Servicing Radio and Television with a Vacuum Tube Voltmeter
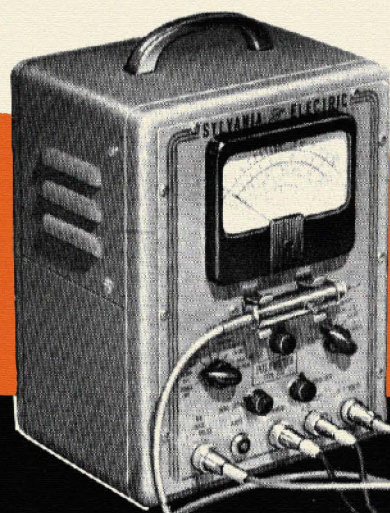
SERVICING

RADIO AND TELEVISION

WITH A

VACUUM-TUBE VOLTMETER

*The information in this manual is furnished without
assuming any obligations*

TABLE OF CONTENTS

PREFACE

The versatility of the modern all-purpose vacuum-tube voltmeter is so extensive that a group of separate meters would be needed to replace it. The universal vacuum tube-voltmeter offers the service technician maximum single-instrument utility. In the one instrument are combined the separate functions of high-resistance dc voltmeter, high-impedance ac voltmeter, wide-range rf voltmeter, wide-range ohmmeter, and dc milliammeter,

The Sylvania Polymeter is a multi-purpose electronic instrument of the most refined design. This instrument has been kept up to date by constant improvements in its design. The Polymeter has become noted for its high stability and wide range of application.

This book describes applications of the universal vacuum-tube voltmeter-ohmmeter in radio and television servicing and miscellaneous experimental work. Space has not permitted inclusion of all possible applications, since they are many. We have made a selection of tried and proven procedures and offer them with the sincere hope that they will lighten the ever-increasing burden of the radio and television service technician.

SYLVANIA ELECTRIC PRODUCTS INC.

Sylvania Polymeter

Type 221Z

CHAPTER 1

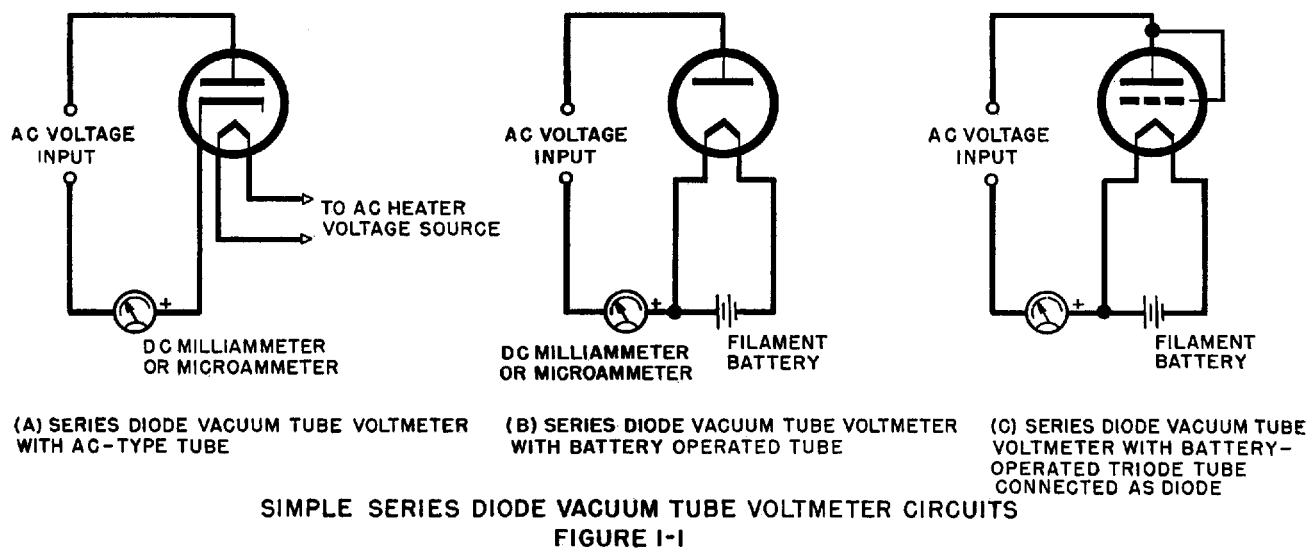# THE VACUUM-TUBE VOLTMETER

1.1 DIODE TYPE

The simplest possible vacuum-tube voltmeter consists of a diode tube connected in series with a dc milliammeter or microammeter. This arrangement is shown in Figure 1-1. The tube may have an ac operated heater (such as types 6AL5, 6H6, 7A6, 12AL5, 12H6, 9004, 9005, or 9006) or it may have a battery operated filament (such as type 1A3). In some applications, a triode tube is converted into a diode by connecting together its grid and plate electrodes, as in Figure 1-1(C).
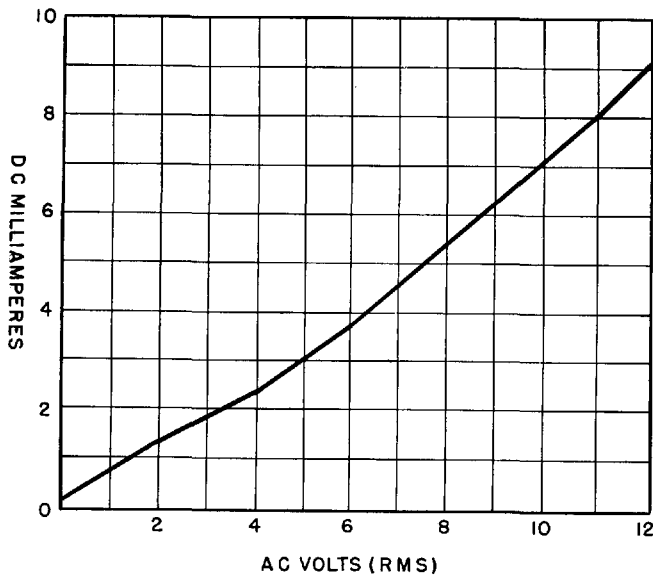
The arrangements shown in Figure 1-1 are all variations of the *series diode* circuit, so called because the ac voltage under measurement, diode tube, and indicating meter are connected in series with each other. This circuit operates by virtue of the one-way conduction, or rectifying property, of the diode. That is; the unknown ac voltage is rectified by the tube and the resulting dc plate current passed through the meter. The deflection of the meter is proportional to the applied ac voltage. The meter scale accordingly may be graduated directly in ac volts. A dc microammeter is required for the measurement of low ac voltage values, while a milliammeter is satisfactory for higher values. Figure 1-2 shows a typical calibration curve obtained with a series diode circuit employing one section of a 6H6 tube. From this graph, it will be noted that the meter reading is not exactly zero when the applied ac voltage is zero. This is due to *contact potential* of the tube; that is, the steady, small flow of current resulting from electrons emitted by the hot cathode. Higher ac voltage values may be measured with the same indicating meter by adding a suitable multiplier resistor to the circuit (See Figure 1-3A).

In any of the circuits given in Figure 1-1, current flows through the meter only during positive half cycles of applied ac voltage. The tube can pass no current when its plate is negative with respect to cathode. These circuits therefore measure only the value of the positive half-cycle. The negative half-cycle voltage can be measured, however, by reversing both the tube and meter connections in the circuit, as shown in Figure 1-3(B). In the series diode circuits, the meter deflection is proportional to the *average* value of the applied ac voltage, but this does not prevent graduating the meter scale in more convenient rms voltage values. Such an rms calibration will hold only for sine-wave voltages, the meter reading being 70.7% of the peak value of complex waves. The addition of a high-capacitance by-pass capacitor to the circuit, as shown in Figure 1-3(C) makes the meter deflection proportional to the *peak* value of the applied ac voltage. The capacitor charges approximately to the peak value of the applied voltage and between charging intervals the discharge of the capacitor is limited by the meter resistance.

One drawback of the simple series diode type of vacuum-tube voltmeter is its loading effect upon the circuit under test. Full power for operating the meter is drawn from the test voltage source, and the diode circuit consequently exhibits a relatively low impedance. The resistance "seen" by the circuit under test is equal closely to one-half the diode load resistance. When no multiplier or load resistance is used in the

(A) SERIES DIODE VACUUM TUBE VOLTMETER WITH AC-TYPE TUBE

(B) SERIES DIODE VACUUM TUBE VOLTMETER WITH BATTERY OPERATED TUBE

(C) SERIES DIODE VACUUM TUBE VOLTMETER WITH BATTERY-OPERATED TRIODE TUBE CONNECTED AS DIODE

SIMPLE SERIES DIODE VACUUM TUBE VOLTMETER CIRCUITS
FIGURE 1-1

CALIBRATION CURVE FOR SERIES DIODE
VACUUM TUBE VOLTMETER USING
ONE HALF OF 6H6 TUBE

FIGURE 1-2

circuit, this resistance is one-half that of the current meter itself. In order to keep the resistance of the instrument circuit high, a high value of load resistance must be employed—and this necessitates use of a sensitive microammeter as the indicator.

