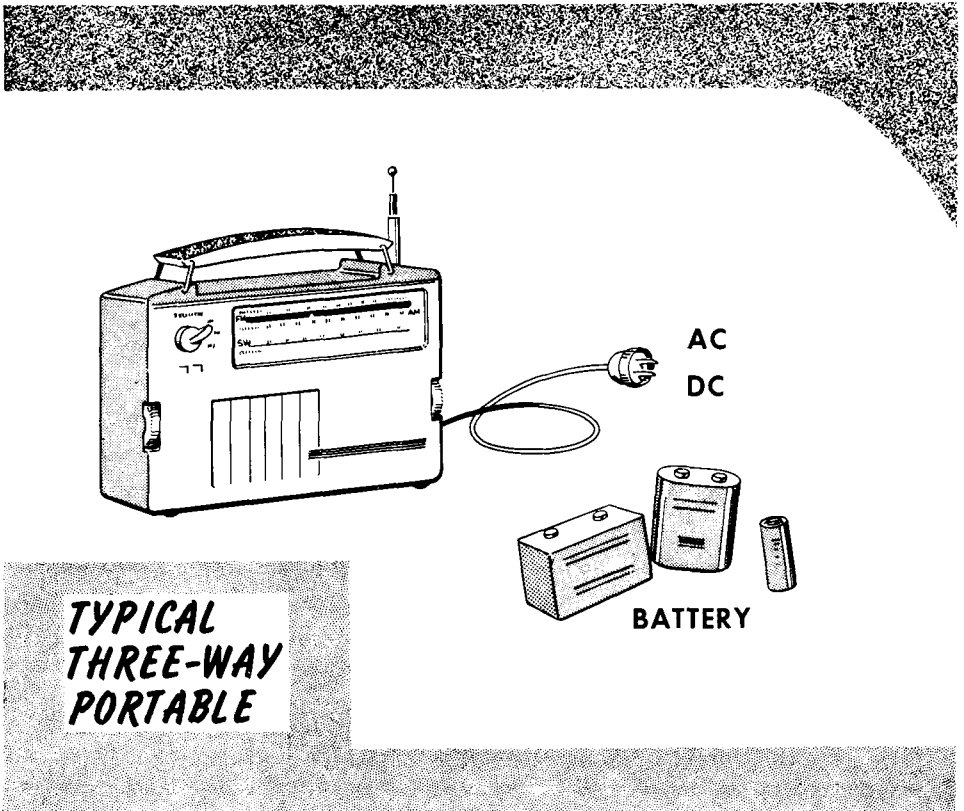
The tubes used in portable radios have 1.4-volt or 2.8-volt center tapped, directly-heated filament cathodes that operate on dc. When filament voltage is applied, there is no warm up time, resulting in instant tube operation.

The main difference between a normal radio and a portable radio, besides the tubes used, is the power supply. Some portables are operated by batteries only, and others have a combination power supply that operates on ac, dc, or batteries — "three-way" portables.

Battery Operated Portables

One of the defects common to battery operated portables radios is weak batteries. When checking batteries it is best to use one of the special battery testers available. These will check a battery under load, and have a good-fair-bad meter scale. Actually seeing this reading on the meter is more impressive to a customer than taking the serviceman's word for the battery condition as read on a voltmeter. Labeling batteries with the store's name and date of purchase will protect the customer from purchasing weak batteries, and protect the store from receiving defective batteries in exchange for new ones under the guise that they were defective upon purchase. If no battery tester or substitute battery is available, batteries can be checked under load by leaving them plugged in to the receiver. With the receiver turned on, a voltmeter check of the battery voltage will determine whether or not it is run down. Over a 10 per cent reduction in the rated voltage indicates a weak battery.

When testing for open tube filaments be sure to use an ohmmeter that does not use more than a single cell in the ohmmeter circuit. When using a tube tester be very careful to set it for correct filament voltage.

loop antenna hidden in cover

hinge antenna lead

TYPICAL BATTERY OPERATED PORTABLE
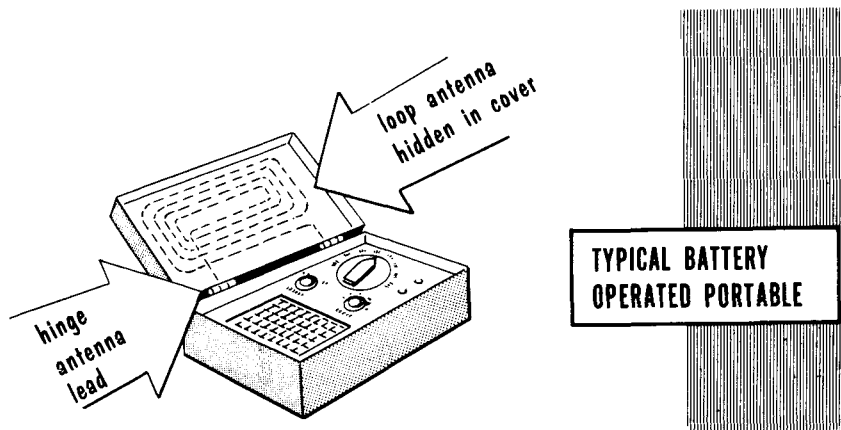
The converter tube used in most battery-operated receivers, the type 1R5, is fussy, particularly in regard to the filament and or B+ voltage. Usually all the other stages will work but not the converter, although the tube checks good on a tube tester.

If the filament and or B+ voltage is a little low, the tube may not operate. If the tube is old and its emission has dropped off, it may become intermittent. The best test of a questionable type 1R5 tube is replacement with a good duplicate.

Portable receivers are subject to considerable rough handling, which often leads to open filaments, and mechanical defects such as broken cases, open loop antenna leads, etc. A typical complaint is distortion caused by sand from the local beach settling between the voice coil and pole piece of the speaker.

SCHEMATIC OF BATTERY OPERATED PORTABLE

Pentagrid Converter   I-F Amplifier   Detector--First Audio Amplifier   Power Amplifier

X

AVC Filter

X

X

R1

X

+

Filament Supply

A

B

+

+
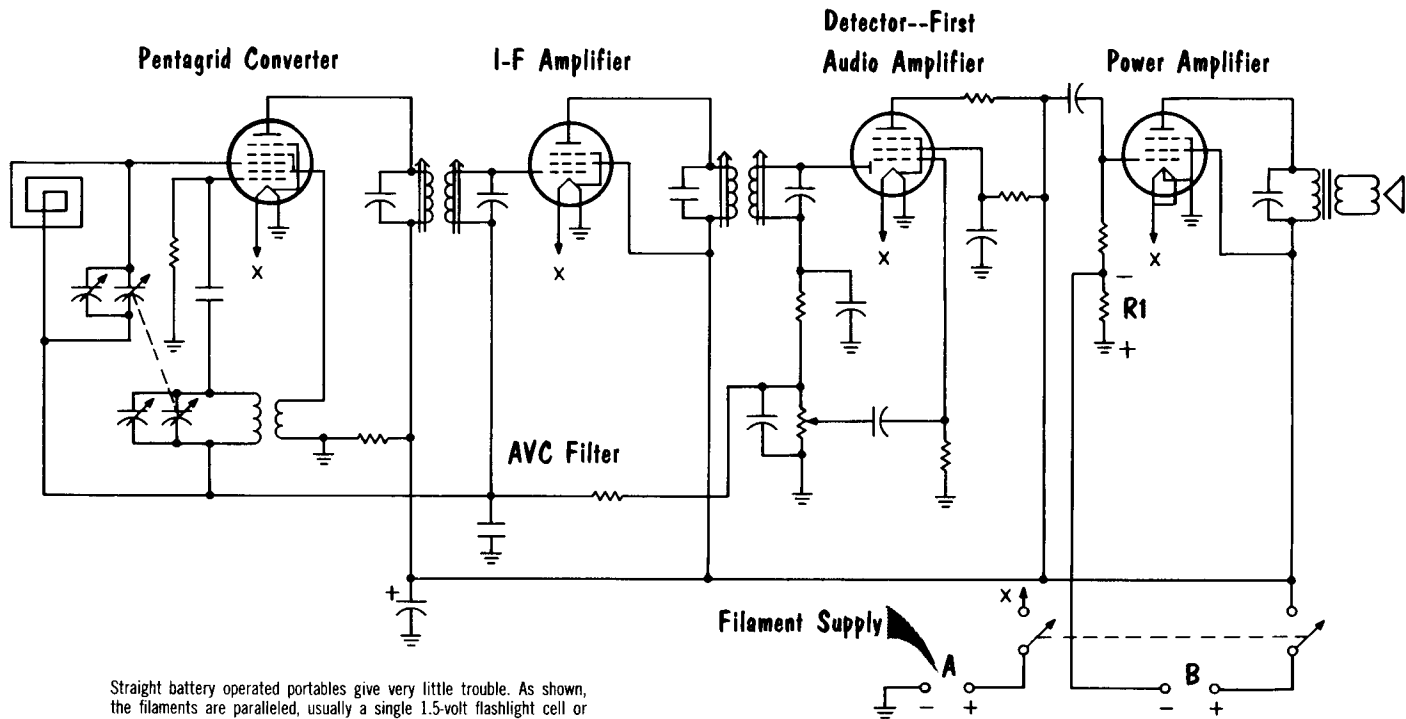
Straight battery operated portables give very little trouble. As shown, the filaments are paralleled, usually a single 1.5-volt flashlight cell or two or more cells in parallel, for increased life. Notice the method used to obtain bias for the power output stage. The current flow through R1 will provide a voltage drop with the polarities as shown. The grid return resistor is tied to the negative end of R1 to provide bias for the power output tube.

Battery, AC-DC (Three-Way) Portables

The d-c voltage for the filaments is obtained either from batteries, or the d-c output of the rectifier. A series resistor is used to drop the voltage to the required value for the series wired filaments. Any sudden surge in line voltage would cause a slight increase in voltage to the filaments, and the increase will be distributed among all the filaments. Because of this no one filament will have too large a value of filament voltage, preventing excessive filament burnouts.

A precautionary measure before servicing a three-way portable receiver is to test the filaments of each tube. Filament burnouts are a common failure, and it is possible to have a whole series of filaments open up. An example might be forcing a battery plug into the battery socket so as to put B+ on the filament series. When a set is brought in for repair it is best to check the filaments first to forestall any possible claims by a customer that the filament burnouts were caused by the serviceman.

In some older receivers the rectifier was a type 117Z3 tube, requiring warm-up time for the rectifier filaments. Newer semiconductor rectifiers permit instant operation. The rectifier must handle not only the plate and screen currents, but also the filament currents. To insure pure dc on the filament (to prevent hum), high-value filter capacitors are used in the filament filter circuit.

Basic 3-Way Portable Power Supply

With directly-heated filament cathodes, plate current for each tube would normally flow through the ground end of the filament string and through each filament to the cathode concerned. To prevent excessive cathode current from flowing through some of the tube filaments, shunt resistors are used. These resistors perform two functions — they act as cathode bias resistors and they distribute the current flow through multiple paths. Should a shunt resistor require replacement, use a 10% or better tolerance resistor since to a large degree it determines the amount of current flowing in the filament circuit.

With the set switched to battery operation and performing satisfactorily, but not performing at all on line current, it is a safe assumption that the defect is in the power supply stage.

Battery, AC-DC (Three-Way) Portable (cont'd)

A three-way portable receiver will have two switches in the power supply circuit. One is used to switch from battery to a-c line operation, and the other is a special switch used as a precaution to prevent one from plugging the line cord into an a-c receptacle while the receiver is battery operated. The two switches are often mechanically combined in the rear of the chassis by a device that automatically switches the receiver to battery operation upon plugging the line cord plug into a special receptacle. The receiver cannot operate on batteries unless this is done.

The possible defects in a three-way, portable-radio power supply with no voltage output and a-c at the rectifier, include an open rectifier, an open surge-limiting resistor, or an open filter resistor. Should either filter capacitor short, there would be no B plus. A defective changeover switch would also cause a loss of B-plus voltage. In battery operation a loss of B plus could be caused by an open changeover switch, or a shorted filter capacitor.

Reduced B-plus voltage could be the result of a defective rectifier, or an increase in the value of the surge limiting resistor, or the filter resistor. High leakage in either the input or output filter capacitor could also cause a reduction in B-plus voltage. A shorted 40-mfd-filament filter capacitor could cause a high current drain to lower the B-plus voltage.

Filament string problems can be difficult to trace since the possibility of opening a tube filament inadvertently always exists. It would be best to check this circuit with the tubes removed and using ohmmeter readings. An open shunt resistor, or one that has increased in value, will cause an increase in current causing a quick filament burnout. This problem is present in either the ac-dc or battery-operate position. Occasionally the added current will burn out the filaments over a period of time, showing up by recurrent filament opening of specific tubes.

A reduced resistance in the series voltage-dropping resistor of the filament circuit will permit increased current to flow in the filament string. Depending upon the value of increased current the filaments will open up in time. An increased resistance will cause a reduction in the filament current flow, resulting in reduced filament voltages which in turn causes intermittent or no operation of the receiver.

Should the 0.1-mfd or the 100-mfd, low-voltage filament-circuit capacitor become leaky, it would draw excessive current causing the opening of tube filaments. This will occur in either the ac-dc or battery-operate position. In battery operation an open change-over switch, safety switch, or on-off switch could cause the loss of filament voltage. To keep the drain on the supply batteries down to a minimum, the filaments are designed to draw only the lowest power necessary for proper tube operation. Since the transfer of heat to an indirectly heated cathode involves much greater energy losses than when the filament is itself the cathode of the tube, battery types, in which filament power must be a minimum, generally never have a separately heated cathode.

Battery, AC-DC (Three-Way) Portable (cont'd)

On-Off
Volume
Control

B BATTERY

3V4   1T4   1U5   1R5

A BATTERY

Safety Switch
Shorted by
Line Cord Plug
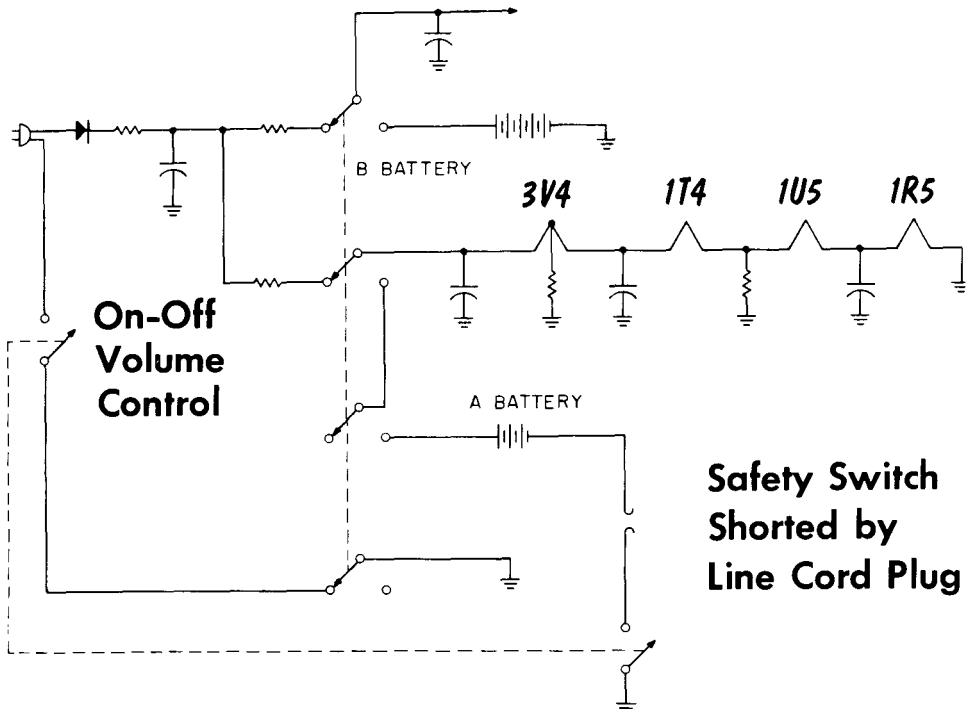
Typical Three-Way Portable Power Supply

In some three-way portables, the tuning capacitors are prevented from touching the chassis (a floating ground is used) by the use of rubber grommets. Because these sets are carried around, the grommet may become scraped and cause a short. This can cause loss of signal. To test for this condition, connect an ohmmeter from the B-minus bus to the chassis. A slightly frayed grommet can cause intermittent trouble.

With the exception of the power supply, the stages used in a portable
    receiver are identical to those used in an ordinary receiver. Identical
    steps are taken in locating the defects of a portable receiver.
Portable receivers have directly-heated-filament cathode-type tubes for use
    with batteries: they require no warm-up time.
Portable receivers capable of operating on ac, dc, or batteries, are popularly
    called "three-way" portables.
It is best to test batteries with a special tester that checks them under load
    and gives a good-fair-bad reading. Where none is available, the battery
    may be tested under load by turning the receiver on and checking for
    a reduction in battery voltage.
In using an ohmmeter to test the tube filaments of a battery-operated tube,
    be sure the ohmmeter's operating voltage does not exceed that of the
    tube's filament.
The converter tube used in many portable receivers, the type 1R5, is sen-
    sitive to low filament and/or B-plus voltage.
Portable receivers take a lot of physical abuse, leading to many physical
    defects such as broken cases, sand or dirt in the speaker, jamming the
    voice coil to the pole piece, broken antenna leads, etc.
To prevent excessive cathode current through the filaments, shunt resistors
    are used. They also act as bias resistors.
A three-way portable has two switches in the power supply circuit. These
    prevent plugging the line cord into an a-c receptacle when battery
    operated.
When tracing filament string problems, turn the receiver "off," remove the
    tubes, and take ohmmeter readings.
In three-way portables using a floating ground, the variable capacitor is
    often electrically and mechanically isolated by rubber grommets.
    These grommets can wear, causing intermittent short circuits.

REVIEW QUESTIONS

1. What precautions should be taken with test probes when servicing
    portable receivers? Why?
2. Explain why visual tests for operating filaments cannot be done with
    battery operated tubes.
3. In testing a battery under load, over *what* percentage of reduction
    in voltage indicates a weak battery?
4. In addition to low filament or B-plus voltage, what other cause would
    make a 1R5 converter tube operate intermittently?
5. What precautions should be taken before servicing a three-way port-
    able receiver?
6. Explain why filament circuit problems are best checked by removing
    the tubes and taking ohmmeter readings.
7. When replacing a filament shunt resistor, what is the resistor tolerance
    rating that should be observed?
8. Two switches are used in the power supply of a three-way portable.
    Describe the function of each switch.

Servicing Automobile Receivers

Automobile radio-receiver repair is perhaps the most neglected yet lucrative area in the field of receiver repair. Repairing auto radios requires additional time, mainly for the removal and installation of the receiver. Because of the extra time, extra charges have to be made which would not be encountered in home radio repairs.

An important adjunct in obtaining a large auto-radio repair trade is a convenient, enclosed parking and drive-in facility so that the work can be done in any weather. Some special tools, similar to those used by auto mechanics, are helpful — a set of ratchet wrenches ranging from $3/8$-inch to $3/4$-inch, open end and box wrenches ranging from $3/8$-inch to $7/8$-inch, etc.

Auto Radio Removal Problems

"fader" control

Dual Speaker Volume Control
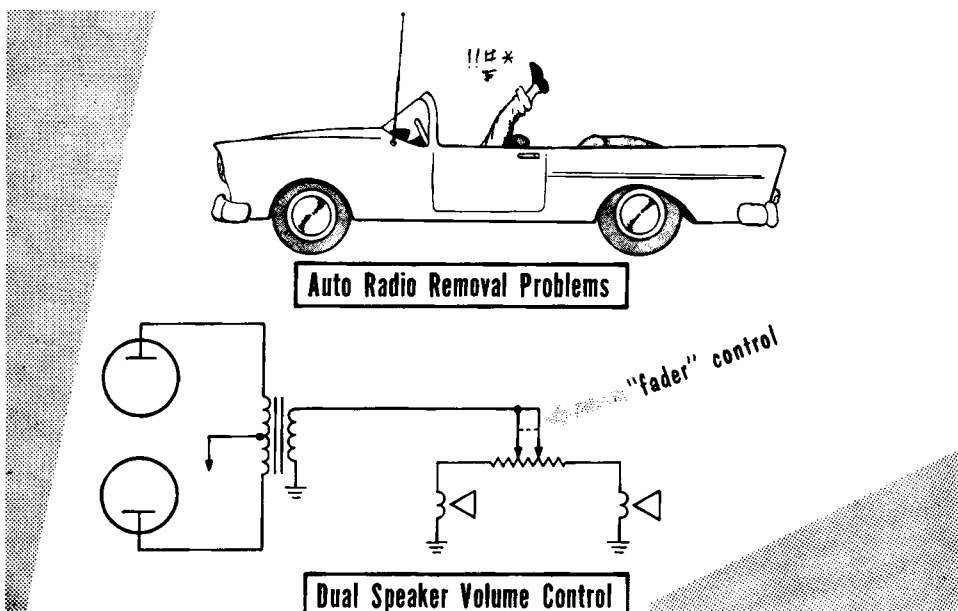
One of the most vexing problems in auto radios is illustrated above. This is the persistent effort of automobile manufacturers in making it a battle of wits and patience to remove an automobile radio.

An innovation that has become standard in many automobiles is a rear-seat speaker in addition to the speaker mounted on the dash board. The rear-seat speaker is usually switched in and out of the circuit by a three-way switch that selects either the front speaker, rear speaker, or both.

Another method of controlling the front and rear speaker is with a special fader control, as shown, which is a special volume control with two ganged adjustable taps. By moving the control in one direction, one speaker increases in volume while the other speaker decreases. When the control is set at an extreme end position, one speaker will be at full volume, and the other speaker will be turned off. At the center position both speakers will receive equal volume.

R-F Amplifier Stage

Automobile radios have disadvantages — they must operate with a short whip antenna, and they often operate at long distances from the broadcasting station. To overcome these disadvantages the majority of auto radios have a stage of r-f amplification. A typical r-f amplifier circuit used in an auto radio is shown. The circuit features variable inductance tuning (slug tuned) which is prevalent in auto radios. Slug tuning is better suited for the vibration and shock encountered in an auto radio. The plate circuit of the r-f amplifier stage is tuned with the output signal RC coupled to the r-f grid of the converter.

To aid in aligning the r-f amplifier to the short antenna, either a special trimmer capacitor, or the tank-circuit trimmer capacitor is made accessible through a capped hole in the side of the receiver. To align the circuit, the auto receiver is tuned to a weak signal at the high end of the band, approximately 1400 kc, and the trimmer is set for maximum output.
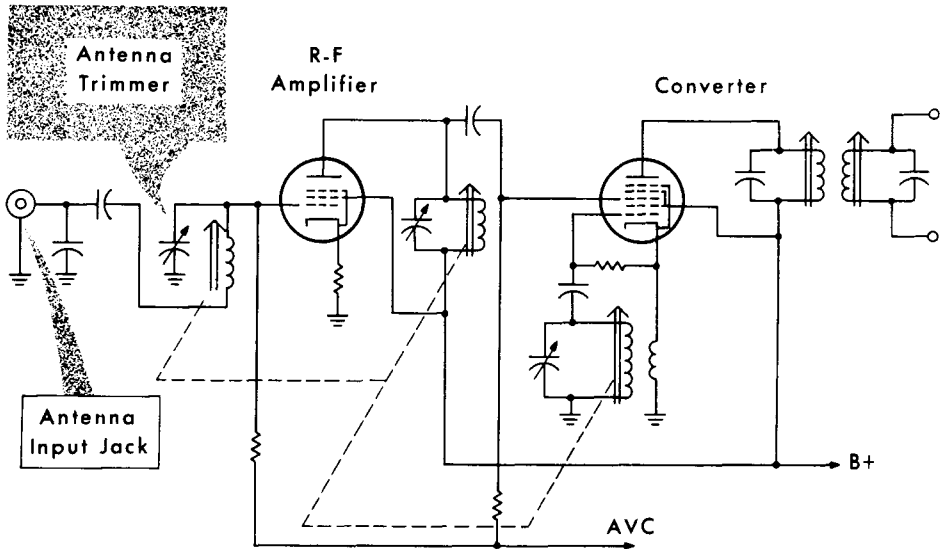
Servicing the r-f amplifier stage in an automobile is no different than servicing the r-f amplifier in a house radio. The only problem peculiar to the auto radio is the possibility of an open antenna lead-in to the receiver.

Slug-Tuned
R-F Amplifier Stage

The auto antenna, although a separate item mechanically, is electrically part of the r-f stage. Antennas are usually installed by the automobile dealer when the automobile is purchased. However, replacements are an important item since the antenna is exposed to the weather and other hazards. A substitute antenna on the service bench need only be a short length of wire with an antenna plug at one end.

Power Supply
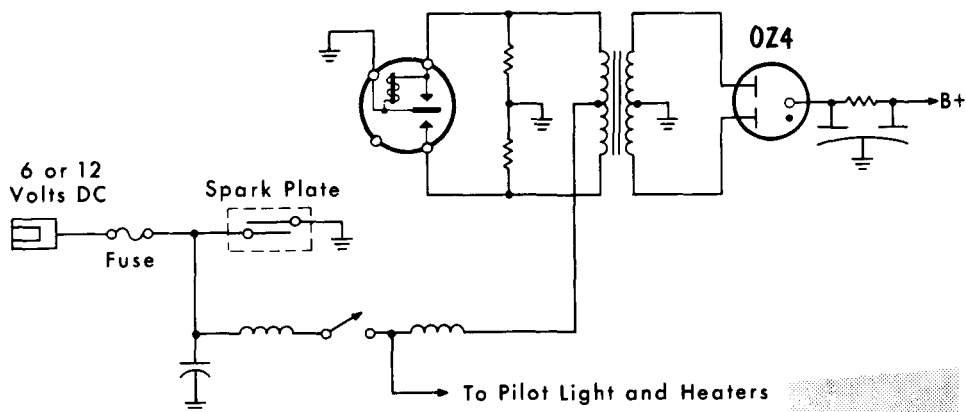
AUTO-RECEIVER VIBRATOR TYPE POWER SUPPLY

It has been said that perhaps 95% of the difficulties in an auto radio are in the power-supply stage, see figure; this is probably true. The output d-c voltage, filter circuit will usually have low capacity rectifiers. The a-c frequency of a vibrator is usually 115 cps; the full-wave-rectifier ripple frequency is thus 230 cps, requiring less capacity for adequate filtering. In many receivers the rectifier tube is a type 6X4, or a similar rectifier tube with a separate heater and cathode. Although the cold-cathode type 0Z4 rectifier has many advantages, it can become fussy as it gets older by not always firing when the receiver is first turned on. Racing the car motor will usually increase the generator output voltage and the voltage applied to the receiver by a small amount, helping to fire the 0Z4 rectifier. When this occurs the rectifier should be replaced.

A common difficulty is intermittently "blowing" open the fuse. This results from either of two troubles, or a combination of both. A worn vibrator with pitted points will have a tendency to arc as it operates. Occasionally the arc will cause the points to weld together, causing excessive current drain that will quickly blow the fuse. Giving the vibrator a sharp tap will temporarily free the points. A bad buffer capacitor quite often is the contributing cause to bad vibrator points. As a result changing the vibrator without changing the buffer capacitor is an invitation to a quick repeat performance of a defective vibrator. Vibrator manufacturers often guarantee the replacement vibrator only if the buffer capacitor is replaced at the same time.

An aid in checking troubles is in listening carefully for the vibrator buzz. Many vibrators are well isolated and clamped with a piece of sponge rubber to quiet them. If it is not buzzing, the fuse is not blown, and if the pilot light and tubes are lit, the difficulty is in the vicinity of the vibrator.

Power Supply (cont'd)

To check an auto-radio power supply with no voltage output, listen for the buzzing of the vibrator. If it is not buzzing, test the fuse; if the fuse is good, check the applied battery voltage through to the on-off switch. The high value of current flowing through the switch is a common cause in its opening or burning out. Be sure the spark plate or filter capacitor is not shorted, and check for an open filter coil. Voltage should be present at the center tap of the primary of the transformer. To check the transformer the battery voltage should be present at both ends of the primary winding and at the vibrator. points. The vibrator should be checked by replacing it with a good substitute.

bench set-up for checking
AUTO RECEIVER

Output current meter of battery eliminator is useful as a check for short circuit.

Typical values: For 6 volts—approximately 6 amps up to 10 amps (push-pull)

For 12 volts—approximately 3 amps up to 5 amps (push-pull)

check current for short circuits
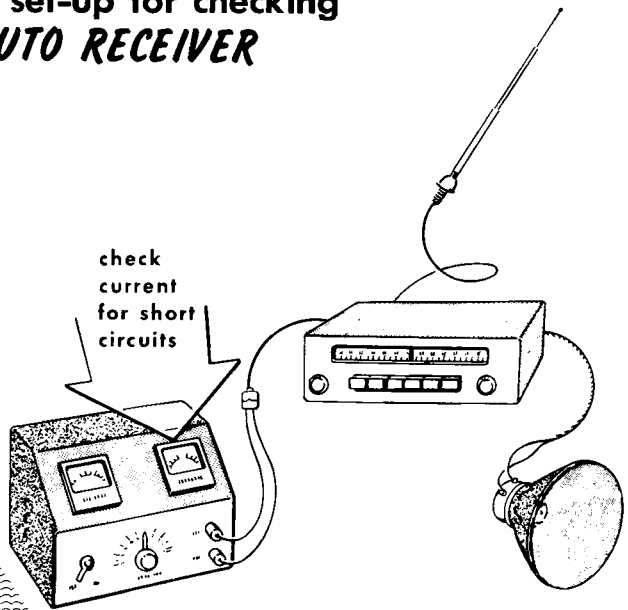
If the vibrator is buzzing, check for high-voltage ac to the rectifier plates, being sure that the center tap of the secondary is at ground. If no d-c voltage is present at the cathode, the rectifier tube should be checked by replacement with a substitute. With a good rectifier tube, a loss of output voltage could then be either a shorted filter capacitor or an open filter resistor.

Low output voltage from the power supply could be due to a leaky buffer capacitor, a defective rectifier tube, or leaky filter capacitors. Should the filter resistor change and increase in value, the output voltage would also be reduced.

Signal Seeker

The signal seeker is a special circuit in which pressing a button on the radio panel will tune the receiver to the next station. If this station is not desired the button can be pressed again to seek the next station on the dial, etc. To prevent the receiver from tuning in on all stations, a sensitivity control causes the signal seeker to stop only at the more powerful local stations.

To operate the tuning circuit a spring-powered motor is used. Mounted on the motor shaft is a paddle wheel that serves two purposes: The large air resistance of the paddle wheel acts as a speed governor, and a relay-actuated latching arm locks the paddle wheel when the desired station is in tune.

A typical signal seeker circuit is shown. Resistors R3 and R4 comprise a voltage divider supplying bias for tubes V5 A and B. When on station the paddle wheel is locked in position, and the cathode of V5A then gets its bias through R1. Relay K1, in the plate circuit of V5B has a small amount of current flowing through it, but not enough to actuate the latching arm.

To initiate the signal seeking action, the button on the front panel is pressed, momentarily changing S1 from position A to B. In position B the secondary of the output transformer is opened and the receiver is muted. In addition, a path for the B plus applied to relay K1 is now available through S1B to ground, actuating the relay.

With relay K1 actuated the latching arm is moved away from the paddle wheel, and the spring motor then tunes the receiver to seek a new signal. At the same time the latching arm removes the ground from contact #1. The cathodes of V1 and V2 now return to ground through the sensitivity switch. The setting of the sensitivity switch determines the bias for V1 and V2, in turn determining the sensitivity of the receiver for the stations received.

With the latching arm grounded through contact 2, resistors R1 and R2 are now parallel to bias resistor R4. The parallel circuit divides the voltage, reducing the cathode bias of both tubes. Because of the low plate voltage of V5A the tube remains cut-off. The high plate voltage of V5B and the reduced bias causes it to conduct heavily, keeping relay K1 actuated. Although S1 is pressed momentarily to initiate the actuation of relay K1, the heavy current flow through V5B will keep the relay actuated when S1 is released.

When tuning in on a station the signal provides a rectified AVC voltage that is developed across resistors R5 and R6; this is applied as bias to the grid of V5A. At the same time, the i-f signal is coupled to the grid of V5A through C1. As the station is being tuned in, the positive-going portions of the i-f signal will reach an amplitude that overcomes the bias and triggers tube V5A into conduction. The relationship of the AVC bias voltage and the amplitude of the i-f signal is carefully set to cause tube V5A to conduct just before the signal is tuned to maximum at the center frequency. This relationship remains the same regardless of the strength of the signal being tuned.

R-F Amplifier

V1

I-F Amplifier

V2

1st AF

Detector

V3

C1

B+

Phase
Inverter

V4

R5

R6

Push-Pull
Output

V5A   *V5B*

Paddle
Wheel

B+

K1

B+

R3

B

A

R1

R2

R4

S1

1   2

Sensitivity
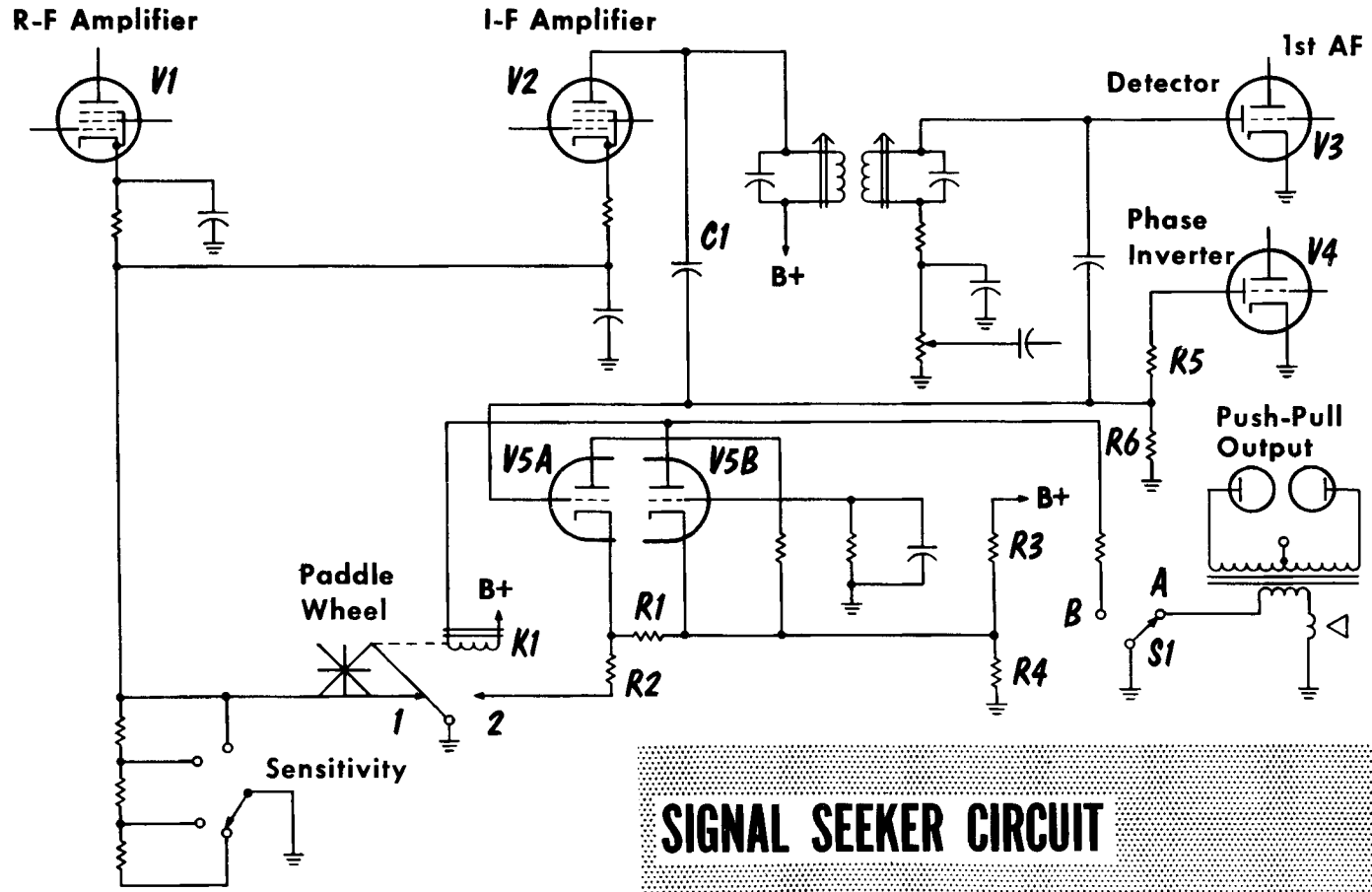
SIGNAL SEEKER CIRCUIT

Signal Seeker (cont'd)

When V5A conducts, the negative-going plate connected to the grid of V5B, will cause tube V5B to cut-off and stop conducting. With V5B non-conducting, relay, K1 is de-energized and the ratchet snaps back to lock the paddle wheel and stop the tuning motor.

Tube V5A is triggered at the correct moment before the signal is completely tuned in to the center frequency. This in turn causes tube V5B to cease conducting and lock the paddle wheel. The small time delay between the initiation of this action, plus the inertia of the spring motor, will result in the station being tuned to the center frequency when the tuning motor stops.

When the tuner reaches the high frequency end of the dial, it automatically closes S2, energizing the solenoid K2. Solenoid K2 returns the tuner to
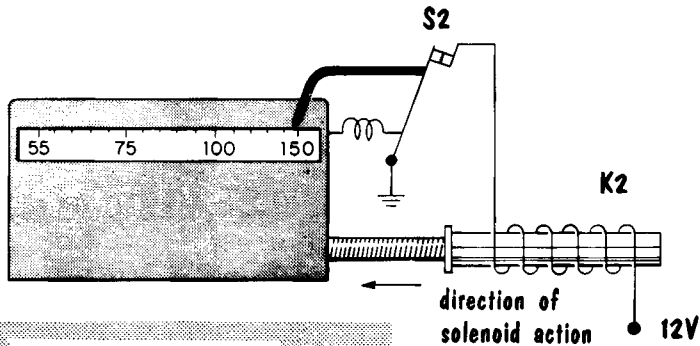
BAND RESET MECHANISM

the low frequency end of the band. At the same time, while moving the tuner away from the high end of the band, a spring opens S2, de-energizing the solenoid. When the solenoid moves the tuner it also winds the spring power motor.

To check for this the receiver should be set for manual tuning to determine if any signal is being received. A defect in the tuned stages that will cause a weak signal will cause the signal seeker to stop at only the very strong signals, if at all.

In servicing the signal seeker of the type shown, all voltages should be checked to coincide with the listed values. The tubes should be checked if the signal seeker does not stop at a station or does not keep the locking rachet relay energized while seeking a station. If closing S1 does not energize relay K1, check for an open relay coil or a defective tube V5B.

If the signal seeker does not stop tuning with an adequate input signal, check tube V5A. If C1 is open, or there is a loss of AVC voltage from R5 and R6, tube V5A will not trigger.

Ignition Interference

Mounting the receiver in the passenger compartment with the fire wall acting as a shield, is an aid against interference caused by the arcing at the spark plug points. The antenna is mounted clear and free of the car with the sheet metal of the car acting as a shield. The antenna lead-in is shielded to prevent noise pickup where the lead-in runs through the car. The remaining problem is the lead bringing the voltage from the battery. The battery is common to both the radio and the ignition system and has a large value of noise pickup. Filter circuits are placed at the voltage-input terminal of the receiver to remove this noise. The filter circuits incorporate low-resistance chokes to suppress the high-frequency interference. Special spark plate capacitors also help filter the interference. With all these precautions interference from the ignition system becomes a minor problem.

There is still the possibility of ignition noise becoming a problem from either a car's ageing, or operating the receiver in remote locations with weak signals. To remove ignition noise from the distributor points, a

generator
spark plugs
points
ignition coil

fire wall

static discharge
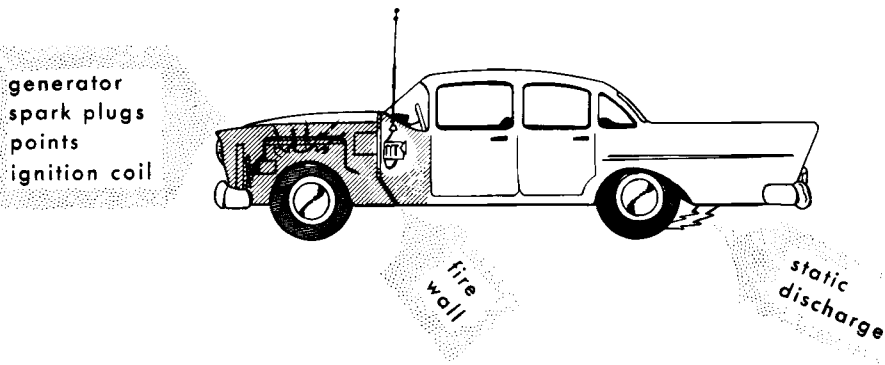
Typical INTERFERENCE Sources

suppressor resistor is mounted in the high-voltage lead just as it enters the distributor. An incorrect spark plug gap could cause interference. The gap should be checked and correctly set by a competent automobile serviceman. If the gap is correct, spark plugs using built-in resistors can be used for additional noise suppression. A high-pitched whine that changes with the motor speed indicates arcing at the generator brushes. To help quench this arc a capacitor is mounted on the generator case with one foil grounded to the case, and the other foil placed at the armature terminal.

Static electricity that is discharging from the wheels to the car frame, results in a periodic popping sound on the radio. The static electricity builds up due to the wheel rims or brake drums being insulated from the ground by the tires, and having a poor ground return to the car frame. To overcome this problem, special conducting powder is blown inside the tire and tube to discharge the static electricity through the tires.