Another drawback of the series diode vacuum-tube voltmeter is its requirement of a completed dc return path for operation of the indicating meter. This path usually is supplied by the output circuit of the test voltage source. However; when no such path (such as an output transformer winding) is available in the voltage source, a resistor must be connected between the ac input terminals of the instrument.

Any dc component present in the output of the test voltage source will be impressed upon the diode tube in the series circuit along with the ac and will cause an erroneous deflection of the meter. To eliminate this difficulty, a series capacitor may be introduced to block out the undesirable dc component. This is accomplished in the *shunt diode* vacuum-tube voltmeter circuit (See Figure 1-3D). In this circuit, the meter deflection is proportional to the peak value of the applied ac voltage, since the coupling capacitor is charged closely to the peak voltage value and its capacitance is sufficiently large as not to discharge appreciably through the meter. The circuit shown in Figure 1-3(D) is a negative peak measuring arrangement. Reversing connections of both the diode and meter converts the circuit into a positive peak voltmeter.

1.2 TRIODE TYPE

The triode type circuit in a vacuum-tube voltmeter
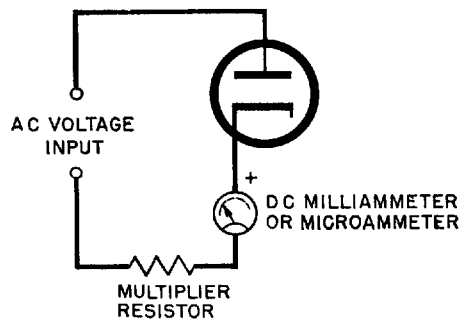
(A) USE OF MULTIPLIER RESISTOR TO
INCREASE RANGE OF METER.
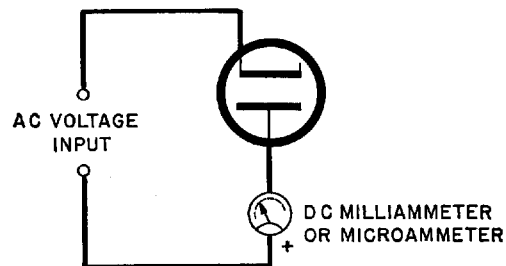
(B) CIRCUIT FOR NEGATIVE HALF CYCLE
MEASUREMENTS.
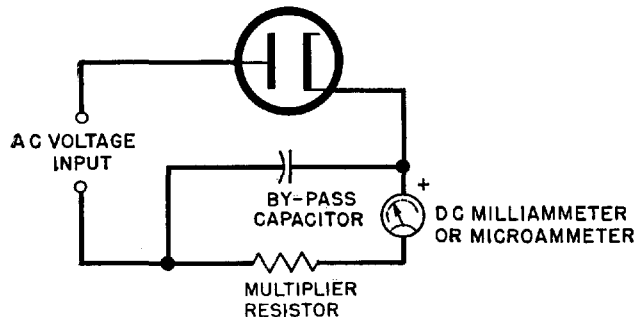
(C) SERIES DIODE PEAK VOLTMETER
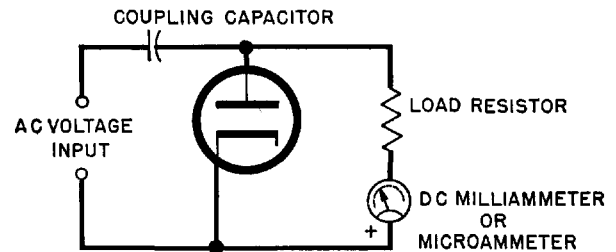
(D) SHUNT DIODE CIRCUIT

FURTHER DIODE VACUUM TUBE VOLTMETER CIRCUITS,
FIGURE 1-3
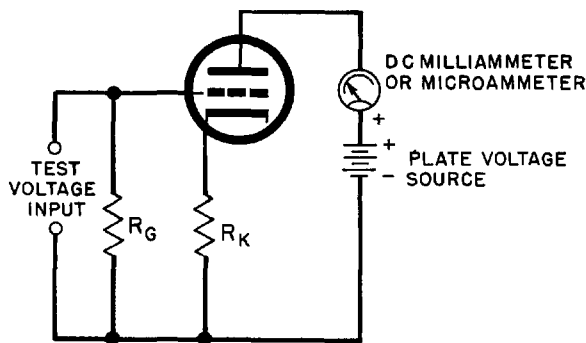
**BASIC TRIODE VACUUM TUBE VOLTMETER
CIRCUIT**

FIGURE 1-4

overcomes the problem of low input resistance which causes loading of the test circuit, a condition present in the diode type. There are numerous triode voltmeter arrangements. One basic triode vacuum-tube voltmeter circuit is shown in Figure 1-4.

The triode circuit offers both sensitivity and extremely high input resistance. These are desirable features in a vacuum-tube voltmeter. Operation of the circuit is based upon the change in plate current which occurs when a voltage is applied to the grid-cathode input circuit. A dc milliammeter or microammeter connected in the plate circuit shows this change. The meter scale accordingly may be graduated to read the value of an unknown voltage applied to the grid.

The grid resistor, R_g, is made high, generally from 5 to 20 megohms. A high resistance R_k in the cathode introduces degeneration which serves to stabilize operation of the circuit, improve linearity of meter response, and divorce operation of the circuit substantially from the tube characteristics. The triode circuit

is usually used for dc measurements, but can be adapted to measure ac voltages.

1.3 ZERO SETTING

When the triode circuit is switched on, plate current will flow through the tube, even when no test voltage is applied to the input terminals, and this current will deflect the meter from zero. Some means must be provided to balance out this initial current and thus return the meter to zero.

Figure 1-5 shows two methods of zero setting. The first (Figure 1-5A) employs an auxiliary battery or other source of smooth dc connected to the meter in reverse polarity to buck out the initial plate current. A rheostat permits adjustment of the voltage applied to the meter to the exact value required to set the pointer back to zero. This method, while practical, has the disadvantage that it requires a separate bucking battery.

In Figure 1-5(B), the plate voltage source also supplies the bucking voltage for zero-setting the meter. In this arrangement, a 4-arm resistance bridge is formed by R_1, R_2, R_3, and the internal plate-cathode resistance (R_p) of the tube. One arm (R_3) of the bridge is made variable for balancing the bridge. During the zero-setting process, the current meter acts as the bridge null detector, reading zero when R is set properly to balance the bridge. The conditions for balance are expressed by the formula: $R_3/R_p = R_2/R_1$. This balancing circuit is widely used in triode voltmeters.

After the steady plate current has been balanced out of the meter, the latter will be free to respond to plate current *changes* resulting from application of test voltages to the tube grid. However, the values of R_1, R_2, and R_3 must be chosen properly, with respect to the internal resistance of the meter, otherwise the larger part of the important plate current changes will pass through R_3 instead of through the meter. This will show up as decreased sensitivity of the in-
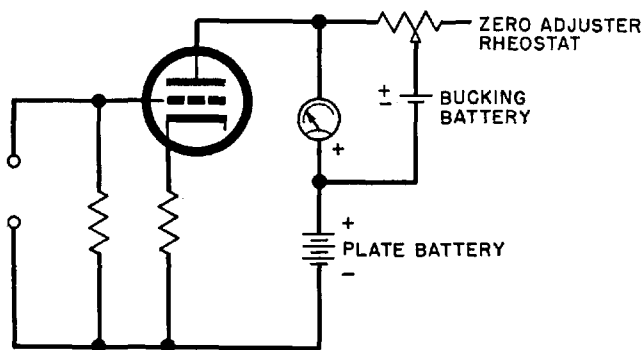
(A) BATTERY-TYPE ZERO-SETTING CIRCUIT
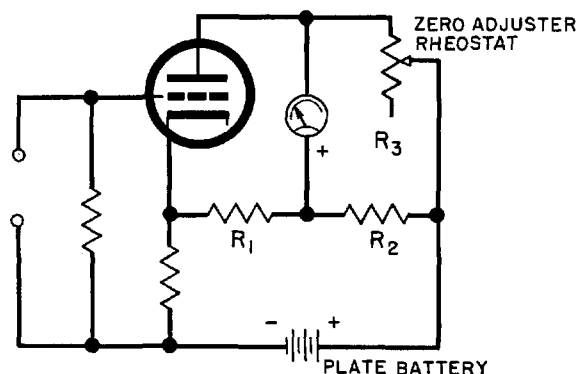
(B) BRIDGE-TYPE ZERO-SETTING CIRCUIT

**ZERO-SETTING CIRCUIT
FIGURE 1-5**
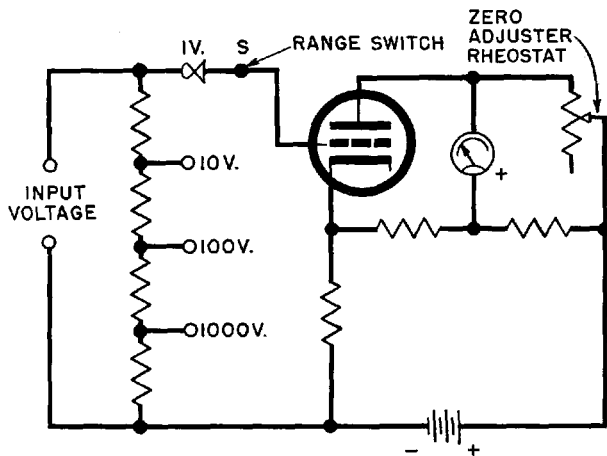
VOLTAGE RANGE SWITCHING CIRCUIT
FIGURE 1-6

strument; the meter will not be deflected very far up-scale by a given input test voltage. To remove this effect, R_3 is made as high as practicable, compared with the internal resistance of the meter, and R_2/R, is adjusted accordingly.