Auto radio repair requires additional time for the removal and installation of the receiver.

Tools similar to those used by auto mechanics are helpful in removal, installation, and servicing of automobile receivers.

A popular item used in many cars is a rear seat speaker controlled by a three-way switch or a fader control.

Automoble receivers operate under disadvantages: they use a short antenna and may have to operate at long distances from the radio station.

Because of vibration and shock, most automobile receivers use slug tuning.

To help align the r-f amplifier stage to the short antenna, a trimmer capacitor is accessible through a capped hole in the side of the receiver.

The greater majority of difficulties in an automobile receiver occur in the vibrator-operated power supply.

The power-supply filter capacitors are of smaller capacity because of the higher ripple frequency in a vibrator power supply.

A common difficulty is intermittent "blowing" fuses because of worn vibrator points, a defective buffer capacitor, or both.

An audible buzzing sound is an aid in checking the operation of a vibrator.

High-value current will often burn out the on-off switch.

The signal seeker is a special circuit which tunes the receiver to the next station by pressing a button or bar on the radio panel.

A sensitivity control is used to prevent the receiver from tuning in all stations including undesired weak stations.

A spring-powered motor operates the signal seeker tuning circuits.

The use of r-f filter chokes, and special spark-plate capacitors at the battery voltage input lead to the receiver helps reduce ignition interference to a minimum.

A common cause of ignition interference is an incorrect setting of the spark plug gap.

REVIEW QUESTIONS

1. What is an important help in being able to service automobile receivers in any type of weather?
2. Describe the operation of a fader control.
3. Why do the majority of automobile receivers employ a stage of r-f amplification?
4. What may be used as a substitute antenna for an automobile receiver being serviced on the bench?
5. Describe a common problem with the type OZ4 rectifier and how the problem is observed?
6. What symptom is indicated by intermittent fuse blowing?
7. Why must the buffer capacitor also be replaced when the vibrator is being replaced?
8. In the signal seeker circuit, what are the two purposes of the paddle wheel mounted on the motor shaft?
9. What device can be used to remove ignition interference caused by the distributor points of a car ignition system?

GLOSSARY

Accelerating Anode: An anode placed at a high potential (2000 v) to accelerate the electron beam in a cathode ray tube.
A-C Voltmeter: A rectifier circuit combined with a d-c voltmeter to measure a-c voltage.
Alignment: Adjustment of the receiver's tuned circuits for maximum selectivity, sensitivity and output.
Amplifier: A circuit using tubes or transistors to increase the signal voltage, current or power. Used at r-f, i-f, and audio frequencies.
Antenna: A device consisting of a predetermined length or shape of wire or rods, used to radiate and/or absorb r-f energy.
Attenuator: A voltage divider used to remove a portion of the signal with the least possible loss of signal frequencies.

Balance Control: Used to adjust and balance out bucking currents in an a-c rectifier circuit for a-c voltmeters.
Battery: A device used for converting chemical energy to electrical energy.
Blocking Capacitor: A capacitor used to permit the passage of the a-c components while blocking the d-c component of a varying d-c voltage.

Cathode Ray Oscilloscope: An instrument used to display a-c voltage waveforms.
Cathode Ray Tube: A specially constructed tube allowing control and display of applied a-c voltage waveforms.
Components: An inclusive term for all individual devices used to make up a receiver.
Contact Bias: A grid bias voltage developed by the stray electrons that strike the grid on their way to the plate.
Copper Oxide Rectifier: A series of tightly clamped, copper oxide coated discs separated by lead washer. It is used as a meter circuit rectifier.
Current Limiting Resistor: A resistor placed in the circuit to impede and limit current flow.
C-W Signal: An r-f signal of continuous frequency and continuous amplitude.

D'Arsonval Meter Movement: Most commonly used meter movement consisting of a coil balanced between the poles of a magnet.
Deflection: The back and forth, or up and down movement of the electron beam in a cathode ray tube.
Dynamic Mutual Conductance: The quotient of a small change in plate current divided by the small change in control grid voltage producing it, with all other electrode voltages held constant.

EM Speaker: Using a coil of wire to generate an electromagnetic field for a dynamic loudspeaker.

Floating Common: Where the B-minus common return line is isolated from the receiver chassis.
Fluorescence: The property of a phosphor in emitting light when struck by an electron beam.
Focusing: Controlling the electron beam in a cathode ray tube to converge at the faceplate for a sharp spot of light.

Grid-Dip Meter: Used to find the frequency of a resonant circuit.

Harmonic Frequencies: An integral multiple of a fundamental frequency. The second harmonic is twice that of the fundamental or first harmonic.
High-Fidelity: An audio circuit capable of handling, without loss or distortion, the full range of audio frequencies.

Loading: Using a low impedance meter circuit to measure small values of voltage in a high impedance circuit.

Modulation: The process of varying the amplitude (AM), the frequency (FM), or the phase (PM) of a carrier wave in accordance with a signal conveying intelligence.
Multimeter: A combination of multipliers and shunts using a single, basic meter movement to allow a wide range of metering.
Multiplier: A resistance used in series with a basic meter movement to extend its range in reading voltages.

Oscillator: A circuit used to convert dc to ac at a frequency determined by the circuit constants.

Peak Inverse Voltage: The maximum voltage applied between anode and cathode when the rectifier is not conducting.
PM Speaker: Using a permanent magnet to generate an electromagnetic field for a dynamic loudspeaker.
Power Supply: A source of voltage, both ac and dc, for application to the receiver circuits.
Probe: A small self-contained holder used as an extension lead from the meter to the circuit being probed. May contain isolating resistors, multiplier resistors, or detectors as determined by the use of the probe.
Push-pull: Two amplifier circuits connected in such a way that one operates on a positive alternation and the other operates on the negative alternation.

Retrace: The electron beam in cathode ray tube drawing a portion of the signal on the faceplate as it is being pulled back to start a new trace.

Sawtooth Voltage: A voltage shaped as a tooth in a saw, used for deflection in a cathode ray tube.
Shielding: Metallic covering used to prevent magnetic or electrostatic coupling between adjacent circuits.
Shunt: A resistance, or impedance, paralleling another component or circuit.
Signal Injection: Use of a signal generator to inject a substitute signal in a receiver.
Signal Tracing: Using a signal tracer to detect and amplify signals in tuned circuits up to the detector and as an audio amplifier to detect audio signals after the receiver detector.
Slug Tuning: Varying the value of inductance in tuning a resonant circuit.
Spark Plate: A specially constructed mica capacitor used at the input of the battery voltage to an automobile receiver. The construction aids in effective removal of high-frequency noise generated in the auto ignition system.
Synchronization: Sweeping the beam across the face of a cathode ray tube in step with the signal under observation.

Thyratron: A gas-filled tube employing a grid for control of the tube's ionization or "firing" point.
Time Constant: The time of rise or decay of voltage or current in an RC or RL circuit, as determined by the values of RC or RL.

Volt-Ohm Milliameter (VOM): A combination of multipliers and shunts using a single basic meter movement to allow a wide range of metering of voltage, resistance and current.
Vacuum Tube Voltmeter (VTVM): A vacuum tube operated multimeter providing increased sensitivity.

Variable Frequency Oscillator (VFO): An oscillator circuit whose output frequency can be tuned over a specified range, usually employing a calibrated dial allowing resetting of the output frequency.

Vibrator: An electromechanical device used to switch the d-c voltage of a battery to an interrupted d-c voltage similar to a square wave for application to the primary of a power transformer.

Voice Coil: A low impedance coil connected to the speaker cone and inserted in an air gap in the speaker's magnetic field. Applying an audio signal to the voice coil causes it to move axially against the magnetic field to produce sound waves.

Whip Antenna: A short vertical antenna usually mounted on an automobile.

INDEX TO VOL. I

NOTE: A cumulative index covering both volumes in this series is included at the end of Volume II.

Basic

Radio Repair

VOL. 2

MARVIN TEPPER
Electronic Services Division
Raytheon Company

Author of
FUNDAMENTALS OF RADIO TELEMETRY
BASIC RADIO

JOHN F. RIDER PUBLISHER, INC., NEW YORK
a division of HAYDEN PUBLISHING COMPANY

PREFACE

Knowledge of radio receiver and transmitter circuits is one part of the job. An equally important part is to be able to apply this knowledge to the maintenance and repair of defective receivers or transmitters.

These books are a logical extension of *Basic Radio,* and are presented in a manner calculated to best instill a common-sense approach to servicing. Too often the author has observed good knowledge of circuits being wasted by a complete lack of an approach, or a poor approach to circuit trouble-shooting and repair.

The context of these books reflects an application of practical servicing procedures. The approach is to illustrate by a combination of words and pertinent artwork, as close an approximation as possible of repair techniques as they would actually be done on a workbench.

Starting as a single volume, it soon became apparent that there was more to say than could be covered in a single book. Rather than weaken its value the contents were expanded and placed in two volumes, allowing coverage of all phases of radio receiver and transmitter servicing.

The contents are carefully laid out. Beginning with an exhaustive discussion of the test equipment used in servicing, it goes into a complete discourse on significant aspects of different components. The next section thoroughly covers a most important subject, servicing procedures. No one servicing technique is favored—all are covered equally. The approach to superheterodyne receiver servicing was carefully set up to closely approximate the approach taken when actually serving a receiver. Servicing of each circuit is taken in the order most likely to be followed during actual receiver repairs. This also holds true for the chapters on portable, automobile, and FM receivers.

It was felt that to try and combine discussions of equivalent tube and transistor circuits side by side would be confusing. Accordingly a completely separate discussion is used on transistor receivers, allowing full concentration on servicing procedures peculiar to these receivers.

The final section, transmitter servicing, covers a neglected area. Previously very little has been written on this subject. The approach and coverage has been unstinting, covering all types of circuits, including FM and single sideband.

Those of you with extracurricular work activities will appreciate the long-enduring patience of my wife Celia, and my daughters Ruth and Shirley, who waited for me to compile and write these books, and then finally to rejoin the family.

MARVIN TEPPER

Milton, Mass.
June 1963

Contents — Volume Two

Servicing FM Receivers

The stages of an FM receiver are identical with those of an AM receiver. An FM receiver differs mainly in the frequency of operation and the detector circuits. The operating frequency (88-108 mc) of FM receivers finds the r-f and oscillator circuits using coils of only a few turns of heavy wire and tuning capacitors with only a few plates. The i-f tuned circuits usually operate at 10.7 mc with adjustable inductance (slug tuned) i-f transformers. See page 2-2 for a typical FM receiver circuit.

A block diagram of an FM receiver is shown in the illustration. Note the frequencies of the various stages. The detector stage can consist of a limiter-discriminator or a ratio detector. Although the ratio detector generally does not require a limiter preceding it, it may be found in some expensive models.

```
   ┌──────────┐                              ┌──────────┐
   │   r-f    │                              │   a-f    │  ◁))
   │ amplifier│                              │ amplifier│
   └──────────┘                              └──────────┘
    88-108 mc

┌──────────┐  ┌──────────┐  ┌──────────┐  ┌──────────┐
│          │  │ wideband │  │          │  │          │
│  mixer   │  │   i-f    │  │  limiter │  │ discrim- │
│          │  │ amplifier│  │  10.7 mc │  │  inator  │
└──────────┘  └──────────┘  └──────────┘  └──────────┘
                 10.7 mc
┌──────────┐   200 kc bandwidth   ┌──────────┐
│  local   │                      │  ratio   │
│oscillator│                      │ detector │
└──────────┘                      └──────────┘
 98.7-118.7 mc               may be used instead
                             of limiter-discriminator

            ┌──────────────┐
            │ FM RECEIVER  │
            └──────────────┘
```
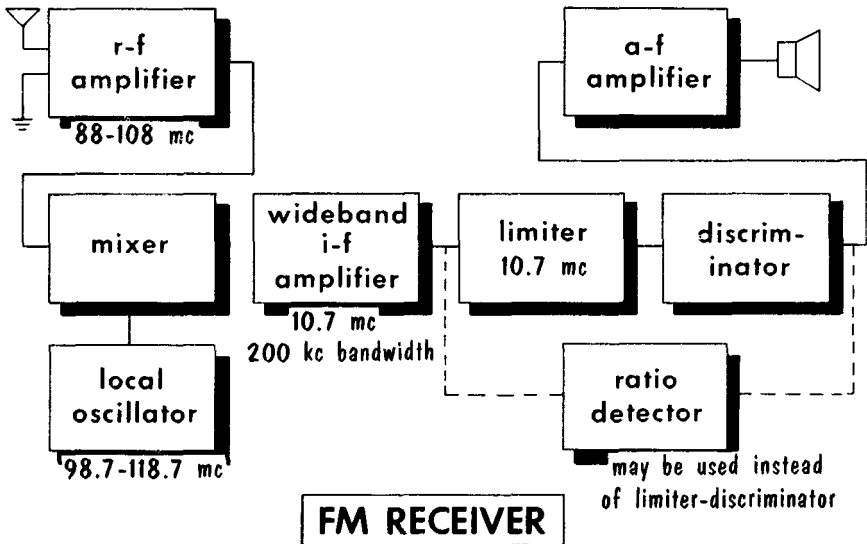
The average FM transmitting station is a low-power (in comparison to AM) local station depending mainly upon line-of-sight reception for local coverage. Because of the low power, the majority of FM receivers incorporate an r-f amplifier stage and two i-f amplifier stages. A typical commercial FM receiver is shown. For centrally located receivers a built-in antenna is sufficient for good reception. For receivers located in fringe areas, an outdoor FM antenna is required. Since line-of-sight reception is the rule for FM operation, the outdoor antenna must be as high and as clear of obstructions as possible.

Decoupling filters in the plate leads in the i-f and r-f stages of FM receivers are common. Many signal tracers will not operate at the frequencies encountered in FM tuned circuits. To isolate defective stages in an FM receiver, signal injection may be required.
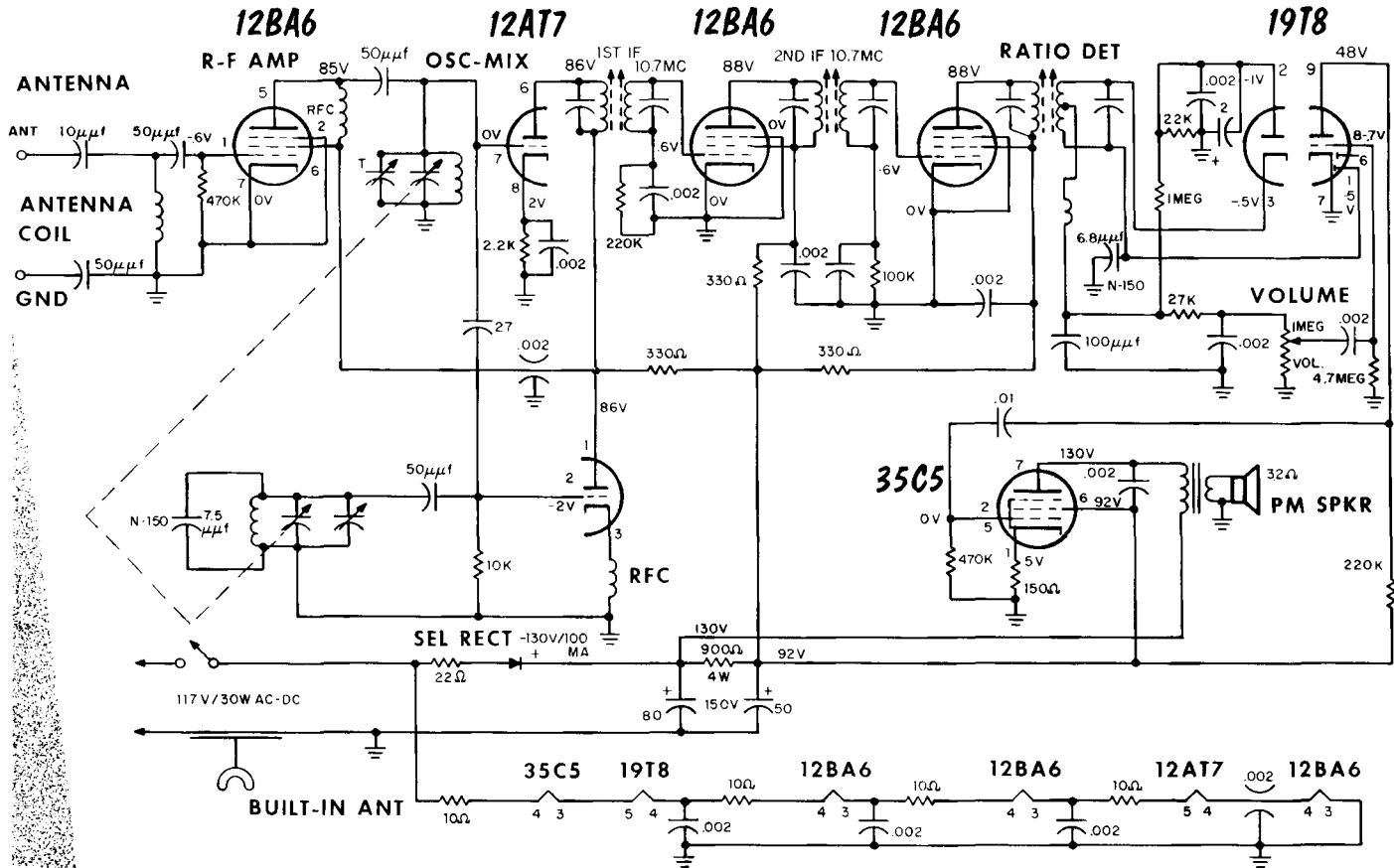
TYPICAL FM RECEIVER CIRCUIT

FM Discriminator and Limiter

The discriminator is sensitive to AM as well as FM, and because of this the stage preceding the discriminator is a limiter stage used to remove amplitude variations. The limiter stage operates at low plate and screen voltage for sharp cutoff and quick saturation. Grid leak bias is used. The control grid of the limiter is a valuable check point — reading the value of the bias with a VTVM can determine whether any signal is present at the limiter grid. Should the input signal to the grid of the limiter be low
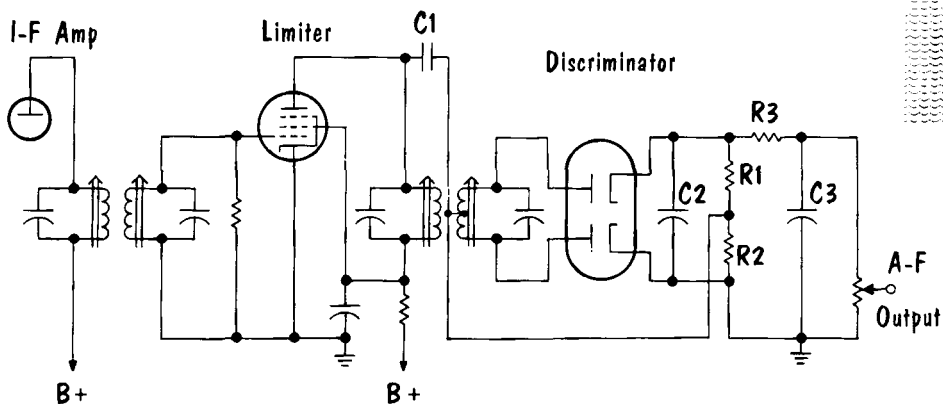
FM Discriminator Circuit

due to either a weak station or misalignment, the tube will not operate as a limiter but as an amplifier. With no limiting action a high noise level will be present with the detected signal.

Resistor R3 and capacitor C3 comprise the de-emphasis network. The detected signal voltage is developed across R1 and R2. At the center frequency the output voltages across R1 and R2 are equal but opposite, cancelling each other. With a modulated signal the difference voltage is taken from the top of R1 and developed across the volume control from where it is applied to the audio amplifier circuits.

With no audio output, the bias voltage at the grid of the limiter should be checked with a VTVM. If no bias is present, it can mean that either the preceding tuned stages are defective, feeding no signal, or that the limiter stage is defective. Voltage readings should be taken to check the limiter stage. With plate voltage present the primary of the detector transformer is presumed good. With plate and screen voltage present the tube should be checked by substituting a good tube. If the plate and screen voltages are correct and the tube checks good, lack of grid bias indicates loss of signal input to the grid.

FM Discriminator and Limiter (cont'd)

A continuity check should be made of the secondary of the i-f transformer. The grid resistor should be tested to see if it has opened and the grid capacitor should be checked for an open or short circuit. If all these tests indicate the limiter stage is operating correctly, then the difficulty is in the preceding stages. The action of a limiter is shown in the illustration.

With a signal applied, and the limiter stage working properly, the detector stage is checked for no output. Coupling capacitor, C1, should be tested for a short circuit. The continuity of the secondary of the discriminator transformer should be tested, including the center tap connection. The

OUTPUT FM
SIGNAL CONSTANT
IN AMPLITUDE

LIMITER

SYSTEM

Input

Output

INPUT FM
SIGNAL VARYING
IN AMPLITUDE
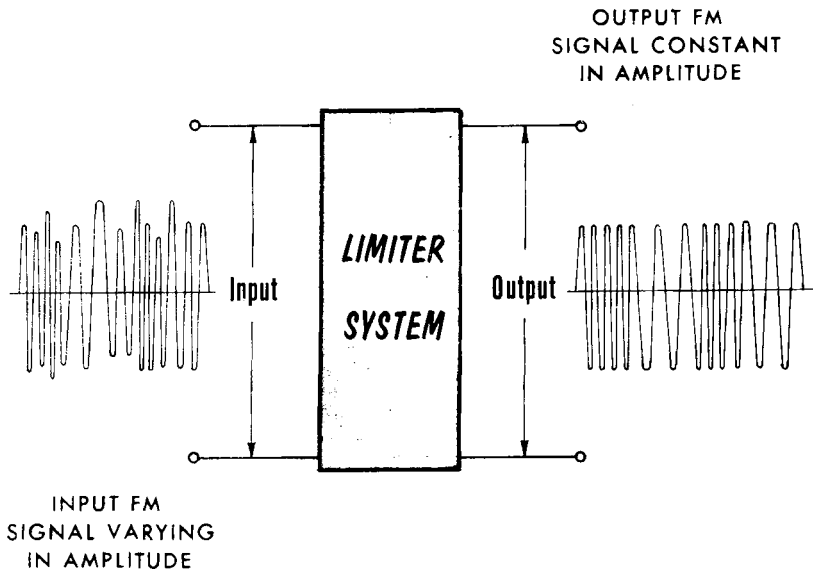
detector tube rarely gives trouble, but it should be checked. Should capacitors C2 or C3 short, the signal will be lost. An open resistor — R1, R2, R3 — or an open volume control can also cause a loss of the signal.

Low discriminator output accompanied by a high noise level and low grid leak bias of the limiter grid, indicates a weak input signal. The weak input, as previously mentioned, can be due to either a defect in the r-f or i-f tuned stages, or to misalignment. With an adequate input signal to the limiter, a low output could be caused by misalignment of the detector transformer, low emission of the detector tube, or high resistance leakage of C1, C2, or C3.

Ratio Detector

The reference voltage in a ratio detector is usually developed by a coil coupled to the detector transformer winding. The high value of R1 and capacitor C1 presents a large time constant that will quench any sudden change in voltage caused by noise or other amplitude changes. De-emphasis is provided by R2 and C2. The signal voltage developed across capacitor C2 is coupled to the volume control from where it is applied to the audio amplifier stages.

RATIO DETECTOR CIRCUIT
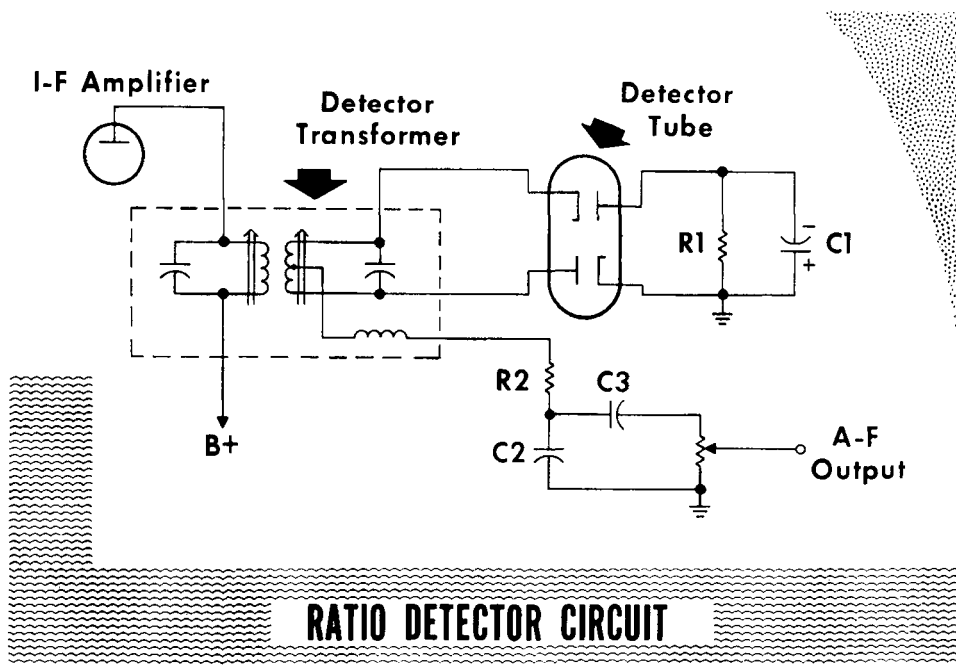
With no signal output from the ratio detector, the preceding i-f amplifier stage and detector stage should be checked by injecting a signal at the grid of the i-f amplifier stage. With a signal present in the preceding i-f amplifier stage and no detector output, the primary of the detector transformer is checked by checking the plate voltage of the i-f amplifier tube. The secondary of the detector transformer and the coupling coil should be tested for continuity. The detector tube should be replaced with a good tube. No output voltage would be developed if capacitor C2 should become short circuited. An open resistor R2 or open volume control would also cause the loss of the output signal.

A reduced output signal could be caused by misalignment of the detector transformer or low emission in the detector tube. A shorted time-constant capacitor, C1, would also cause low output. If capacitor C2 becomes leaky or resistor R2 increases in value, the result would be a reduction in the output signal. When R1 or C1 opens the signal may have a high noise level.

Gated Beam Detector

The special action of the gated beam tube and the tuned circuit in the quadrature grid, combine to provide FM detection. Plate current flows continuously regardless of signal conditions, permitting self bias by use of a cathode resistor. The setting of the cathode bias sets the operating point for the incoming signal. If the bias control is set to the wrong value, it will result in a high noise level. The output current pulses of the signal are integrated by R1 and C1 to provide an output signal voltage. Resistor R2 is used to improve the frequency response of the circuit.

GATED BEAM DETECTOR
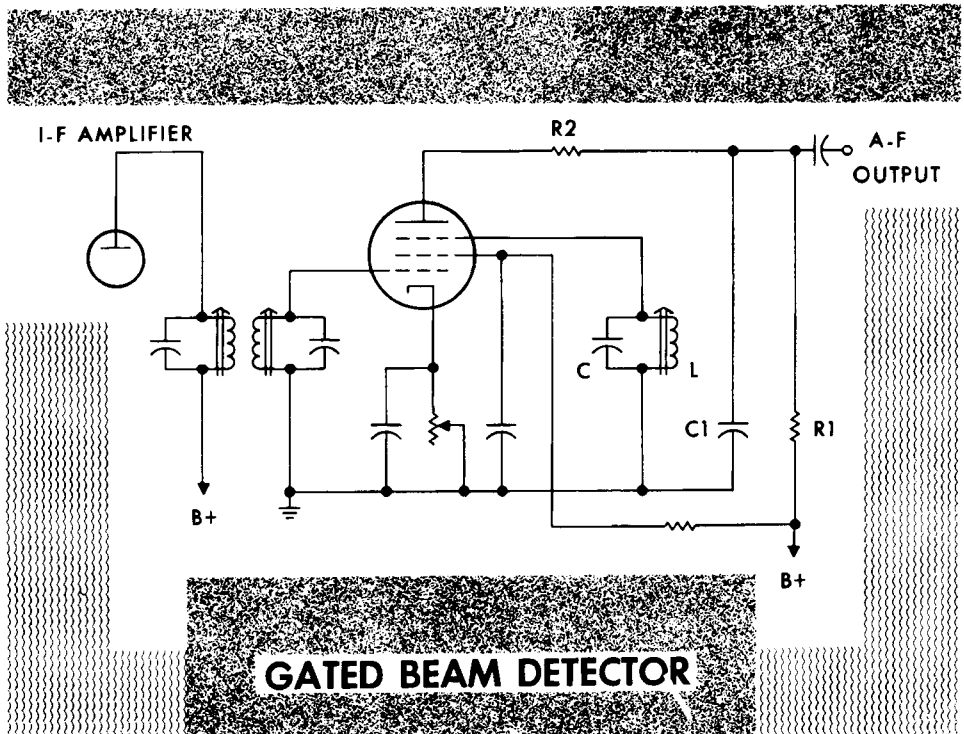
With a signal at the output of the preceding i-f amplifier stage and no detector output, the first step is to check all voltages. If the voltages check correctly, the tube should be replaced with a good substitute. To check the continuity of the secondary of the i-f transformer, the value of cathode-bias voltage should be read with a voltmeter placed between the cathode and control grid. With an ohmmeter, a test should be made for an open coil or shorted capacitor, or possibly an open capacitor in the LC circuit of the quadrature grid. Should C1 short it would result in loss of plate voltage.

With a good signal at the plate of the preceding i-f amplifier stage but a weak output from the detector stage, check for reduced values of voltage at the plate and accelerator grids. If the i-f transformer is misaligned, it can cause reduced output. Check the cathode for proper bias.

FM Receiver Alignment

The instruments required for alignment are the r-f signal generator and vacuum-tube voltmeter. In alignment of FM receivers the popular method is to align the detector circuit, limiter circuit where used, followed by the i-f circuits and tuning circuits.

Proper alignment of the primary winding will adjust the linearity of the S curve. Balancing the output, and placing the intermediate frequency of 10.7 mc at the center of the linear portion of the S curve, is the job of the secondary winding. The output of the generator is placed at the limiter grid, point A, in series with a 0.01-mfd capacitor. The VTVM is placed across R2, observing polarities. The output of the r-f signal generator is set to provide sufficient voltage drop across R2 for ease in tuning. The primary of the discriminator transformer is tuned for maximum output as indicated by the VTVM.
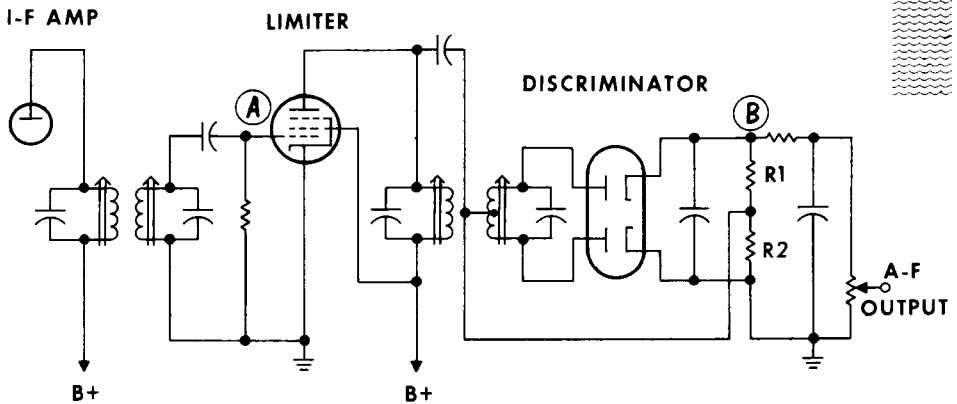
Discriminator Alignment Points

The VTVM probe is then shifted from the top of R2 to point B to read the output voltage. The output of the discriminator transformer secondary is zero at resonance, which is difficult to read on a normal meter scale. To aid in tuning to zero, most VTVM's have a zero center scale to which the VTVM should be set. The secondary of the discriminator transformer is then tuned for zero output. To spot check the detector linearity, the output of the r-f signal generator may be shifted 50 kc above and below the resonant frequency. This should result in output voltages of equal value but opposite polarity.

FM Receiver Alignment (cont'd)

Should an exact check be required, the output of the r-f signal generator should be varied in equal steps from 10.5 mc to 10.9 mc. Readings of the output voltage may then be plotted on a graph providing an S curve of the circuit.
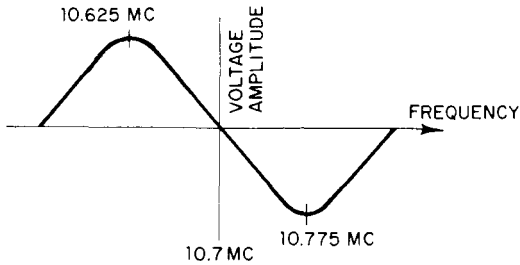
FAMILIAR "S" CURVE

For I-F Alignment, VTVM is Placed Here
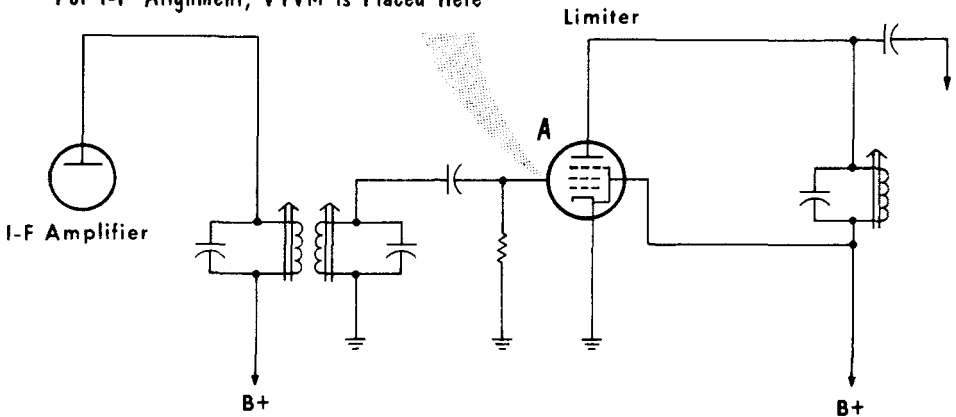
To align the i-f amplifier stages, the VTVM is placed in the grid circuit of the limiter, point A. The output of the r-f signal generator is placed at the r-f of the mixer or converter tube in series with a 0.01-mfd capacitor. The i-f transformers are then aligned for maximum output as indicated by the VTVM. The order of alignment is to start with the output i-f transformer, followed by the interstage i-f transformer, if one is used, then alignment of the input i-f transformer.

The tuned r-f amplifier, converter or mixer, and oscillator circuits, are aligned for maximum output and correct tracking. The procedure is identical with that explained for AM receivers.

FM Receiver Alignment (cont'd)

The ratio detector circuit may be of the balanced-detector type. The output of the r-f signal generator is placed at the grid of the output i-f amplifier stage, point A, in series with a 0.01-mfd capacitor. To align the primary of the detector transformer, the VTVM is placed across C1, observing

RATIO DETECTOR ALIGNMENT POINTS
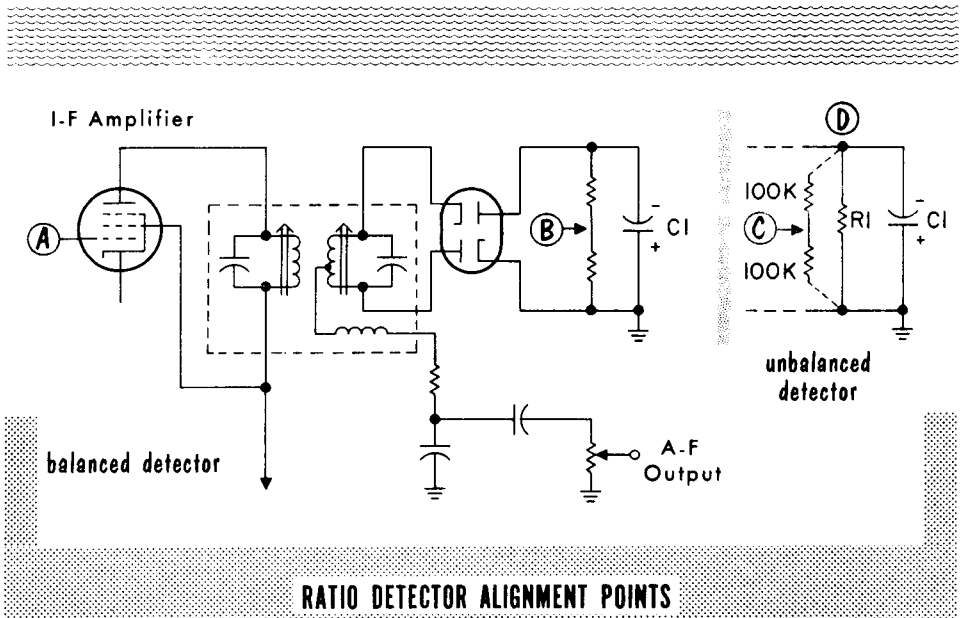
polarities. The primary of the detector transformer is aligned for maximum output as indicated by the VTVM. To align the secondary of the detector transformer in a balanced circuit, the VTVM is placed between point B and ground. The secondary of the detector transformer is then aligned for zero output.

In the unbalanced detector circuit, placing the meter from point D to ground does not provide zero readings. To obtain a zero reading the meter must be at the center of R1. To obtain this center tap, two 100K resistors are temporarily placed across R1 as shown. The center of these resistors, point C, is where the meter lead is placed to obtain a zero reading.

To align the i-f amplifier stages the VTVM is placed across C1, observing polarities. The output of the r-f signal generator is placed at the r-f grid of the mixer or converter tube in series with a 0.01-mfd capacitor. The i-f transformers are then aligned for maximum output as indicated by the VTVM in the same order previously mentioned for the discriminator-type receiver.

The gated-beam detector circuit has two adjustments. The cathode bias resistor is adjusted for a quiet noise-free signal. The quadrature coil is adjusted for both maximum signal output and best fidelity.

An FM receiver differs from an AM receiver mainly in the frequency of operation and in the frequency of the receiver tuned circuits.

The average FM transmitter is low-powered in comparison to an AM transmitter. Reception depends mainly upon line-of-sight.

Because of low power transmission, most FM receivers employ an r-f amplifier stage and two i-f amplifier stages.

FM discriminators, being sensitive to AM as well as FM, require a limiter stage preceding the discriminator.

The control grid of the limiter stage is a valuable check point for presence of signal.

A low-level signal input to the limiter causes it to act as an amplifier with a resulting high-level noise output.

A ratio detector does not require a preceding limiter stage.

In the gated beam detector, continuous plate current flow permits use of cathode bias. The cathode bias control sets the operating point for the signal input.

An r-f signal generator and a VTVM are required for alignment of an FM receiver.

Most VTVM's have a zero center scale to aid in setting the detected output to zero volts.

To spot check detector linearity, the output frequency of the r-f signal generator is shifted 50kc above and below the center frequency. This should provide output voltages of equal value and opposite polarity.

Alignment of the i-f amplifier, r-f amplifier, oscillator, and converter or mixer circuits is similar to AM receivers.

In an unbalanced detector, two 100K resistors are placed across the detector load resistor, the connection of the two resistors forming a temporary center tap.

The gated beam detector circuit has only two adjustments. The cathode bias control is set for a quiet noise-free signal, and the quadrature coil is set for maximum output and best fidelity.

REVIEW QUESTIONS

1. What is the operating frequency range of FM receivers?
2. What is the most common value of intermediate frequency used in FM receivers?
3. Name the two most common types of FM detector circuits.
4. Why do we require a VTVM to read the grid bias of the limiter stage?
5. Describe the purpose of a de-emphasis network in an FM detector?
6. What are some of the possible reasons for a weak output signal containing a high noise level?
7. In a gated beam detector circuit, what will happen if the cathode bias control is set to the wrong value?
8. In alignment of an FM receiver, list the circuits to be aligned, and the order in which they should be aligned.
9. What is the detector output voltage at the center frequency (intermediate frequency)?

Handling Transistors

Preceding all instructions on transistor receiver servicing, instructions for the care and handling of the transistors themselves is a must. What better way to make a point then through humor? The accompanying illustrations of how *not* to use transistors speak for themselves.

How NOT To Use A Transistor

(1) **Twist and yank** the leads excessively when assembling into equipment. If you listen closely you can hear the **snap**

(2) **Overheat** the leads with a big soldering iron. Leads are going out of style anyway
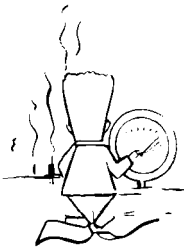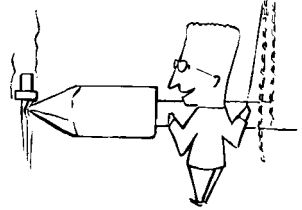
(3) **Ignore** the published ratings and **exceed** them. This will cause the transistor to **overheat**

(4) **Insert** the transistor into the test equipment while the power is **on** making sure the order in which the leads make contact is switched. This may cause immediate ruin
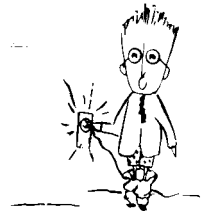
(5) **Spread** the transistors in an open aisle when assembling, so they have a better chance of getting stepped on
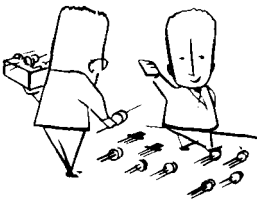
(6) If the transistor does not fit into the equipment properly, **put a screwdriver** onto the case and **hammer it** into place

Courtesy of General Transistor Corporation

Handling Transistors (cont'd)
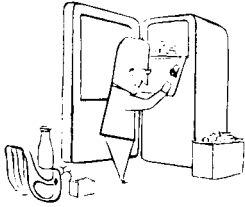
(7) **Avoid overheating** transistors on hot days by placing in freezing compartment of nearest refrigerator, being careful to avoid contamination from the chopped liver nearby

(8) **Forget about** the Ico, assume it equals zero, then you'll really end up with **nothing**
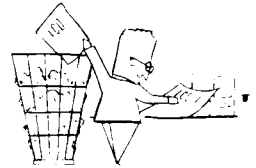
(9) In order to **burn out** the transistor thoroughly — be sure there is leakage to power line in soldering iron.
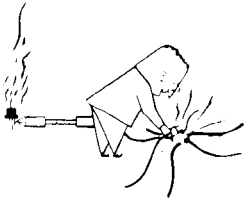
(10) Check transistor with **high voltage or high current** ohmmeter for continuity

(11) **Ignore** circuit variations as a function of temperature, and join the **F.C.C.** (Fatal Circuit Club)
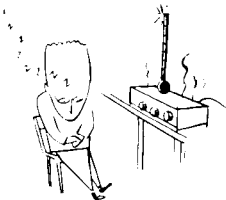
(12) Dip soldering — **immerse completely** in solder.