1.4 RANGE SWITCHING

The circuits shown thus far will accommodate only a single voltage range limited by the full scale value of the meter. This condition usually is not desirable, since a versatile voltmeter must be able to check a wide variety of voltages.

A multi-range instrument is obtained with the circuit given in Figure 1-6. The grid resistor is divided into appropriate sections constituting a potentiometer or voltage divider. As the grid of the tube is switched successively across lower values in the resistance string, the input voltage is divided, and the voltage appearing at the grid always is a safe value which can be handled by both tube and meter. Voltages higher than the basic range of the tube circuit thus can be handled.

This is the simplest method of voltage range switching. In some vacuum tube voltmeter circuits, the cathode resistance is switched to various values simultaneously with the grid resistance.

1.5 POLARITY SWITCHING

It is desirable in vacuum-tube voltmeters used to measure dc voltages to incorporate some form of polarity switching. This prevents shifting the test leads or external circuit connections when the meter is unintentionally deflected downward.

Figure 1-7 shows an arrangement for polarity switching. A double-pole double-throw switch is employed to reverse the meter connections.

1.6 BALANCED TRIODE PUSHPULL CIRCUIT

Some of the practical difficulties experienced with simple triode vacuum-tube voltmeter circuits are (1) zero drift, (2) necessity to re-set to zero when switching ranges, and (3) instability due to fluctuations in line voltage, plate voltage, and tube characteristics.

The balanced triode pushpull vacuum-tube voltmeter circuit corrects these conditions by means of symmetrical operation. Figure 1-8 shows this circuit. While two separate tubes are shown in the drawing, a dual triode tube is preferable. R_3 is a high resistance common to the cathodes of both tubes and is large in comparison to the individual cathode resistors R_1 and R_2. The high value of R_3 makes this resistor more important than the tube characteristics in determining the cathode current. Thus, small excursions of plate current due to tubes and power supply are largely masked out.

When a positive dc test voltage is applied to the grid of tube V_1, this tube passes plate current and the junction point of R_1, R_2 and R_3 becomes more positive. This increased positive potential is impressed upon the cathode of V_2 and acts to reduce the plate current of the latter tube. In this way, the plate current of V_2 decreases as that of V_3 increases. This action greatly minimizes any degeneration which otherwise might result from the high value of R_3, and the sensitivity of the vacuum-tube voltmeter accordingly is not impaired.

While batteries are shown in Figure 1-8 for simplicity, both plate and bias voltages are derived from a common ac-operated power supply in modern vacuum-tube voltmeters of the balanced type.

AC voltages may be measured efficiently by preceding the circuit of Figure 1-8 with a diode rectifier similar to the type shown in Figure 1-3(D).

1.7 MODES OF OPERATION OF TRIODE VACUUM-TUBE VOLTMETERS

Adjustment of the grid bias voltage of the triode permits the point of operation to be set at any desired point along the grid voltage-plate current curve of the tube.

The operating point may be set along that portion
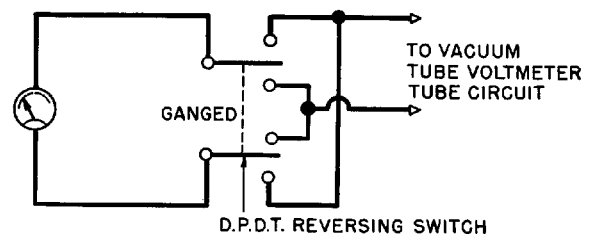
POLARITY SWITCHING ARRANGEMENT
FIGURE 1-7
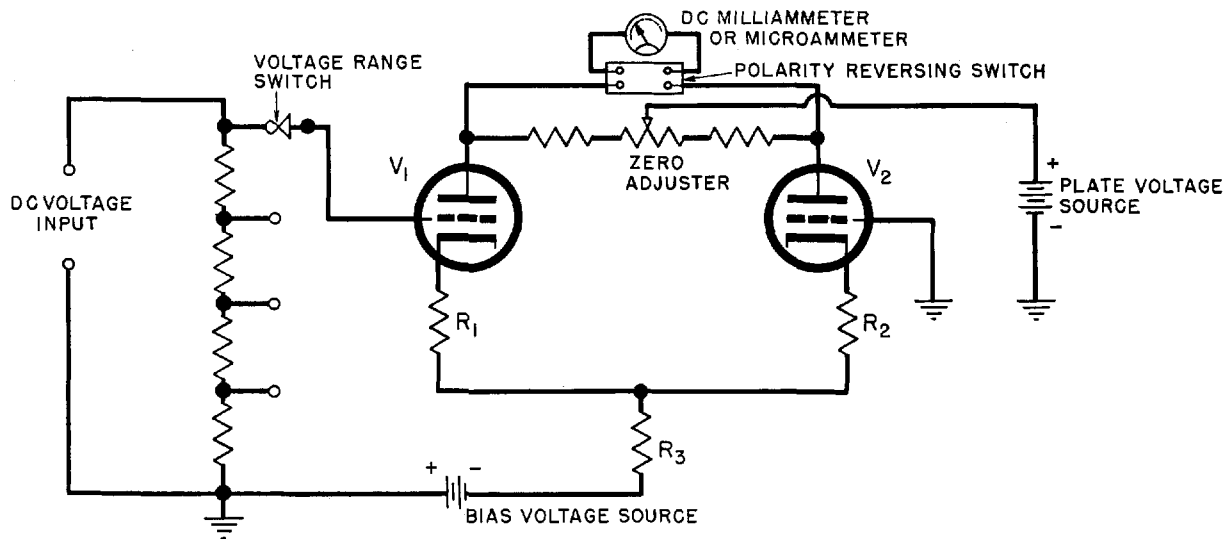
BALANCED TRIODE VACUUM TUBE VOLTMETER CIRCUIT
FIGURE 1-8

of the curve (near plate current cut-off) where square-law operation is obtained. In this condition, the plate current variations are proportional approximately to the square of the applied signal voltage. When the bias voltage is set for grid operation at a point somewhat more positive than cut-off (the exact value depending upon the particular tube type), full-wave square-law operation is obtained. When the bias voltage is somewhat more negative than the cut-off value, peak operation is obtained—that is, the plate current changes resulting from application of an unknown voltage to the grid are proportional approximately to the peak value of the applied voltage. Along a portion of the tube curve, meter response may approach linearity in some circuits. The latter condition is not usual, however, and special meter faces are required in most cases.

1.8 RECTIFIER-AMPLIFIER INSTRUMENT

While triode vacuum-tube voltmeters can be adapted to the direct measurement of ac voltages, best results are obtained by rectifying the unknown ac voltage with a shunt diode circuit and applying the resulting dc output voltage to a high-resistance dc vacuum-tube voltmeter of the types shown in Figues 1-6 and 1-8. The excellent rectifying properties and simplicity of the diode are utilized. At the same time, the input circuit of the vacuum-tube voltmeter proper furnishes a high resistance that sharply reduces the loading effect on the circuit under test. In this arrangement, the dc vacuum-tube voltmeter portion of the circuit functions as a dc amplifier. Modern multi-purpose vacuum-tube voltmeters make wide use of the rectifier-amplifier principle.