How NOT To Use A Transistor

Courtesy of General Transistor Corporation

Transistor Testing

A vacuum tube, although a sealed evacuated unit, does give some indication as to its operation, if only by the heat, light, or continuity of the filament. This may not be much of a test of the tube's ability to operate, yet it is better than none, and often is a handy check for series string filament circuits. However, with transistors no such quick check is available. Transistors are hermetically sealed units with very little heat radiating from its elements, unless it is a power transistor. As a result, transistors must have some type of tester to indicate their condition. The tube testers used by the average service technician is a far cry from that used in a laboratory, but for servicing of receivers it is adequate. The same condition holds true for transistor testers. The main checks of a transistor consist of determining whether it is open, shorted, or leaky, and whether it has sufficient current gain.

BASIC CIRCUIT

for testing p-n-p transistors

P-N-P

R1

R2

CURRENT INDICATING
METER
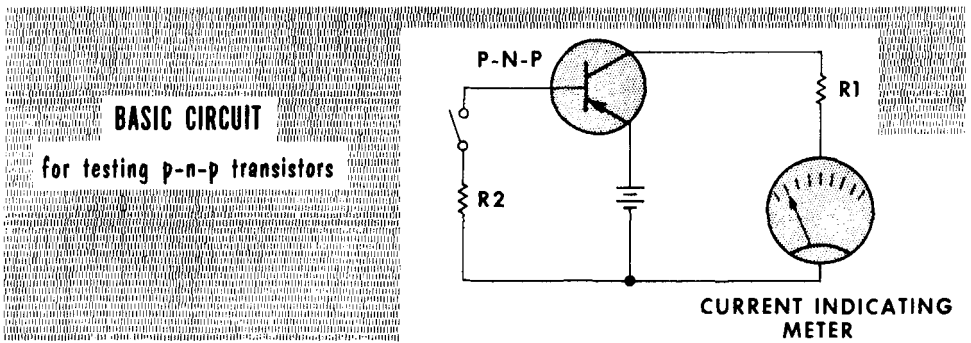
With the switch in the base circuit open, the battery voltage is placed between collector and emitter in series with a current-indicating meter, and current-limiting resistor, R1. The current flow between emitter and collector will be leakage current. Part of the leakage current is that of I_{co}, the small reverse current, caused by light and heat, that flows in a reverse biased junction breaking up some of the valence bonds. Another determining factor of leakage current is the *beta gain* found in common emitter circuits. *Beta gain* is the ratio of a small change in collector current divided by the small change in base current that caused it, which may vary from 10-40 or more. Leakage current between the emitter and collector is roughly equal to I_{co} times beta. A good transistor will have a small leakage current of only a few microamperes. High leakage current, or a short between the emitter and collector, will provide appropriately high current readings on the meter scale.

Closing the switch in the base circuit will place a small forward bias on the base through resistor R2. The small, emitter-to-base forward bias will result in increased collector-circuit current flow as indicated on the meter. This permits a rough approximation of the collector-current meter reading to be used as a measurement of beta gain. When a transistor shows no leakage current, and no collector current gain when the switch is closed, it indicates an open transistor.

Transistor Testing (cont'd)

The schematic diagram of a commercial-type junction-transistor tester is shown. Two transistor sockets are provided — one for the p-n-p type transistors, and one for n-p-n types. The battery is so placed in the circuit as to provide proper polarities for each socket. With no transistor in either socket there will be no drain from the battery. As a result no on-off switch is required. Placing a transistor in the correct socket results in an immediate reading of the meter scale, indicating the transistor's leakage. Pressing the spring-return switch applies current to the base of both transistor sockets. The transistor under test will have a forward emitter-to-base bias applied, resulting in increased collector-current flow. The reading on the meter will indicate the transistor gain, and it should show a gain of not less than one full division (0.25 ma). As previously mentioned, the absence of a reading of either leakage current or gain indicates an open transistor.
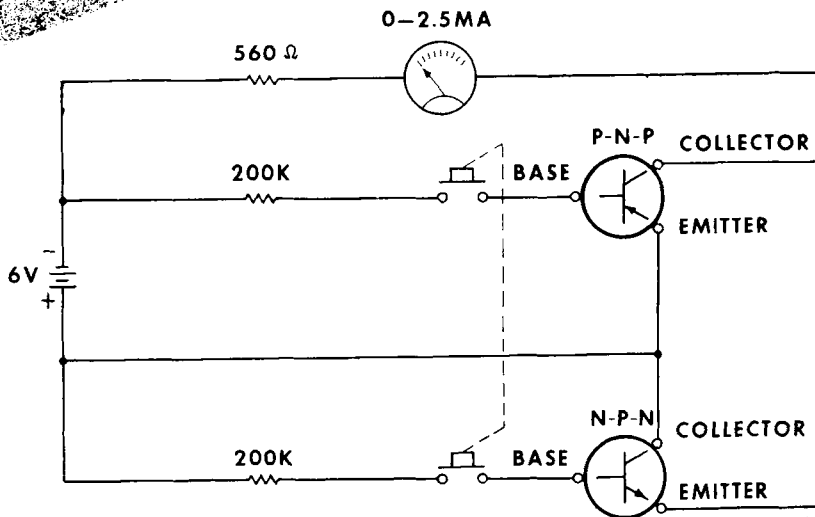
N-P-N and P-N-P Transistor Tester

With the exception of laboratory-type instruments, most of the transistor testers on the market have no facilities for testing high-current power transistors. Power transistors require currents of amperes as compared to those of milliamperes for ordinary junction transistors. The meter movements required must be low-resistance high-current ammeters. A meter resistance of one ohm with one ampere flowing, will cause a one-volt drop across the meter. In low-voltage transistor circuits this is prohibitive. The values of the meters required will be dependent upon the type of power transistor under test.

Transistor Testing (cont'd)

To test power transistors the data supplied by the manufacturer must be used as a guide. Temperature ratings in the area in which the power transistor is being tested should not exceed 25°C. (77°F.). Heat sinks have to be used where specified; if they cannot be used, forced-air cooling with a fan must be used. The high currents used in power-transistor testing requires that extreme caution be used to insure application of the correct polarities to the transistor under test.
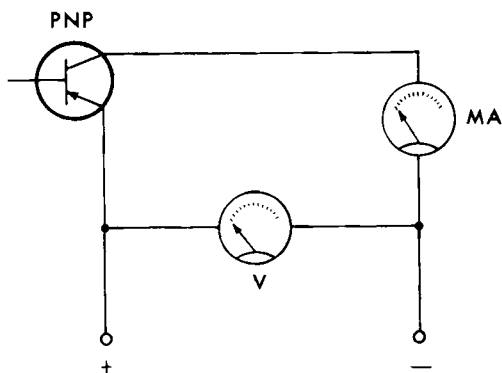
Basic Circuit Used TO CHECK Emitter Leakage

TYPICAL *Power Transistor Case* CONFIGURATIONS
designed for maximum heat dissipation
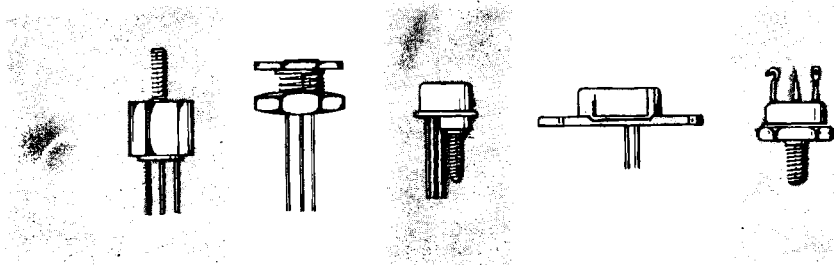
A basic circuit to check the collector-to-emitter leakage for a common emitter circuit is shown above. The voltage applied may be from a specially filtered, auto-radio power supply, whose value is determined by the transistor specifications. The voltmeter is used to monitor the applied voltage, and the milliammeter to read leakage current. The leakage-current reading should be taken quickly to prevent any possibility of thermal "runaway". The leakage current should not only be small — it should be steady. A fluctuating leakage indicates a defective transistor. The value of leakage current measured should be referred to the manufacturer's ratings.

Transistor Testing (cont'd)

To test a transistor with an ohmmeter, *not* a shunt type, is an approximate method of testing, but will detect completely-defective transistors. Being performed with the d-c voltages of the ohmmeter, the test gives no indication of transistor gain. Knowing that from base to either the collector or emitter is the equivalent of a diode, we can test the transistor by treating it as two diodes with a common lead at the base.

LOW R   HIGH R   LOW R   HIGH R
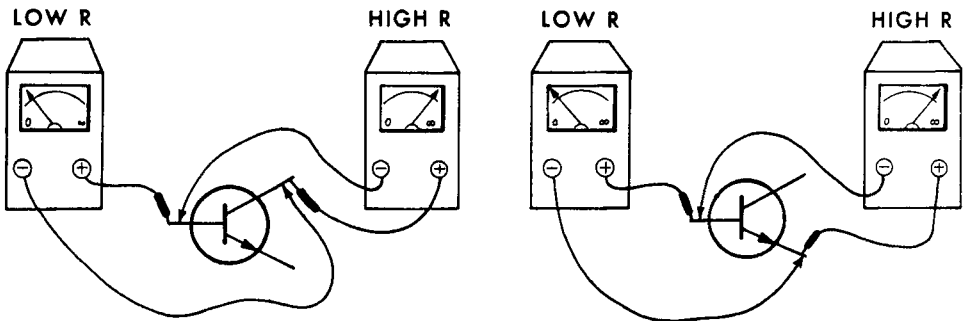
TESTING N-P-N TRANSISTORS WITH AN OHMMETER
low resistance should be 50-500 ohms   high resistance should be 50K
to 5 megohms   forward-to-back ratio should be 100:1 or better

LOW R   HIGH R   LOW R   HIGH R
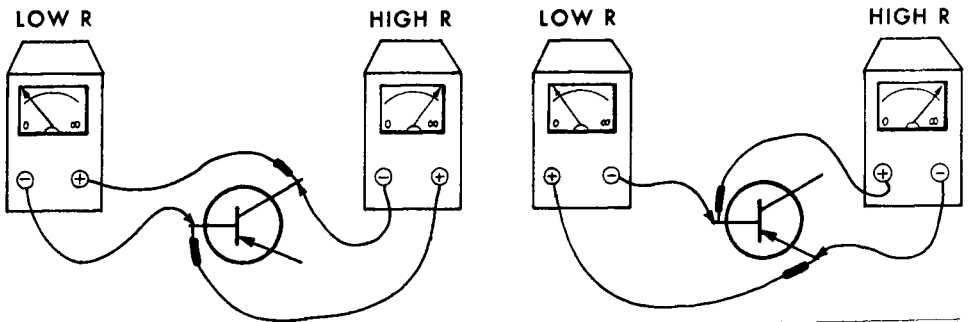
TESTING P-N-P TRANSISTORS WITH AN OHMMETER

To use the ohmmeter (20,000 ohms per volt, or VTVM) certain precautions must be taken: Do not use a shunt-type ohmmeter. Be sure of the polarities of the test leads. Do not use the high (R × 10,000) scale for ohmmeters using a 9-volt, or higher, battery. Do not use the low (R × 1) scale because the ohmmeter current flow may be as high as 0.01 amperes, too high for low-current r-f and i-f transistors. To be safe, use a R × 10 and/or R × 100 scale, depending upon the type of ohmmeter used.

Transistor Testing (cont'd)

POWER TRANSISTOR TESTER CIRCUIT
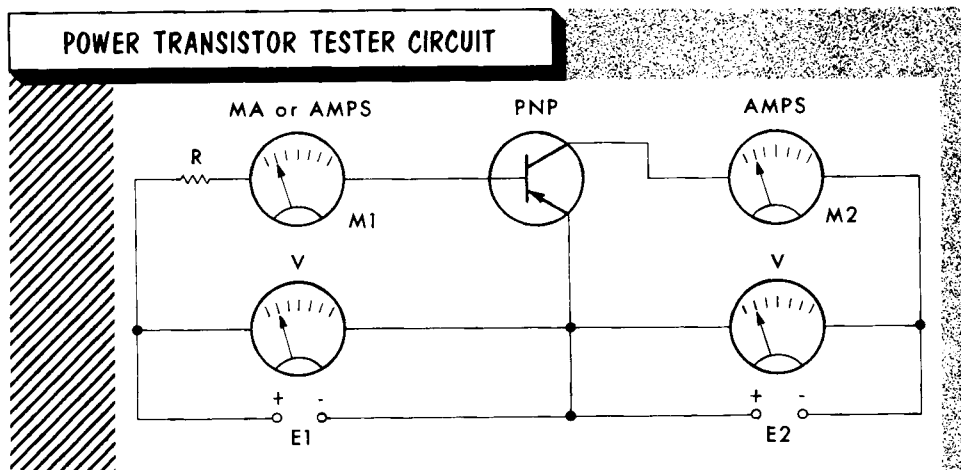
The base current, as indicated by M1, should initially be set at zero by application of zero voltage to points E1. The collector voltage as set at E2 should be steady, and at the value given by the transistor data. The voltage applied at E1 is varied in steps, until a maximum value is reached according to the transistor data. Each setting of the voltage at E1 will provide a reading of M1 and M2. The values of base-to-emitter voltage versus base-to-collector voltage, and the corresponding base and collector current flow, can be compared to those listed in the manufacturers' ratings or curves. At all times caution should be observed not to exceed the listed ratings.

To test the power transistor for beta gain, the following steps should be taken: (Again a word of caution: do not exceed ratings to any degree or the transistor may be damaged.)

1. Voltage E1 is set to zero.
2. Voltage E2 is set to the rated value.
3. Voltage E1 is increased until the reading of M2 indicates the correct collector current for the rated collector voltage.
4. Voltage E1 is then increased slightly to obtain a slightly increased collector current reading of M2; record this reading.
5. Record the base current indicated by M1.
6. Voltage E1 is reduced to have the collector current reduced from that of step 3 by an amount equal to that used in step 4; record the reading of M2.
7. Record the base current indicated by M1.

Beta equals the difference in collector current as read in steps 4 and 6, divided by the difference in current recorded in steps 5 and 7, being sure that all values of current are the same, i.e., milliamperes or amperes. The majority of power transistors will have a beta gain of approximately 25 to as high as 50.

Transistor Operating Voltages

Typical Operating Voltages

```
8.2v
0.6v
        N-P-N
0.4v
```

```
0.7v
8.1v
        P-N-P
8.3v
```
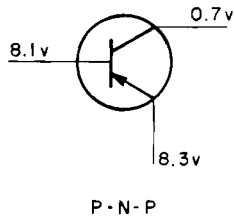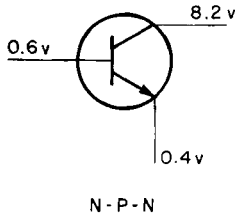
Open Transistor Voltages

```
9v
0.7v
        N-P-N
0v
```

```
0v
8.3v
        P-N-P
9v
```
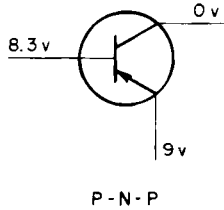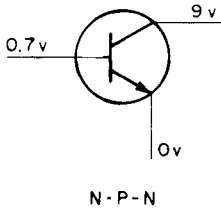
The effect of an open lead **within** the transistor will be the same whether it is an open base, emitter, or collector lead.

In an open n-p-n with no emitter current flow, the emitter will drop to zero volts. There will be no IR drop across the collector load, and the collector will be at the full source voltage. The base bias voltage will be close to its normal value as set by the voltage divider.

In an open p-n-p transistor there is no current flow in the emitter circuit; the emitter is at the full source voltage value. With no collector current flowing the collector is at zero volts. The base bias voltage is close to its normal value as set by the voltage divider.

Shorted Transistor Voltages

```
LOW
NORMAL
        N-P-N
HIGH
```

```
HIGH
NORMAL
        P-N-P
LOW
```
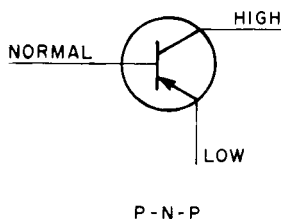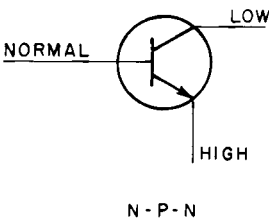
The increased current flow due to a short or partial short circuit between the collector and emitter in an n-p-n transistor, will cause an increased IR drop across the collector load, reducing the voltage between collector and ground. The increased emitter-current flow will cause an increased IR drop across the emitter resistor, resulting in an increased value of emitter voltage. The base bias will remain at its normal value.

The reversal of polarities in a p-n-p transistor with a short between collector and emitter results in an increased IR drop through the collector load, causing a higher collector voltage. The increased emitter current causes an increased IR drop across the emitter resistor. The base bias will remain at its normal value.

Transistor Operating Voltages (cont'd)

Open Collector Circuit N-P-N

0 - 0.1 v

0.4 v

0 - 0.1 v
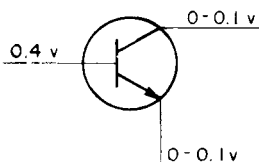
In typical common or grounded emitter circuits in an n-p-n transistor, the collector voltage will drop to zero volts. The current flow from the emitter will return through the base circuit, and may be enough to cause a slight emitter bias voltage. This slight voltage will also show up at the open collector. The base bias will remain close to its normal value as set by the voltage divider.

Open Collector Circuit P-N-P

8.9 v

8.5 v

8.9 v
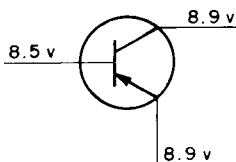
An open collector circuit in a p-n-p transistor will have the emitter voltage increase to almost that of the source. The open collector circuit will cause the collector to assume the same voltage as the emitter. The base bias voltage will also increase slightly over its original value.

Open Emitter Circuit N-P-N

9 v

0.75 v

0.75 v
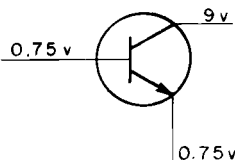
In an n-p-n transistor with an open emitter circuit, the base voltage remains about the same value since it is derived from a voltage divider. The emitter assumes the base voltage value. There is zero bias between the base and emitter. In some circuits an open emitter will cause a very slightly, negative base bias; normally, the base is biased positive in respect to the emitter. With no collector current flowing the collector voltage is the same as that of the source.

Open Emitter Circuit P-N-P

0 v

8.0 v

8.0 v
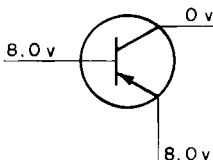
In an open emitter circuit of a p-n-p transistor, the fixed base-bias voltage is assumed by the emitter. There is zero bias between base and emitter. With no current flowing in the collector circuit, the collector voltage is zero.

Open Base Circuit N-P-N

9 v

0 v

0 v
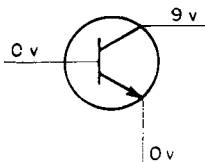
An open base circuit in a n-p-n transistor is essentially an open transistor circuit. With no base-to-emitter circuit there will also be zero voltage at the emitter. There is zero bias between base and emitter. There will be no IR drop through the collector load, the collector assuming the value of the voltage source.

Open Base Circuit P-N-P

0 v

9 v

9 v
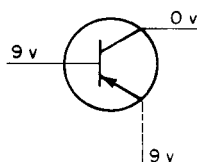
An open base circuit in a p-n-p transistor causes the base to assume the same voltage as the emitter. The emitter circuit is also open, causing it to assume the value of the voltage source. There is zero bias between the base and emitter. With no current flowing in the emitter-to-collector circuit, the collector voltage becomes zero.

Power Sources

All transistor receivers operate with various cells or batteries. Penlight, flashlight, and mercury cells in series are a common source of power. Another source is the 9-volt battery. The penlight or flashlight cells are rated at 1.5 volts, and mercury cells at 1.4 or 1.35 volts.

To properly check a battery or cell, it must be tested under load. If a commercial battery tester is not available, take a meter reading of the battery or cell with it placed in the receiver and the receiver turned on. A reduction of 10% or more in a conventional 1.5-volt cell (1.35 volts) or 9-volt battery (8.1 volts) is a sign of a deteriorated cell or battery that should be replaced. A reduction of 5% or more in a mercury cell (1.33 or 1.28 volts), indicates it should be replaced.

Battery Substitute
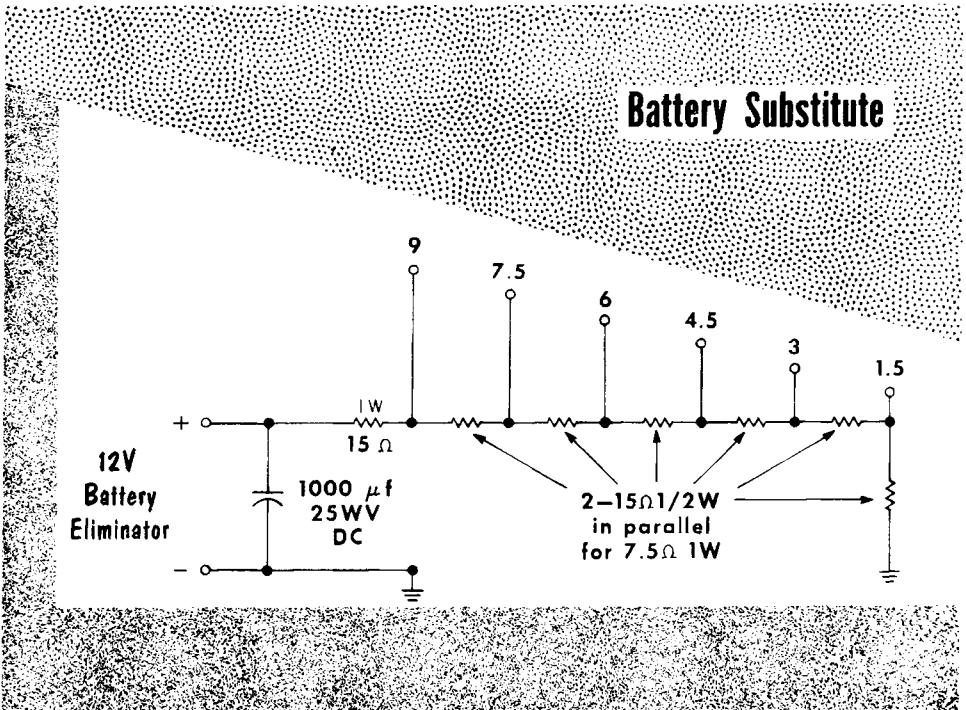
Note carefully that a basic assumption throughout all the following transistor receiver servicing notes will be that the battery has been carefully checked and found in good operating condition. It would be pointless to constantly repeat what should be an obvious first step in repairing a transistor receiver — a check of the voltage source.

Despite the advertising claims of "leak-proof" cells or batteries, many receivers will require servicing of badly corroded, battery snap-on plugs or corroded coil holders. Where necessary replace the snap-on plug rather than risk an intermittent or high-resistance connection due to a corroded connector.

Power Sources (cont'd)

Specially designed power supplies with variable output voltages, and metered to read the receiver current drain are commercially available. A common practice is the use of automobile-radio battery eliminators with additional filtering on the output. A battery eliminator can be used as a replacement or test power source for various voltage values by the addition of an external filtered voltage divider.

Increasing the receiver volume will correspondingly increase the current drain from the battery. Where a receiver is played with both loud volume and for extended periods of time, battery consumption will increase at a rapid rate. For receivers using push-pull power output, the added current drain of a receiver played at loud volume can be enough to cause a customer to inquire as to the reasons for the increased battery consumption.
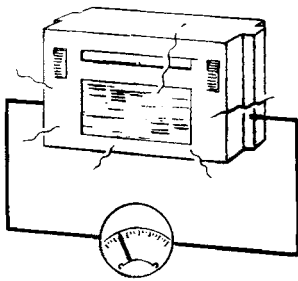
BATTERY
CURRENT
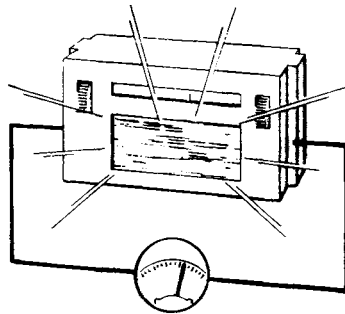
BATTERY
CURRENT

INCREASED *Volume Results in*
INCREASED *Battery Drain*

Despite the low internal impedance of a battery or cell, transistor receivers use an electrolytic, filter decoupling capacitor across the source voltage. The capacitor value will vary from approximately 50-150 mfd. A defective capacitor can cause motorboating, howling, squealing, etc. by loss of a low impedance path. To check for an open filter capacitor, or a reduction in capacity, bridge the suspected capacitor with a good capacitor of equal or higher capacity. Be sure to use a capacitor with sufficient voltage rating and carefully observe polarities. A shorted or partially-shorted capacitor will cause excessive battery-current drain.

Proper handling of transistors is important. Physical abuses (improper storage, soldering, handling leads, etc.) and electrical abuses (improper value of applied voltage, improper polarity of applied voltage, etc.) should be avoided.

Transistors, being hermetically sealed units, give no obvious checks for their operation as tubes do; they require a transistor tester.

The main tests of a transistor are for shorted or open current paths, excessive leakage, and current gain.

Testing a transistor with an ohmmeter (*not* a shunt type) is an approximate method of testing; it gives no indication of transistor gain.

When testing power transistors for beta gain, do not apply voltages exceeding the manufacturers ratings for the transistor.

In testing transistor circuits for correct operating voltages, you should know the approximate values of voltages when the circuit in operating properly. Open or short circuits within the transistor will cause changes that should be recognized.

The voltage readings of properly operating transistor circuits can be compared to readings taken when circuit elements (other than the transistor) are defective, such as open collector loads, etc.

To properly check a battery or cell, test it under load. A reduction of 10% or more in a conventional cell or battery, or a reduction of 5% or more in a mercury cell indicates it should be replaced.

An obvious first step in repairing a transistor receiver is a check of the voltage source.

Specially designed power supplies with variable output voltages, and metered to read receiver current drain are commercially available.

A common practice is to use an automobile-radio battery eliminator with additional filtering on the output.

Increasing the receiver volume correspondingly increases the current drain from the battery.

REVIEW QUESTIONS

1. Describe the proper methods of handling a transistor.
2. What type transistor does give some physical indication as to its operation? How does it give this indication?
3. How do transistor testers used by service technicians compare to those used in laboratories?
4. Describe beta gain.
5. When testing a transistor, what does absence of a reading of either leakage current or beta gain indicate?
6. In testing power transistors, why must the leakage-current reading be taken quickly?
7. When using an ohmmeter to test a transistor, we test the transistor as being the equivalent of what type device?
8. What precautions must be taken when testing transistors with an ohmmeter?
9. What is the voltage rating of a mercury cell?

Serving Techniques

The discussion of servicing of any electronic unit must, by its nature, be general. The best method of repairing a defective electronic unit — in this case a transistor receiver — is to know the correct operation of the receiver. When a receiver is not functioning at all, or not functioning properly, a technician armed with the knowledge of what is correct can probe the receiver to determine what is no longer correct. The difficulty may be electrical or mechanical, but knowledge will enable a quick determination of the difficulty, and result in speedy restoration of the receiver to its original operating condition.
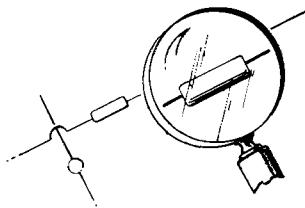
MAGNIFYING GLASS
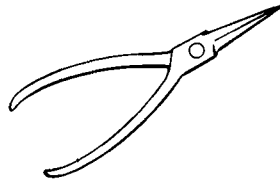
NEEDLE NOSE PLIERS
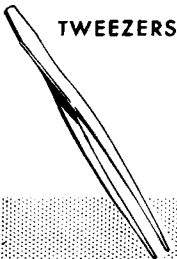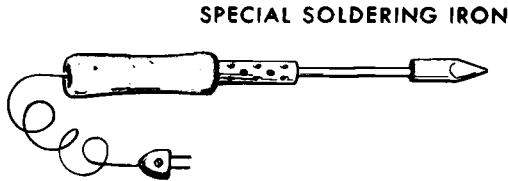
TWEEZERS   SPECIAL SOLDERING IRON

SPECIAL TOOLS are needed to remove and replace defective components

The majority of transistor receivers are compact, crowded units using miniaturized components to take advantage of the small size of a transistor. Printed circuit construction is used almost exclusively, calling for specialized techniques and tools to remove and replace defective components.

To aid in working with miniaturized components and printed circuits wiring, special tools are helpful. These include a magnifying glass, tweezers, small-size diagonal cutters, small-size needle-nose pliers, light-weight low-wattage soldering irons, special shaped soldering iron tips, etc.

Many of the special tools will be accumulated through experience in servicing transistor receivers. The components used in transistor receivers, particularly capacitors, usually have low ratings. Some capacitors are rated as low as 3 volts working voltage. This requires special precautions against testing with normal capacitor checkers that apply high voltages, and testing with ohmmeters using a battery voltage higher than the capacitor's working voltage.

Servicing Techniques (cont'd)

Often it will be found that the trouble is other than a transistor. Barring applications of incorrect voltages due to component defects, the transistor itself will give very little trouble. More trouble may be experienced from the miniaturized components with their low ratings. Typical will be open coils, open windings in i-f transformers, leaky or shorted capacitors, capacitors with less than the rated capacity, troublesome tuning units whether inductive or capacitive, etc.

When a wired-in transistor or diode requires replacement, or testing, special care must be taken in removing the transistor from the circuit. When unsoldering the transistor leads a heat sink must be applied to the lead just above the soldering iron. A convenient heat sink is a pair of long nose pliers clamped to the lead. The pliers are also used to remove the lead as well as remove heat. There are times when using pliers as a heat sink is not advisable, or cannot be done. For such instances a heat sink may conveniently be made by soldering two pieces of copper to an alligator clip as illustrated. Clipping this to the lead for use as a heat sink will leave

PROBE PRECAUTION

Cover or tape to prevent short circuits

SOLDER

SOLDER

HEAT SINK   COPPER
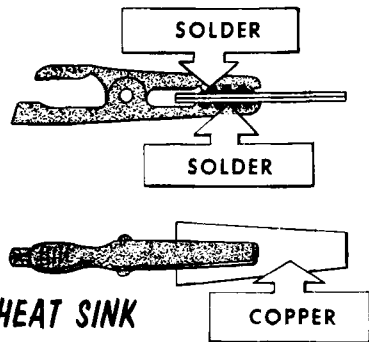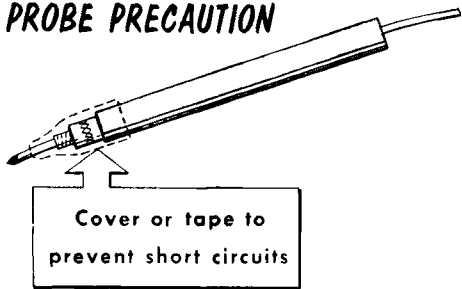
one hand free for servicing the receiver. All of the above requirements of heat removal for unsoldering the transistor lead hold true when the lead has to be resoldered to its terminal. When replacing transistors in push-pull audio circuits, it is best when possible to replace both with a matched pair.

When using the test probes of a meter, an accidental slip may cause a short circuit and/or place an excessive voltage on a transistor element. A safety precaution, see figure, is to insulate by the use of tubing, or tape, all but approximately $\frac{1}{8}$-inch of the end of the probe tip. This short length will prevent accidental short circuits, yet have sufficient bare metal to make contact with any point being measured. A sharp point on the probe is helpful where a coating of varnish or other protective insulating material is placed over the printed circuit. The increased number of electrolytic capacitors calls for an awareness of the polarity of the ohmmeter leads. This will vary with different instrument manufacturers. The safest method is to use a separate voltmeter to determine the polarity of each of the ohmmeter's test leads, and mark them carefully, either on the test lead, the test probes, or both.

Servicing Techniques (cont'd)

Dynamic methods of servicing a transistor receiver have a lot in their favor. The use of signal tracing, or signal injection, can be helpful in quickly locating the troublesome stage. Test equipment used to service transistor receivers should have isolated transformer-type power supplies to prevent accidental application of line voltages to the transistor receiver. If the test equipment does not use a transformer-type power supply, an isolation transformer should be used.

The signal generator, in addition to use for alignment, can be helpful in servicing transistor receivers. For signal injection be sure to use a blocking capacitor (0.01 mfd for rf, and 0.1 mfd for af). Use a low-level input signal. In some circuits the signal can be induced by clipping the generator lead to an insulated resistor, or a plastic or cardboard encased capacitor that does not have the outside foil at ground. Another method of coupling the signal is to place the generator output to a loop antenna. The signal output radiated by the loop antenna can be adjusted by either varying the space between the loop and the receiver, or by reducing the generator output.

Noise Generator
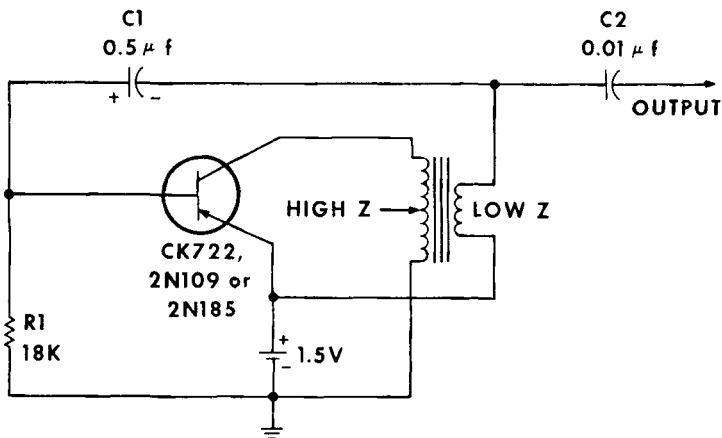
Another form of signal injection is the noise generator. The broad-band output of the noise generator can be applied either directly by a probe, or it can be radiated by a loop antenna. Preferably the noise generator should have an output amplitude control. The best use of a noise generator is for quick isolation of the defective stage.

Servicing Techniques (cont'd)

455 KC

TO AUDIO
AMPLIFIER
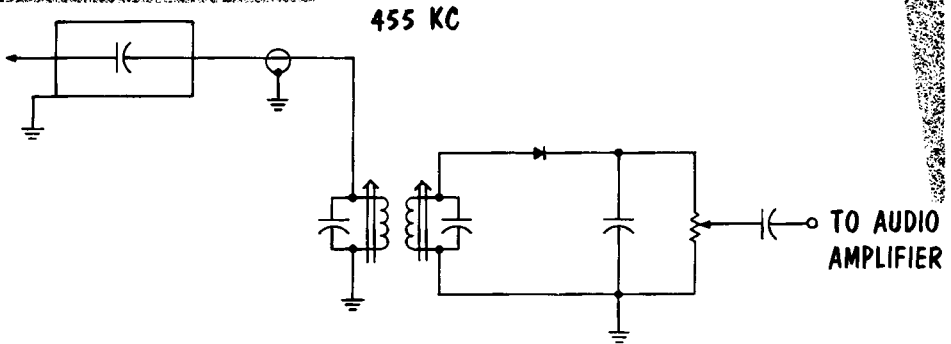
TUNED INPUT DETECTOR CIRCUIT

A signal tracer can be of help in following the path of signal; however, the low impedance of a transistor circuit can create a problem in that the signal tracer can *load* the circuit under test. The majority of signal tracers use a diode detector, often placed in the probe, for r-f and i-f signal tracing. A tuned circuit detector, the output of which is applied to the audio amplifier portion of the signal tracer, will reduce loading and allow tracking of r-f and i-f frequencies. Although the input of the detector is tuned to an intermediate frequency, it will also work at broadcast frequencies.

The grid-dip meter has many uses — an important one is to check the oscillator circuit. Tuning the grid-dip meter against the oscillator will indicate if the circuit is open, and/or the frequency to which the oscillator is tuned. You can also "beat" the grid-dip meter against the oscillator for a beat-frequency output signal indicated by the speaker of the receiver under test. If the receiver output stages are disabled, the beat frequency generated between the grid-dip meter and the oscillator can be heard by detecting the output of the grid-dip meter. The grid-dip meter can also be used to check the r-f and i-f tuned circuits. Another use of the grid-dip meter is as a substitute signal generator. Although the dial calibration of the grid-dip meter is not as accurate as that of a signal generator, it can be used for quick *go-no-go* tests. For example, if the oscillator circuit of a receiver is suspected of being inoperative, tune the receiver to local broadcast station frequency; then set the grid-dip meter to a value 455 kc higher. The grid-dip meter acting as a substitute local oscillator will inject sufficient signal to restore operation.

Servicing Printed Circuits

Printed circuits are used in many tube-type radios, and almost exclusively in transistor radios. These circuits are laminated plastic boards with a thin sheet of copper foil bonded to one side. By various photographic and etching processes, some of the foil is removed leaving thin ribbons of foil to act as conductors. Where components are mounted, holes are punched in the board with the copper foil encircling the hole. The component lead is then inserted through the hole and soldered to the copper foil. Wire leads are soldered while the wire is going straight through the hole, and lugs or tabs are bent over and soldered to the foil. The soldering is done all at once by dipping the completed board deep enough into a pot of molten solder to solder all the lugs and wire leads. The board is then cleaned and a coating of varnish is usually applied to prevent dust and moisture from causing short circuits.

TO REPAIR BREAKS...

...use a
wire jumper

...to see if there
are breaks in foil
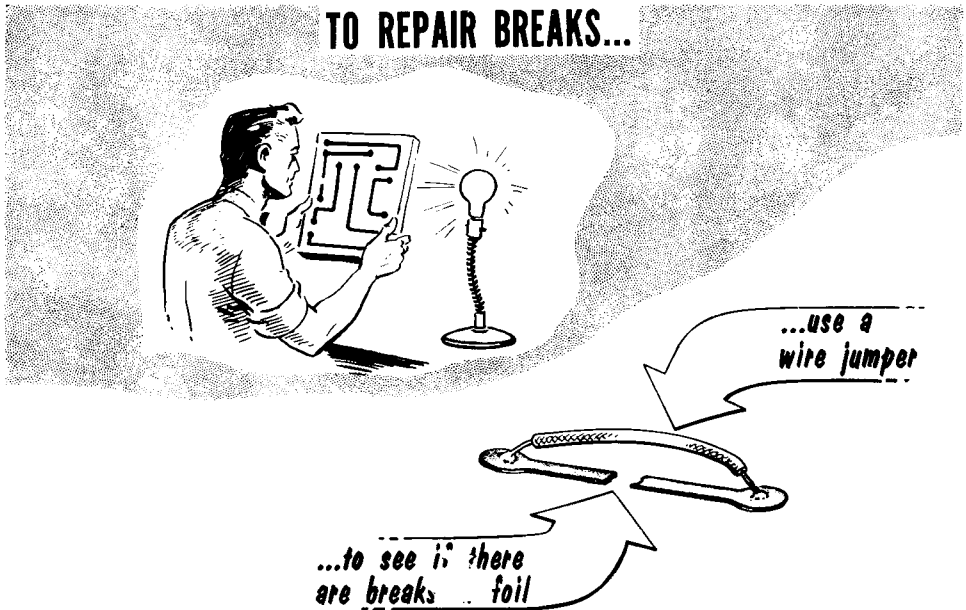
HOLD PRINTED CIRCUIT TO LIGHT...

A fine break or an intermittent crack in the copper foil can be difficult to find, requiring the use of a magnifying glass. Small breaks in the copper foil can be repaired by cleaning the insulating varnish from the printed conductor at either side of the break, and placing a jumper of solder across the break. A large break in the foil can be repaired by jumping the open section with a wire soldered at each end as shown.

Servicing Printed Circuits (cont'd)

The printed circuit board, when removed from the radio case, should be handled with care, as it is easily cracked and broken. When soldering a lead, the soldering iron should not be applied for too long a period to prevent overheating and breaking the copper foil. The soldering iron should be of small size, approximately 35 watts dissipation. When soldering be careful not to let any blobs of solder fall on the board and cause a short circuit.
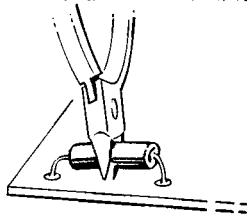

1 cut the defective component   2 cut the component from
  in two pieces   the circuit at the leads
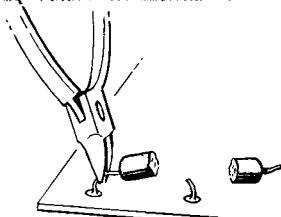
When changing a defective component with short leads, cut the component in half with diagonal cutters, see figure. After the component is cut in half, each half should be cut by the diagonal pliers until the end of the lead inside the component is reached. The ends are then cleaned and formed into a loop.
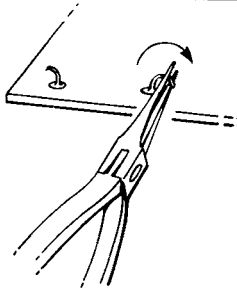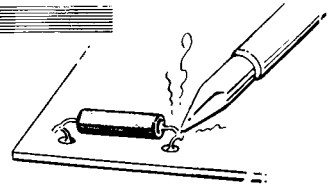
4 solder the replacement

3 loop the two leads

The leads of the replacement component are then formed into a loop and entwined about the loops of wire formed from the leads of the old component as illustrated. The loops are crimped together and soldered.