Figure 1-9 shows the basic arrangement of the rectifier-amplifier type of vacuum-tube voltmeter. The rectifying "front end" of the circuit is a conventional shunt diode. On positive half-cycles of applied signal voltage, the coupling capacitor, C_1, is charged to a value equal closely to the peak value of the signal voltage. The dc output voltage of the diode consequently is equal approximately to the peak ac value.
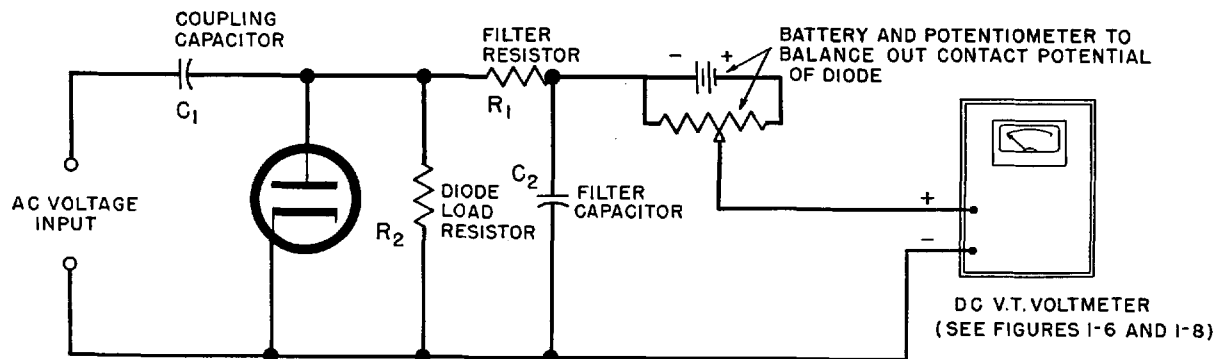
ARRANGEMENT OF THE RECTIFIER-AMPLIFIER
VACUUM TUBE VOLTMETER
FIGURE 1-9

The dc vacuum-tube voltmeter will indicate this peak value if its dc scales are read directly. Usually, there is a voltage dividing resistor network following the diode which reduces the dc output voltage to the rms value.

The diode load resistor, R_2, is made high, usually a number of megohms. This is permissible, since the dc vacuum-tube voltmeter requires no appreciable signal current for its operation. Filter resistor R_1 and filter capacitor C_2 remove any fluctuations present in the rectified output of the diode. The auxiliary battery and potentiometer R_3 serve to buck out the steady dc voltage (due to diode contact potential) present when no signal voltage is applied. If not bucked out, this voltage would cause an erroneous deflection of the meter. In modern rectifier-amplifier type instruments, the separate balancing battery is not required. Some dc vacuum-tube voltmeters utilize a crystal diode for signal rectification. The crystal diode has no contact potential effects and requires no bucking voltage but the vacuum-tube diode has a higher inverse voltage rating.

The diode rectifier circuit (either tube or crystal) often is enclosed completely within the case or handle of a cable-end probe in order that the diode might be placed close to the voltage source. This eliminates long connecting leads, a decided advantage when making rf voltage measurements. At high radio frequencies, even short leads introduce appreciable impedance and stray capacitance, and impair accuracy of measurement.

1.9 VACUUM-TUBE OHMMETER

It is a relatively simple matter to adapt the dc vacuum-tube voltmeter for resistance measurements. The vacuum-tube ohmmeter obtained permits higher resistance measurements than can be made easily and

safely with non-electronic meters. One billion ohms commonly mark the top limit in instruments designed for the service trade. Ohmmeter ranges are provided in most modern service-type vacuum-tube voltmeters.

Figure 1-10 shows the basic circuit arrangement of the vacuum-tube ohmmeter. One of the several precision range resistors is connected in series with the unknown resistance and a small battery (usually 3 volts). The dc vacuum-tube voltmeter is connected across the unknown resistance and therefore reads the voltage drop across the latter.

In use, the meter first is adjusted without the unknown resistance in the circuit and with the "unknown" terminals "open." In this condition, the voltage drop across the range resistor is negligible, since the vacuum-tube voltmeter draws negligible current. The full battery voltage therefore is applied to the tube grid. The vacuum-tube voltmeter then is adjusted to read full-scale by means of an "OHMS ADJUST" rheostat in series with the indicating milliammeter or microammeter. When the unknown resistor then is connected to the terminals, it forms a voltage divider with the range resistor and causes the meter to read lower than the initial full-scale value. The lower the unknown resistance value, the closer to zero will be the voltmeter reading. The unknown resistance value may be calculated by multiplying the selected range resistance value by E_m/E_b, where E_m is the meter voltage reading when the unknown resistance is connected to its terminals, and E_b is the voltage of the ohmmeter battery. To eliminate the necessity of computations, a special ohms scale may be inscribed on the meter card on the basis of the formula just given.

A function switch in the modern, multi-purpose vacuum-tube voltmeter sets the instrument up automatically as an electronic ohmmeter similar to Figure 1-10 when this switch is in its OHMS position.
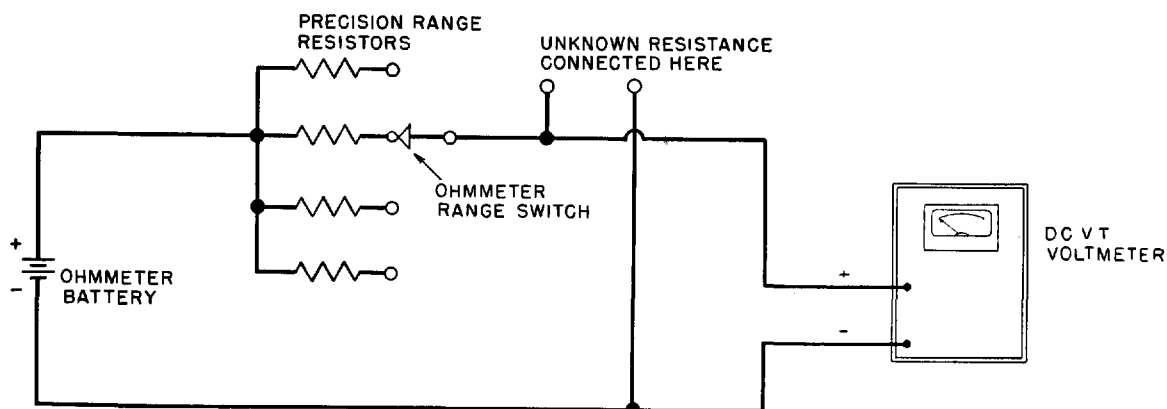
VACUUM TUBE OHMMETER CIRCUIT

FIGURE I-I0

1.10 ADVANTAGES OF THE MODERN VACUUM-TUBE VOLTMETER

The vacuum-tube voltmeter is superior to ordinary ac and dc voltmeters in all forms of radio, television, and electronic testing. This improved instrument is used almost exclusively in many laboratories and shops. Continued research and development have produced steady improvements in vacuum-tube voltmeter design. Listed below are the leading advantages of the modern vacuum-tube voltmeter.

High Input Resistance on DC Ranges. The input resistance is at least 15 megohms. This feature enables voltage measurements to be made reliably in high-impedance circuits without drawing appreciable power from these circuits and disturbing their operation. Prior to adoption of the vacuum-tube voltmeter, it was impossible to obtain accurate high-impedance voltage measurements directly with moving coil meters.

High Input Impedance on AC Ranges. This feature, which is comparable to that of high dc resistance, makes practicable the measurement of af and rf signal voltages without detuning or disturbing operation of high-impedance signal circuits. The power in such circuits often does not exceed a few milliwatts, and no appreciable amount of loading by the instrument can be tolerated.

High Sensitivity. Because the vacuum-tube voltmeter utilizes the amplifying property of the vacuum tube, sensitivity is easily obtained. An unknown dc or rectified ac voltage is applied to the tube grid, which takes practically zero power, and the tube amplification makes possible the use of a relatively rugged current meter in the plate circuit for indication of this voltage. The low-resistance meter used alone would cause undesirable loading of the circuit under test, but the tube and meter combination provides high input impedance (or resistance) and high sensitivity at the same time.

Wide Frequency Response. The ac vacuum-tube voltmeter will check voltages accurately over a wider range of frequencies than is possible with any other type of single instrument. The useful frequency range of the electronic instrument extends from the lowest power-line frequencies, through the entire audio-frequency spectrum, to radio frequencies of several hundred megacycles. Special vacuum-tube voltmeters permit measurements up to several thousand megacycles at low voltages.

Wide Voltage Range. A single vacuum-tube voltmeter of modern design will measure ac and dc voltages from a few tenths of a volt to several thousand volts. The useable range is of the order of 500,000 to 1. Special purpose instruments will extend the range down to a few millivolts.

Resistance Measurements. Modern dc vacuum-tube voltmeters are equipped for direct reading of resistance. The electronic ohmmeter has provided a wider range of resistance measurements than hitherto
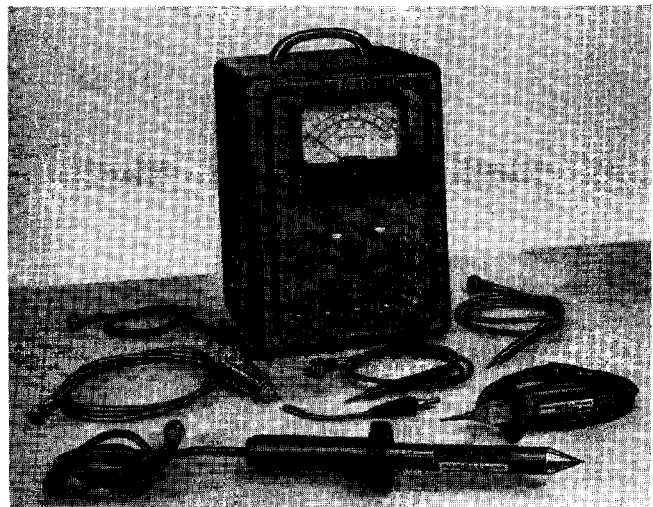
Figure 1-11.

THE POLYMETER TYPE 221Z WITH ACCESSORIES.

The two DC Voltage Multiplier probes (large 30 kv. and smaller 10 kv.) are center. The three "regular" probes (DC, AC, and COMMON), and the tube-type probe rest in front of the instrument.

was obtained with a single non-electronic meter and test battery. Average coverage is from one-tenth ohm to 1000 megohms (1 billion ohms). This corresponds to a complete resistance range of 10 billion to 1.

Protection of Indicating Meter. Sensitivity of the vacuum-tube voltmeter circuit permits use of a fairly rugged current meter as the indicator. Such a meter is not as susceptible to burnout and mechanical injury as a more delicate instrument. Moreover, the accidental application of an excessive test voltage will overload the tube grid, i.e. more than maximum plate current on the tube cannot flow through the meter and cause damage either to the indicating meter or tube, except under extreme circumstances.

Stability. In the modern vacuum-tube voltmeter circuit, drift effects are minimized by proper design. The meter reading therefore does not vary appreciably from zero, once having been set. Also the zero reading does not shift appreciably when voltage ranges are

VACUUM TUBE VOLTMETER
FIGURE I-I2

13
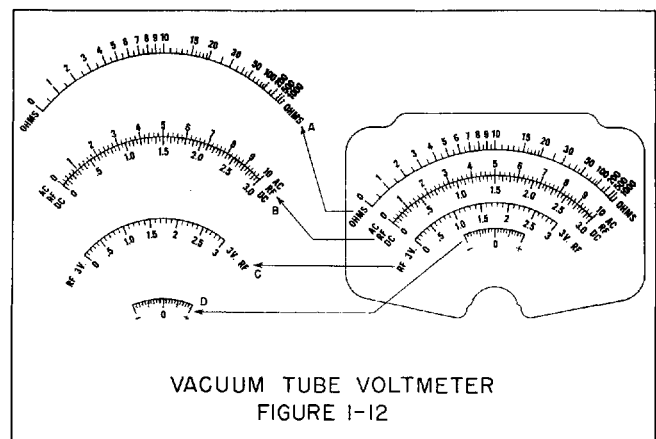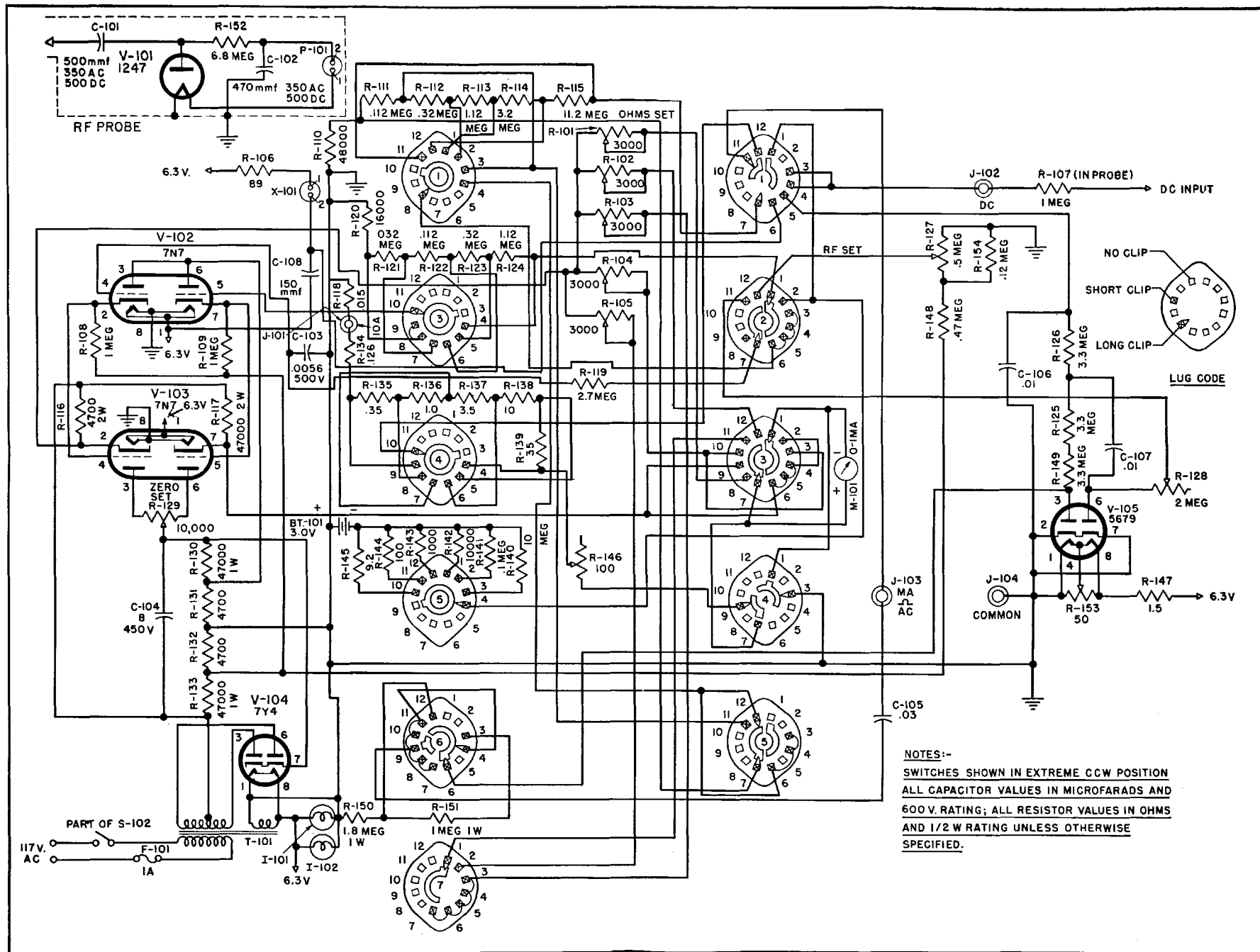
FIGURE 1-13   SCHEMATIC CIRCUIT—SYLVANIA TYPE 221Z

switched, nor does an indicated voltage reading vary because of tube or circuit fluctuations. These advantages are obtained largely through the use of the balanced circuit.

Provision for Additional Functions. Although primarily a voltmeter, the modern vacuum-tube voltmeter is well-known also as an ohmmeter, and often is adapted for current measurements from a fraction of 1 milliampere to several amperes. This instrument may be used to study or monitor any phenomenon which can be converted into a voltage.

1.11 THE SYLVANIA POLYMETER TYPE 221Z

The latest Sylvania multipurpose meter, the Polymeter Type 221Z, is an outstanding general-purpose electronic tester. This instrument embodies all of the features which contribute to high stability, maximum sensitivity, and wide utility. The circuit of the Polymeter (See Figure 1-13) is essentially that of a balanced triode dc vacuum-tube voltmeter, using type 7N7 dual triodes. In the circuit, V-103 is the output tube. For maximum isolation, a second 7N7 dual triode, V-102, is operated ahead of the voltmeter circuit proper as a cathode coupled dc amplifier. For ac voltage measurement, two separate diode rectifiers may be switched-in ahead of the complete dc vacuum-tube voltmeter circuit. One of these is the low-frequency rectifier (V-105) contained within the instrument. The other is the rf rectifier (V-101) enclosed in the external cable-end rf probe.

The designers of the Sylvania Polymeter Type 221Z aimed to produce a single unit which would make unnecessary the use of several separate instruments for complete professional trouble shooting. An examination of the following functions and ranges of the Type 221Z will reveal how the fundamental requirements for a universal instrument have been met in the design of this particular unit.

*DC Voltage. 0.05 to 30,000 Volts.* The six basic dc voltage ranges are 0-3, 10, 30, 100, 300, and 1000 volts. An accessory high-voltage, safety-type dc voltage multiplier (Type 223) converts the 1000-volt dc range to 0-10,000 volts. A second safety-type external dc voltage multiplier (Type 225) converts the 1000-volt dc range to 0-30,000 volts. Both of these multiplier probes are shown with the Polymeter in Figure 1-11. Up to 1000 volts, measurements are made by means of a test probe of the pencil type, containing a 1-megohm isolating resistor. The total input resistance of the instrument is 17 megohms on all dc ranges. 16 megohms of this resistance are in the range-switching voltage divider string; 1 megohm in the dc probe.

AC Voltage. 0.1 to 1000 Volts. The six ac voltage ranges are 0-3, 10, 30, 100, 300, and 1,000 volts. The 0-3 volt ac range is specially inscribed on the meter card (See Figure 1-12). All other ac voltages are read on the same scales provided for the dc voltages. A separate, shielded test probe is provided for ac measurements to minimize body capacitance and stray pickup effects. AC voltage measurements with the ac probe may be made at all frequencies between 20 cycles and 15 kc. At higher frequencies, it is advisable to employ the special rf probe which eliminates long leads and has a high frequency input circuit. Input impedance on the ac voltage ranges corresponds to 2.7 megohms and 194 $\mu\mu$fds when the special ac probe is used.