The soldering iron used for removal of components should be of a higher wattage than that used to solder components to the printed circuit. More heat is required for clean "unsoldering". A typical value would be a 60-watt iron or a soldering gun.

Servicing Printed Circuits (cont'd)

To remove components mounted with multiple lugs running straight through holes in the board, the soldering iron is applied to one lug. When the solder becomes molten the component is wiggled back and forth while the iron is removed. The continuous wiggling prevents the solder from adhering and will result in a broken connection after the solder has cooled. Repeating this process with the remaining lugs will permit removal of the defective component.
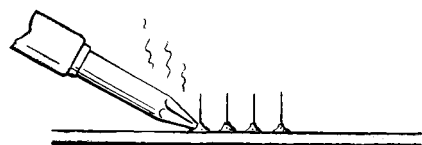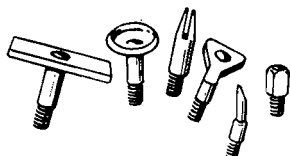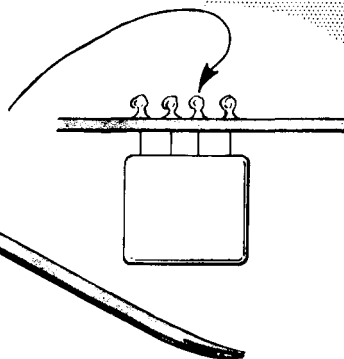
HEAT Solder Connections Till Molten
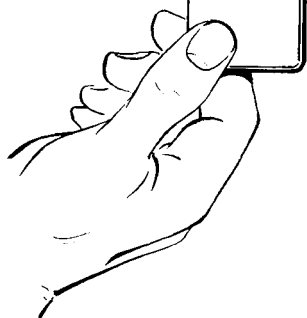
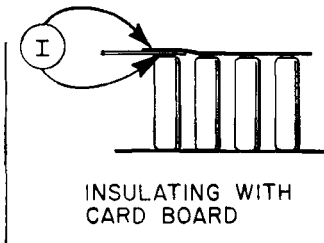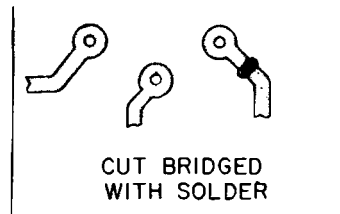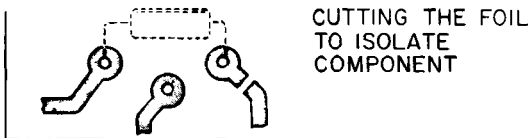Gently **WIGGLE** Component

Solder Removing Tool
used to remove this

Special Soldering Iron Tips

Components held in place with bent-over lugs require a different method of removal. One type of soldering aid available has a stainless-steel wire brush at one end and a pointed or slotted probe at the other end. Applying the soldering iron to the bent-over lug will cause the solder to melt; the molten solder is then carefully brushed off the lug and copper foil by the stainless steel brush. After the solder is removed the probe end is used to straighten the bent-over lug. With the lug straight the connection can be broken by wiggling the component with the soldering iron applied as previously mentioned. Various special-shaped soldering-iron tips designed for removing printed circuit components are also available.

Printed Circuit Component Testing

In testing components mounted on printed circuit boards, we often have to *lift* one end to be sure the component being tested is not being paralleled by another component. In printed circuits *lifting* one end to isolate a component creates a problem, such as unsoldering bent-over lugs of a control or i-f transformer. The possibility that the work may be needless and only lead to damaging the component or the board, further aggravates the situation. A quick way out is to carefully *cut* the printed circuit lead to the end of the component. The cut should be made carefully with a sharp penknife blade, or a pocket-type razor knife. Depending upon the type of board, a straight cut may provide sufficient separation. If necessary two close cuts may be made with a narrow strip of foil lifted to make a clean separation. After checking the component, carefully clean the foil on both sides of the break and fill the gap with solder. For testing or substituting transistors, or other multiple-lead devices, cut all but one of the leads.

CUTTING THE FOIL
TO ISOLATE
COMPONENT

CUT BRIDGED
WITH SOLDER

INSULATING WITH
CARD BOARD

LIFTING ONE
END OF SNAP-
ON PLUG
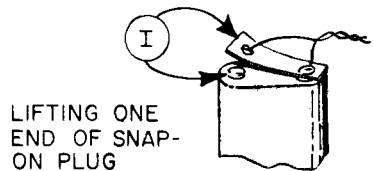
Transistors are current-operated devices. As such, current readings are often more meaningful than voltage readings. To take current readings brings up the same problem mentioned above — the problem of *lifting* one end of a circuit to allow insertion of a current reading meter. This problem is solved by cutting the printed circuit lead as previously mentioned. Depending upon the type of receiver, there are various methods of measuring the entire receiver-current drain. For receivers using a series of cells for a power source, the end cell can be insulated from the cell-holder contact by a piece of cardboard or paper. Placing the current meter on either side of the insulator will close the circuit and provide a meter reading. For receivers using a battery and snap-on plug, snap on only one end of the plug, and then place the current meter between the battery terminal and the free end of the plug. In all cases, carefully set the polarity of the meter leads to prevent *pegging* the meter needle backwards. Typical receiver-current values for small pocket portables are between 5 to 15 milliamperes, with larger multi-band portables draining from 10 to 25 milliamperes from the source. These readings should be taken with the receiver tuned off-station for no-signal operation.

Single-Ended Audio Power Output Stage

A preliminary word of caution when handling power transistors used for audio power output circuits: *Be sure to check if insulating washers are used between the chassis and the transistor.* When insulating washers are used, be very careful to replace them when removing and replacing the power transistor.

A typical single-ended, class A power amplifier is shown. Operating class A, collector current will flow constantly, requiring a heat sink to insure the dissipation of the heat developed by the current.
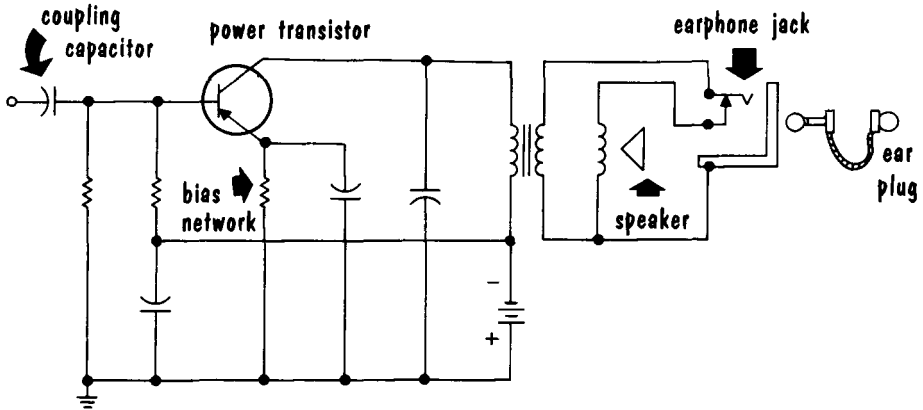
AUDIO POWER OUTPUT CIRCUIT

For a distorted signal output, check for a defective speaker with the voice coil rubbing against the pole piece. A defective transformer having shorted turns will cause a mismatch. Incorrect bias voltages on the emitter or base of the transistor will also cause distortion. Be sure to remove the transistor before testing the output transformer or any of the voltage-divider or bias resistors. Check the coupling capacitor and the capacitor across the output transformer primary for excess leakage resistance.

The earphone jack is a normally-closed type. That is, when the ear plug is not plugged in, the contacts are closed, permitting the loudspeaker to operate. Conversely, when the ear plug is inserted, the contacts are separated; only the ear plug is connected to the secondary of the transformer. If the spring contact should become loose, intermittent operation of the receiver may result.

Single-Ended Audio Power Output Stage (cont'd)

Reduced output can be caused by the same difficulties that cause distortion. A defective output transformer with shorted turns will cause reduced output. Check for correct bias voltages at the emitter and base of the transistor. Remember to remove the transistor before testing the output transformer or any resistors. Check the coupling capacitor for reduced capacity.
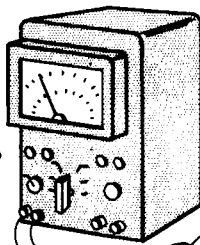
FOR REDUCED OUTPUT...

Use

... a test speaker and plug with earphone jack for quick check of receiver's speaker
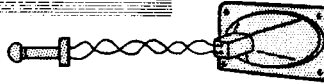
multimeter

set for output

Use

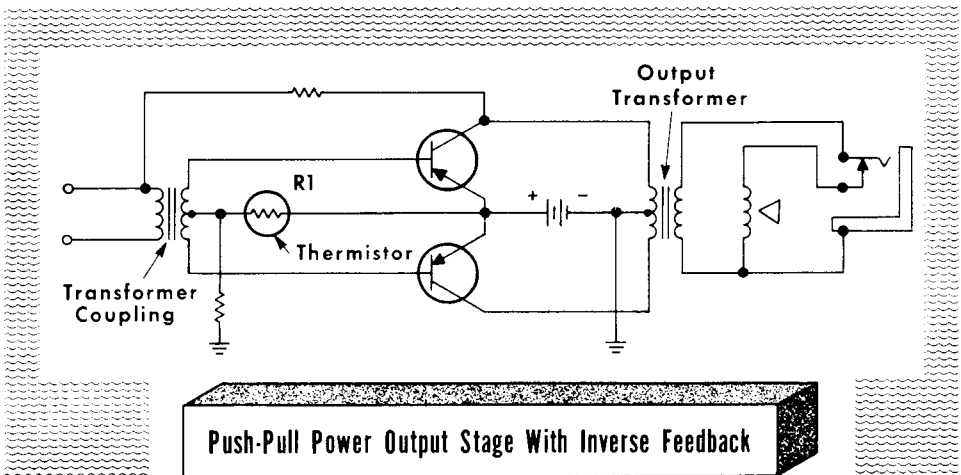... a plug with test leads for test or alignment

For no output, check the earphone jack for a closed circuit from the output transformer through the speaker voice coil. Check the speaker for an open speaker-voice-coil winding. On rare occasions a receiver used at a beach may have grains of sand "freezing" the voice coil in the speaker pole piece. Another check is for correct bias voltages. Check for a defective transistor. The absence of collector voltage could be due to an open primary winding in the output transformer, or a shorted capacitor across the primary winding of the output transformer. Check the base bias voltage; if incorrect check the values of the resistor voltage divider, and for a leaky coupling capacitor. Check emitter bias voltage; if too high look for a defective transistor or open bypass capacitor. Too low an emitter bias can be a defective transistor or a change in value of the bias resistor. Low emitter bias can also be a result of low collector voltage. Be sure to remove the transistor before making ohmmeter checks.

Push-Pull Audio Power Output Stage

A typical push-pull power-output stage uses transformer coupling to accomplish phase inversion and an output transformer to match the push-pull transistor impedance to the speaker impedance. Usually this stage is operated class AB, with the transistors biased close to but not quite at cutoff. To prevent thermal runaway and maintain a constant bias, thermistor R1 is used in the bias circuit. A reminder: before making any ohmmeter checks of circuit components, be sure to remove the transistor.

For a distorted output, check for a defective speaker with the voice coil rubbing against the pole piece. A defective input or output transformer having shorted turns will cause a mismatch, or an open feedback resistor may cause distortion. Incorrect bias voltages may be due to a defective thermistor, or a change in resistance value.

Push-Pull Power Output Stage With Inverse Feedback

Reduced output can be caused by many of the same difficulties that cause distortion. A change in the feedback resistor value could provide excessive feedback. Shorted turns in the input or output transformer will cause reduced output; incorrect base bias voltage due to a change in value of the bias voltage divider network can also cause reduced output.

For no output, check the earphone jack for a complete circuit from the output transformer secondary to the speaker voice coil. Check for an open speaker-voice-coil winding. If the receiver has been used at a beach, grains of sand may "freeze" the voice coil in the speaker pole piece. Check the collector voltage; if no voltage is present, check for an open primary winding in the output transformer. Check the base bias voltage; if no voltage is present, check for an open secondary winding in the input transformer, or an open resistor or thermistor in the bias voltage-divider network. The previous checks have tested all but the primary winding of the input transformer. If open it would cause loss of output. This can be checked by reading the collector voltage of the audio amplifier transistor driving the input transformer.

Audio Driver or Audio Amplifier Stage

A typical audio amplifier or audio driver stage amplifies the signal developed across the detector load (volume control), and applies it to drive the audio power-output stage.

For distortion, or reduced output check the base bias; if incorrect, check the bias voltage-divider network. A reduced-value coupling capacitor will reduce the input signal, causing distortion. Check the emitter bias; if incorrect check the emitter resistor and bypass capacitor. An open emitter

DRIVER
TRANSFORMER

VOLUME
CONTROL

some circuits
may have
tone control
circuit
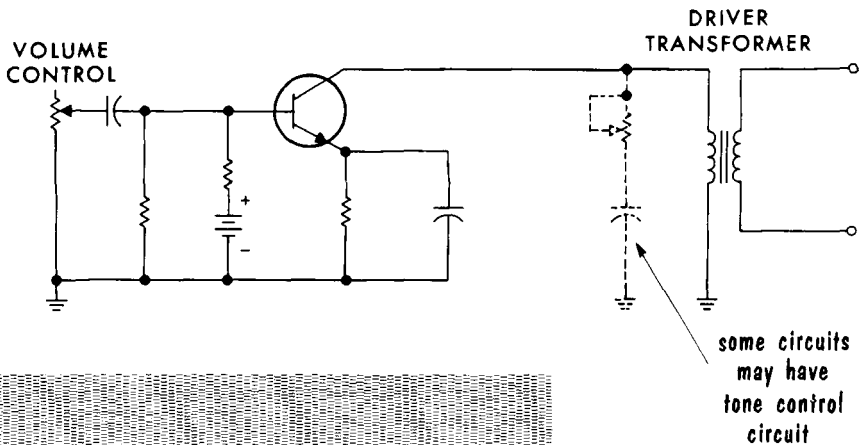
Audio Amplifier Circuit

bypass-capacitor may also cause low output or distortion. Shorted turns in the primary of the driver transformer or a shorted tone-control capacitor may be a source of low volume or distortion.

With no output, check the collector voltage; too high a collector voltage may be the result of a defective transistor. Circuits using an n-p-n transistor may have too low a collector voltage as the result of a defective transistor. The absence of collector voltage may be due to an open primary winding in the driver transformer. The earphone jack, because of sufficient output of the audio driver, may often be found in the driver circuit. If so, the jack should be checked for an open circuit. Check the base bias; if the wrong value of voltage, or no voltage is present, check the bias voltage-divider network. Test for an open coupling capacitor.

Most transistor receivers are compact, crowded units, using miniaturized
    components on printed circuit boards.
Special tools are used to repair and remove miniaturized components from
    printed circuits.
Transistors do not give much trouble, but most of the difficulties will be
    from the miniaturized components with their low ratings.
When removing or inserting a diode or transistor, use a heat sink.
To prevent accidental slips on a crowded printed circuit board, tape over the
    test probes exposing about 1/8-inch of bare metal.
To prevent accidental application of line voltages to the receiver, operate
    all test equipment with transformer isolated power supplies.
A popular method of coupling the signal generator output to a receiver is
    to place the generator output to a loop antenna and then place this
    loop antenna close to that of the receiver.
A broad-band noise generator helps to quickly isolate a defective stage.
A signal tracer using a tuned input reduces circuit loading and allows
    tracking of r-f and i-f frequencies.
Breaks in the copper foil conductors can be bridged by jumpers of solder
    for small breaks, and wire jumpers for large breaks.
The soldering iron used for removal of components should be of a higher
    wattage to permit clean "unsoldering."
To take readings of the battery current drain, isolate a cell from its holder
    by using a piece of cardboard. For receivers using a battery plug, only
    one end need be snapped on, leaving the other end free for series
    insertion of the current meter.
When working with power transistors be sure to check if insulating
    washers are used between the transistor and chassis.
Thermistors may be used in the base to emitter bias circuit to prevent
    thermal runaway.

REVIEW QUESTIONS

1. Name some of the specialized tools that help in servicing miniaturized
    components on printed circuit boards.
2. What tool constitutes a convenient heat sink for use in inserting or
    removing a diode or transistor?
3. What precaution should be followed when replacing a transistor in a
    push-pull amplifier?
4. Why is it helpful in servicing printed circuits to have a sharp point
    on the meter probe tip?
5. Describe one method for determining the polarity of the test leads of
    an ohmmeter.
6. Describe some of the uses of the grid-dip meter as a test instrument
    for transistor receiver servicing.
7. What is the purpose of the coating of varnish usually applied to
    printed circuit boards?
8. What precautions must be taken when handling power transistors?
9. What qualities of a thermistor help prevent thermal runaway?

Power Detector and AVC Stage

A power detector provides both detection and amplification. By biasing the transistor at or near cutoff, one-half the modulated input signal is rectified. The amplified output at the collector has the r-f element bypassed to provide the detected-amplified, audio output signal. Varying the arm of the volume control varies the total series value of the collector load, which consists of the load resistor in series with a portion of the volume control. Varying the value of the collector load will vary the value of the detector output signal. The base bias is developed by a voltage divider
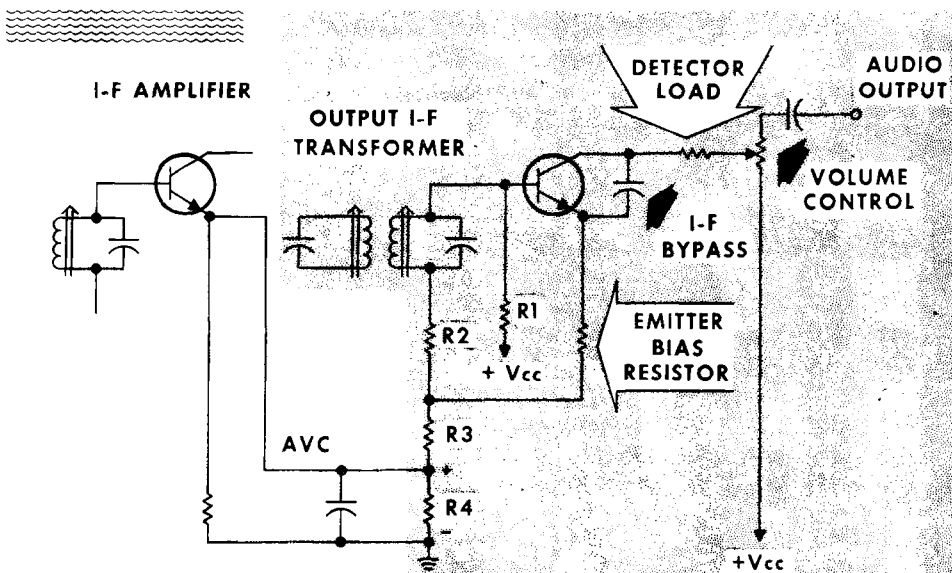
POWER DETECTOR

consisting of R1, R2, R3, and R4, with R4 bypassed to provide a steady d-c output which is used as the AVC voltage. Application of an input signal to the base will have the negative-going portion cut-off by the base bias, and the positive-going portion of the signal voltage will add to the bias voltage across R2, R3, and R4. The signal-developed increase in positive voltage across R4 is filtered and fed back to the emitter of the i-f amplifier as the AVC voltage.

To check for oscillations causing howling and squealing, look for an open AVC bypass capacitor allowing positive feedback to the i-f amplifier stage. An open i-f bypass capacitor in the collector-to-emitter circuit could also be the cause of oscillations. Should the i-f bypass capacitor require replacing, be careful to place it in the same position as the original capacitor. Placed incorrectly it could cause feedback between the output and the input of the stage causing oscillations.

Power Detector and AVC Stage (cont'd)

Reduced output or distortion can be the result of a defective transistor or a defective AVC or i-f bypass capacitor. Check for a defective winding of the output i-f transformer. Check the base and emitter bias voltages; if there are any discrepancies check the voltage-divider network. Distortion
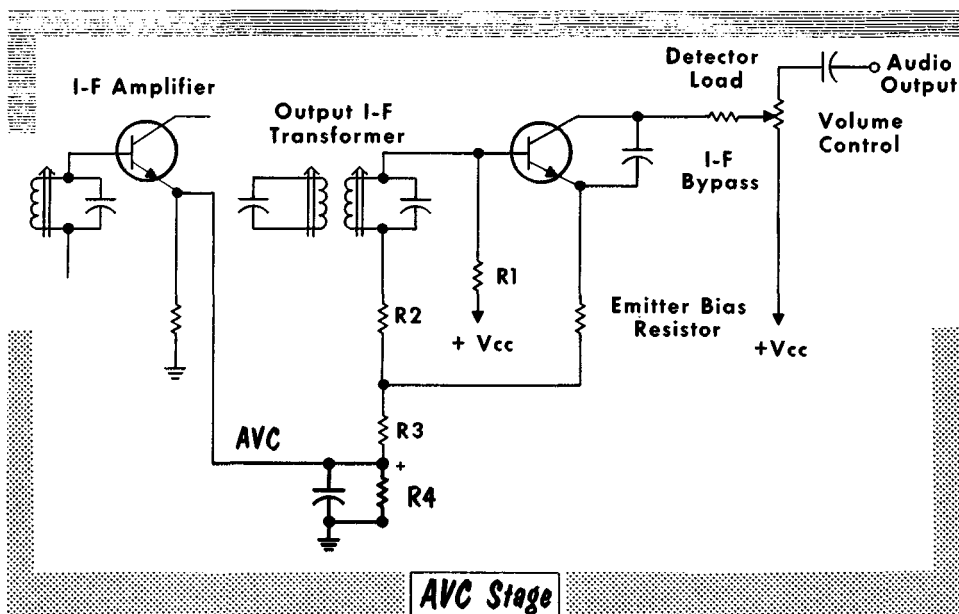

or reduced output could also be caused by a change in the value of the detector load in the collector circuit, or a change in value of the coupling capacitor in the output circuit. If there is a marked change in the value of either R2, R3, or R4, it may cause the distortion, and, naturally, the defective component should be replaced. In some extreme cases, a defective transistor may be the cause of distortion. Care should be taken when making the component change that no other components are damaged during the replacement. A low-wattage iron should be used on the transistor leads if they are to be soldered.

Loss of output can be caused by a defective transistor, an open winding in the output i-f transformer, or a shorted i-f bypass capacitor. An open, collector load resistor or an open connection at the wiper arm of the volume control could also cause loss of signal. Check for an improper value of base and or emitter bias voltage; if there are any discrepancies in the values, check the voltage-divider network. An open coupling capacitor can also cause the loss of the output signal. For loss of the collector voltage, check the collector load resistor and the volume control. For printed-circuit boards, check the connecting lugs of the volume control to be sure they are well soldered to the printed-circuit terminals.

Diode Detector and AVC Stage

The diode detector stage is also the source of the AVC voltage used to control the gain of one or more i-f amplifier stages. The polarity of the detector diode output is determined by the polarity of the AVC bias voltage required at the i-f amplifier, which in turn is determined by whether the i-f amplifier is an n-p-n or p-n-p transistor.

Oscillation (howling and squealing) can be caused by an open AVC bypass capacitor allowing positive feedback of the detected signal. Another cause could be an open r-f bypass capacitor across the volume control in the detector circuit.
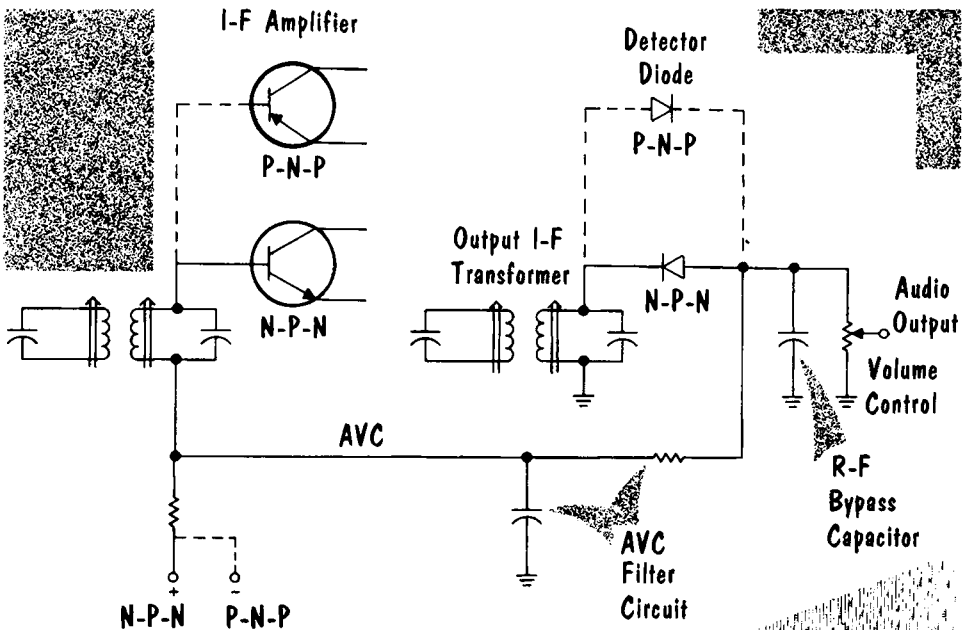
DETECTOR CIRCUIT FOR I-F Amplifier

Reduced or distorted output may be the result of a defective diode, an open or reduced-value AVC bypass capacitor, or an open or reduced-value r-f bypass capacitor. A defective winding of the output i-f transformer may also cause reduced output or distortion.

With no output, check for a defective diode, an open winding in the output i-f transformer or a shorted r-f bypass capacitor. For printed circuit boards, check the connecting lugs of the volume control to be sure they are well soldered to the printed circuit terminals.

I-F Amplifier Stage

Intermediate-frequency amplifiers employ high-gain, high-Q tuned circuits. High-gain and high-Q circuits require negative feedback to prevent unwanted oscillations. This negative (degenerative) feedback is called *neutralization*. Another feature often found in i-f amplifier circuits is an overload diode, which prevents overloading the i-f amplifier on signals so strong that even the AVC voltage is insufficient to decrease the receiver gain.

Oscillations in i-f amplifier stages may be due to feedback. However, another possible cause in high-gain low-impedance circuits could be high-
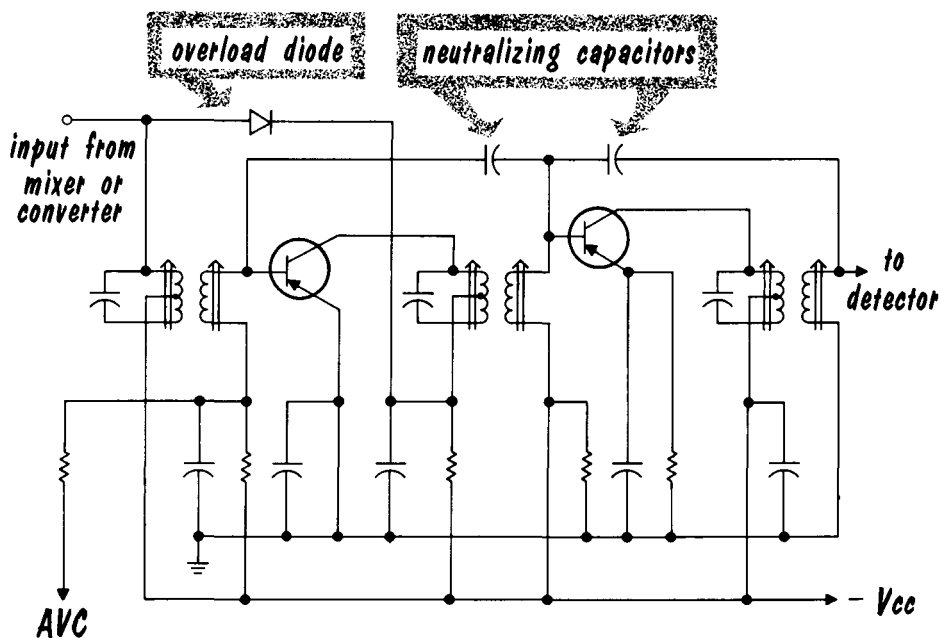
I-F AMPLIFIER Circuit

resistance solder connections or high-resistance ground returns. Check all solder connections for *cold solder* joints. To test the ground returns, use a jumper wire to parallel the ground-return lead being checked. An aged capacitor may lose some of its capacity, and become a poor bypass capacitor. Bridge the suspected capacitor with a good capacitor of the correct value. Bridging suspect capacitors will also check for possible open neutralizing or bypass capacitors. A remote possibility, unless the receiver has been tampered with, is the necessity of realigning the i-f amplifier tuned circuits. When inserting a replacement transistor in an i-f stage, check its gain; if too high it could cause oscillation.

I-F Amplifier Stage (cont'd)

Reduced gain and or distortion can be the result of an overload diode conducting at all times due to improper bias voltages. Distortion on strong signals could be due to an open overload diode. For wrong values of bias voltage, check voltage-divider values. Series dropping resistor values should also be checked where wrong bias values are indicated. Alignment may be off-peak, causing reduced output. When alignment of the tuned circuits indicates that it is peaking off the correct i-f value, check for shorted turns or defective capacitors in the i-f transformer. For receivers using power detectors, check the value of AVC voltage applied to the i-f stage.

Complete loss of signal can be due to defective transistors. For defective i-f transformers, the transformer winding can be checked for continuity by voltage readings. Before making any ohmmeter check of the transformer windings, remove the transistor. For wrong values of bias voltage, check both the voltage dividers and series dropping resistors. A fused (shorted) overload diode or shorted neutralizing capacitor will also cause complete signal loss. Where transistor sockets are used, be sure that the transistor is properly seated in its socket.

For Loss of Output Check...
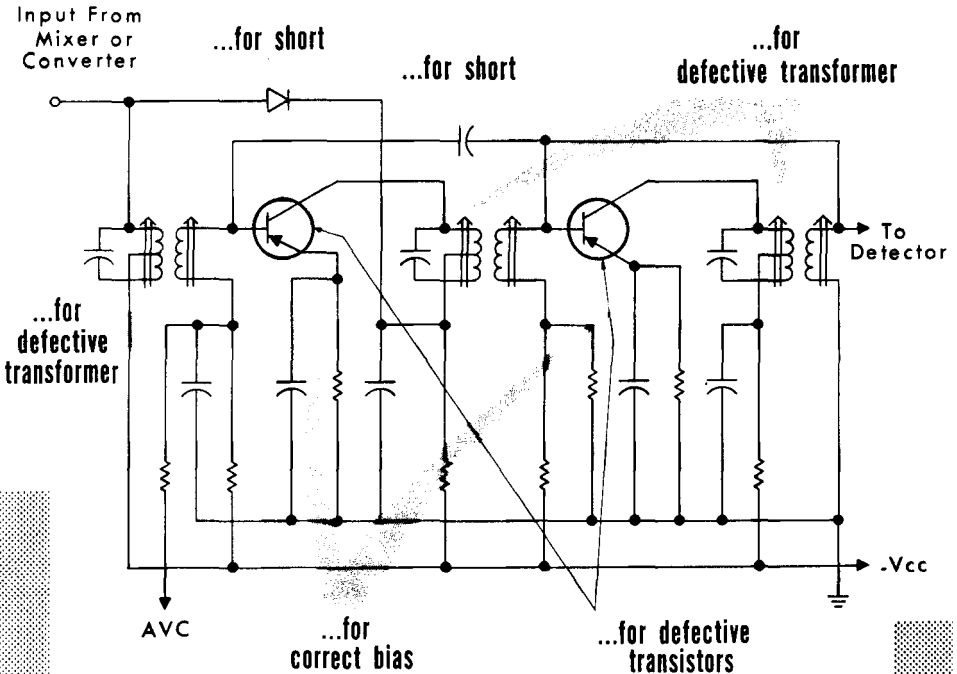
Reflexed IF-AF Amplifier Stage

For economy the last i-f amplifier stage may double as an i-f and a-f amplifier. The collector circuit has two output leads. The i-f transformer couples the i-f signals to the detector, and the detected a-f signals are returned to the base, amplified, and then applied to the driver transformer. The i-f transformer has too low an impedance for the af to develop any signal, and capacitor C3 will bypass any i-f signals, keeping them from the driver transformer.

I-F and A-F AT BASE
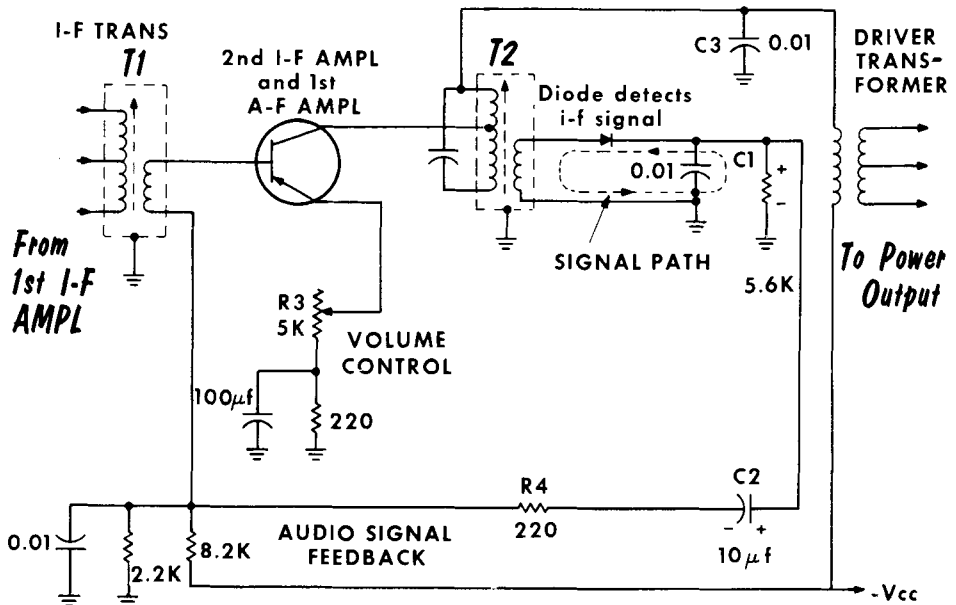
REFLEXED IF-AF AMPLIFIER

Oscillations can be caused by open or reduced-value bypass capacitor C3, emitter bypass capacitor, or the base-bias voltage-divider bypass capacitor.

Reduced volume or distortion can also be the result of a reduced-value bypass capacitor. Check the base bias voltage; for improper values of bias voltage, check the voltage-divider values. The output i-f transformer may be off-peak and in need of alignment.

For complete loss of signal, check the detector diode and/or the i-f amplifier transistor. Check the voltage on the base for an open secondary winding in T1. Check the collector voltage for an open primary winding in T2, or an open primary winding of the driver transformer. Check with an ohmmeter for an open secondary in T2.

Converter Stage

The converter stage combines the functions of the mixer and oscillator stages. Use of a single transistor results in an economy. In populous areas high-power transmitters provide a strong signal, easing the need for a stage of r-f amplification. Application of AVC voltage to the converter stage can cause variation of the oscillator's frequency, which can only be overcome by careful design. Because of its sensitivity to this problem, the majority of converter circuits do not have AVC voltage applied to it.

VACUUM TUBE RADIO BEING
USED TO CHECK OSCILLATOR
SIGNAL FROM TRANSISTOR RADIO

LOOP
ANTENNA

TWEET

Another Working Receiver
Can Be Used To Check
Oscillator Frequency
and Calibration

TRANSISTOR RADIO
UNDER TEST
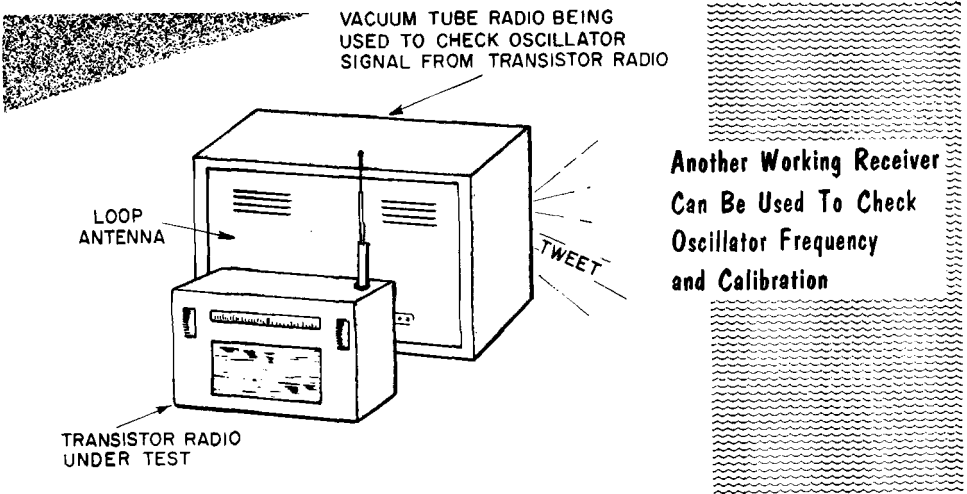
There are two quick checks to test the converter circuit for oscillation. Use an operating radio receiver (tube or transistor), and set it to a local station at the upper end of the broadcast band. Set the dial of the transistor receiver under test to a setting of 455 kc lower than that of the local station, and rock the dial of the transistor receiver under test back and forth about the dial setting. If the converter circuit is oscillating, it will cause a whistle in the operating radio receiver. The whistle is a result of a heterodyne caused by the converter oscillator producing a signal at the same frequency as the local broadcast station. This results because the transistor receiver under test has its dial set to such a value that the converter oscillator, which is tuned to 455 kc above the dial setting, is at the same frequency as the broadcast station. The two signals are beating with each other to form a "beat" frequency.

Another oscillation test of the converter circuit is to read the emitter voltage. With the meter probe on the emitter lead, the oscillator tuning capacitor can be shorted with a jumper or screwdriver, depending upon the construction of the tuning capacitor. With the rotor and stator shorted together, oscillation will cease and the emitter voltage reading should change value. When the converter oscillator is working, the emitter voltage should vary slightly as the oscillator circuit is tuned from one end of the band to the other.

Converter Stage (cont'd)

Intermittent operation is more frequent in the converter stage than any other stage. As in all oscillator circuits, feedback can be critical. In this case the feedback amplifier is the converter transistor. A good transistor should be substituted for the one in question. Checking the transistor with a transistor tester may not reveal a low, alpha cut-off frequency. The oscillator coil should be carefully checked for intermittent connecting leads.
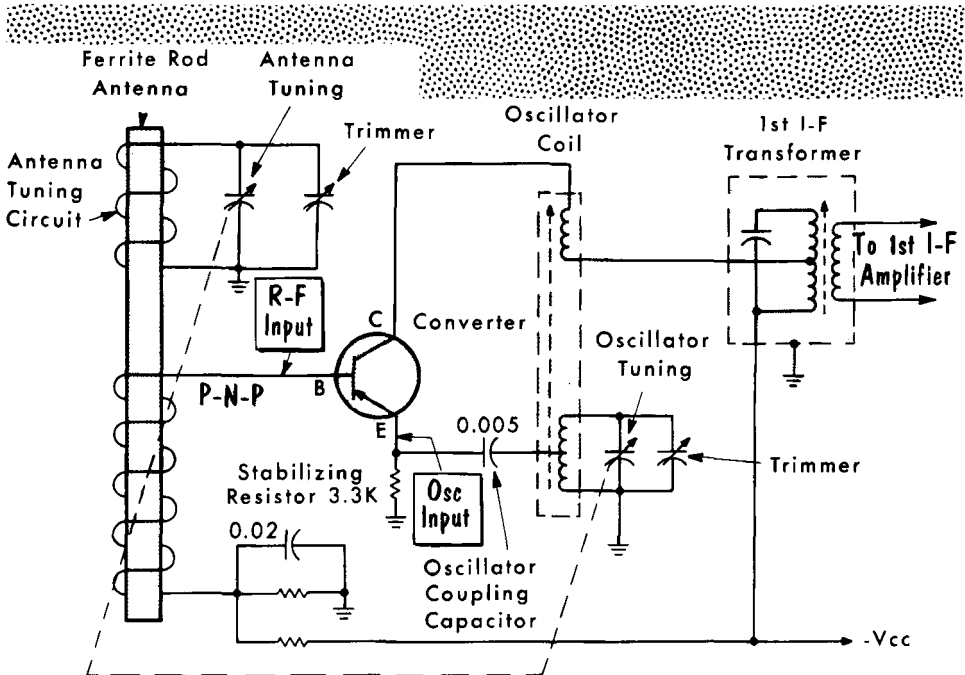
TRANSISTOR CONVERTER STAGE

Carefully check the circuit against the latest schematic diagram. Later production runs of a receiver may have different values or types of components, which is particularly true in converter circuits. Certain values, especially those of resistors setting bias voltages, or certain components, particularly coils and transistors, will be changed if the values or components used are found to be marginal.

The narrow spacing between the rotor and stator plates of the tuning capacitor is a common cause of intermittent operations. Dirt or sand between the plates will cause them to warp and short.

Converter Stage (cont'd)

Low converter-stage gain can be a cause for a weak signal output. In addition to the possibility of a defective transistor, the alignment of the tuned circuits should be checked, particularly the alignment for oscillator tracking. Another probable cause is a defective antenna coil, or cracked-antenna-coil ferrite rod.