RF Voltage. 0.1 to 300 Volts. The five rf voltage ranges are 0-3, 10, 30, 100, and 300 volts. A special tube-type rf probe, enclosed in a hand-size metal shell (See Figure 1-14) is provided for rf measurements. This important accessory is described separately later in this section. Input impedance on the rf voltage ranges corresponds to 2.3 megohms and 3 $\mu\mu$fds. The frequency range over which rf voltage may be measured is 10 kc to 300 Mc. A special scale is provided on the meter card for the 0-3-rf volt range (See Figure 1-12). All other rf voltages are read on the same scales provided for dc voltages.

DC Current. 50 Microamperes to 10 Amperes. The seven current ranges are 0-3, 10, 30, 100, 300, and 1000 milliamperes, and 0-10 amperes. All currents are read on the corresponding scales provided for dc volts. Thus, the 0-3-milliampere range is read on the 0-3 volt scale.

Resistance. 0.5 Ohm to 1000 Megohms. The six resistance ranges are 0-1000, 10,000, and 100,000 ohms; and 0-1, 10, and 1000 megohms. Readings are taken on the OHMS scale times the range switch setting.

Special Electrical and Mechanical Features. The Polymeter test probes are connected to the instrument by means of microphone-type connectors, seen along the lower edge of the front panel in Figure 1-11. Use of this screw-type connector prevents accidental pulling out of the test leads during use.
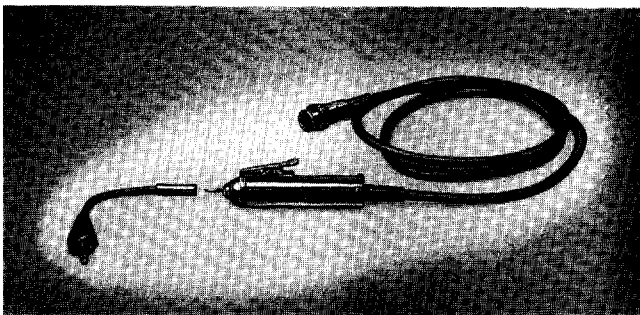
Figure 1-14.

CLOSEUP OF THE RF PROBE.

The heavy metal shell encloses and shields the tube and associated circuit components. The nose of the probe is made of low-loss plastic. Note that the alligator-type ground clip is welded directly to the metal shell for the shortest possible connection. For low-frequency measurements, where lead length can be tolerated, the extension lead (seen directly in front of the rf probe) is screwed to the protruding contact pin.

The external high-voltage multiplier probes have been designed for maximum safety to the operator. Each has a large-diameter perpendicular safety flange which serves the double purpose of keeping the user's fingers away from the metal contact pin and of increasing the surface leakage path along the insulating probe handle. Insulation used in construction of these high-voltage probes is effective beyond requirements. The contact pins protrude through translucent plastic probe noses, and are made of nickel-plated brass. They have been rounded and polished to minimize high-voltage corona.

The rf probe is of unique design. This probe is shown separately in Figure 1-14. It contains a special diode tube (Sylvania Type 1247) which allows much higher voltages to be measured than can be handled by the crystal probes used with some vacuum-tube voltmeters. The alligator groundclip of this probe is welded directly to the metal shell near the probe nose, as may be seen in Figure 1-14. This enables the entire probe to be clipped to the chassis of the device under test, thereby insuring the shortest possible ground connection. For high-frequency measurements, the probe contact pin is touched directly to the "hot" point of the circuit under test to give the shortest possible connection. At lower frequencies, where lead length can better be tolerated, a short, insulated extension lead with a alligator clip on one end (See directly in front of the rf probe in Figures 1-11 and 1-14) is provided. This lead has a threaded metal plug on one end which may be screwed to the end of the rf probe contact pin to extend the latter's length. When not being used, the rf probe is held in place close to the front panel of the Polymeter by the two spring brackets mounted directly under the meter (See Figure 1-11). A shielded cable terminated with a 3-pin male plug connects the rf probe to the instrument. A separate ZERO SET potentiometer (R-127 in Figure 1-13) is provided for the rf ranges of the Type 221Z. This potentiometer operates independently of the main ZERO SET (R-128) of the dc vacuum-tube voltmeter, but the instrument first must be zeroed on the dc ranges before switching to rf. This is an improvement welcomed by operators who have been annoyed formerly by the spurious deflection ordinarily accompanying insertion of a tube-type rf probe.

The Type 221Z Polymeter operates on 105 to 125 volts ac (50 to 60 cycles) and consumes 30 watts.

Figure 1-12 gives a full-size view of the meter scales of the large square indicator.

1.12 RULES FOR USE OF THE VACUUM-TUBE VOLTMETER

Damage to the instrument can be prevented, accuracy preserved, and useful life prolonged by observing several simple rules for using the universal vacuum-tube voltmeter. These rules are listed below.

(1) When checking voltages or currents, always switch the meter to its highest-voltage range first; then switch successively to each lower-voltage range until the unknown value is indicated in the upper third of the scale.

(2) Check *all* settings of the meter switches carefully before touching the test probes to the circuit under test.

(3) Keep the fingers close to the rear end of each test probe handle. This minimizes body capacitance effects and protects the operator from electric shock.

(4) When checking a high-voltage circuit, first connect the test prods to the circuit. THEN, switch-on the circuit voltage. This rule is especially important when using the dc voltage multiplier probes.

(5) The lowest voltage range (0-3 volts ac or dc) is subject to stray ac pickup, because of the sensitivity of this range. The "high" test probe acts as an antenna. For this reason, the instrument should be set to zero with the two test probes attached to the instrument. To minimize stray pickup when making rapid point-to-point tests, the "high" probe should be gripped with the fingers back toward the rear end of the probe handle. This condition has been minimized through the use of special shielded leads now supplied as standard equipment for the Type 221Z.

(6) During long test periods, check the zero setting occasionally. Best stability will be obtained if the instrument is allowed to run *continuously* during the entire test period.

(7) Never allow the instrument to standby for protracted periods of disuse when switched to its OHMS position. This will discharge the ohmmeter battery prematurely.

(8) It is a good rule to keep the instrument switched to its 1000-volt range when standing idle. The test leads need not be disconnected.

(9) When checking current (milliamperes or amperes) in high-voltage circuits, remember that the instrument case could be at high potential and therefore should be considered a shock hazard. However, current in high-voltage circuits can often be measured without this hazard by breaking into the negative or return-circuit connection at or near ground potential.

(10) Touch the contact pins of the AC and COMMON test prods together after checking ac voltages in circuits which also carry high dc voltages. The ac coupling capacitor in the vacuum-tube voltmeter circuit becomes charged by the dc component and can deliver a disturbing shock if the two probe contact pins come in contact with the operator. Touching the prods together will discharge the capacitor.

(11) Never attempt to measure the resistance of a resistor which has current flowing through it. Switch off the current and, preferably, disconnect one terminal of the resistor from the circuit before making measurements.

CHAPTER 2

RADIO RECEIVER TESTS
AND MEASUREMENTS

2.1 DC VOLTAGE MEASUREMENTS
IN A TYPICAL AM SUPERHETERODYNE

Since many of the voltages in a radio receiver must be measured across high resistances, the vacuum-tube voltmeter is the only practical instrument which will give quick, accurate readings. Voltage measurements serve to establish the operating condition of the receiver and therefore are invaluable in all trouble-shooting routines and in making adjustments to the circuit components.

The following paragraphs describe a systematic point-by-point method of checking voltages in a typical AM superheterodyne receiver (See Figure 2-1). The same method would be employed in any comparable circuit. The voltage readings obtained may be compared with those given in the circuit diagram and data supplied by the set manufacturer or listed in the popular service manuals. The numbers given in this discussion refer to similarly numbered circuit points in Figure 2-1.

Set the Polymeter to DC VOLTS. Unless otherwise noted in the directions following, the polarity switch must be set to its positive ($+$) position. For several tests, the abbreviation *NEG.* indicates that the negative ($-$) polarity will be required. Connect the COMMON test lead permanently (by means of a clip connector) to point 2 which is the chassis, or B-minus connection. When some figure other than 2 is given (such as 5-17), this means that the COMMON lead is removed from point 2 temporarily for this test only and that the voltage is to be measured between the two numbered points (such as 5 and 17, listed above). Observe all of the rules given in Section 1.12 of Chapter 1.

Following are the systematic voltage check points: 3 (NEG), grid voltage tube V_1. 6, plate voltage tube V_1. 7, screen voltage tube V_1. 8, cathode voltage tube V_1. 9, B voltage rf stage. (voltage here and no voltage at 6 indicates open primary coil). 10 (NEG), grid voltage tube V_2. 12, cathode voltage tube V_2 (should be same value as voltage at 10). 13, screen voltage tube V_2. 14, plate voltage tube V_2. 15, B voltage 1st detector stage (voltage here and no voltage at 14 indicates open primary of 1st if transformer). 16 (NEG), grid voltage tube V_3. 18, cathode voltage tube V_3. 19, plate voltage tube V_3. 20, screen voltage tube V_3. 21, B voltage 1st if stage (voltage here and no voltage at 19 indicates open primary 2nd if transformer). 22 (NEG), grid voltage V_4. 25, plate voltage tube V_4. 26, screen voltage tube V_4. 27 B voltage tube V_4 (volt-

age here and no voltage at 25 indicates open primary 2nd detector input transformer). 31, cathode voltage tube V_5. 32 (NEG), grid voltage pentode section V_5 (should be same value as voltage at 31). 33, plate voltage V_5. 34, screen voltage tube V_5. 35, screen supply circuit voltage list af amplifier stage (voltage here and no voltage at 34 indicates open resistor R_{15}). 36, no voltage (voltage would indicate leaky capacitor C_{15}). 37, B voltage first af amplifier stage (voltage here and no voltage at 33 indicates open resistor R_{17}). 38 (NEG), grid voltage tube V_6. 39, cathode voltage tube V_6 (should be same value as voltage at 38). 40, plate voltage tube V_6. 41, screen voltage tube V_6. (voltage here and no voltage at 40 indicates open primary in output transformer). 48, plate voltage tube V_7. 49 (NEG), grid voltage tube V_7 (absence of voltage here, if circuit continuity is perfect, indicates that circuit is not oscillating). 50 (NEG), same as 49. 51, B voltage oscillator stage (voltage here and no voltage at 48 indicates open resistor R_{23}). 52, screen voltage tube V_7 (excessive voltage here indicates open resistor R_{22}). 53, high-tap output voltage power supply circuit. 54, low-tap output voltage power supply circuit. 55, rectifier output voltage before filter (voltage here and no voltage at 53 indicates open filter choke, CH, or shorted output filter capacitor, C_{20}).

Connect an unmodulated signal generator to terminals 1 and 2, tune in signal with receiver. Reduce the generator output to a low value, and check avc voltage (with meter set to DC VOLTS) between the following points: 4-5, 5-17, 5-23, 5-30, 29-30, and 30-31. This voltage should increase as the signal generator output is increased, and vice versa.

DC current may be measured at any circuit point (such as in the plate line to a tube) by breaking the line temporarily at that point and inserting the Polymeter (set to MA.). The positive test lead must be connected to the circuit point nearest the positive terminal of the supply voltage.

It is also possible to determine current values from voltage drops across resistors of known value. The dc voltage across the resistor is measured with the Polymeter, and this value divided by the ohmic value of the resistor. The result is the current flowing through the resistor, expressed as a fraction of an ampere. For example; suppose the voltage drop across a 50,000-ohm plate resistor in a tube circuit is found by measurement to be 50 volts. The plate current of the tube then is $50/50,000 = 0.001$ ampere $= 1$ milliampere. This method of determining current is very convenient, since it entails no breaking of circuits.
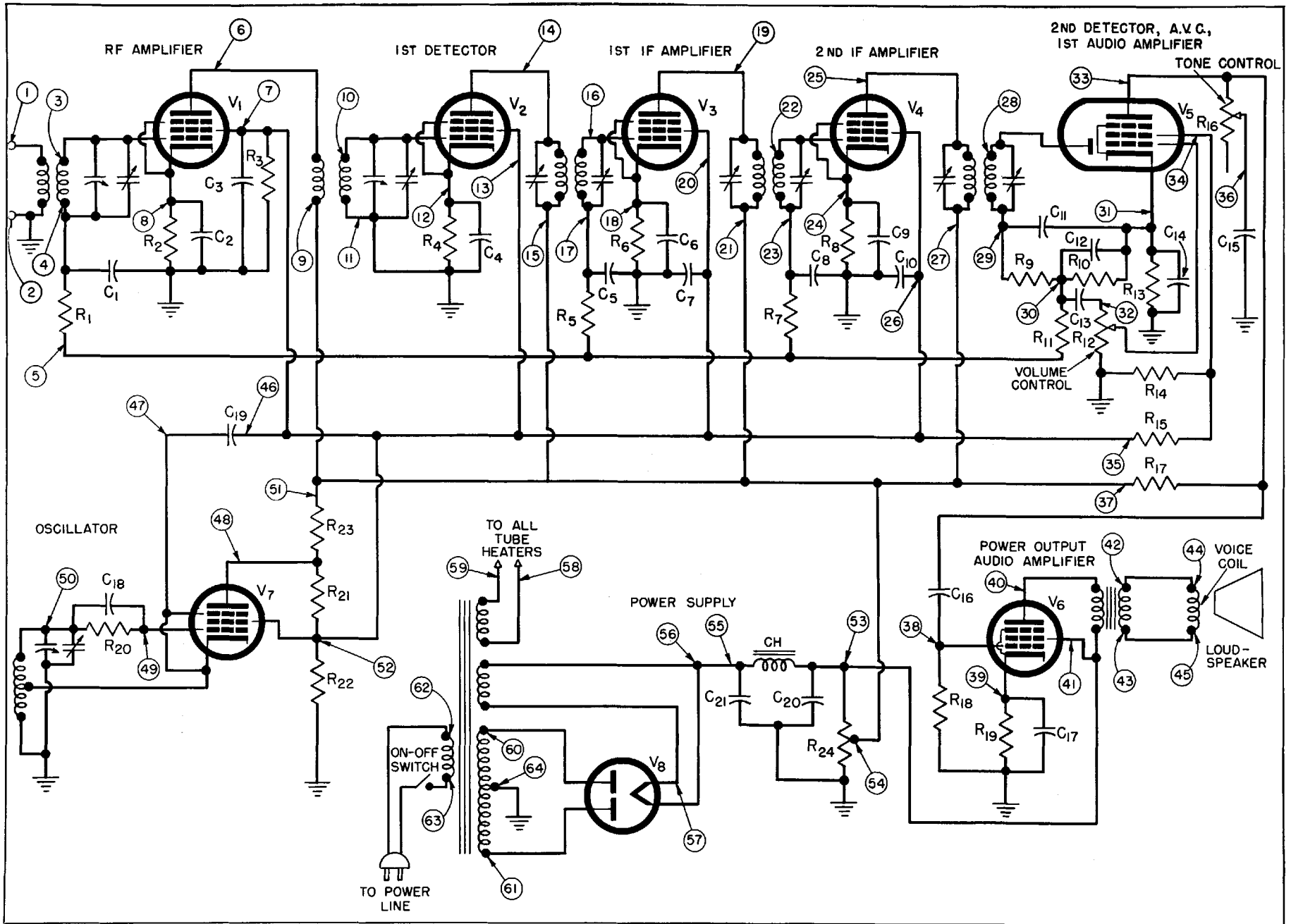
FIGURE 2-1   TYPICAL AM SUPERHETERODYNE RECEIVER WITH TEST POINTS

18

2.2 AC VOLTAGE MEASUREMENTS IN THE RECEIVER

AC voltage measurements, often overlooked by service technicians, should not be neglected when checking receiver operating characteristics. The vacuum-tube voltmeter (set to AC VOLTS) and used in accordance with the rules given in Section 1.12, Chapter 1, may be employed to check ac voltages between the following points in the circuit given in Figure 2-1: 56-57, rectifier filament voltage. 58-59, receiver tube heater voltage. 60-64, voltage of top half of high-voltage secondary winding of power transformer. 61-64, voltage of lower half of high-voltage secondary. 60-61, voltage of entire secondary winding. 62-63, power-line voltage (operation of ON-OFF switch can be checked during this test).

2.3 SIGNAL LEVEL MEASUREMENTS

The Polymeter may be used to measure *directly* the actual signal voltage in each stage of a receiver. The meter is set to RF VOLTS and the external rf probe employed for signal strength measurements in the rf amplifier, 1st detector, oscillator, if amplifiers, and 2nd detector. In rf stages, where the signal is ordinarily relatively low, the Dynamic Signal tracing Technique (Section 2.4) must be employed. For measurements of signal voltage in the two audio amplifier stages (See Figure 2-1) and across the loudspeaker voice coil, the meter is set to AC VOLTS, and the regular ac probe used. The rf meter also may be used to measure signal strength in the limiter, discriminator, and ratio detector stages employed in FM receivers and in the sound channels of television receivers.

Using point 2 (See Figure 2-1) as the common ground point, feed a modulated signal into the antenna input terminals of the receiver, tune-in the signal carefully, and use the rf probe to measure signal voltages at the following circuit points: 3, 6, 10, 14, 16, 19, 22, and 28. Check oscillator rf output voltage at 46 and 47. Switch the Polymeter to AC VOLTS and measure audio signal voltage at points 30, 32, 33, 38, and 40. Check the loudspeaker audio signal voltage between 42 and 43, and 44 and 45.