A completely-inoperative oscillator circuit will usually be indicated by incorrect bias voltages. When this occurs check the bias voltage divider, the transistor, and all coil windings. In addition to the possibility of an open oscillator-coil winding, check for an open oscillator coupling

If Oscillator Is Completely Inoperative,

Ferrite Rod
Antenna

Antenna
tuning

Trimmer   Oscillator
Coil

1st I-F
Transformer

Antenna
Tuning
Circuit

R-F
INPUT

C

P-N-P   B

E

0.005

TO 1st I-F
AMPLIFIER

Check
Oscillator
Tuning

Check
Bias

Stabilizing
Resistor 3.3K

0.02

OSC
INPUT

Trimmer

Check ALL
Coil Windings

Bias
Voltage
Divider

Check
OSCILLATOR
COUPLING
CAPACITOR

-Vcc
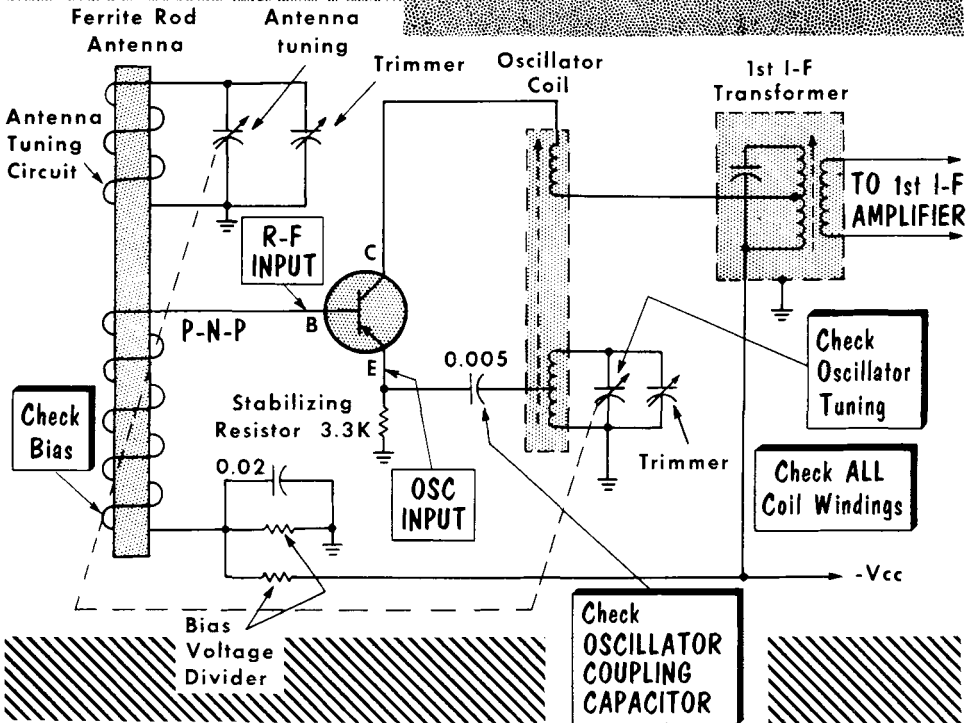
capacitor. Be sure to remove the transistor before making any ohmmeter check of the oscillator coil or the base lead through the r-f input coil. Compact tuning capacitors are prone to shorting between rotor and stator, either by dirt or sand, or any other reason for warping and shorting the plates.

Should all components check out good and the converter stage still is inoperative, there is the remote possibility of a defective i-f transistor loading the i-f transformer. In turn this reduces feedback through the oscillator coil to prevent oscillations.

A power detector uses a transistor biased at or near cutoff to have it rectify
    one-half of a modulated signal while at the same time amplifying the
    other half of the signal.
The polarity of a detector diode is determined by the polarity of the AVC
    bias voltage required at the i-f amplifier, which in turn is determined
    by whether the i-f amplifier is an n-p-n or p-n-p transistor.
I-f amplifiers use high-gain high-Q tuned circuits requiring negative feed-
    back to prevent unwanted oscillations.
Some i-f amplifier circuits employ an overload diode to prevent overloading
    of the i-f circuits on extremely strong signals.
When replacing a transistor in an i-f amplifier stage, be careful not to insert
    one with higher gain. Excessive gain could cause oscillations.
A reflexed i-f, a-f transistor amplifier stage is a single stage that amplifies
    an i-f input signal, then, after detection the audio frequency signal
    is fed through the same amplifier. Because of the differences in fre-
    quency there is little or no interaction.
Application of AVC voltage to a transistorized converter circuit can cause
    variations of the oscillator frequency. Because of this most converter
    circuits do not have an AVC voltage applied to it.
Intermittent operation is more frequent in the converter stage due to
    critical feedback paths.
Checking the transistor with a normal transistor tester may not reveal a
    low alpha cut-off frequency.
One quick check for oscillation in a converter circuit is to beat its output
    against that of another receiver. Another quick check is to monitor
    the emitter voltage; it should vary slightly as the oscillator is tuned
    from one end of the band to the other.
Component values in a converter circuit are often changed during produc-
    tion runs. To check this the receiver should be compared with the
    latest available schematic diagram.

REVIEW QUESTIONS

1. Why can't a diode be used as a power detector?
2. What is the name given to the use of negative feedback to remove
    oscillations in an i-f amplifier stage?
3. What is the simplest method of checking for open or reduced-capacity
    AVC bypass capacitors?
4. What is the advantage of an overload diode over AVC bias?
5. Describe the method used to check for cold solder joints in the ground
    return connections.
6. What is the main reason for using a reflexed i-f, a-f amplifier
    circuit?
7. When testing the local oscillator by beating it against that of another
    receiver set to 1050 kc, what should the dial setting be for the receiver
    under test?
8. Shorting the stator and rotor of the tuning capacitor causes a change
    in the voltage of what element of the converter transistor?

Local Oscillator-Mixer Stage

MIXER

P-N-P

TO R-F AMPLIFLER

R-F INPUT

TO 1ST. I-F AMPLIFLER (455 KC)

OSCILLATOR INPUT

TO AVC OR BASE BIAS

STABILIZING RESISTOR 3.9K

DECOUPLING NETWORK

0.05

470

$-V_{cc}$

Typical Mixer - Oscillator Stage

OSCILLATOR

8.2K

BIAS VOLT. DIVIDER

P-N-P

330

0.05

ENERGY FEEDBACK

OSC COIL

OSC TRIMMER

4.7K

0.02

0.005

2.7K

C1 0.01

OSC TUNING

GANGED TO ANTENNA AND R-F TUNING

PROVIDES A-C GROUND FOR BASE
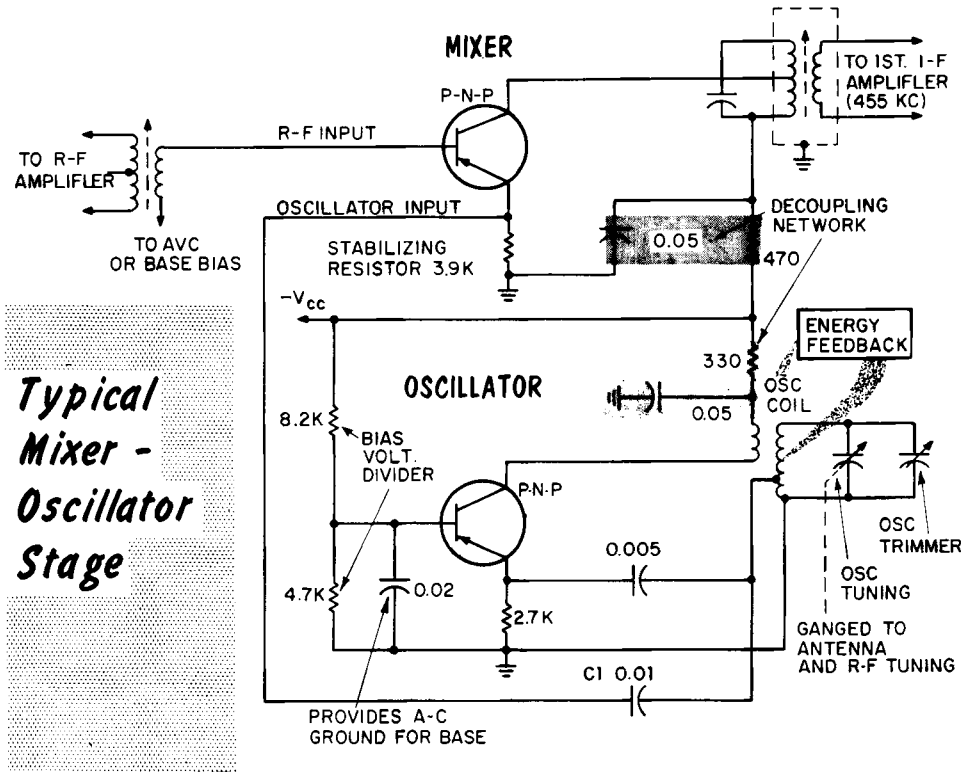
The more costly multiband and AM-FM receivers will, for the most part, use a separate local oscillator and mixer stage. Higher gain, application of AVC to the mixer, plus the improved stability of a separate oscillator are the major advantages.

As in the converter stage, a quick check of the oscillator is to use an operating receiver: set it to a local station at the upper end of the broadcast band, and set the dial of the transistor receiver under test to a setting 455 kc lower than that of the local radio station. Rock the dial of the transistor receiver under test back and forth about the dial setting. If the converter circuit is oscillating, it will cause a beat note whistle in the operating receiver.

Another quick check for oscillations is a reading of the emitter voltage. With a meter probe on the emitter lead, short the rotor and stator plates of the tuning capacitor either by a jumper or a screwdriver. Shorting the tuning capacitor will stop oscillations and change the meter reading. When the oscillator is operating, the emitter voltage will vary slightly as the oscillator circuit is tuned from one end of the band to the other.

Local Oscillator-Mixer Stage (cont'd)

For intermittent operation of the oscillator, the first check should be of the transistor. Checking it in a transistor tester may not reveal a low, alpha cut-off frequency; it is best to replace with a good substitute. Check the oscillator coil for any intermittent connecting leads. Look for dirt or sand between the rotor and stator of the tuning capacitor, or for any warping causing the tuning capacitor to short. Check the circuit against the latest schematic diagram, looking for different values or types of components. Any marginal values or types of components may be changed in a later production run.

Although it will not have as pronounced an effect as in a converter stage, misalignment of the local oscillator can cause a reduced output to the mixer. Decoupling resistors, particularly the resistor in the $-V_{cc}$ lead to the oscillator collector, should be checked for excessive voltage drop causing a reduction in the oscillator output. Reduced oscillator output can also be a result of a change in value in the feedback capacitor from the oscillator coil to the emitter, or a defective mixer stage loading the oscillator emitter circuit.

An inoperative oscillator will often be indicated by incorrect bias voltages. Before checking bias circuits with an ohmmeter, be sure to remove the transistor. Check the bias network, being sure to check the capacitor be-

PARTICLES OF SAND CAN CAUSE SHORT

WARPED PLATES
CAN CAUSE SHORT
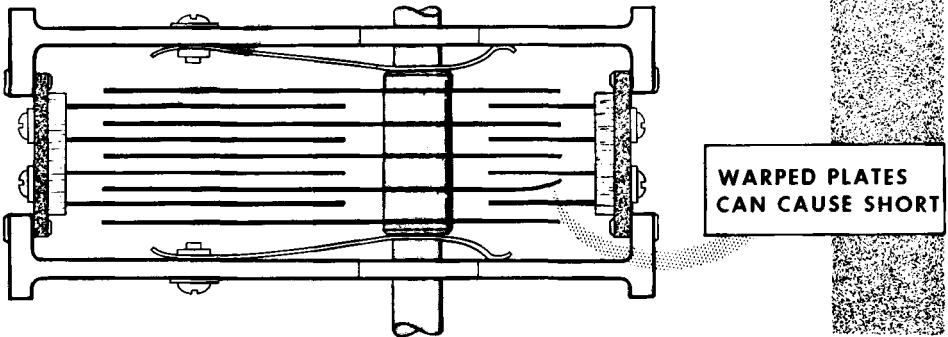
tween base and ground. Check the oscillator coil windings for continuity and check for a shorted C1, the coupling capacitor between the oscillator and mixer.

To check the mixer stage for low output, with the oscillator known to be working, check the bias voltages, particularly the AVC bias voltage. Check for misalignment of the i-f transformer at the output, or the r-f transformer at the input to the mixer. For an inoperative mixer check the transistor, and check for an open oscillator coupling capacitor, C1. The primary of the i-f transformer can be checked to the impedance matching tap by measuring the collector voltage. To test for continuity in the remainder of the winding, an ohmmeter is used after removal of the transistor. Check the secondary of the r-f transformer by reading the value of base bias voltage.

R-F Amplifier Stage

Multiband receivers, or AM-FM receivers will often contain a stage of r-f amplification. Operating at higher frequencies, the r-f amplifier stage requires a transistor with a high alpha cut-off frequency. In addition to increased gain and selectivity, a stage of r-f amplification will reduce the overall noise level on weak signals, and is an aid in elimination of image frequency response. The r-f amplifier stage usually operates with AVC bias, enabling the receiver to handle strong signals that could normally cause overloading and distortion.
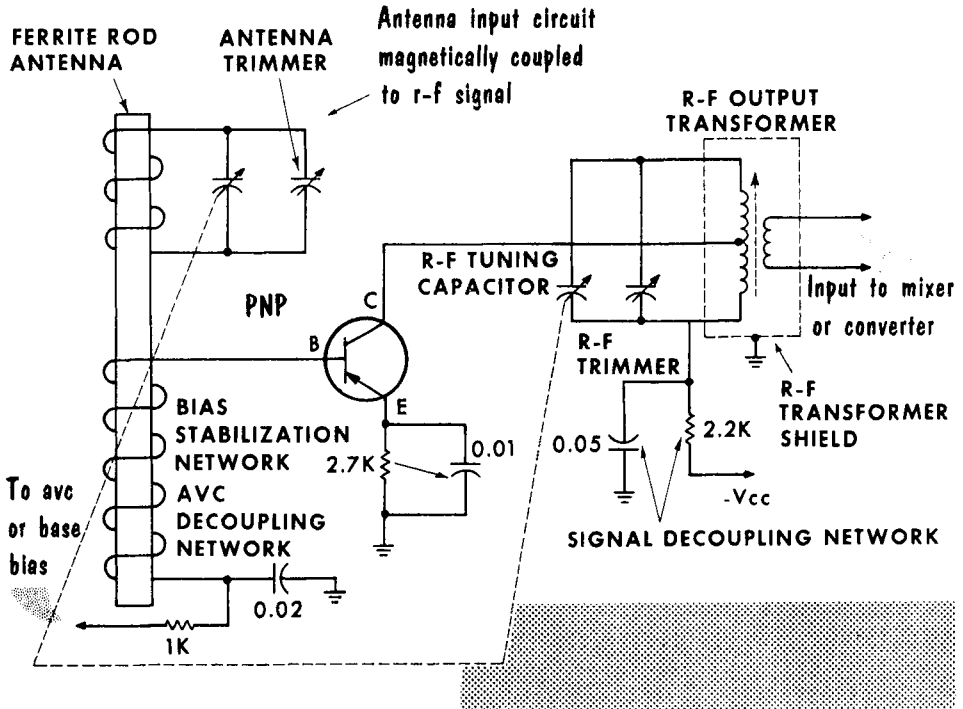
Any noise generated in the r-f amplifier, the first stage in the receiver, will be disproportionately loud at the output. Therefore, any rubbing, or dirt between the stator and rotor of the tuning capacitor will be quickly apparent as the receiver is tuned throughout the band. In multiband receivers, the bandswitch can also cause a high noise level when changing bands. To clean a noisy bandswitch, use a conducting lubricant such as the type used for television tuners. A noisy transistor is another possibility that should be checked by replacing with a substitute.

R-F Amplifer Stage (cont'd)

The high-gain high-Q circuits used in the r-f amplifier are prone to break into undesired oscillations, particularly when the decoupling capacitors open or lose capacity. In circuits using neutralization, check for an open feedback capacitor.

For low gain check the alignment of the antenna and r-f trimmers. Check for an open antenna coil or a possible break in the antenna ferrite rod. An incorrect value of base and/or emitter bias can also cause reduced gain. Check for an open, emitter bypass capacitor. Another possible cause is an incorrect AVC bias voltage, reducing the stage gain.

For an open r-f stage, if the transistor is suspected of being inoperative, a quick check is to remove the transistor and apply a 0.01-mfd capacitor from the base to collector socket terminals. This will couple the signal to the mixer stage. The receiver gain and sensitivity will be reduced; however, this test will quickly indicate an open transistor. In multiband receivers a defective band switch may allow operation on one band but not another. This may also be the result of an open coil or coil lead in either the antenna or r-f tuned circuits. Check for dirt, sand, or any other cause for warped plates resulting in a short in the r-f or antenna tuning capacitor section. Sometimes a piece of solder that has become dislodged may manage to stick in the capacitor plates, and short the aforementioned circuits. In removing the obstacles, care should be taken that the plates are not bent. Bent or warped plates, although not shorting out the tank circuits, may introduce tracking error. An excellent method for reaching hard-to-get places is to use a vacuum cleaner. Shaking the receiver may not always work, and may even loosen a soldered connection which will give trouble later. Check all bias voltages, particularly the AVC bias values.
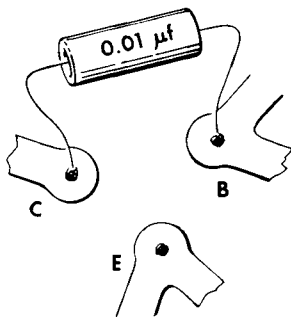
Using a CAPACITOR to Bridge Suspected OPEN TRANSISTOR

Hybrid Auto Receiver

Many methods have been devised to overcome the maintenance problem of auto-radio-vibrator power supplies. One of these employs specially de-signed vacuum tubes using 12 volts for filament, screen, and plate voltage. These tubes perform satisfactorily as voltage amplifiers, but they are not suitable for power amplification. Power output transistors are used to over-come this problem. The transistors are mounted on the outside of the metal cabinet enclosing the receiver, thus using the entire cabinet as a heat sink. This combination of tube and transistor creates a "hybrid" radio receiver.

Aside from the 12-volt filament, plate, and screen voltage, the greater por-tion of the receiver circuit is conventional. The differences are that the cathodes of the r-f and i-f amplifiers are placed directly at ground for maximum gain. Impedance coupling is used between the r-f amplifier and converter for maximum gain. The grid closest to the cathode of the 12DL8, detector-audio amplifier, is not the control grid but an "accelerator" grid having a 10-volt positive potential applied to it. The accelerator grid's positive potential, and its location next to the cathode will cause it to pull a large number of electrons from the cathode to increase plate current. This increased plate current is conventionally controlled by the control grid, pin 7, of the tube. As is common in many auto radios, a low frequency of 262.5 kc is used as the i-f. The full value, AVC bias voltage is applied to the i-f amplifier, with a reduced value applied to the r-f amplifier to provide higher gain in the r-f amplifier circuit.

In the transistor output circuit, a rheostat in series with a thermistor forms a variable voltage divider. The rheostat is used to reset the base bias when replacing the output transistor (bias must always be set with the speaker and output auto transformer connected). The thermistor prevents thermal runaway and helps maintain a steady base bias under varying temperature conditions. Because of the high collector current (about 1 ampere), the emitter resistor has a very low value of 0.47 ohm. Very high values of electrolytic filter capacitors are required because of the low impedance of the output transistor.

A word of caution: be sure the speaker and output (auto) transformer are always connected in the circuit before turning the receiver on or making any checks.

For distortion and/or reduced output, check for a warped, speaker voice coil rubbing on the pole piece. Check for incorrect bias voltages, being sure to check the collector current value set by the rheostat. Check the thermistor value with an ohmmeter. Another possibility is shorted turns in the output (auto) transformer.

Loss of output can be the result of a defective transistor; check carefully for a short between collector and emitter. It can also be a result of the speaker plug being out of its socket, or an open speaker voice coil. An open output (auto) transformer winding is checked by the presence of collector voltage — normally zero voltage. Some receivers use a special
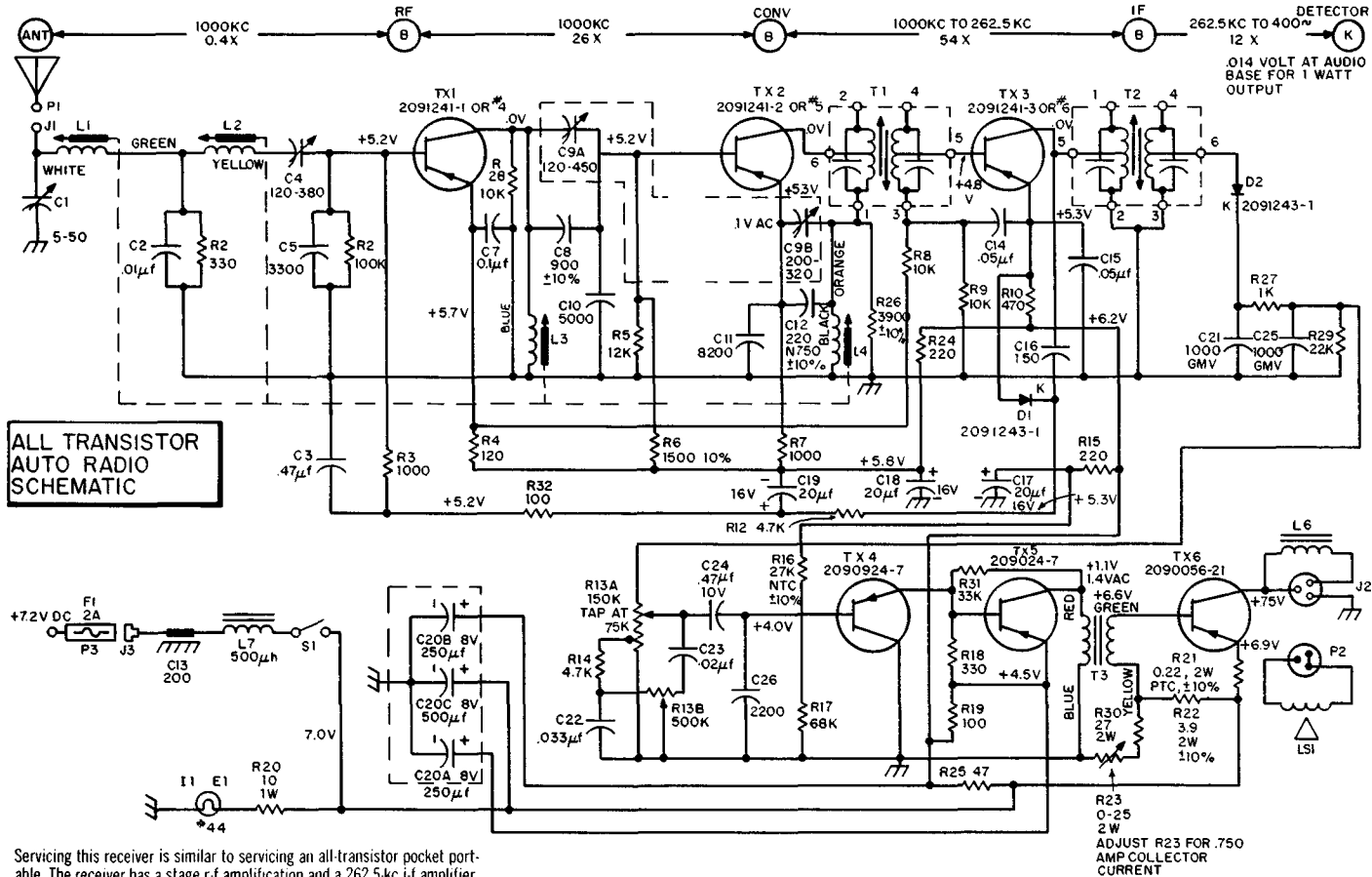
Hybrid Auto Receiver (cont'd)

interlock switch or plug which will open the collector circuit by removing the speaker. Check this interlock for an open circuit. Check for a shorted insulating washer between the transistor and the receiver case, or, when a separate heat sink is used, check for a short between the insulated heat sink and the metal case. The emitter resistor acts as a fusible resistor; check for an open resistor resulting from excessive current flow.
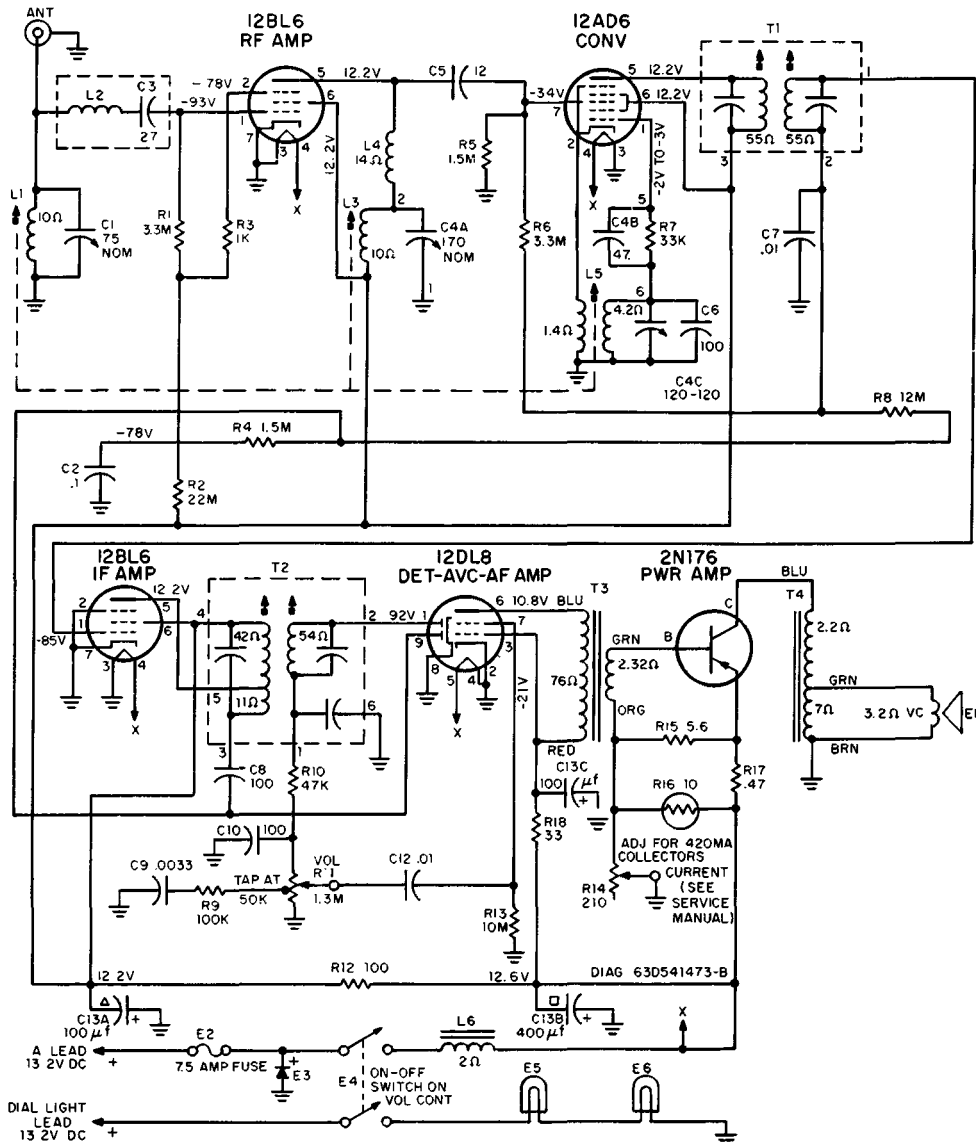
Hybrid Auto Receiver Schematic

	1000KC	RF	1000KC	CONV	1000KC TO 262.5KC	IF	262.5KC TO 400~	DETECTOR
ANT	0.4 X	B	26 X	B	54 X	B	12 X	K

.014 VOLT AT AUDIO
BASE FOR 1 WATT
OUTPUT

**ALL TRANSISTOR
AUTO RADIO
SCHEMATIC**

TX1 2091241-1 OR #4
TX 2 2091241-2 OR #5
TX 3 2091241-3 OR #6
TX 4 2090924-7
TX 5 209024-7
TX 6 2090056-21

D1 2091243-1
D2 2091243-1

P1
J1
L1
WHITE
C1 5-50
GREEN L2
YELLOW
C4 120-380
+5.2V
R 28 10K
.0V
C9A 120-450
+5.2V
C2 .01µf
R2 330
C5 3300
R2 100K
C7 0.1µf
C8 900 ±10%
C10 5000
L3
R5 12K
+5.7V
BLUE
+53V
.1V AC
C9B 200-320
ORANGE
BLACK
C11 8200
C12 220 N750 ±10%
L4
R26 3900 ±10%
R8 10K
C14 .05µf
R9 10K
R10 470
CI5 .05µf
+5.3V
+6.2V
R27 1K
+4.8V
R24 220
C16 150
C21 1000 GMV
C25 1000 GMV
R29 22K
K D1 2091243-1

C3 .47µf
R3 1000
R4 120
R6 1500 10%
R7 1000
+5.8V
C19 20µf 16V
C18 20µf 16V
C17 20µf 16V
+5.3V
R15 220
R32 100
+5.2V
R12 4.7K

F1 2A
+7.2V DC
P3 J3
C13 200
L7 500µh
S1
C20B 8V 250µf
C20C 8V 500µf
C20A 8V 250µf
R13A 150K TAP AT 75K
C24 .47µf 10V
R16 27K NTC ±10%
+4.0V
R14 4.7K
C23 .02µf
C26 2200
R13B 500K
C22 .033µf
R17 68K
R31 33K
R18 330 +4.5V
R19 100
RED
+1.1V 1.4VAC
+6.6V GREEN
BLUE
T3
YELLOW
R21 0.22, 2W PTC, ±10%
R30 27 2W
R22 3.9 2W ±10%
+75V
+6.9V
L6
J2
P2
LS1
7.0V
I1 E1
R20 10 1W
#44
R25 47
R23 0-25 2W
ADJUST R23 FOR .750 AMP COLLECTOR CURRENT

Servicing this receiver is similar to servicing an all-transistor pocket portable. The receiver has a stage r-f amplification and a 262.5-kc i-f amplifier. A diode detector is followed by two direct-coupled stage of audio amplification, and transformer-coupled to a single-ended power-output stage. AVC bias is developed by a separate rectifier in the i-f amplifier stage.

Multiband and AM-FM transistor receivers most often use separate local
oscillator and mixer stages.

Transistors used in oscillator circuits should be checked by a known good
substitute.

Although not as pronounced as in a converter stage, misalignment of the
local oscillator can cause a reduction in mixer output.

Multiband and AM-FM receivers often contain a stage of r-f amplification.

A stage of r-f amplification reduces overall noise level on weak signals and
aids in eliminating image frequency response.

The r-f amplifier stage usually operates with AVC bias.

Noise generated in the r-f amplifier, the first stage in the receiver, will be
disproportionately loud at the output.

The high-gain high-Q circuits of the r-f amplifier easily break into
oscillations.

To check a suspected open transistor in the r-f amplifier stage, a 0.01-
microfarad capacitor can be placed from base to collector terminals
to couple the signal to the mixer stage.

Aside from the 12-volt filament, low screen and plate voltages, the tube
circuits of a "hybrid" auto radio are for the most part conventional.

For maximum gain the cathodes are placed directly at ground.

The 12DL8 detector-audio amplifier uses an "accelerator" grid between
the control grid and cathode. The accelerator grid is used to pull large
numbers of electrons from the cathode.

A rheostat is often used to reset the base bias when changing power output
transistors.

Because of the high collector current (about one ampere), the emitter
resistor has a very low value of 0.47 ohm. This resistor can also act as a
fuse, opening when excessive emitter current flows.

Some receivers use a special interlock switch or plug that opens the col-
lector circuit if the speaker is removed.

REVIEW QUESTIONS

1. What are the three major advantages of using a separate local oscil-
lator and mixer stage?

2. What effect does a stage of r-f amplification have on a receiver's gain
and selectivity?

3. What do we call the inverse feedback used to prevent oscillation in
some r-f amplifier circuits?

4. Describe one method of checking a bandswitch on a multiband receiver.

5. Why is no power supply required for a "hybrid" auto radio?

6. Why are the audio power output transistors mounted on the outside
of the receiver cabinet?

7. Why is impedance coupling used between the r-f amplifier and con-
verter of the "hybrid" auto receiver?

8. What is the purpose of the thermistor in the audio power output tran-
sistor circuit?

9. Why must bias always be adjusted with the speaker and output auto
transformer connected?

General Symptoms

Repairing a defective transmitter requires the same reasoning and logic applied to repairing a defective receiver. When faced with a defective transmitter, we do not grab a soldering iron and diagonal cutters and dig in, but we try to reason the difficulty by observing with three of our senses all that can be seen, heard, and, where applicable, smelled. An obvious first step, but too often overlooked because it is obvious, is to check the presence of a-c power to the transmitter. This test includes checking that a-c power is available at the outlet, and that it is being applied to the transmitter power supply as indicated by a pilot light or other form of power indicator. This first step should include observing all power supply fuses.

smoke and odor of burning material

lit tube filaments

power source

CONNECTIONS

meter readings

harmonic filter

high voltage indicator

a-c power indicator

to receiver
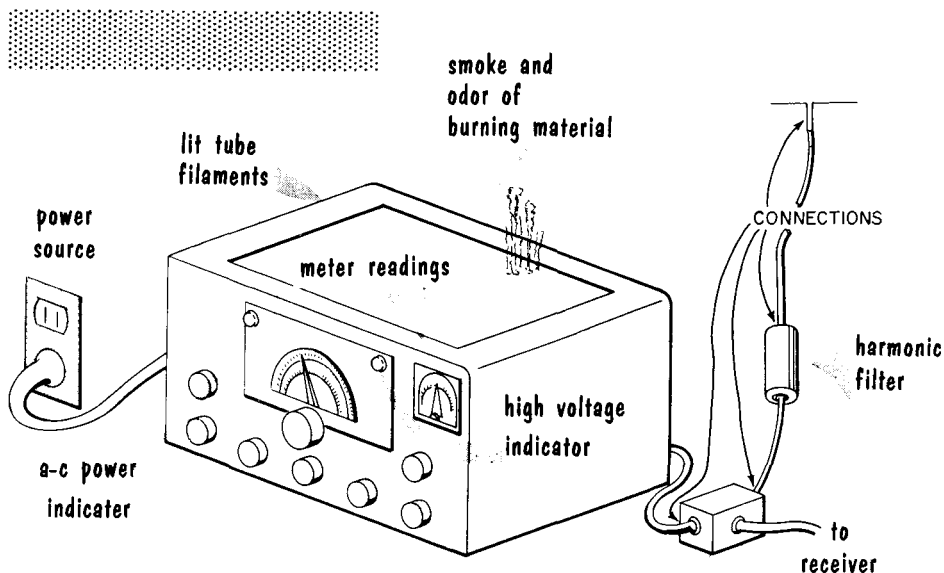
VISIBLE testing points

antenna changeover relay

A visible test should be made for the on-or-off presence of pilot-light or dial-light indicators, for lit tube filaments, overheated tube plates, smoke, and charred components. Another obvious, but often overlooked, problem is an improperly set or accidentally moved dial knob, and/or switch settings. Meter readings should be taken and compared to the correct readings obtained during normal transmitter operation. A visible check should also be made of the various connections used to couple the microphone to the input amplifier, the transmitting key to the keying jack, the operating voltage to the antenna changeover relay, the r-f output of the transmitter, the connectors at the input and output of a harmonic filter (where used), the input and output of the antenna changeover relay, and the connector or connection of the transmission line to the antenna.

General Symptoms (cont'd)

Audible tests can be made for any possible arcing, particularly in the final amplifier stage. Relays can be checked by listening for their "pull-in" or "drop-out" noise as they are controlled. A test receiver can be tuned in to the operating frequency and used to check for transmission of a signal, the signal strength, and for a distorted signal.
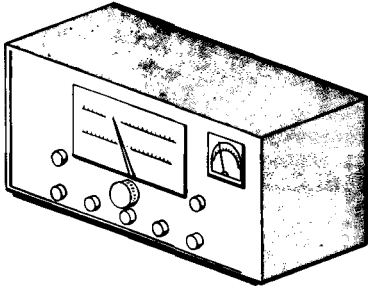
TRANSMITTER   RECEIVER
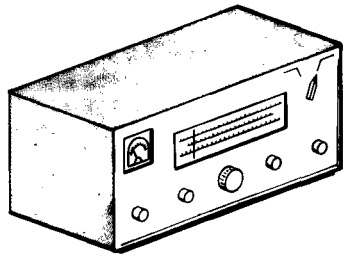
USE A RECEIVER for quick checks of TRANSMISSION, TRANSMISSION QUALITY and STRENGTH, FREQUENCY SETTINGS and STABILITY, and availability of CW and/or AM

The sense of smell can be used to determine if any components are over-heating.

Other checks can be made by determining if the problem is on one particular band of frequencies or on all bands. For AM-CW transmitters, tests can be made to determine if the transmitter is defective on either CW, or AM, or both. Meter readings may indicate that the transmitter is tuning correctly up to the final amplifier, but the final cannot be tuned. This would call for a check of the transmission line or any device in the transmission line such as harmonic filters, changeover relays, and, at the end of the transmission lines, the antenna. Some transmitters use control circuits allowing operation from a remote or central operating position, which must be checked for possible defects.

Meter Readings

Metering is required not only for tuning a transmitter, but also for moni-toring it. If not already listed in the instruction manual of the transmitter, it would be wise to list all normal-operating meter readings when the transmitter is operating properly. These readings serve as a valuable means of comparison when troubleshooting a defective transmitter.
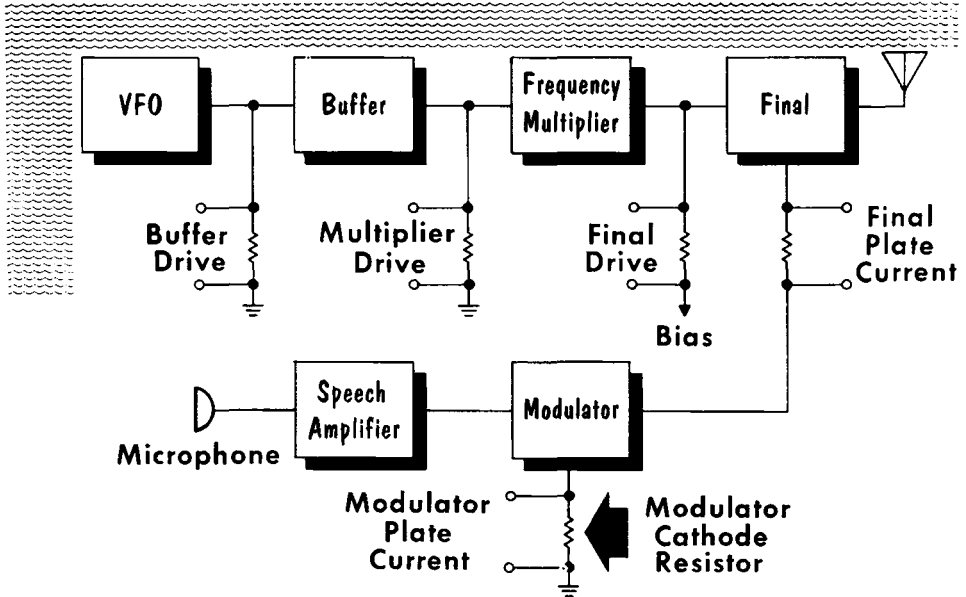
Typical METERING POINTS

A low power transmitter and its typical metering circuits is shown in the block diagram. Meter readings can be taken in either of two manners: from the oscillator output to the final, or from the final back to the oscillator output. For this discussion we will start with the oscillator. It should supply sufficient drive to the buffer stage over the entire tuning range. If there is insufficient drive, check to see if the oscillator is defective on all bands or on one band alone. Many transmitters are designed to be able to switch the oscillator, or the buffer stage following the oscillator, to act as a crystal oscillator. Where this feature is available, and the oscillator drive is low or absent, a crystal should be inserted in the crystal holder and the switching circuits set to use the crystal oscillator. In transmitters using the buffer as a crystal oscillator—in which the use of a crystal restores the drive—the restoration would be indicated by the presence of a driving signal at the input to the frequency multiplier. In transmitters using the oscillator tube as a crystal oscillator—in which the use of a crystal restores the oscillator output—the restoration would be indicated by the presence of a driving signal at the input to the buffer.

Meter Readings (cont'd)

The buffer stage is often fixed-tuned and has no tuning adjustments. Its proper operation can be checked by the presence of a driving signal at the input to the frequency multiplier stage. In buffer circuits using tuning adjustments, these adjustments are set for a maximum input signal to the frequency multiplier. A meter reading of sufficient input to the buffer, and a meter reading showing no input or insufficient input to the frequency multiplier, indicates a defect in the buffer stage. These meter readings should be checked on all bands.

INPUT

RFC

(Screen-to-Cathode Voltage)

OUTPUT

M2

M4

(Grid-to-Cathode Voltage)

M5

M7

(Grid Current)

M1

M3

(Screen Current)

(Plate Current)

BIAS

(Cathode Current)

(Plate-to-Cathode Voltage)

M6

B+
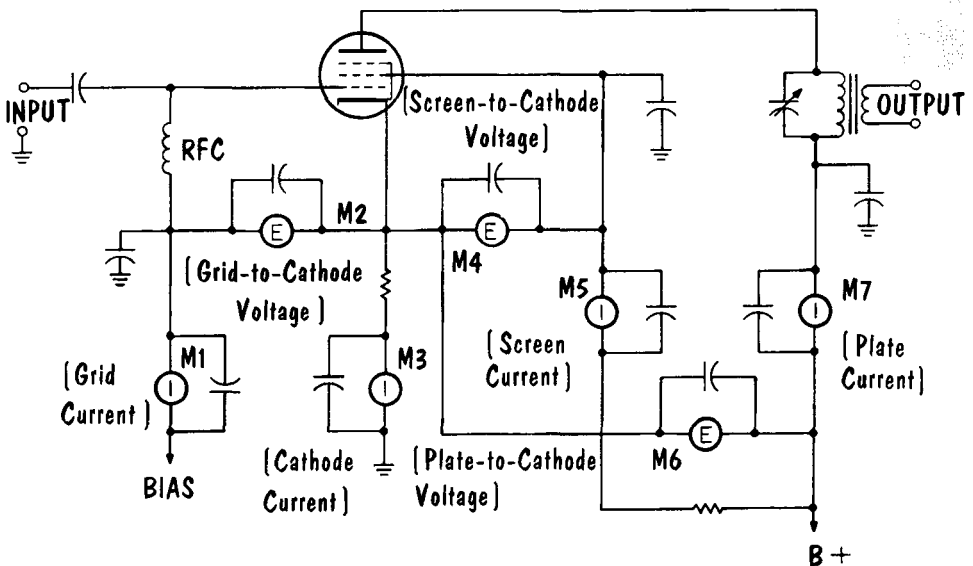
TYPICAL PLACEMENT OF METERS
IN A TRANSMITTER CIRCUIT

The frequency multiplier stage is checked in the same manner as the buffer stage. When operating properly it should provide sufficient drive to the final stage. As the bands are changed, or the frequency within a band is changed, the frequency multiplier should be retuned for maximum output to the final stage. A meter reading of sufficient input to the frequency multiplier, and a meter reading of no input or insufficient input to the final stage, indicates that the defect is in the frequency multiplier stage. The meter readings should be checked on all bands. Typical placement of meters in a transmitter circuit is shown in the illustration.

Meter Readings (cont'd)

The final amplifier has a metered input indication of the drive in the grid circuit; its output indicator is the plate-current meter setting. With the proper amount of drive to the input of the final, the output circuits should be tuned for the correct plate current as determined by the type of power amplifier tube used. Any reduction in drive will result in an increase in the

Driver Plate

Driver Plate Tuning

Power Amplifier Grid

Tuned For Minimum

Tuned For Maximum

TUNING A COUPLING STAGE
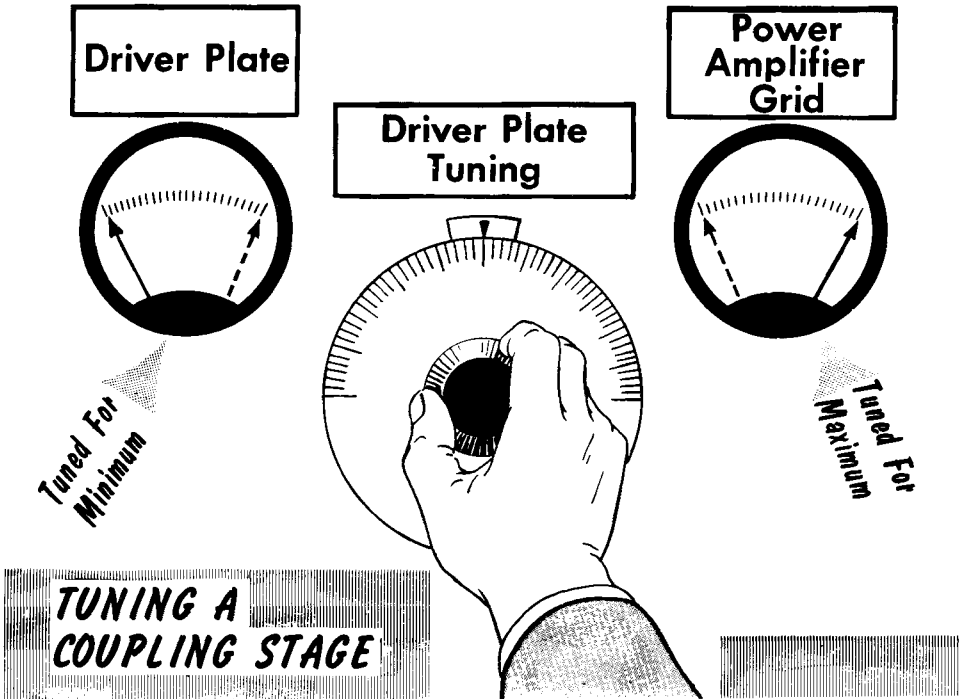
plate current reading. With sufficient drive to the input, but with a severe dip in the output tuning that results in a low level of plate current, check for loss of the output load. This could be either a disconnected transmission line or antenna. To check, place a dummy load on the output connector and retune the output. If the plate current reading returns to normal, the difficulty is with the transmission line or antenna. If the reading remains low, the difficulty is within the final stage.

For AM transmission, a quick check of speech amplifier and modulator circuits is to observe the cathode current readings of the modulator. The meter should read the correct current value and should deflect back-and-forth in step with any speech input to the microphone. The plate-current meter reading of the final should also be deflected, although very little, in step with the speech input to the microphone; this checks whether the final stage is being modulated.

Neutralization

Radio-frequency amplifier circuits in which the input and output frequencies are identical create a problem. Undesired positive feedback through tube interelectrode capacities will cause the amplifier to oscillate. To prevent this, a small portion of the output signal is fed back, out of phase (negative feedback), to the input circuit to neutralize the undesired positive feedback. The negative feedback signal is usually coupled from the output back to the input through a variable capacitor. This allows for adjusting the negative feedback value as determined by the amount of undesired positive feedback. Using a variable capacitor also allows readjusting the negative feedback when a new tube is inserted in the amplifier circuit.

There are various methods of checking for the presence of positive feedback requiring the installation or readjusting of neutralizing circuits. One method disables the oscillator by removing the oscillator tube. With the

REMOVING the OSCILLATOR TUBE *will disable the oscillator*

Oscillator Tube
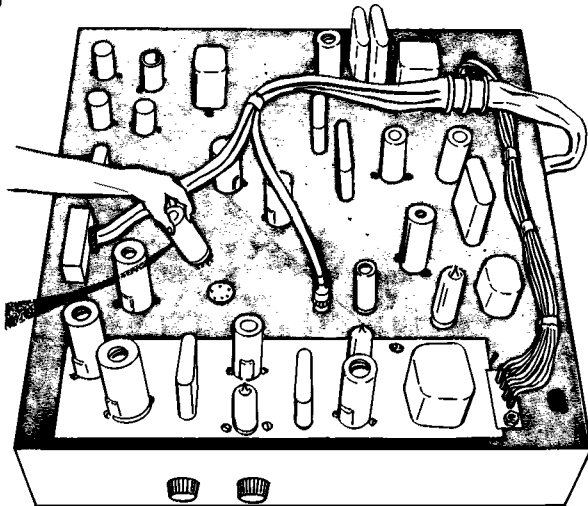
oscillator disabled any presence of rf at the output of the transmitter, or as indicated by grid current readings, indicates that one of the amplifier stages is self-oscillating. The meter readings can be used to help locate the specific stage at fault. With the oscillator disabled, check the grid drive to the buffer—there should be none. If the buffer circuit uses tuning adjustments in the plate tank circuit, tune through the range while watching the grid-drive meter reading. If tuning the plate tank circuit develops grid drive, self-oscillation is indicated.

Neutralization (cont'd)

A method of checking the individual stage under suspicion removes the plate voltage to the amplifier tube. For tetrodes and pentodes the screen grid voltage must also be removed. The drive signal is applied to the input grid of the circuit as in normal operation. An r-f indicator is inductively
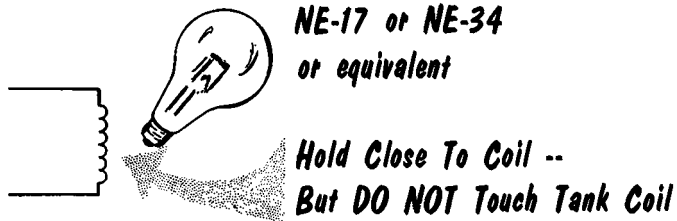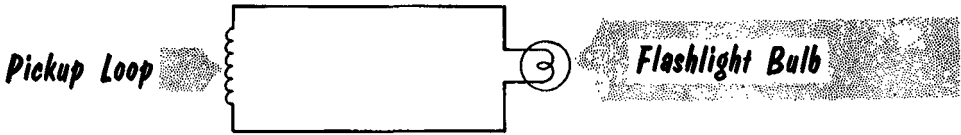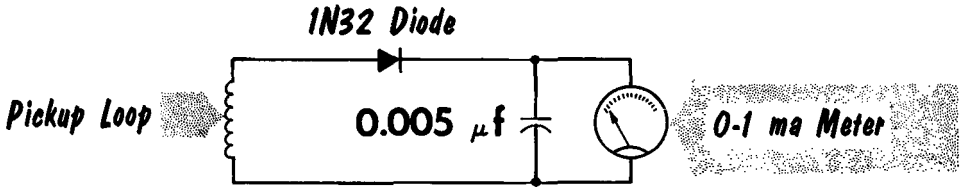
R-F INDICATORS

coupled to the output tank circuit and the tank circuit tuned through its range. The presence of rf in the output circuit is indicated by a glow on a neon lamp or a meter reading of an r-f indicator. The presence of rf in the output indicates that positive feedback is present, requiring neutralization or adjustment of the neutralization circuit.

A similar method of checking individual stages without the use of an r-f indicator also requires removal of the plate voltage of the amplifier tube. For tetrodes and pentodes the screen grid voltage must also be removed. With the drive signal applied to the input grid of the amplifier stage, tune the output tank circuit; it should have very little, or no effect, on the value of input drive signal. A marked increase in the meter reading of grid drive while tuning the output tank circuit indicates the presence of positive feedback.

Neutralization (cont'd)

When adjustment of neutralization of an r-f amplifier is required the following steps can be taken:

> WARNING: Use caution when working with the plate and screen supply voltages, particularly in the final stage, where lethal voltages may be present.

1. Remove the plate supply voltage. For tetrodes or pentodes also remove the screen grid supply voltage.

2. Couple an r-f indicator to the plate tank inductor.

3. Apply a drive signal to the input grid of the amplifier.

4. Set the adjustable neutralizing capacitor to minimum capacity.

5. Tune the output tank circuit for maximum on the r-f indicator. (This should be when the plate tank circuit is tuned to the same frequency as the input drive signal.)

ADJUSTMENT OF NEUTRALIZATION IN POWER AMPLIFIER CIRCUIT
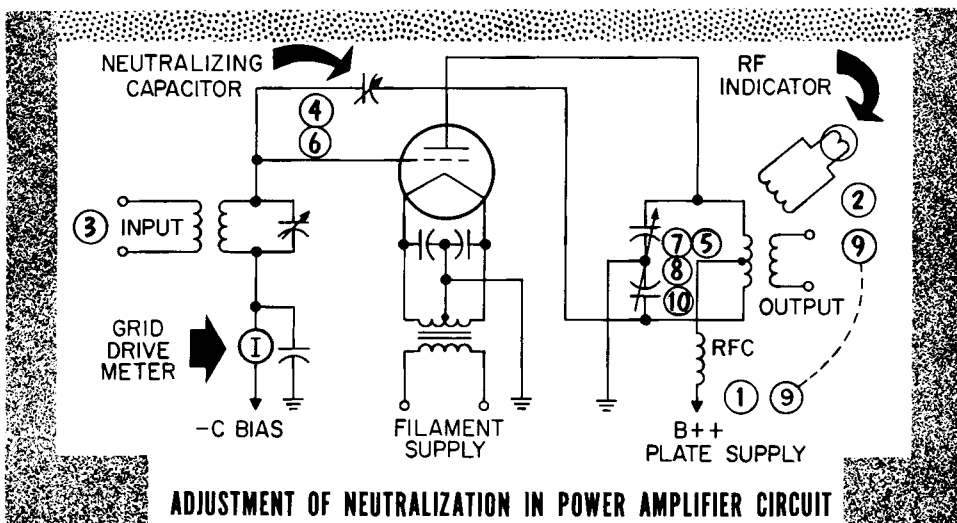
6. Tune the neutralizing capacitor for a zero reading on the r-f indicator.

7. Tune the plate output tank circuit throughout the tuning range. There should be a zero reading on the r-f indicator throughout the range.

8. Tune the plate output tank circuit throughout the tuning range. There should be no change in the grid drive reading.

9. Remove the r-f indicator and apply plate and screen voltage.

10. Check the circuit again, with the plate and screen voltage applied. With no drive signal, tune the plate output tank circuit throughout the range. There should be no grid drive reading.

Neutralization (cont'd)

POWER AMPLIFIER CIRCUIT

NEUTRALIZING
CAPACITOR

R-F
INDICATOR

INPUT

OUTPUT

GRID
DRIVE
METER

RFC

-C BIAS   FILAMENT   B++ PLATE
                 SUPPLY   SUPPLY
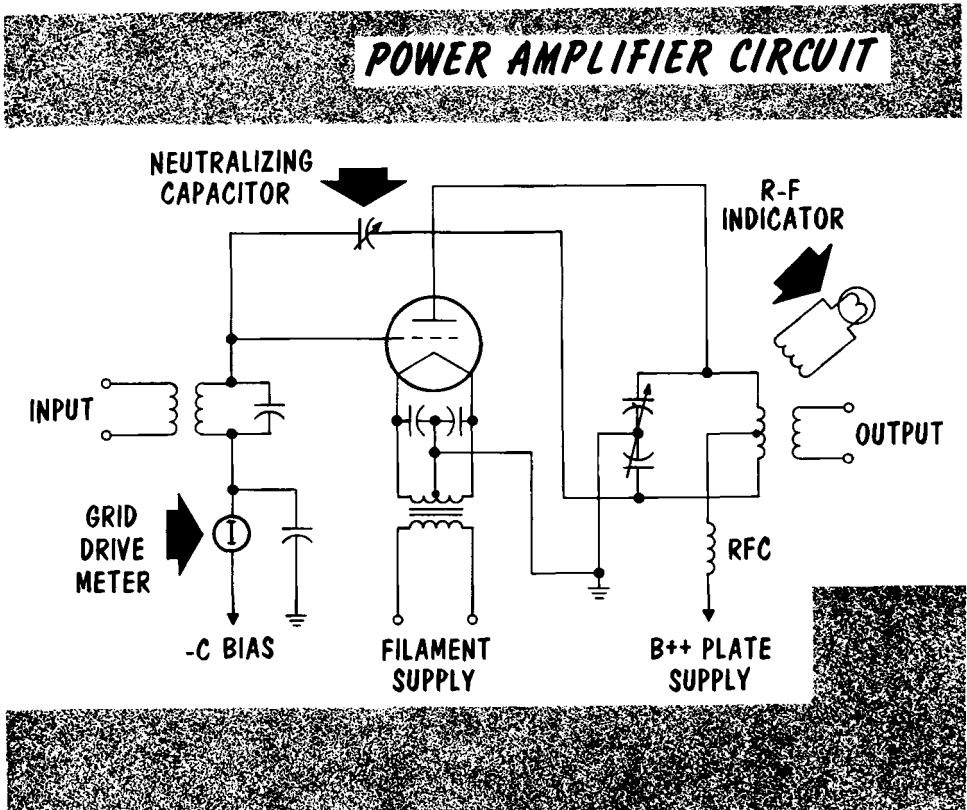
For situations in which an r-f indicator is not available and the amplifier circuit has a grid drive meter in the input circuit, the following abbreviated neutralization procedure can be used: Remove the plate supply voltage. For tetrodes and pentodes also remove the screen grid voltage. Tune the output plate tank circuit until the grid reading suddenly changes. Adjust the neutralizing capacitor to remove the change or fluctuation. Rotate the output tank circuit tuning capacitor, and readjust the neutralizing capacitor each time the grid reading changes. The stage is neutralized when the grid reading remains unchanged as the output tank circuit is tuned through the range.

When no amount of adjustment will completely neutralize the amplifier stage, the following possibilities can be investigated: long or open leads in the neutralizing capacitor feedback circuit, and undesired coupling between the input circuit components and the output circuit components due to improper or too-close placement. In higher-frequency circuits: unbypassed filament leads, poor, or no shielding between the input and output circuits, and the neutralizing capacitor is too close to the strong electromagnetic field of the output circuit tank coil.

Parasitic Oscillations

As in an unneutralized r-f amplifier stage, parasitic oscillations make their presence known by creating an output at the final stage either with no oscillator drive signal applied to the buffer stage, or a signal output at a frequency other than that to which the transmitter is tuned. The parasitic oscillations may modulate the signal at the original frequency causing the output signal to have a rough tone. It is best to check stage by stage to find the stage containing the parasitic oscillations; then check the defective stage to find the component or lead causing the oscillations. A stage that contains parasitic oscillations will show a strong increase in plate current. The excessive plate current can, in time, depending on its value, ruin the tube.

With no grid drive coupled to a stage, there should be no grid-current meter reading, and, depending upon the circuit, there should be a specific value of plate current. Tuning the input and/or output circuits should have no effect on the grid- or plate-current meter readings. If parasitic oscillations are present, grid current will flow and plate current will increase. Be careful: plate current can increase to a dangerous value and quickly ruin the tube; be prepared to quickly remove power to the transmitter.

Upon locating the stage that contains the parasitic oscillation, the next problem is to locate the components or leads that cause the trouble. A neon bulb indicates parasitic oscillations by glowing when placed close to the field being generated by the undesired oscillatory circuit. Low frequency parasitic oscillations cause the neon lamp to ionize; however, the color is yellow instead of the usual pink, and the glow is near the glass envelope not on the electrodes. High-frequency parasitic oscillations cause the neon lamp to glow purple near the electrodes.

LONG LEAD CAN HAVE INDUCTANCE AND WILL RESONATE WITH THE STRAY CAPACITY TO GROUND

STRAY CAPACITY CAN RESONATE WITH CHOKE WINDINGS

R-F CHOKE

PARASITIC OSCILLATIONS MAY BE INTERMIT-TENT; ABOVE OR BELOW THE NORMAL AMPLIFIER FREQUENCY; OR MAY COME AND GO.
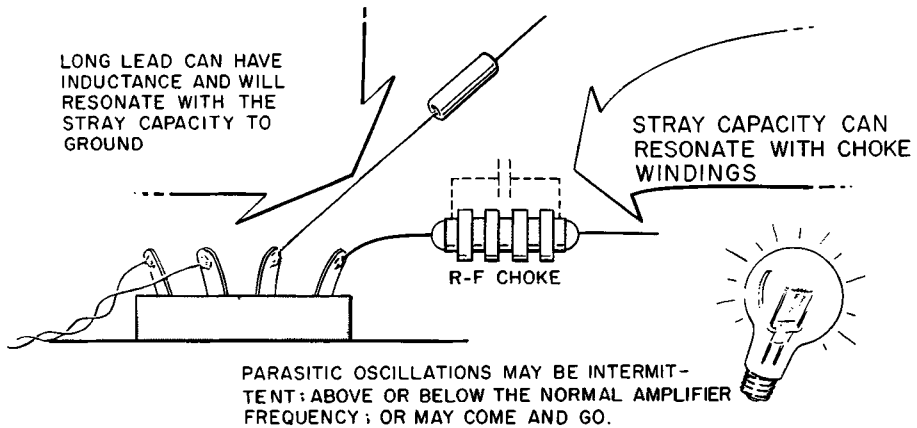
PARASITIC CIRCUIT

Parasitic Oscillations (cont'd)

Upon locating the stage containing the parasitic oscillations, a grid-dip oscillator is used to locate the components or portion of the circuit that is resonating, and the undesired frequency to which it is resonating. When tuning the grid-dip oscillator through the various bands of frequencies, look for a shallow dip. The undesired parasitic tank circuit usually works against stray capacity and is a low-Q circuit.
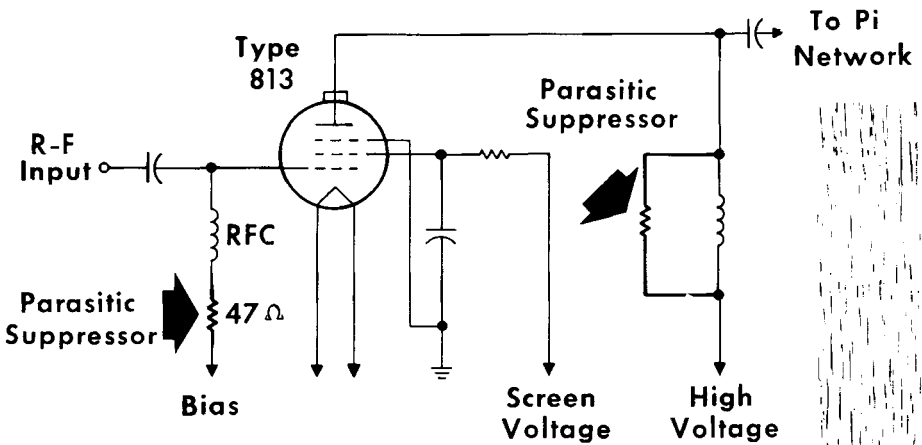
PARASITIC Suppression

If the parasitic oscillation is low in frequency and in the grid circuit of the r-f amplifier, place a low value resistor (47-100 ohms) in series with the r-f choke. If the undesired resonant circuit is in the plate-circuit r-f choke, place a medium value resistor (8.2-12 K) across the r-f choke. In both cases, the resistor lowers the Q of the undesired resonant circuit to a value so low it will not oscillate.

In triode r-f amplifiers (single-ended or push-pull) using neutralization, the wiring leads of the neutralizing circuit are prone to cause parasitic oscillations. The cure for this can be shorter wiring leads, and better placement of the leads (keep input grid and output plate-circuit leads as far away from each other as possible). In high-frequency circuits the use of heavier wire or a flat ribbon conductor reduces any undesired lead inductance, particularly in long leads. However, this is done at the expense of increased stray capacity due to the large physical size of the conductor, requiring extreme care in placement of the lead.

Parasitic Oscillations (cont'd)

Another method of preventing parasitic oscillations in leads to tube sockets (typical is the screen lead to a tetrode or pentode) uses 5 to 10 turns of enameled wire wrapped around the outside of a low value resistor (47 ohms). The resistor is placed as close as possible (consistent with good construction practice) to the tube socket lug.

Low- and medium-power tetrodes, such as the type 807, are susceptible to parasitic oscillations in the plate lead from the cap on top of the tube. The cure here is a low value resistor (47 ohms, 2 watts) with 5 to 10 turns of enameled wire wound around the outside.

Type
813

R-F
Input

RFC

47 Ω

Bias

Parasitic
Suppressor

To Pi
Network

Short
Lead
Lengths

.01   .01

Screen
Voltage

High
Voltage

These Can Prevent Parasitic
Oscillations Due To Long
Filament Leads

Steps To Prevent Parasitic Suppression
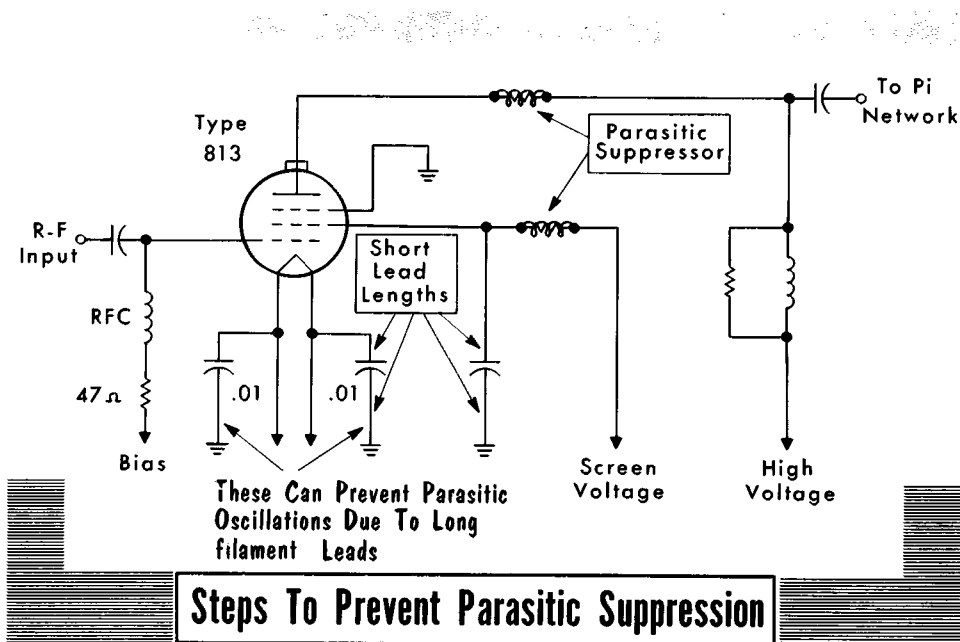
The following procedure can be used for checking circuits containing parasitic oscillations where the plate current is so high that power must be removed. Place an adjustable transformer in series with the power supply to allow control of plate and screen grid voltage. Filament voltage must be kept constant; if necessary use an external filament transformer. Place a dummy load on the output of the circuit—a lamp bulb will do. Use a value lamp bulb as determined by the tube ratings—for example, an 807 could use a 100 watt bulb. With no grid drive signal, slowly increase the plate and screen voltage to the circuit. The instant it breaks into parasitic oscillations check the plate current. If it is over the safe value, reduce the setting of the adjustable transformer, trying to maintain the parasitic oscillations while not exceeding a safe value of plate current. With the oscillations continuing and plate current at a reasonable value, proceed to troubleshoot the circuit as previously discussed.

Repairing a defective transmitter requires the same reasoning and logic applied to a defective receiver. Try to reason the difficulties by observing with three of our senses—sight, sound, and smell.

Meter readings should be taken and compared to the correct readings taken during normal transmitter operation.

Audible tests can be made for arcing and for the "pull-in" or "drop-out" noise of relays.

The buffer stage in many transmitters is fixed-tuned, and has no tuning adjustments.

With sufficient drive to the input of the final amplifier, a severe dip in the output tuning resulting in a low level of plate current indicates loss of the output load.

R-f amplifier circuits in which the input and output frequencies are identical can cause the amplifier to oscillate.

Negative feedback, called neutralization, is used to remove the undesired oscillations.

With the oscillator disabled, any presence of rf at the transmitter output indicates that a stage is self-oscillating.

During adjustment of neutralization of an r-f amplifier, observe caution when working with plate and screen supply voltages, particularly in the final stage where lethal voltages may be present.

Parasitic oscillations make their presence known by creating an output at the final stage with no oscillator drive signal. They may modulate the signal at its output frequency to give the output signal a rough tone.

A grid-dip oscillator helps to locate the parasitic oscillator circuit.

Low value resistors are used in circuits prone to break into oscillation. These reduce the Q of the circuit, preventing oscillation.

REVIEW QUESTIONS

1. Name two obvious, but often overlooked, problems that could cause defective transmitter operation.

2. Describe the visibile checks that should be made of a defective transmitter.

3. What advantage have we in testing a defective AM-CW transmitter?

4. What type of checks can be made in a defective transmitter that uses either an external crystal or the built-in, tunable oscillator circuit?

5. What quick checks can be made of the speech amplifier and modulator circuits of an AM transmitter?

6. Why must safety precautions be observed when neutralizing r-f amplifier circuits, particularly final amplifiers?

7. Briefly describe the abbreviated method for neutralizing a circuit with no r-f indicator.

8. What are some of the possible problems that can be investigated when no adjustments will completely neutralize an amplifier?

9. What precautions must be taken regarding tube plate current in a circuit containing parasitic oscillations?

Checking Transmitter Output

Assuming you have checked your transmitter-final-output-stage meter readings, but, after calling a station there is no returning answer, the obvious thought arises: "Is the transmitter signal getting out?" Depending upon the situation, an amateur station may change frequency within the band, or change bands. A commercial station may have to change to other specific frequencies, usually denoted as *calling* frequencies. If other stations can be raised on these other frequencies ask for signal reports. Signal reports enable you to evaluate your present reports with previous reports. When no response is received after numerous calls, the problem may be remedied by arranging (via the telephone) with a local station to monitor your signal and report as to its strength and clarity.
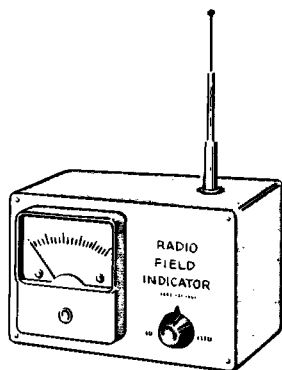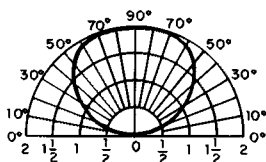
Typical Radiation Pattern

Field Strength Meter

When the reports are adverse, and the output of the transmitter is either missing, or reduced from normal, or altered in any way, various devices and checks are made to localize the difficulties. One method uses a field strength meter. This is a low-Q resonant circuit with a calibrated dial and a crystal detector applying the output directly to a sensitive meter, or to a transistorized amplifier whose output is applied to a meter. A portable antenna with dimensions close to those of the operating frequency is used for signal pick-up. A field strength meter must be used no less than five wavelengths away from the transmitting antenna, preferably further. The field strength meter measures the intensity of the radiated field. Traveling away from the transmitter while measuring at regular intervals, allows a plot of the radiation pattern. This plot shows any *dead-spots* or how efficient a directional antenna is performing in addition to checking the strength of the radiated signal.

Checking Transmitter Output (cont'd)

To check within the station area, a simple r-f monitor can be used. This is a low-Q resonant circuit (tuned to the operating frequency) using a crystal detector and a pair of earphones or a meter as a load. Because of an area of high radiation, a short (18 inches or less) lead will act as a suitable antenna. For use in the immediate area, the r-f monitor will permit readings indicating the presence and strength of a radiated signal.

A VSWR indicator placed in the transmission line will indicate any change in the VSWR measurements. A drastic change indicates a defect in either the transmission line or the antenna. To isolate the trouble where the

R-F Ammeter
or R-F Voltmeter

VSWR Indicator
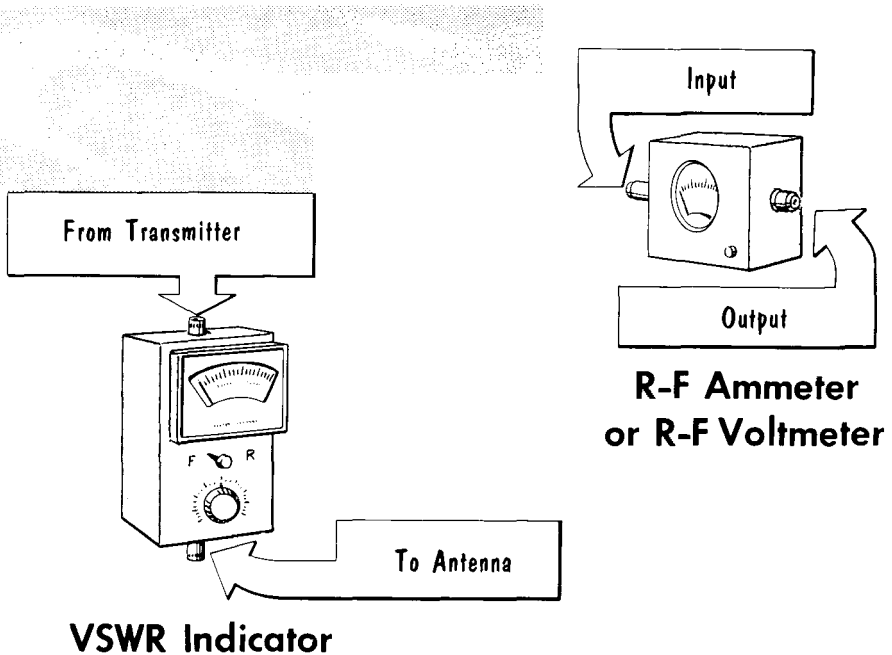
antenna is readily available, a dummy load capable of handling the transmitter output and having the same impedance as the antenna is placed at the end of the transmission line. This determines whether the difficulty is in the line or antenna. If the VSWR reading returns to normal, it indicates the antenna is at fault; if the reading remains changed, it indicates the trouble is in the transmission line.

An r-f ammeter or r-f voltmeter inserted between the transmitter output and the transmission line is often used to tune for maximum output or for setting the output to within prescribed limits. An r-f ammeter consists of a thermocouple built-in to a sensitive d-c meter. The thermocouple, two dissimilar metals, is placed alongside a resistance wire through which the r-f current flows. The heat of the resistance wire causes the thermocouple to generate a low-value d-c voltage that is proportional to the r-f current.

Checking Transmitter Output (cont'd)

The d-c voltage of the thermocouple is applied to the d-c meter, which is calibrated in power readings. A similar instrument is the r-f voltmeter in which a portion of the output current is developed across a calibrated load resistor, rectified by a crystal diode, with the rectified voltage applied to a calibrated d-c meter. The r-f ammeter or r-f voltmeter readings indicate whether there is any transmitter output and whether it is of the proper output level as compared to previous readings.

A quick check for transmitter output is the use of a dummy load containing a meter providing calibrated output readings. The dummy load is placed directly at the output of the transmitter to check for an output or to check the output level. If the output is present in its correct value, the transmission line is replaced, and the dummy load placed on the output of any succeeding device placed in the transmission line. Most often the output of the transmitter is coupled to a bandpass filter to reduce or eliminate undesired harmonic frequencies. The dummy load is then placed at the output of the filter to be sure there is no loss between the transmitter output and the

Used to Check Output
or Output Level
of Transmitter

Calibrated Dummy Load
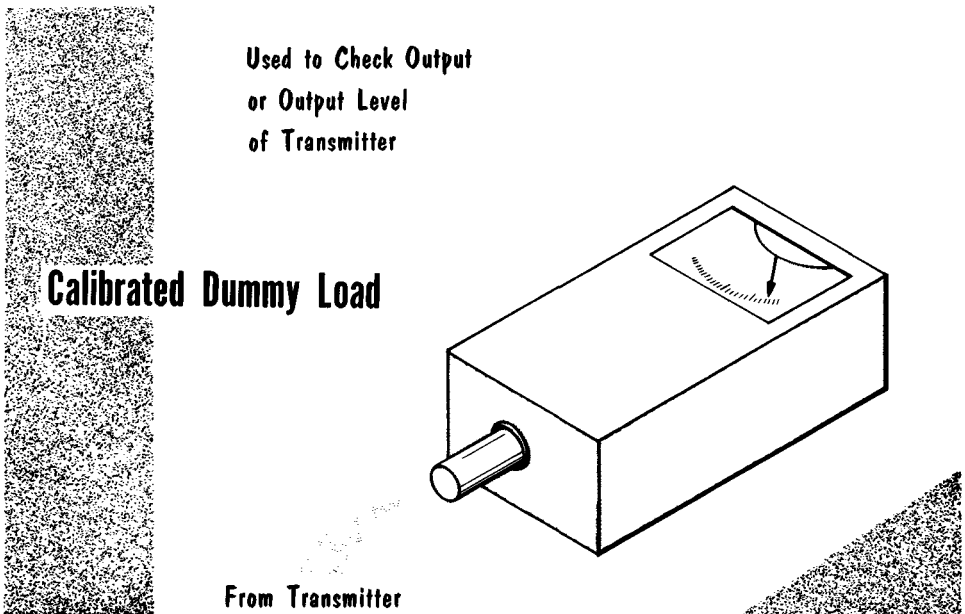
From Transmitter

filter output. Another device often found in the transmission line is an antenna changeover relay used to switch the antenna between the receiver and transmitter. This too should be checked by placing the dummy load at its output to be sure there is no loss between the transmitter and the relay output.

Any reports or checks of a full-strength, unmodulated carrier output from an AM transmitter indicates loss of modulation within the transmitter modulation circuits. These will be discussed later in the book.

Frequency Stability

Legal requirements are that the transmitter output frequency stay either within sharply-defined limits or on a specified frequency. From the time a transmitter is first turned on, a warmup period should be allowed for the oscillator circuit components to steady down. The transmitter can be used within three minutes, but at least one-half hour should be allowed for proper oscillator stability. Following a one-half-hour warmup time, any
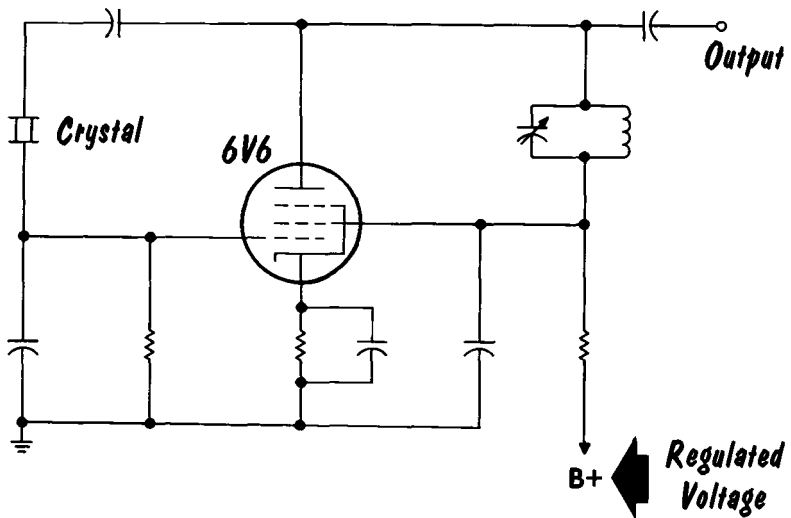
Typical PENTODE-OPERATED PIERCE OSCILLATOR

continued change in frequency constitutes a *drifting* oscillator which requires repair. The factors affecting stability must be recognized to effect any repair of a drifting oscillator circuit.

Assuming an oscillator circuit that has been drift-free but is now drifting, the following areas should be checked for any changes. The most important factor is heat. Any reason for a sudden or continuous change in temperature must be checked. Where a fan is used for cooling, be sure it is operating properly, and that all ducts and perforations are free-and-clear to allow unimpeded air flow. Another important factor is plate and or screen voltage, which should be from a regulated voltage source, if possible. A minimum form of regulation is obtained from a gas tube or zener diodes. To check the source, place a meter on the output and observe the reading for any voltage fluctuations.

Frequency Stability (cont'd)

Too-close coupling of the oscillator to the succeeding stage permits any change in the succeeding stage to be reflected back to the oscillator. This varying load on the oscillator output can result in erratic frequency changes. Components must be snugly mounted to prevent any vibrations from moving them, in turn varying the output frequency. This is a particular problem in mounting the plate tank coil and capacitor. Another source of difficulty is a gradual changing of a component value due to heat. Two examples are resistor values and small-value capacitors. Resistors should be mounted free-and-clear to allow adequate ventilation. Capacitors should be of high quality, designed to maintain a constant capacity under high-ambient-heat conditions. High-quality mica capacitors are preferred. Some

CHECK LOADING
OF NEXT STAGE

OUTPUT

FRACTURED
CRYSTAL   CRYSTAL   RIGID
                                                     MECHANICAL
                                                     MOUNTING
DEFECTIVE   LOOSE
CRYSTAL   ELECTRODES
HOLDER

                                                     REGULATED
CHECK   B +   VOLTAGE
COMPONENTS
FOR CHANGED
VALUES
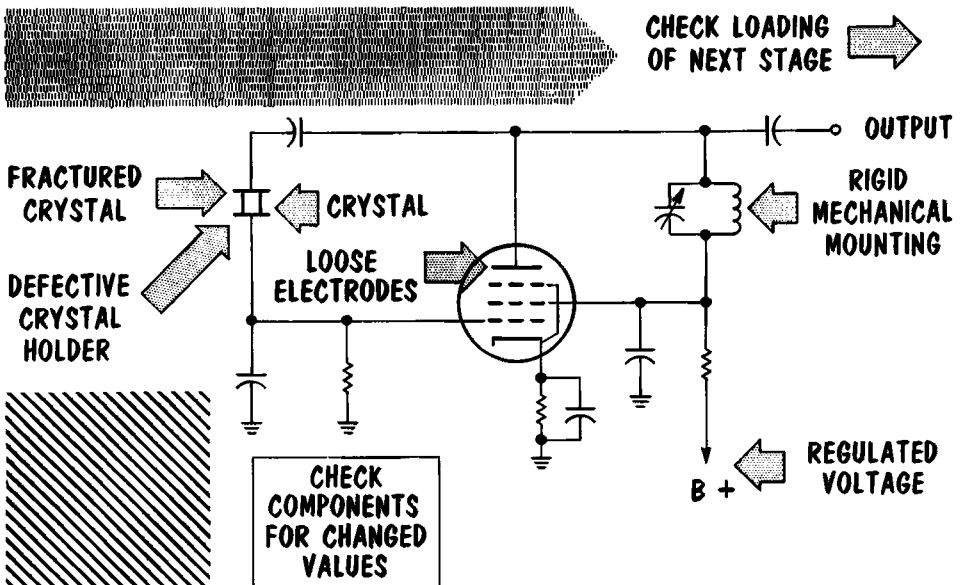
Frequency Drifting Check Points

circuits are designed to use negative- or positive-coefficient capacitors to overcome drift; these should be checked to be sure they are operating as rated. Ovens used to mount the crystal on the oscillator should be checked with a thermometer to insure that it is maintaining a constant temperature. The crystal can be checked for cracks or chips, and the crystal holder can be inspected for possible flaws.

An erratic change in oscillator frequency, particularly when the chassis is vibrated, may be a result of loose electrodes within the oscillator tube. To check this replace the tube. Allow one-half hour warmup for the replacement tube, and then gently tap the tube or vibrate the chassis to be sure the output frequency remains constant.

Frequency Measurement

Frequency measurements are required to determine any drift in the output frequency of a transmitter. There are various methods of measuring frequency, with the simplest and one of the best using a receiver. To check the output frequency of a transmitter requires that the receiver dial be accurately calibrated. The receiver can readily be calibrated by comparing the accuracy of its dial calibration with reception of the signal broadcast by the National Bureau of Standards. The National Bureau of Standards broadcasts from station WWV in Washington, D.C., and WWVH in Puunene, Hawaii at 2.5 mc and harmonics of this frequency. Signals are transmitted at 2.5, 5, 10, 15, 20, and 25 mc. These transmissions are coded to pro-

WWV

Calibrating

THE RECEIVER

5 mc
10 mc
15 mc

CALIBRATION

WWV	Dial Reads
5	5.1
10	10.25
15	15.20
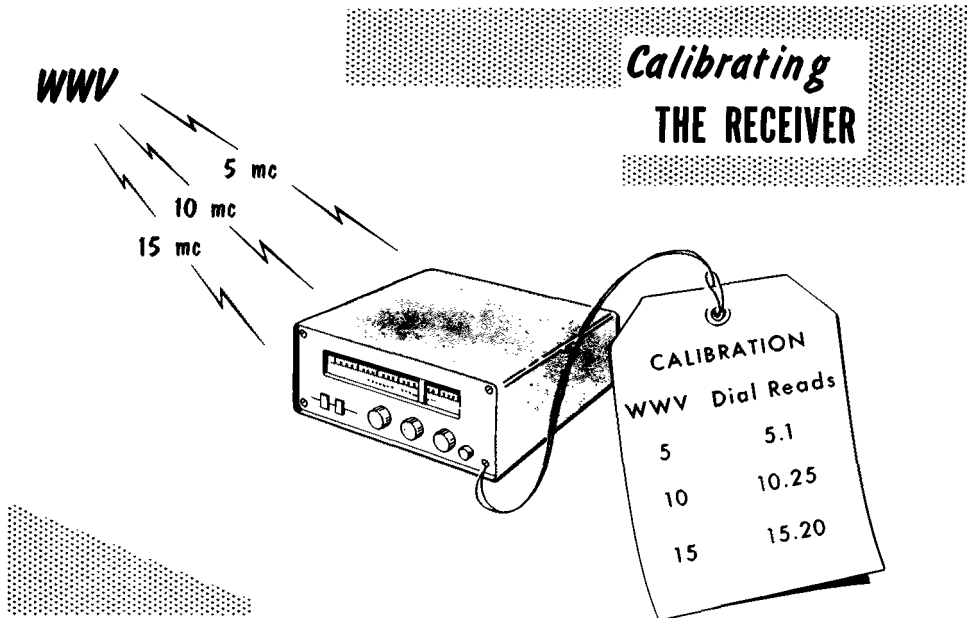
vide correct time plus information regarding propagation conditions. The frequency of transmissions is accurate to within 1 part in 100 million (1 part in 10°). This means that at 10 mc the transmitter frequency will be off by no more than 0.1 cycle in every ten million cycles. Although this accuracy is lost in transmission over distances involving sky wave reception, it is still a remarkably accurate signal suitable for calibrating all but the most demanding equipment requirements.

With the receiver tuned to WWV, the dial is calibrated by noting the difference in dial reading, and the transmitted frequency, and listing it on a sheet of paper. This difference will probably vary with each band. It is best to calibrate with the nearest-value WWV signal that falls on the band being checked. Some receivers have mechanically-constructed dial devices that allow repositioning of the dial pointer or dial scale to calibrate the receiver. Others have local oscillator-trimmer capacitors that are used to reset the local oscillator to zero beat with the signal of WWV.

Frequency Measurement (cont'd)

A secondary standard is a crystal oscillator using a 100-kc crystal with a buffer amplifier whose output is rich in harmonics. The secondary standard can be an external accessory or it can be built-in to the receiver. The output of the secondary standard is coupled to the antenna input of the receiver, providing checkpoints every 100 kc on the dial. At intervals, the secondary standard should also be checked against WWV for calibration.

To calibrate the transmitter, only the oscillator circuit need be operating. Many transmitters have provisions that allow B+ to be applied only to

SIGNAL
FROM
OSCILLATOR

TRANSMITTER   RECEIVER
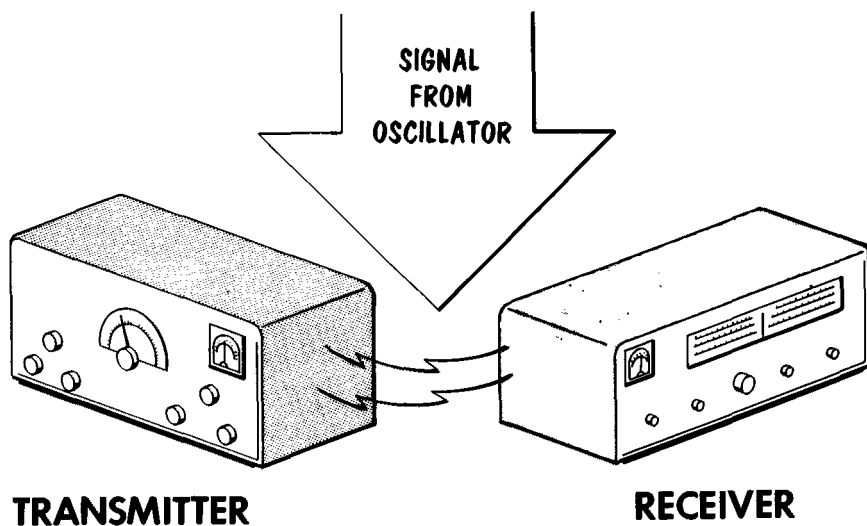
CHECKING FREQUENCY

the oscillator circuit for checking or comparing the oscillator frequency. The output of the oscillator alone is usually sufficient to radiate over a short area in an enclosed room, allowing its signal to be picked up by the calibrated receiver. With the receiver set for CW reception, tune it for zero beat with the transmitter oscillator signal. To be sure it is the correct signal, turn the transmitter oscillator on and off; the beat note should go on and off in step. To overcome inaccuracy in the alignment of the receiver's BFO, turn the BFO off, and operate the receiver with AGC and the r-f gain reduced for a low reading. Carefully tune the receiver until the S meter reads maximum for the reception of the carrier signal. Note the dial setting — it should be the same as that obtained using the BFO.

Variable Frequency Oscillator

In the VFO circuit shown, the tank circuit is tuned to resonance by the tank coil and a zero-temperature-coefficient fixed capacitor. To vary the oscillator over the desired range, a small value variable capacitor is placed
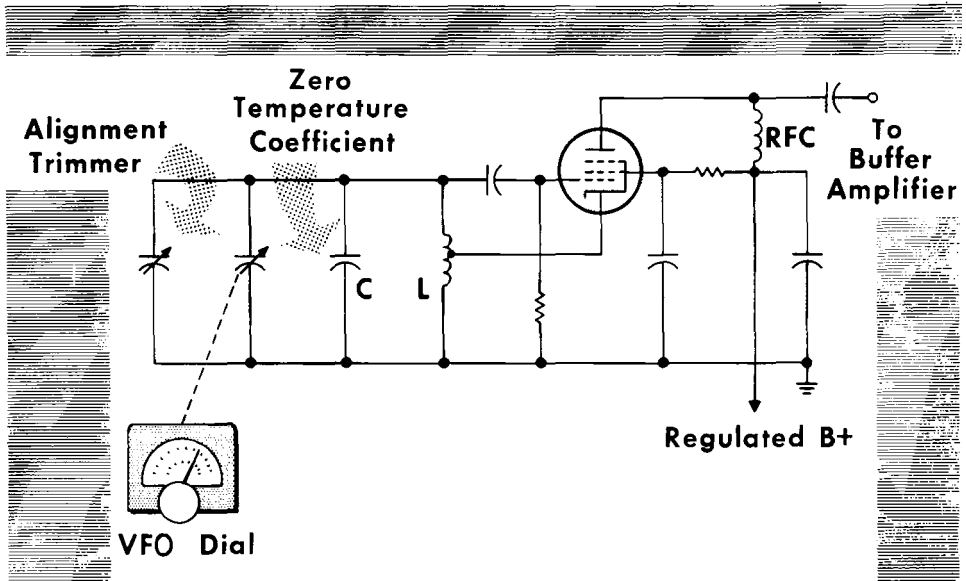
TYPICAL *Variable Frequency Oscillator* CIRCUIT

parallel to the tank circuit. Another small value variable capacitor is paralleled to the tank circuit; it is used for alignment purposes. Although the oscillator is tuned through only one band of frequencies, the frequency multiplier stage will provide an output at harmonic frequencies. The harmonic frequencies are also calibrated on the dial.

Reduced output may be caused by reduced feedback, a defective tube, or reduced voltage. Reduced feedback will usually be caused by any change (usually shorted turns) in the number of turns in the feedback portion of the coil, which will also have an effect on the output frequency. The most likely cause is an aged tube with reduced emission and resulting reduced plate current. Another likely cause is reduction of either screen or plate voltage. Screen voltage changes can be caused by either a change in the screen dropping resistor, or a partial short circuit in either the screen bypass or B-plus bypass capacitor.

Reduced plate voltage can be caused by a partial short in the B-plus bypass capacitor, or a shorted screen bypass capacitor. A shorted coupling capacitor may reduce the plate voltage. This will be determined by the design of the grid circuit of the following buffer amplifier.

Variable Frequency Oscillator (cont'd)

Reduced B-plus voltage reading can be either as a result of a short circuit in the oscillator, or a defect in the B-plus source. To check, lift the B-plus lead from the source and measure the value of B plus. If it rises to its regular value, it indicates the defect is in the oscillator circuit. If it remains reduced in value, it indicates the defect is in the voltage source.

Complete loss of output can be quickly checked by taking a reading of the grid bias; it will be zero if there is no oscillation. A plate voltage reading should then be taken. A high plate-voltage reading indicates the possibility of an open cathode return through the tank coil. A zero plate-voltage reading indicates an open r-f choke in the plate circuit, or a shorted B-plus bypass capacitor.

With the correct values of plate and screen voltage, check for an open grid leak capacitor or resistor. Also, defects in the tank circuit causing the loss
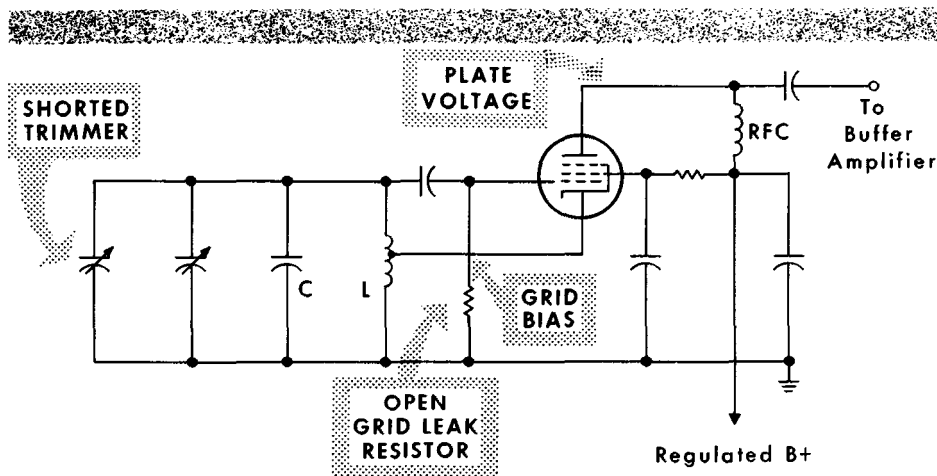
of oscillations can be shorted trimmer, tuning, or tank capacitor, or an open coil.

For drastic off-frequency oscillation, with the transmitter turned off, use a grid dip oscillator to check if the tank circuit is resonant at the frequency indicated on the dial. Any small change in frequency can be corrected with the alignment trimmer. A drastic change requires checking for changed values of the tank circuit components. Any tank circuit component which changes value drastically requires replacement.

Crystal Oscillator

Typical Pentode-Operated *Pierce Oscillator*
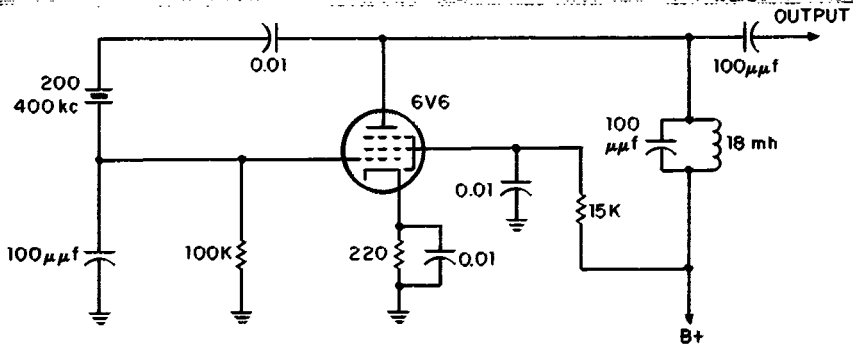
A typical Pierce crystal oscillator is shown above. It has high stability and requires no tank circuit, forming a simple and often used crystal oscillator circuit. A small amount of cathode bias is used to prevent the plate current from exceeding normal limits when the crystal is removed from its holder. The isolating capacitor between the plate and the crystal is used only to remove B plus from the crystal holder.

With an equivalent diagram of the crystal circuit, it can be shown that the Pierce oscillator operates in a manner similar to the Colpitts oscillator. This Pierce oscillator circuit uses the interelectrode capacitances of the tube to obtain the Colpitts configuration. In order to minimize the effect of having to depend on the interelectrode capacitances, which may vary from tube to tube, designers sometimes incorporate a fixed capacitor from plate to grid, thereby making the oscillator less sensitive to a change in interelectrode capacitance.

Reduced output may be the result of a defective tube, reduced voltages, or a defective crystal. An aged tube with reduced emission will also cause reduced ouput. An open cathode-bypass capacitor will result in degeneration to lower the output. An aged crystal that has lost resiliency can also be a reason for low or erratic output. A shorted isolating capacitor applying B plus to the crystal may cause it to become defective and result in a reduced or erratic output. An open isolating capacitor between the plate and crystal may allow sufficient feedback through leakage to sustain oscillation, but the output will be intermittent or low. A partial short circuit in either the screen or B-plus bypass capacitor, or an increase in the value of the screen dropping resistor, will result in low screen and plate voltages to provide reduced output. A shorted coupling capacitor may result in reduced plate voltage. This would be determined by the design of the grid circuit in the succeeding stage.

Crystal Oscillator (cont'd)

A reading of reduced plate and screen voltages can be either a result of a defect in the oscillator circuit or in the B-plus source. To determine which, lift the B-plus lead to the circuit. If the B-plus voltage rises to its correct value, the defect is in the oscillator; if it remains low, the defect is in the voltage source.

For a complete loss of output check all voltages. A high plate-voltage reading will indicate an open cathode resistor or open tube. A loss of

Construction of "Pressure Sandwich Type Mount"

HOLDER CASE

SPACER BLOCK

ELECTRODE

ELECTRODE

NEOPRENE GASKET

FIBER WASHER

SPRING

CONTACT PLATE

SPACER BLOCKS

CRYSTAL

CONTACT PLATE

COVER

PLUGS
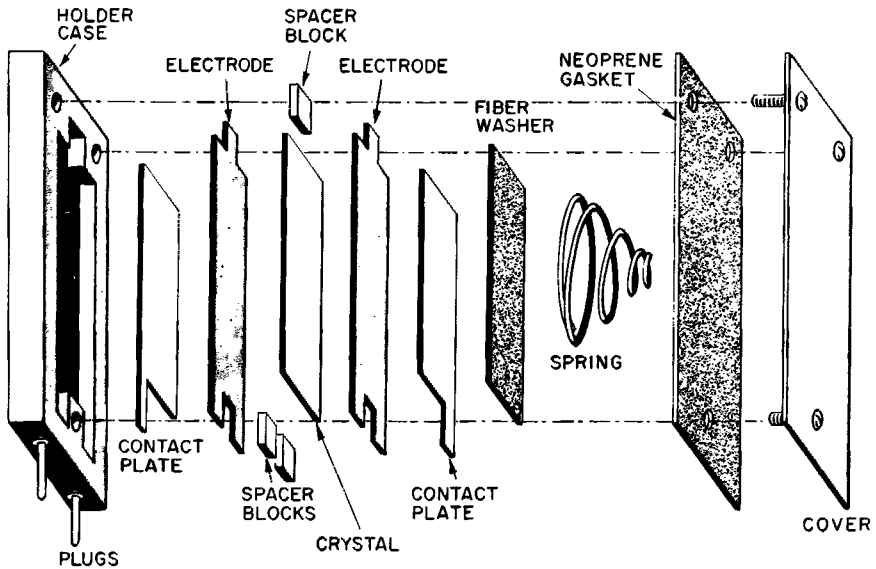
cathode bias voltage will probably be the result of a shorted bypass capacitor. A shorted screen-bypass capacitor or an open screen dropping resistor will result in a loss of screen voltage. A shorted B-plus bypass capacitor will result in the loss of both screen and plate voltage. Take a B-plus reading on the plate side of the crystal holder to check for a shorted isolating capacitor. Application of B plus to the crystal may damage it, causing loss of output. A heavy blow or sharp vibration can fracture the crystal, resulting in loss of output. A typical "pressure sandwich" type mount is shown in the illustration. Never attempt to repair a fractured crystal. They are easily replaced. A change in output frequency, erratic operation or spurious signals from 20 to 60 kc on either side of the carrier frequency may be the result of a crystal damaged by shock or vibration, or a defective crystal mount.

A field-strength meter is a low-Q resonant circuit with a calibrated dial and a crystal detector applying the output to a sensitive meter. With a portable antenna with dimensions close to those of the operating frequency, the meter is used to check signal strength.

To check within the station area, a simple r-f monitor can be used. This is a low-Q resonant circuit tuned at or near the operating frequency. Being used in a high radiation area, it requires a short (18 inches or less) antenna.

A VSWR indicator in the transmission line will indicate any change in the VSWR measurements.

A quick check for transmitter output is a dummy load containing a calibrated meter for measuring a rectified portion of the output signal.

A transmitter can be used within three minutes after turning it on, but at least one-half hour should be allowed for proper oscillator stability.

An accurate method of calibrating a receiver is to compare its dial calibration with reception of signals from the National Bureau of Standards broadcasts from WWV and WWVH.

The receiver dial may be calibrated by noting the difference in dial readings of WWV or WWVH, and the dial calibration. Some receivers use mechanical dial scale or dial pointer positioning devices; others may use a resettable, local oscillator-trimmer capacitor to allow a zero beat with WWV or WWVH.

A grid-dip oscillator is useful in checking the resonant frequency of oscillator tank circuits.

A heavy blow or sharp vibration can fracture a crystal and cause complete loss of output. No attempt should be made to repair a fractured crystal; they are easily replaced.

Fractured crystals can cause less obvious difficulties such as erratic operation or spurious signals on either side of the carrier frequency.

REVIEW QUESTIONS

1. What is the minimum distance that a field-strength meter can be placed from a transmitting antenna?
2. How can we use a dummy load to check for difficulties in either the transmission line or antenna?
3. Describe the construction and action of an r-f ammeter in measuring r-f current.
4. What would reports of a full-strength unmodulated carrier signal indicate for an AM transmitter?
5. What constitutes a drifting oscillator?
6. Name the most important factor to check for in a drifting oscillator.
7. How are negative, or positive coefficient capacitors used to combat drift in an oscillator?
8. In using receivers to test the output of a transmitter, how can we check for accuracy of the BFO?
9. What is the purpose of the capacitor between the crystal and the plate of the tube in a Pierce oscillator?

Buffer Amplifier

The buffer amplifier is used to provide isolation between stages, usually between the oscillator and frequency multiplier stages. The output tank circuit is tuned to the same frequency as the input. Being biased class A, its

BUFFER

AMPLIFIER

OUTPUT

INPUT

High Input Impedance

Biased Class "A" Operation

Tuned to Input Frequency

Drive Control **B +**
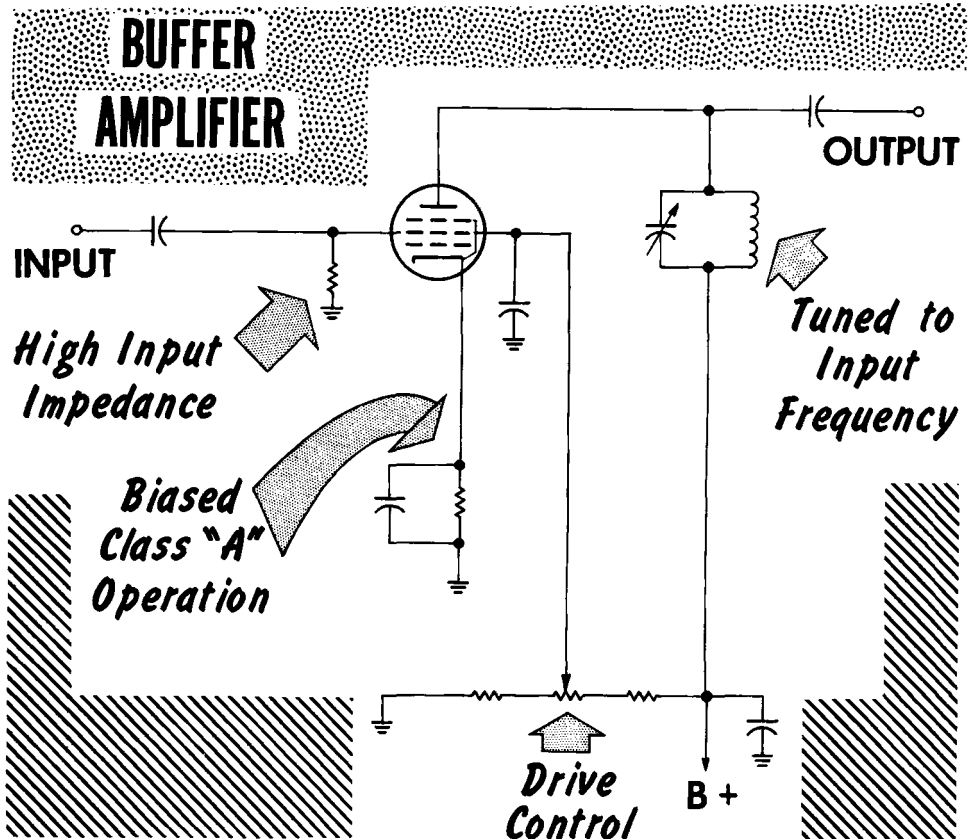
grid circuit always presents a high impedance to the preceding stage to maintain a constant load. To allow changing the output power of the buffer stage, the screen voltage is taken from an adjustable voltage divider using a high-wattage potentiometer as a *drive control*. This permits adjustment for a specific output, or drive level (measured in the grid of the succeeding stage), with varying input levels.

To test for reduced output, check for low values of plate and screen voltages. Low plate voltage may be a result of a partial short in the B plus bypass capacitor. Low screen voltage may be the result of a partial short in the screen bypass capacitor, or changed values in the screen voltage-divider network. An open cathode bypass capacitor will cause degeneration, slightly reducing the output signal level. An aged tube with low emission or reduced input to the grid circuit are other possibilities that must be checked.

Buffer Amplifier (cont'd)

With no output from the amplifier, check for complete loss of input signal. An open plate circuit due to an open cathode resistor is indicated by high plate voltage. Loss of plate voltage could be a result of a shorted B-plus bypass capacitor. A remote possibility is an open coil winding, but more likely the lead connection at either end of the coil may be defective. Any reading of a positive voltage on the grid indicates a shorted coupling capacitor.

When a partial or complete loss of voltage is present at the B-plus terminal, a quick check to determine where the fault lies is to lift the B-plus lead from the terminal. With the B-plus lead lifted, read the B-plus value. If it is still low, the difficulty is in the power supply; if it returns to normal, the difficulty is in the amplifier circuit.

FOR NO OUTPUT CHECK...
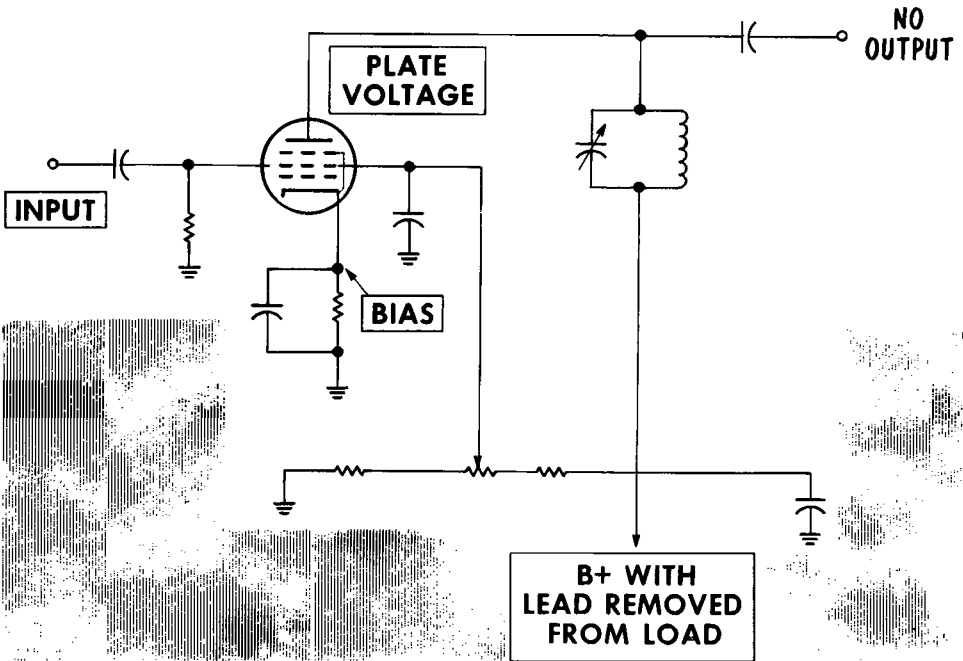
Should the buffer amplifier be operating correctly but provide no control over the drive to the succeeding stage, check the screen-grid voltage-divider network. An open circuit at the ground return would place the potentiometer and the resistor closest to the B-plus line as a series voltage-dropping circuit, with virtually no control over the screen voltage.

Frequency Multiplier
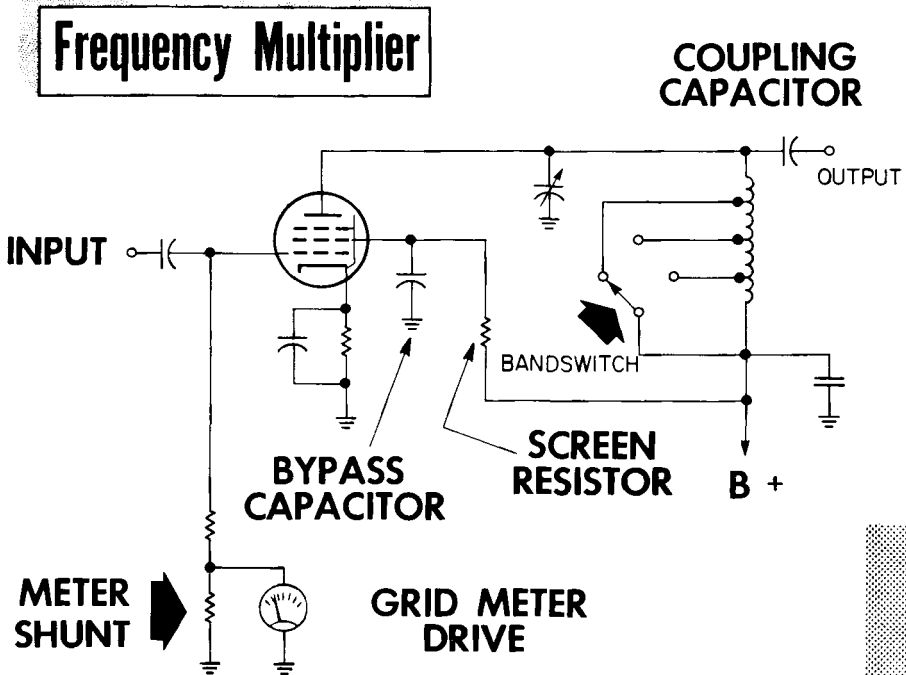
COUPLING
CAPACITOR

INPUT

OUTPUT

BANDSWITCH

BYPASS
CAPACITOR

SCREEN
RESISTOR   B +

METER
SHUNT

GRID METER
DRIVE

A frequency multiplier is used to provide output frequencies at multiples of the input frequency — one with twice that of the input being a doubler, and one with the output being three times that of the input is a tripler, etc. An output frequency differing from input frequency does not often require neutralization. Depending upon circuit design, it may or may not have a tuned tank circuit at the input. When the output is bandswitched, the input is most often RC coupled, relieving the necessity of bandswitching the grid circuit. A current-reading grid-drive meter is used to measure input power. The output is usually tuned by measuring the grid drive to the succeeding stage; when tuned to resonance, it will provide maximum drive. To cover a wide range of frequencies the output tank circuit is usually bandswitched by a tapped coil.

To check for a reduced output signal, the obvious first step is to measure grid drive. Other checks are for a low emission tube and reduced screen and plate voltages. Reduced screen voltage can be the result of a partially-shorted screen bypass capacitor or an increased-value screen series dropping resistor. Reduced plate voltage can be caused by a partial short in the B-plus bypass capacitor. A small reduction of output could be caused by an open cathode bypass capacitor causing degeneration in the grid-cathode input circuit.

Frequency Multiplier (cont'd)

A complete loss of output from the buffer amplifier is indicated by loss of drive to the grid of the succeeding stage. In checking for a complete loss of output signal, the first step is to check for input drive on the grid current meter. With an input signal present but no output, check all

Coupling Capacitor

No Output

Bypass Capacitor

INPUT

Grid Drive Meter

METER SHUNT

BANDSWITCH

Screen Resistor

B+ Supply

All Voltages

B+
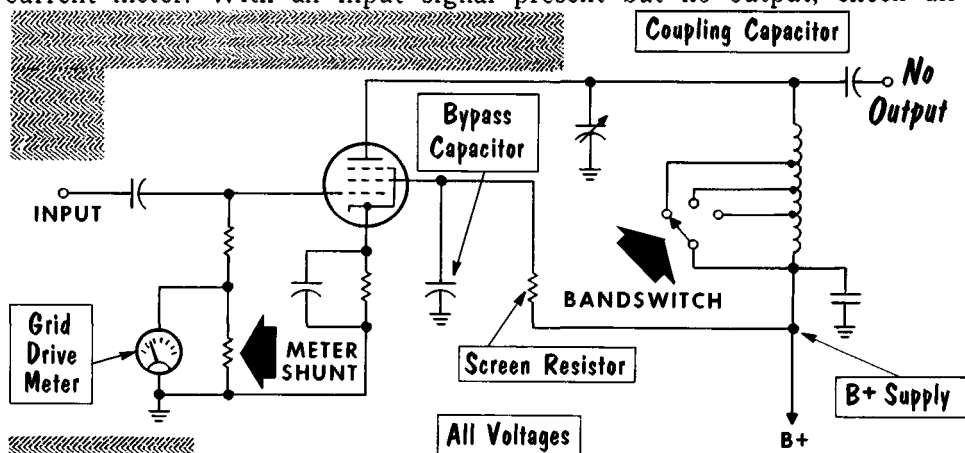
FOR COMPLETE LOSS OF OUTPUT CHECK . . .

voltages. An open cathode resistor causes a loss of grid bias and a high plate voltage. A shorted coupling capacitor is indicated by a high positive-voltage reading on the grid. A loss of screen voltage indicates either an open screen dropping resistor or a shorted screen bypass capacitor. A loss of plate voltage could be a shorted B-plus bypass capacitor or shorted tuning capacitor.

Difficulties in tuning or intermitent operation will usually center around the plate tank circuit and the bandswitch. A very shallow tuning dip indicates that the output circuit is heavily loaded by the succeeding stage. A very sharp dip indicates no load on the output circuit. An intermittent bandswitch due to defective or dirty contacts can be checked by observation of the grid drive meter in the succeeding stage. While observing the meter, flex the bandswitch knob gently to determine any erratic output as a result of the bandswitch flexing. If the buffer stage does not tune normally check for an open bandswitch. A grid dip oscillator or absorption wavemeter is best for checking the tank circuit for correct resonant frequency. When checking the frequency be sure to check the bandswitch position, determining whether the knob may have loosened and possibly be set to the wrong band. For erratic tuning, check the tuning-capacitor mechanical arrangements. Most often the variable capacitor is connected to the tuning shaft by an insulated coupling that could come loose. To check the coupling, check the set screws of both the coupling and the knob at each end of the shaft.

R-F Power Amplifier

Most often the r-f power amplifier stage is the final stage of the transmitter. Coupling the output to a succeeding stage of higher power, through a conventional tank circuit instead of a pi network, would make an r-f power amplifier a driver stage. In the circuit shown the cathode is applied directly to ground and bias is derived by grid-leak method in an RC coupled input. Parasitic suppressors are used at the control grid and plate cap connections. The output circuit is often metered to read both plate and screen current although it is labeled plate current.

To regulate the screen voltage a *clamp* tube is placed between the screen grid terminal and ground. With a grid-drive signal to the amplifier, the resulting negative grid bias cuts off the clamp tube conduction. The applied signal causes the amplifier to conduct, and the resultant screen-grid current flow through the screen dropping resistor causes a voltage drop providing a reduced-value screen voltage. With no signal and reduced screen grid current, the screen grid voltage tends to reach the same high value as the

POWER AMPLIFIER STAGE

Always turn off or remove the high voltage before making any adjustments in the circuits.
Always discharge the filter capacitors with a shorting probe after turning off the high voltage. Never depend upon a bleeder resistor to discharge the filters.
Never operate the transmitter without a properly-fused primary power-circuit, and never use any but the correct-rated-value fuse.
Never leave the primary power supply plugged into the ac source when making adjustments or repairs requiring no power.

plate voltage, which is too high a level for a screen voltage. With the loss of grid drive signal, the low self-bias value at the grid of the amplifier allows the clamp tube to conduct. With the clamp tube conducting, the screen voltage drops to approximately the same value caused by the amplifier tube conducting. The result is a regulated, near-constant screen-grid voltage.

R-F Power Amplifier (cont'd)

In checking for reduced output, voltage readings should be taken to determine if the reduction in output is a result of a reduction in any operating voltage. As previously mentioned, an obvious first step would be to check grid drive or loss of grid bias, both of which will be evidenced by the grid current meter reading. A low value of high voltage may be due to a defect in the modulator stage of an AM transmitter, a defect in the amplifier stage, or a defect in the power source. Low plate or screen voltage will probably be indicated by an excessive no-signal, plate-current meter

FOR NO OUTPUT CHECK...

INPUT

Plate Voltage   RFC   **NO OUTPUT**

RFC

Screen Resistor

SCREEN CLAMP TUBE

Grid Drive

METER SHUNT

Plate Current   METER SHUNT

ALL Voltages

B++   B+ Supply

POWER AMPLIFIER STAGE
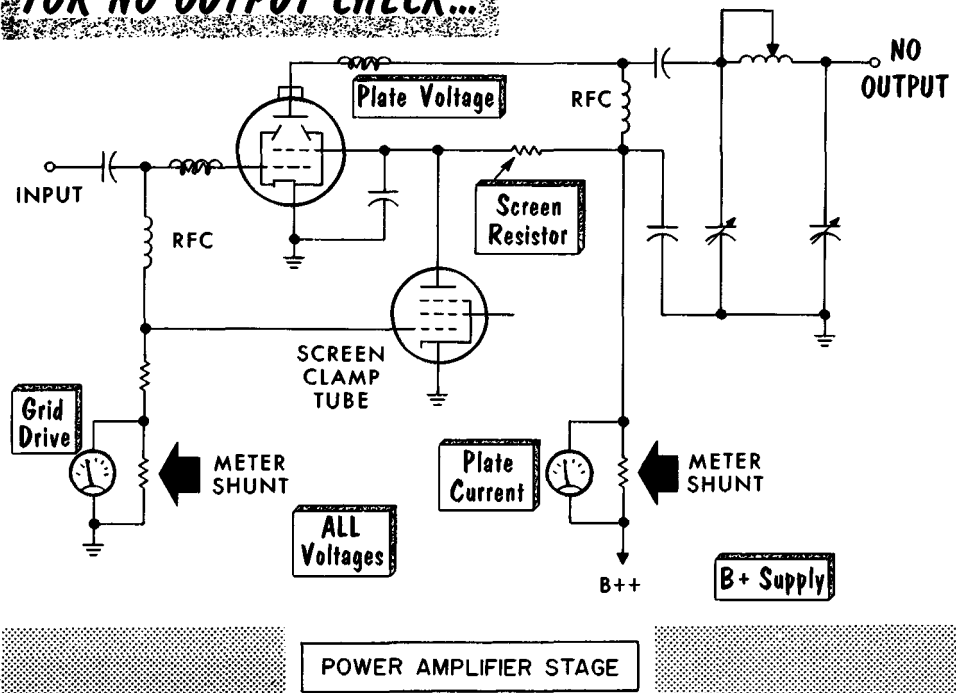
reading, the cause of which may be a partial short in the screen or high-voltage bypass capacitors. Low screen voltage with no increase in screen current may be caused by an increase in the resistive value of the screen voltage-dropping resistor. A high screen-grid voltage would indicate a defective clamp tube or improper operating voltages to the clamp tube.

In checking for no output, with grid drive and grid bias present as indicated by the grid current meter reading, check for loss of plate and screen voltage. With zero plate and screen current reading in the plate current meter, check for the absence of high voltage from the modulator stage. An abnormally high plate-current meter reading with very low or zero screen and/or plate voltage may be caused by a shorted screen or high-voltage bypass capacitor.

R-F Power Amplifier (cont'd)

Resonance in the plate circuit is normally indicated by the dip in plate current readings as the plate tank capacitor is tuned throughout its range. It is always good practice not to apply full plate voltage suddenly, but to increase the voltage slowly, if possible, until the rated voltage is reached. A simple plot of the various current readings over the tuning range will indicate whether the amplifier is tuned properly. The shape of the curve may tell where the trouble lies. Below is illustrated the characteristics for different values of loading.

Maximum

PLATE CURRENT

Excessive Output Load

Normal Output Load

No Output Load

Minimum

TUNING CAPACITOR *fo*
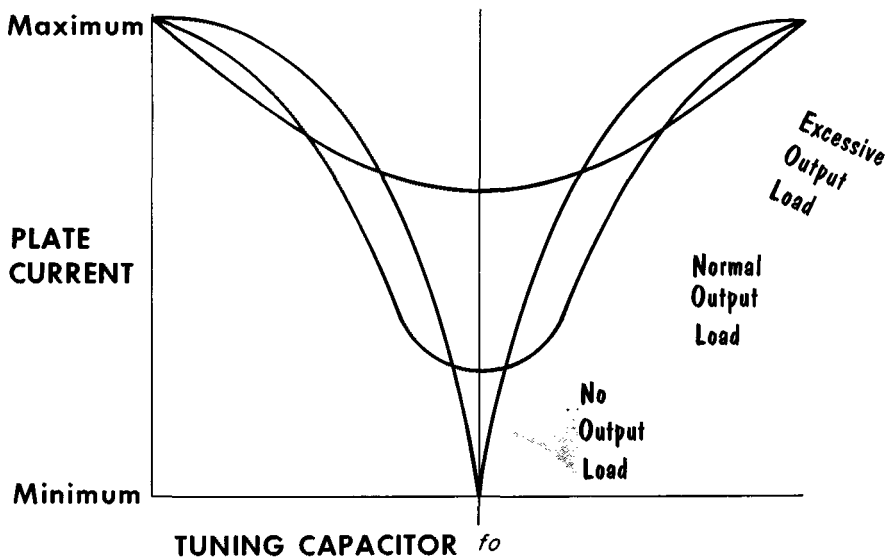
OUTPUT TUNING

Tuning difficulties will vary with the problem. A very sharp dip with reduced plate-current reading will probably be due to a loss of the output load, such as a disconnected antenna, or an open coaxial cable or coaxial fitting. A dummy load should be placed directly at the output connector to check for loss of an output load. A short in the output load, or reduction in impedance causing a heavy load on the output stage will cause a wide, shallow tuning dip in the output circuit. The increased load will be reflected to the grid circuit, requiring increased drive from preceding stages to maintain the required grid drive in the r-f power amplifier. When the output tuning adjustments have no effect on the plate current reading, which remains steady, check for loss of grid drive signal on the grid current meter. In all tuning procedures, whether tuning the output or input, be sure not to exceed the tube ratings, both in grid current values and plate and screen current values.

Transmission Line and Antenna

A properly terminated transmission line will have its output applied to an impedance equal to that of the transmission line. A properly matched transmission line will have its input *see* an impedance equal to that of the transmission line. With these conditions there will be no appreciable signal loss in the transmission line, and all the energy will be delivered to the antenna. Assuming a mismatch at the antenna, there will be energy reflected back down the transmission line to produce standing waves along the line. A VSWR indicator (p. 2-87) inserted in the line is used to adjust the antenna for an impedance match with the transmission line, as indicated by the lowest VSWR reading on the meter.

A high VSWR reading can indicate difficulties in either the transmission line or the antenna. Various different types of transmission lines that may be encountered are shown in the illustration. The majority of transmission lines in use are manufactured coaxial- or ribbon-type lines with constant impedance. The difficulty in the transmission lines is usually due to broken connections to the antenna, poor or broken connections at the coaxial connectors, and loose or defective coaxial connections or connectors. To check the transmission line, remove the connections to the antenna and insert a dummy load. With a matched dummy load, any high VSWR reading indicates the difficulty is in the transmission line, while a low VSWR reading indicates the difficulty is in the antenna.

TYPES of TRANSMISSION LINES USED in RADIO COMMUNICATIONS

CONDUCTOR

| OPEN WIRE |

Two uniformly-spaced
parallel conductors
supported
by spacers

INSULATING SUPPORT
(Polyethylene or Ceramic)

Outer
Covering

POLYETHYLENE
INSULATOR

| COAXIAL CABLE |
| coax |

Solid or multiple-strand
inner conductor
centered within
outer shield

Shield is
outer conductor
(braided)

INNER
CONDUCTOR

| TWIN or |
| RIBBON LEAD |

Two uniformly-spaced
parallel conductors
encased in
polyethylene

INSULATING AND   CONDUCTORS
SPACING MATERIAL

Transmission Line and Antenna (cont'd)

With the transmission line known to be good, a high VSWR reading indicates a defect in the antenna. If the antenna is designed specifically to match the impedance of the transmission line, a high VSWR reading indicates such defects as broken leads, broken or missing elements in a ground plane, etc. If the antenna uses a matching section to match the impedance of the antenna to that of the transmission line, a high VSWR reading is probably due to a defect or change in the matching section.

BRIDGE CIRCUIT VSWR INDICATOR FOR LOW-POWER, 52-OHM COAXIAL TRANSMISSION LINE
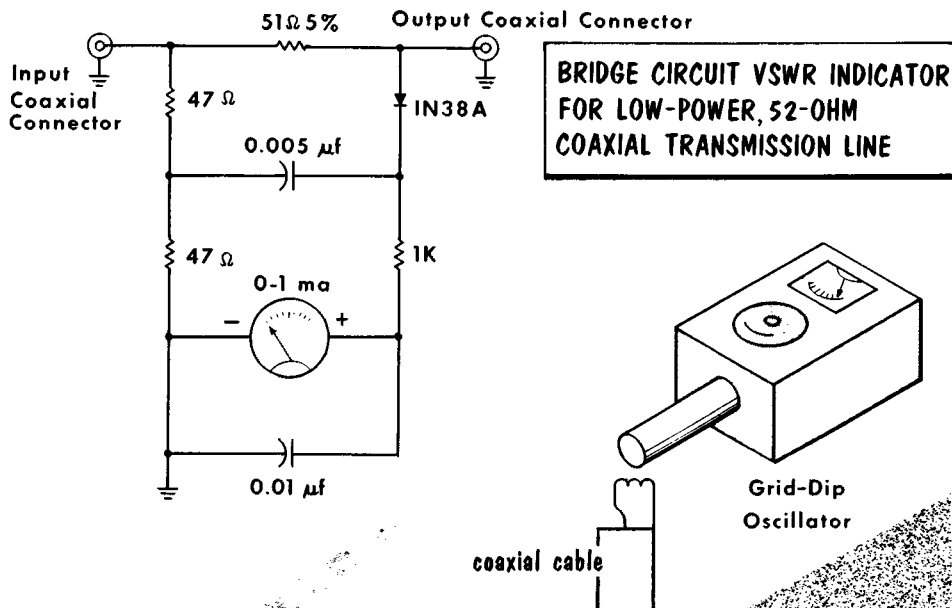
taking resonance reading

A grid-dip oscillator can be used to check an antenna for its resonant frequency. The transmission line is removed from the transmitter. For coaxial lines a portion of the inner conductor is bared and coiled to form a two-turn loop with the end soldered to the outer braid. For 300-ohm transmission line the ends are bared and twisted for a two-turn loop. The grid-dip oscillator is coupled to the loop on the end of the transmission line. Starting at the highest band on the grid-dip oscillator, the frequency of the various dips are noted. The lowest frequency at which a dip is read, is the resonant frequency, while other dips are harmonics.

Resonance readings and VSWR readings will vary with the types of antennas. High-Q antennas, such as Yagis, will resonate sharply at specific frequencies and provide higher VSWR readings off the resonant frequencies. Low-Q antennas, such as long line or basic dipoles, will tune broadly at resonant frequencies and provide a slight increase in VSWR off the resonant frequencies.

Speech Amplifier

Where meter readings indicate an AM transmitter has an r-f carrier output but weak, distorted, or no modulation, the usual first check is to start from the input or speech amplifier stage towards the output or modulator stage. The speech amplifier stage is a high-gain voltage amplifier used to build
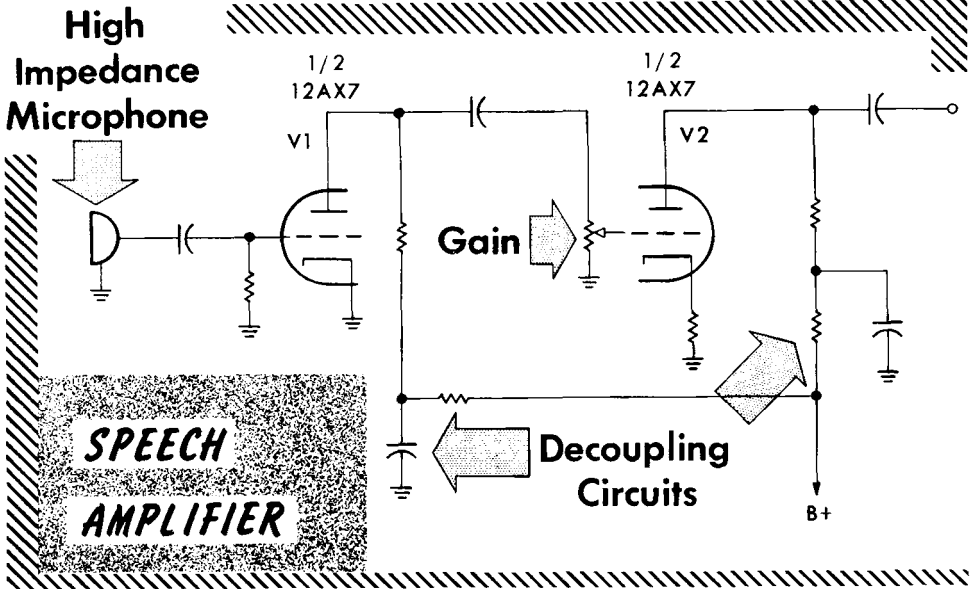
up the input signal voltage from the microphone to a level suitable to apply to a driver or low-power audio-output stage.

The input circuit is usually a high impedance circuit to match a crystal microphone or other high impedance types of microphones. Low impedance microphones are usually found in mobile installations requiring rugged carbon microphones. Their requirements of special input circuits restricts their use. The microphone can be checked by applying the output to an audio signal tracer, or by using a substitute microphone. The use of a substitute microphone in place of a defective microphone is quickly checked by observing the modulation stage plate-current meter readings. The presence of plate current fluctuations when talking into the substitute microphone, will indicate that modulation has been restored.

Reduced or distorted output can be checked by taking voltage readings. Low plate voltage is caused by an increase in the resistor values of either the decoupling resistors or plate load resistors. Another cause is a partial short circuit of either decoupling filter capacitors. Distortion at the microphone input to the grid circuit has to be checked with an audio signal tracer. Distortion at the input of the second stage can be checked by a voltage measurement for the presence of positive voltage at the grid of V2. Any positive voltage present is due to a shorted or partially-shorted coupling capacitor.

Speech Amplifier (cont'd)

A 60-cycle hum that cannot be changed in value with the gain control indicates an open or *floating* grid at tube V2. Some control over the hum indicates an open grid at the input of tube V1. A 120-cycle hum at an audible and annoying level can result from an open, decoupling-network filter capacitor. If the gain control has no effect on the hum, it is probably being developed in the plate circuit of V2. If the gain control does have an effect, the hum is probably being developed in the plate circuit of V1. Depending upon the chassis layout and circuit gain, an open decoupling capacitor in the plate circuit of V1 or V2 can cause positive feedback with its attendant howling and squealing.
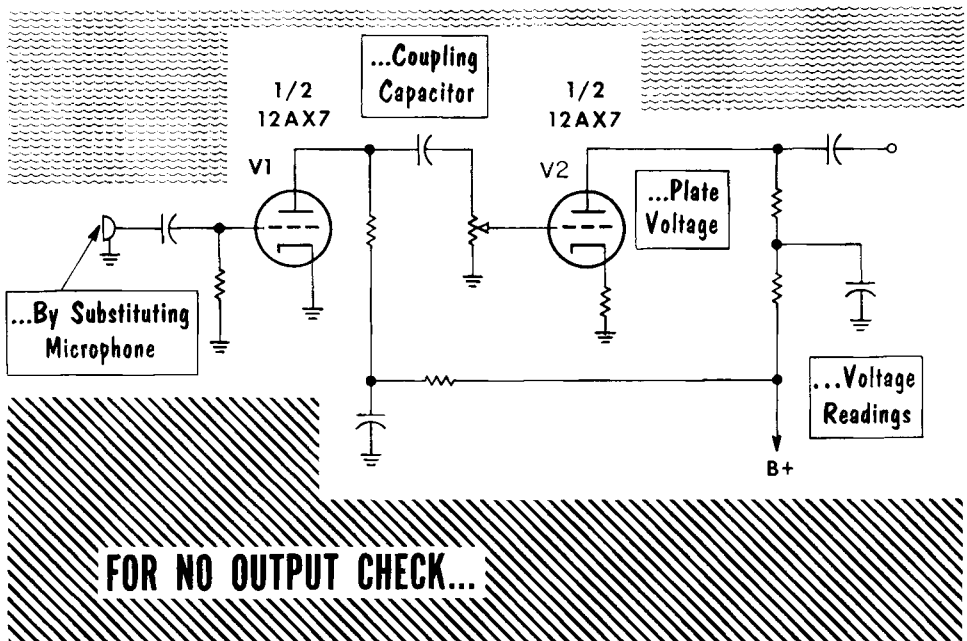
A complete loss of output can be checked by taking voltage readings. The first check point should be the tie point where B plus is applied through the decoupling resistors to the plate circuits of both tubes. If no voltage is present, the lead from the power source should be lifted. If the lead from the power source resumes its full voltage value when lifted, it indicates the difficulty lies in either (or both) of the two preamplifier stages. Should the voltage at the lead from the power source still read zero, the power supply circuits should be checked. Loss of plate voltage to either tube can be due to open decoupling or plate load resistors, or shorted, decoupling filter capacitors. The presence of any positive voltage at the grid of V2 may cause such heavy conduction, and consequent plate voltage drop across the plate load, as to provide a zero or near-zero plate voltage reading. A high plate voltage reading on the plate of V2 may be due to an open cathode resistor.

A buffer amplifier is used to provide isolation between stages. Being biased class A, its grid presents a high impedance to the preceding stage to maintain a constant load.

To change the buffer output power, the screen voltage is taken from an adjustable voltage-divider, high-wattage potentiometer.

A frequency multiplier is used to provide output frequencies at multiples of the input frequency. An output twice that of the input is a *doubler,* one with three times that of the input is a *tripler,* etc.

Loss of output of the buffer, or frequency multiplier stage is noted by loss of grid drive to the succeeding stage.

Most often the r-f power amplifier stage is the final stage of the transmitter. Coupling the output to a succeeding stage of higher power would make an r-f amplifier a driver stage.

The output circuit of the r-f amplifier is often metered to read both the plate and screen current although it is labeled plate current.

To regulate screen voltage, a *clamp* tube is placed between the screen grid and ground.

In AM transmitters, the loss of high voltage to the r-f amplifier may be as a result of a defect in the modulator circuits.

Tuning difficulties vary. No output load is indicated by a very sharp dip in plate current; an excessive load will cause a very shallow dip; no change in plate current could indicate a loss of the input drive signal.

A grid-dip oscillator can check an antenna for its resonant frequency.

The speech amplifier is a high-gain voltage amplifier used to build up the input signal voltage from a microphone to a level suitable to apply to a driver for a low-power audio-output stage.

Mobile installations usually use rugged carbon microphones. The low impedance of the carbon microphone requires special input circuits.

REVIEW QUESTIONS

1. When varying the *drive* control of a buffer amplifier, where do we read the indications of the change in drive?

2. Describe the checks that should be made of the knob, the shaft, and the coupling to the variable capacitor of the frequency multiplier circuit.

3. What type of output circuit is most likely to be found when the r-f amplifier is being used as an r-f power amplifier? A driver?

4. Briefly describe the action of the clamp tube in regulating the screen grid voltage of an r-f amplifier tube.

5. In tuning the output of the r-f amplifier, describe some of the possible causes of a very sharp dip. A very shallow dip. No dip.

6. What determines a properly matched transmission line?

7. In taking VSWR readings, what is desirable—a high reading or a low reading?

8. In VSWR readings what does a high reading indicate? A low reading?

9. What are the indications of an AM transmitter that signifies possible troubles in the speech amplifier circuits?

Driver

For Complete Loss Check...

Driver
Transformer

6AQ5

INPUT

Plate and
Screen
Voltages

Transient
Protection
Capacitor

Push-Pull
Output

B+
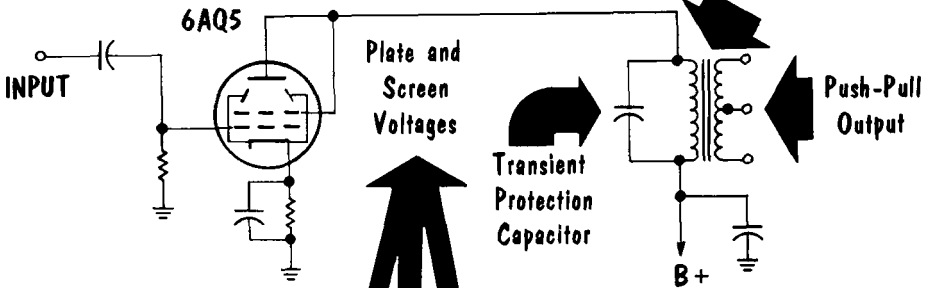
DRIVER STAGE

TOO HIGH: Open cathode resistor

HIGHER
THAN NORMAL: Shorted transient protection
capacitor

ZERO: Open driver transformer short
between turns, and metal core
of driver transformer, shorted
by B+ bypass capacitor

The driver stage is used to convert the signal voltage output of the speech amplifier stage to a power output capable of driving the modulator stage. To achieve power for drive, a power amplifier tube is used in a triode connection to provide the low plate impedance desired in a driver amplifier. The output is coupled to the modulator stage by a driver transformer with a center-tapped secondary to provide push-pull output. A small value capacitor with high voltage rating is placed across the primary of the driver transformer to protect the transformer against high voltage transients developed by the collapsing magnetic fields created by a signal voltage peak. The capacitor also acts as a tone control, reducing the output of high audio frequencies.

For low or distorted output, check for a partial short in the B-plus bypass capacitor, causing a reduced plate screen voltage. A partial short in the transient protection capacitor across the driver-transformer primary winding can cause a reduced and or distorted output. Distortion can be caused by a shorted coupling capacitor placing a positive voltage on the grid. If the grid goes sufficiently positive, it will draw excessive plate current causing the plate to glow red. A shorted cathode bypass capacitor will remove the grid bias and cause distortion by having the tube operate on a nonlinear portion of the plate-current grid-voltage curve. An open cathode bypass capacitor will cause degeneration and a slight reduction in the output level.

Modulator Stage

Caution Note: The high voltages present in the modulator stage are the
same as those present in the r-f power amplifier stage, and require that
the same precautionary measures be strictly observed.

The modulator stage in a plate modulation system is a high power audio
amplifier. The modulation transformer is carefully designed to have the
primary winding match the plate impedance of the modulator tubes, and the
secondary winding is designed to have it match the power amplifier tubes
of the final r-f power-amplifier stage. The high-power, modulator amplifier
circuit is prone to parasitic oscillations in the grid and plate circuits. To
prevent the outbreak of parasitics, low value resistors with a few turns of

driver
transformer
807
modulation
transformer
To R-F Final
Amplifier
Bias
807
plate
current
From High
Voltage
CLASS "B" MODULATOR
B+
250V
B+
350V
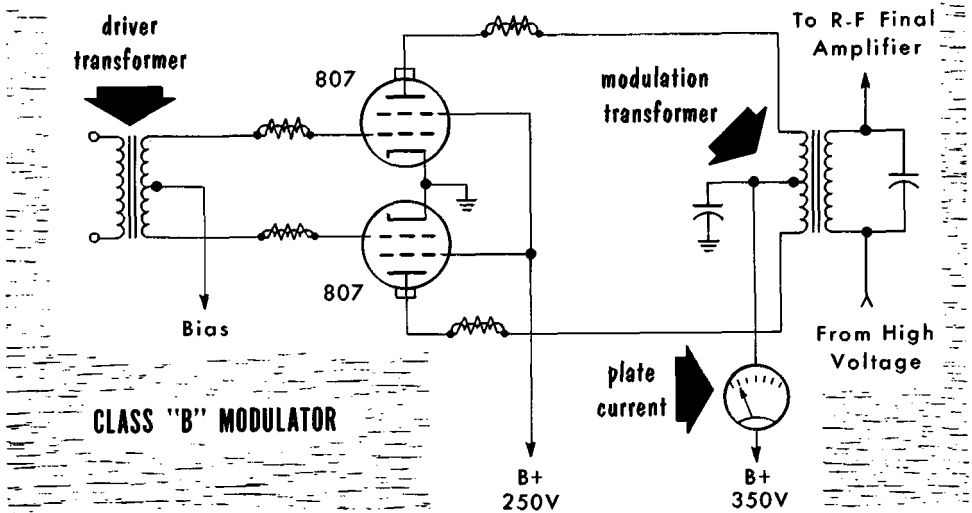
wire wrapped around them are inserted at the grid and plate leads as
parasitic suppressors. To get the power required to modulate the final, the
types of tubes used in the modulator are usually the same types as those
used in the final r-f amplifier stages. Plate current is monitored to check
the circuit operation and to observe the signal fluctuations of the meter
as a modulation monitor. The capacitor across the secondary of the modula-
tion transformer acts to prevent high voltage transients from breaking
down the insulation between the transformer windings and the transformer
laminations. The push-pull circuit requires external bias to place the grids
at the plate current cut-off point for class B operation.

To check for weak or distorted output, check the grid-bias voltage reading
to be sure the tubes are operating on the correct portion of the plate-current
grid-voltage curve. Make sure both tubes are operating correctly and have
matched or closely matched values of mutual conductance. If one tube is
defective it causes the other tube to try and maintain the entire output
alone. An increased plate current reading and a reduced plate voltage
reading could be the result of a partial short circuit in the plate voltage
bypass capacitor.

Modulator Stage (cont'd)

Reduced screen voltage may be the result of a partial short in the screen-voltage bypass capacitor. A cause for both distortion and reduced output would be a partial short in the transient suppressing capacitor across the secondary winding of the modulation transformer, or shorted turns in the primary or secondary winding of the transformer.

Complete loss of output is best checked by taking readings of all operating voltages. With no signal input, check the grid-bias voltage at the grids of the tubes. If no voltage is present, check for the presence of the bias voltage at the center tap of the secondary winding of the driver transformer. If no bias voltage is present at the center tap, check the external bias-voltage source. If the bias voltage is present at the center tap, check for an open transformer winding. For a loss of screen voltage, check for a shorted, screen bypass capacitor or a loss of voltage from the screen voltage source. With the meter indicating zero plate-current flow, check for loss of plate voltage at the plate voltage source. Excessive plate current and zero plate

...Driver Transformer

807

TO FINAL AMPLIFIER

...Modulation Transformer

...Grid Bias

...Bypass Capacitor

807

BIAS

FROM HIGH VOLTAGE

...ALL Voltages

...Plate current

For Loss of Output Check...

B+ 250V

B+ 250V
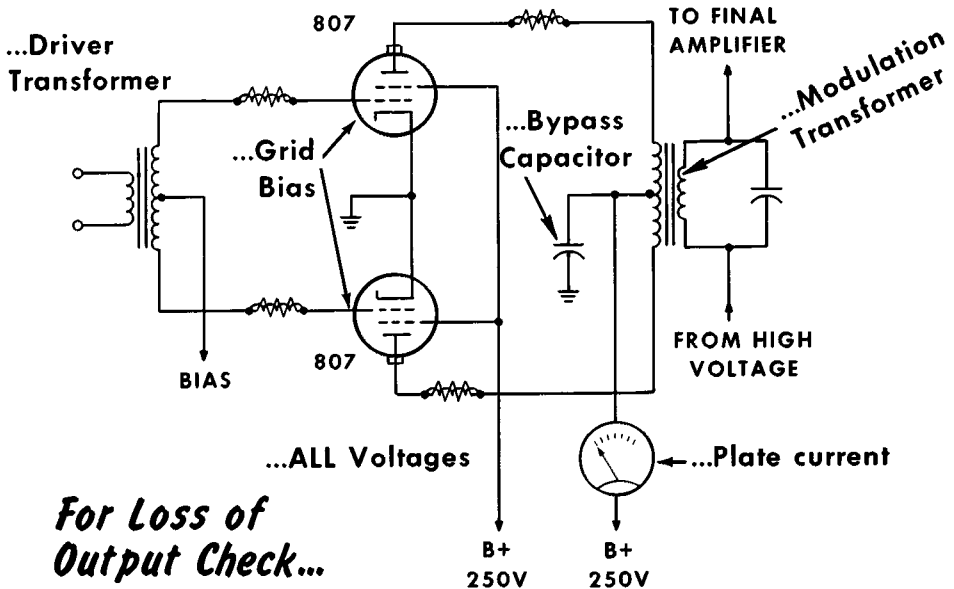
voltage indicates a shorted, plate-voltage bypass capacitor or turns shorted to the laminations in the modulator-transformer primary winding. A shorted, transient suppression capacitor would permit all correct tube voltage readings and allow the high voltage to bypass the modulation transformer secondary winding. The only indication of this would be a slight increase in the high voltage to the r-f power-amplifier stage due to the loss of the voltage drop across the transformer winding.

Reactance Tube Frequency Modulator

By having the plate voltage lead the grid voltage by 90°, a tube can act as an inductor and appear to have the same reactance exhibited by an inductor. Paralleling the inductor of an oscillator tank circuit with the reactance tube, permits changes in the combined inductance represented by the tank circuit inductor and the reactance tube. Varying the value of reactance offered by the reactance tube will vary resonant frequency of the oscillator tank circuit, in turn varying the oscillator output frequency. Applying a

REACTANCE TUBE CIRCUIT
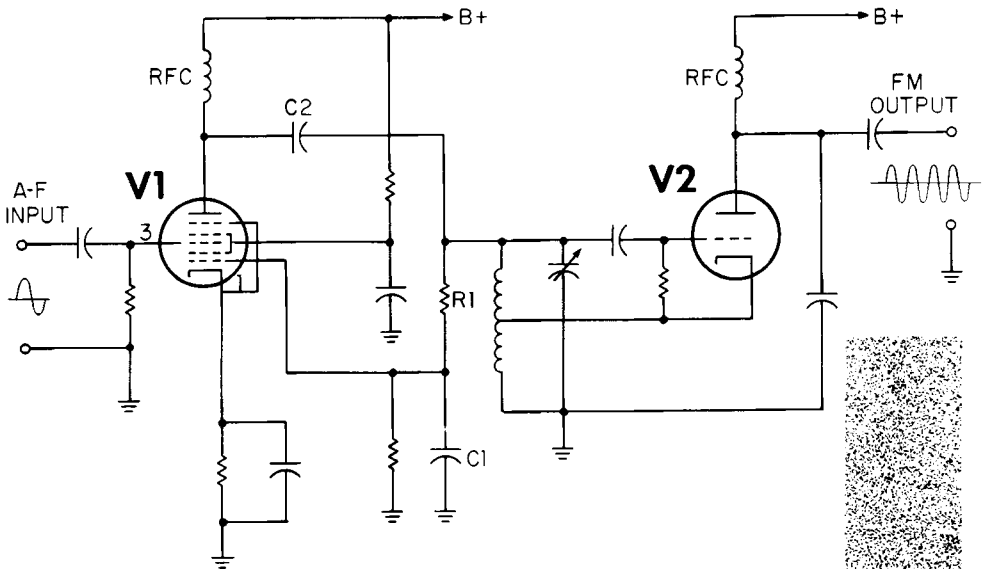
modulating audio signal to the modulation grid of the reactance tube causes the oscillator to change frequency in step with the modulating signal to develop an FM signal.

Since any change or fluctuation in the source voltages for the modulator circuit would create changes or fluctuations in the output frequency, it is imperative that all operating voltages be well regulated. The frequency-modulated output of the oscillator is applied to conventional r-f amplifier stages. The major requirement of the r-f amplifier stages is that they be tuned broad enough to prevent reduction in gain of the extreme frequencies in the wide band of frequencies developed in an FM signal.

Reactance Tube Frequency Modulator (cont'd)

In checking the reactance tube and oscillator stage for difficulties with the FM signal, all the succeeding r-f amplifier stages may be disabled. To check the linearity of the modulation a metered, pure d-c voltage (usually from a battery), capable of swinging from positive-through-zero-through-negative voltage, is applied to the modulator grid of the reactance tube. As the grid voltage varies from the extreme positive value to the extreme negative value, the oscillator output frequency should change in a linear manner. To check the oscillator the output frequency is tuned in on a receiver with a carefully calibrated dial. As the voltage to the reactance tube grid is varied in equal-value small steps, the oscillator output frequency should vary in equal-value changes in frequency. The changes are read by following the output frequency with the receiver and noting the input voltage relation to the output frequency. The relation between grid voltage and output frequency is then plotted — it should be linear throughout.
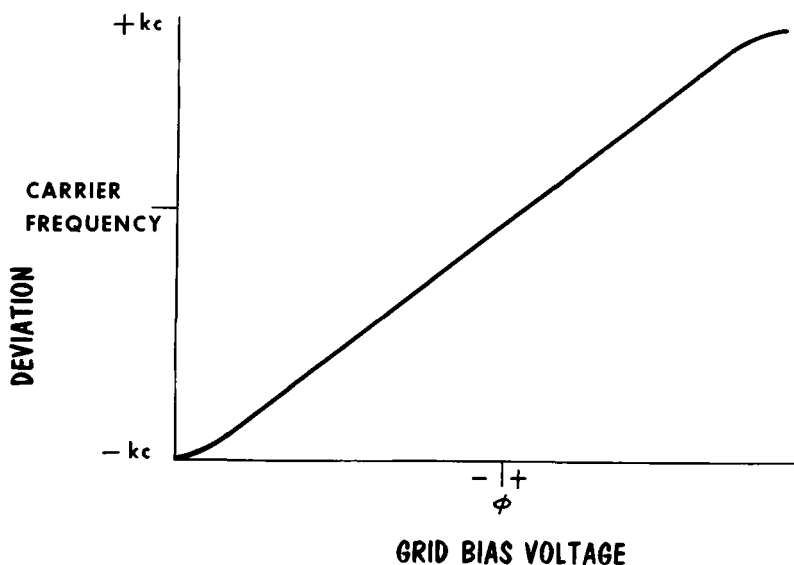
Frequency Deviation Vs. Grid Bias Voltage

The antenna current is metered to check for any inadvertent amplitude modulation of the output signal. The output signal of an FM transmitter should be constant in amplitude; only the frequency should vary. The antenna current value readings should remain constant; if they fluctuate it is an indication that AM is present in the output signal. Most of the AM will be a result of nonlinearity in the reactance-tube modulator stage. Another more remote possibility would be misalignment or narrow bandwidth of the r-f amplifier stages.

Single-Sideband Circuit Checks

Many of the circuits encountered in single-sideband transmitters, such as r-f amplifiers and oscillators, have previously been discussed. Balanced modulators having tuned circuits or other circuit variables are checked by applying a 1000-cycle audio signal to the modulation input. The output of the modulator should consist of a double-sideband signal having a suppressed carrier (3000 kc) with a sideband signal at 2999 and 3001 kc. To check the output frequencies, a receiver set for CW reception is coupled

LINK COUPLING PICKUP

TUNED FOR 2999 kc 3000 kc 3001 kc

RECEIVER

DUMMY LOAD

1 kc

AUDIO OSCILLATOR

B+

R-F OSCILLATOR

3000 kc

The output is usually fed to a crystal or mechanical filter. To check for SSB, there should not be any output at carrier or suppressed frequencies
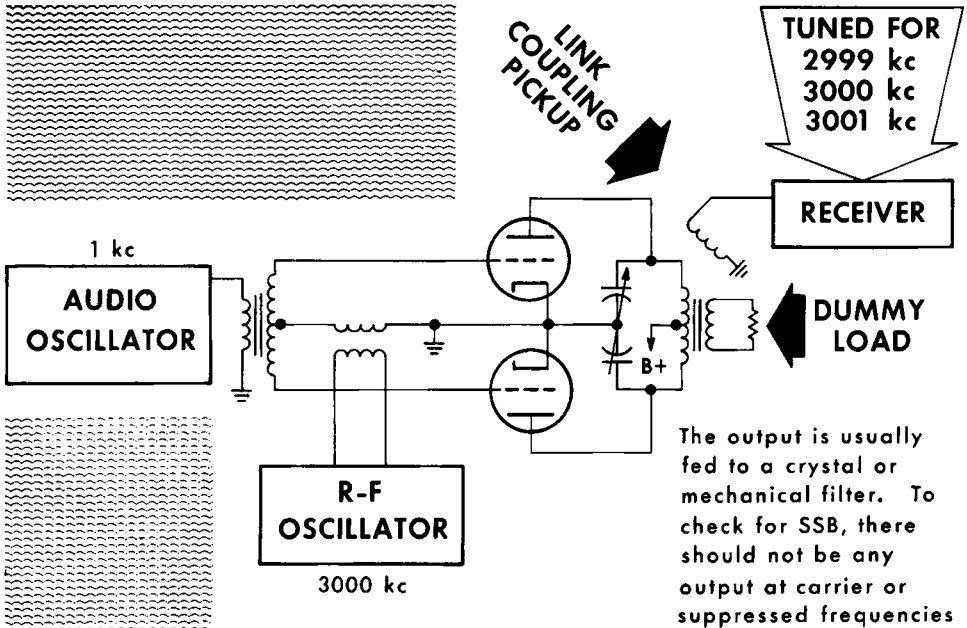
CHECKING A BALANCED MODULATOR

to the output as shown, and tuned to 3000 kc to check for zero output on the carrier frequency. The receiver should have equal amplitude signals at 2999 and 3001 kc.

The usual causes for unbalanced output, in which the carrier is not fully suppressed (aside from tuning adjustments) are defective tubes and tubes that are unmatched and have unequal gain. In transformer-coupled circuits, check for defective transformers; and in RC coupled circuits, check for changes in R and/or C values. Always check that equivalent points in the circuit have equivalent voltage values. For example: that both grids have the same input signal level, that both plates have the same voltage level, etc. Balanced bridge modulators are usually hermetically sealed units. If a test indicates a defect such as an open diode, the entire unit will have to be replaced.

Single-Sideband Circuit Checks (cont'd)

Phasing type circuits are prone to spurious emissions if not carefully adjusted for correct phasing. The arrangement shown checks for correct phasing. With a 1000-cycle audio signal applied to the modulation input, the output frequency should be that of the r-f carrier less (for lower sideband) the 1000-cycle input signal. The output viewed on an oscilloscope should appear as a CW signal with a constant frequency and constant amplitude. The presence of any ripple in the amplitude is a sign of spurious emission, and is due to poor or incorrect phasing, or improperly-adjusted balanced modulators. The deeper the ripple the poorer the suppression of the undesired spurious emissions. A ripple that is 10% of the peak-to-peak amplitude represents about 20 db of suppression, a ripple of 3.3% represents about 30 db, and a ripple of 1% represents a desired value of 40 db of suppression.
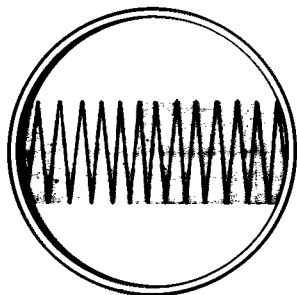
CORRECT OUTPUT
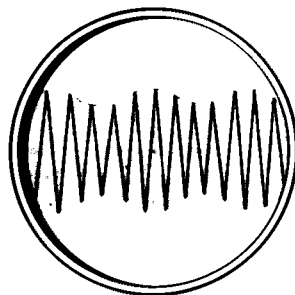
INCORRECT OUTPUT
INDICATING POSSIBILITY
OF SPURIOUS EMISSIONS

OUTPUT FREQUENCY ON OSCILLOSCOPE

Regardless of whether the single-sideband signal is developed by filter or phasing methods, the output must be applied to a linear amplifier, if increased output power is desired. Any presence of nonlinearity in the linear amplifier will result in undesired heterodyning. The resulting products of the sideband frequencies will cause additional undesired frequencies to the transmitted right about the carrier frequency or on what should be the suppressed carrier frequency. These undesired frequencies are known as *splatter*. The usual causes for nonlinearity are excessive grid drive to the input of the linear amplifier, too heavy or too light loading of the output, and poor or unregulated supply voltages fluctuating under load.

Single-Sideband Circuit Checks (cont'd)

Testing the Linear Amplifier

Direct Coupling
to Vertical Plates

Coaxial Cable

1000 ~　　SSB

AUDIO
OSC

FILTER
or
PHASING
CIRCUITS

LINEAR
AMP

Dummy
Load

Oscilloscope

R-F
OSC
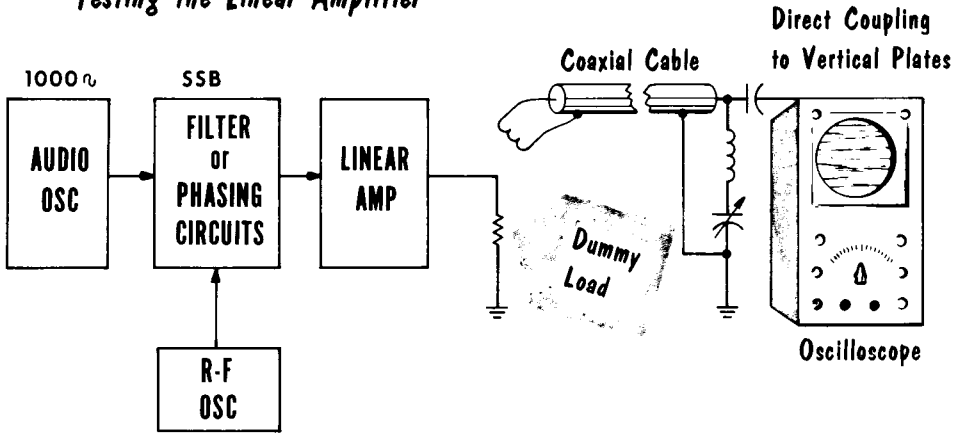
To check the linear amplifier, its output is coupled to a dummy load. A portion of the output is picked off with a loop of two or three turns of wire, and fed through a coaxial cable to a tuned circuit at the input to an oscilloscope. The output of the tuned circuit is coupled directly to the vertical plates of the oscilloscope. The input from the r-f oscillator is set for about one-half the normal input level. The input from the audio oscillator is then set so that its output will result in the oscilloscope patern resembling full modulation, Fig. A. Limiting caused by excessive drive to the linear amplifier or improper loading of the linear amplifier output is shown in Fig. B. Excessive grid bias bucks the correct input drive signal resulting in the pattern shown in Fig. C.

Patterns Produced By Set-Up

C

EXCESSIVE
GRID BIAS

A

B

CORRECT PATTERN　　　　LIMITING
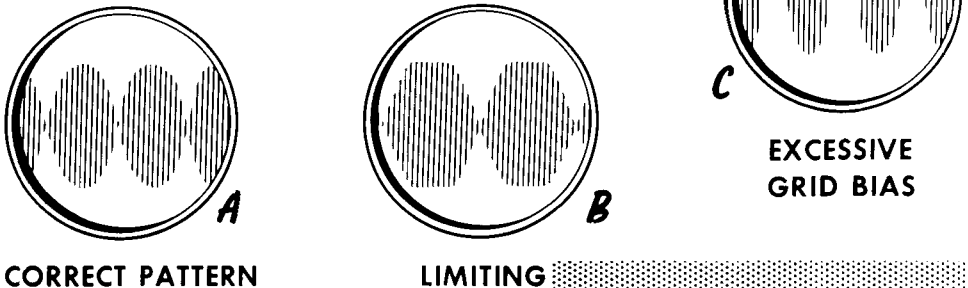
The driver stage converts the signal voltage of the speech amplifier stage to a power output capable of driving the modulator stage.

The high voltage present in the modulator stage is the same as that present in the r-f power amplifier stage, requiring the same precautionary measures.

With the plate voltage leading the grid voltage by $90°$, a tube can act as an inductor and appear to have the same reactance exhibited by an inductor.

Paralleling the inductor of an oscillator tank circuit with the reactance tube, permits varying the resonant frequency of the oscillator circuit by varying the voltage of the reactance tube. Modulating the grid with an audio signal provides an FM signal at the output of the oscillator.

Any change or fluctuation in the source voltages for the FM circuit would create changes in the output frequency. To prevent this all source voltages should be regulated.

Balanced modulators can be checked by application of a 1000-cycle audio signal. The output of a modulator using a 3000-kc r-f oscillator should be zero on the carrier frequency, and equal-amplitude signals at 2999 and 3001 kc.

In balanced bridge modulators using hermetically sealed units, if a test indicates a defective diode, the entire unit has to be replaced.

Phasing-type, single-sideband circuits are prone to spurious emissions if not carefully adjusted for correct phasing.

Presence of ripple in the amplitude of the output signal is a sign of spurious emission. The deeper the amplitude ripple, the poorer the suppression. A ripple of 10% of the peak-to-peak amplitude represents about 20 db of suppression. The desired value of suppression is 40 db, about 1% ripple.

REVIEW QUESTIONS

1. Why are pentode-type power-amplifier tubes often used in a triode connection in driver amplifiers?
2. What types of tubes are usually used in the modulator stage?
3. What would be the indication of shorted, transient suppression capacitor across the transformer winding?
4. Describe the method used to check the linearity of the modulation in a reactance tube FM circuit?
5. How do we check the output of an FM transmitter for undesired amplitude modulation?
6. Describe what is meant by checking that equivalent points have equivalent values in a balanced modulator.
7. With a 1000-cycle audio signal applied to a phasing circuit, what should the output and the amplitude of the output appear as on an oscilloscope?
8. What are the usual causes for nonlinearity in a linear amplifier?
9. Describe the method used to check a linear amplifier.

GLOSSARY

Alpha: The current gain factor of a transistor connected in a common base circuit. Alpha is equal to the ratio of collector current change to emitter current change for a constant collector voltage.

Amplitude Modulation (AM): Varying the amplitude of an r-f carrier in accordance with intelligence.

Beat Frequency: A frequency resulting from the combination of two different frequencies. It is numerically equal to the difference between, or the sum of, the two frequencies.

Beta: The current gain factor of a transistor connected in a common-emitter circuit, Beta is equal to the ratio of a change in collector current to a change in base current for a constant collector voltage.

Buffer Amplifier: An amplifier used to isolate the output of an oscillator from the effects produced by changes in loading in the following stages.

Calibration: The marked graduations of a dial, or any other indicator.

Carrier: The r-f component of a transmitted wave upon which an audio signal or other form of intelligence may be superimposed.

Crystal: A natural substance, such as quartz, or tourmaline, which is capable of producing pressure when under an applied voltage. Under stress it has the property of responding only to a given frequency when cut to a given thickness.

De-Emphasis: A low-pass filter network consisting of an RC filter usually connected at the output of an FM detector to shunt some of the higher audio frequencies.

Detection: The process of separating the modulation component from the signal.

Discriminator: A receiver circuit that removes the desired intelligence from an FM signal by changing the frequency variations to amplitude variations.

Field Strength: Electrical strength of a field.

Frequency: The number of complete cycles per second existing in any form of wave motion, such as the number of cycles per second of alternating current.

Frequency Modulation (FM): A system of superimposing intelligence on a carrier wave by causing the carrier frequency to vary in accordance with the intelligence.

Ground: A metallic connection with the earth to establish ground potential. Also a common return to a point of zero r-f potential, such as the receiver chassis.

Heat Sink: A mass of metal or other good heat conductor used to rapidly dissipate heat energy produced by a transistor.

Limiting: Removal by electronic means of one or both extremities of a waveform at a predetermined level.

Mercury Cell: A primary cell of zinc-mercury construction, featuring constant voltage and a relatively long lifetime.

Neutralization: The process of nullifying the voltage fed back through the interelectrode capacitance of an amplifier tube, by providing an equal voltage of opposite phase.

Phase: The time difference between any point on a cycle and the beginning of that cycle.
Propagation: The transmission of r-f energy through space.

Radio Frequency: Any frequency of electrical energy capable of propagation into space.
Ratio Detector: An FM demodulator that splits the rectified voltages in such a way that their ratio is directly proportional to the ratio of the applied i-f voltages which vary with frequency.
Relay: An electromechanical switch.

S Curve: The shape of the response curve of an FM detector circuit.
S Meter: A meter used to read and indicate the strength of the signal being received.
Sidebands: Frequencies, in addition to the carrier frequency, produced by modulating the carrier with an audio signal.
Single Sideband: A system of radio transmission in which one set of sidebands (either upper or lower) is completely suppressed, and the carrier frequency is partly or completely suppressed.
Standing Wave: A distribution of current and voltage on a transmission line formed by two sets of waves traveling in opposite directions, and characterized by the presence of a number of points of successive maximum and minimum values.

Thermistor: A resistor whose resistance value changes inversely with temperature.
Thermocouple: A junction of two dissimilar metals that produces a voltage when heated by an r-f current.
Transistor: A semiconductor device capable of transferring a signal from one circuit to another and producing amplification.
Tuning: The varying of an inductance or capacitance to control the resonant frequency of a circuit.

Voltage Regulation: A measure of the degree to which a power source maintains its output voltage stability under varying load conditions.

Wave: Basically, an electromagnetic impulse, periodically changing in intensity and traveling through space.

CUMULATIVE INDEX

NOTE: The first number of each entry identifies the Volume in which the information is to be found; the second number identifies the page.