Use of these signal voltage measurements in trouble shooting is described in Section 2.4 of this Chapter.

2.4 DYNAMIC SIGNAL TRACING

In the signal tracing process, a signal, delivered by a modulated signal generator, is followed with a vacuum-tube voltmeter through a receiver from the antenna input terminals to the loudspeaker voice coil. The signal normally undergoes amplification as it is transmitted through the various receiver stages. Loss of the signal or reduction in its strength is an indication of trouble in the stage in which this occurs. The Polymeter is well suited for signal tracing, since it measures readily both rf and audio voltages.

The following is a step-by-step procedure for signal tracing in an AM superhet. Refer to the circuit diagram in Figure 2-1. For the purpose of this test, a good amplitude-modulated signal generator, such as the Sylvania Type 216, having both high- and low-voltage output will be required. The Polymeter rf probe will be used to trace signals in the rf amplifier, 1st and 2nd detector, and if amplifier stages. The regular ac probe will be employed in the 1st and output audio stages, and loudspeaker. (1) Connect the modulated signal generator to the antenna input terminals of the receiver. Temporarily, put the avc of the receiver out of operation. (2) Set the generator and the receiver to the same carrier frequency. (3) Set the Polymeter to RF VOLTS (0-3-volt range), and connect its COMMON test lead to terminal 2 (See Figure 2-1). (4) Set the signal generator output temporarily to HIGH (1 volt approximately). (5) Touch rf probe to 3 and tune receiver for peak deflection of meter. The high output of the signal generator is needed for this step, since the antenna input transformer would not otherwise deliver a signal strong enough at point 3 to deflect the meter. (6) Transfer the rf probe to 6. The signal voltage at this point should be somewhat higher than at point 3, due to amplification in tube V_1. (7) Transfer the rf probe to 10. Here, a still stronger signal should be obtained because of the step-up ratio of the coupling transformer. Re-tune or re-align receiver, if necessary, and decrease signal generator output to prevent overloading of the receiver which now is operating without avc (8) Transfer rf probe to 16. The ratio of the signal voltage here to that at point 10 is a measure of the conversion gain (or loss) in the front end of the receiver. (9) Transfer rf probe to 22. Reduce signal generator output, if necessary. Increased signal here indicates gain in 1st if amplifier. (10) Transfer rf probe to 28. Increased signal here indicates gain in 2nd if amplifier. (11) Transfer rf probe to 46. Meter indication here is rf voltage output of oscillator stage. (12) Transfer rf probe to 47. Difference between voltage at this point and at 46 indicates attenuation in coupling capacitor C_{19}. (13) Switch Polymeter to AC VOLTS. Keep COMMON test lead connected to point 2. (14) Touch ac probe to 30. Voltage here is audio output of 2nd detector. (15) Transfer ac probe to 32. Difference between voltage at this point and at 30 indicates attenuation in coupling capacitor C_{18}. (16) Transfer ac probe to 33. Increased ac voltage indicates gain of audio section of tube V_5. Run volume control R_{12} up and down, noting its effect on voltage reading, to check volume control operation. (17) Transfer ac probe to 38. Run tone control R_{16} up and down to check its effect upon audio output of 1st audio stage. (18) Transfer both ac test leads to 40 and 41. Meter indicates audio voltage developed across the output transformer primary by the audio power amplifier tube V_6. (19) Transfer both ac test leads to 44-45. Meter indicates audio voltage developed across loudspeaker voice coil. (20) After the signal tracing tests are completed, restore the avc circuit connections.
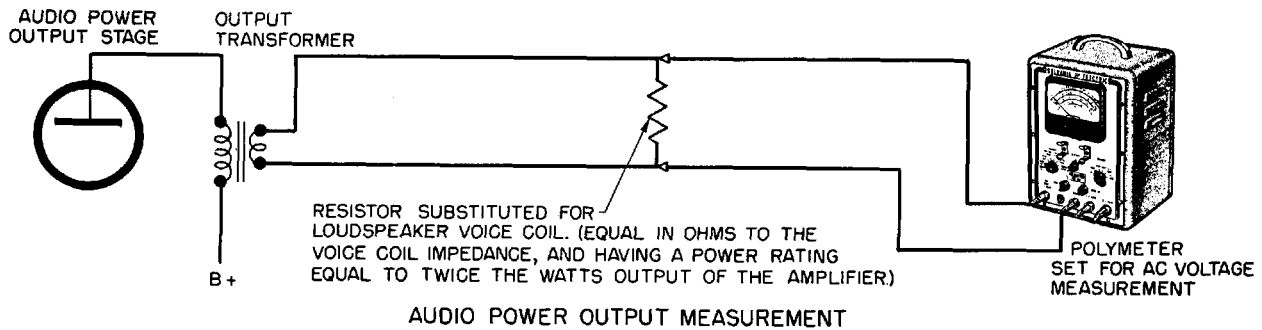
AUDIO POWER OUTPUT MEASUREMENT

FIGURE 2-2

2.5 POWER OUTPUT MEASUREMENT

The undistorted audio power output of a receiver is important information. Figure 2-2 shows a Polymeter setup for measuring power output. The receiver is supplied with a modulated signal from a generator connected to the antenna input terminals. This signal must be tuned in carefully.

For accuracy, as well as a noiseless test, the loudspeaker is disconnected from the receiver and a resistor connected in place of the speaker voice coil, as shown in Figure 2-2. This resistor must have a value in ohms equal to the impedance of the voice coil at the af test frequency used and must have a power rating equal to twice the rated power output of the power amplifier stage. Thus; if the voice coil impedance is 8 ohms and the audio output is 5 watts, the resistor must be rated at 8 ohms and 10 watts.

The Polymeter is used to measure the ac (audio) voltage developed across the load resistor. From this voltage value, the power may be calculated by squaring the voltage and dividing by the resistance. For example, suppose the load resistance to be 6 ohms and the measured voltage 6 volts. The power then is

$$\frac{6 \times 6}{6} = \frac{36}{6} = 6 \text{ watts.}$$

Power output measurements should be made at several settings of both the volume and tone controls, and at various output levels of the signal generator. A cathode ray oscilloscope should be used to check for overloading, or the Polymeter used to keep the signal on the grid of the power tube less than 0.7 times its bias.

2.6 DISCRIMINATOR AND RATIO DETECTOR ALIGNMENT IN FM RECEIVERS

A superheterodyne for receiving frequency-modulated signals differs from a conventional AM superheterodyne chiefly in its use as a special 2nd detector (in the FM set) to convert the frequency-modulated signal into audio. This special 2nd detector may be either a *discriminator* or a *ratio detector*. The discriminator must be preceded by a *limiter* stage, while the ratio detector ordinarily requires no limiter. These special detector circuits are found in television sound channels, as well as in straight FM receivers. Figure 2-3 shows a Polymeter set for DC VOLTS and connected for adjustment of the limiter stage in an FM receiver. Figure 2-4 shows the setup for discriminator adjustments, and Figure 2-5 for ratio detector adjustment.

For limiter adjustment (See Figure 2-3), an unmodulated signal (at the intermediate frequency of the receiver) is fed into the circuit at some point ahead of the limiter stage. The 1st detector (or converter) grid is a good injection point. Each of the if trimmers then is adjusted to give peak deflection of the Polymeter. The lowest signal which will give a good readable deflection of the meter should be used.

For balanced discriminator adjustment, connections are made as shown in Figure 2-4. The Polymeter is set for DC VOLTS. The 0-3-volt range ordinarily is employed. An unmodulated if signal is injected into the receiver ahead of the discriminator stage, as explained in the foregoing explanation of limiter ad-
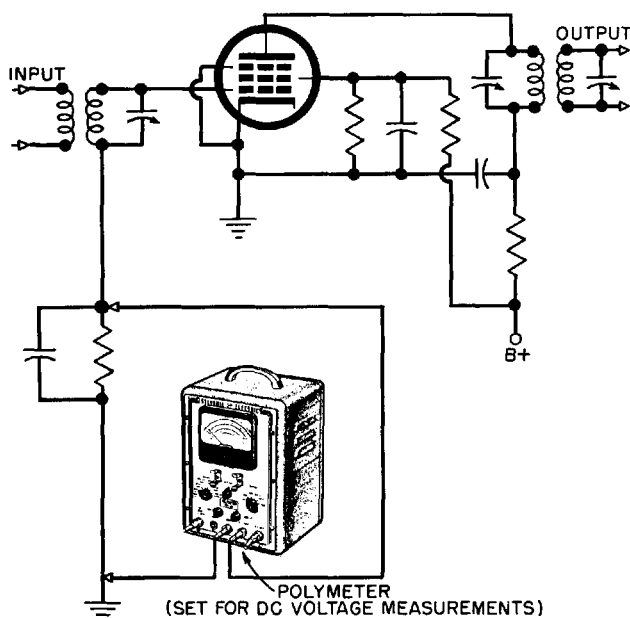
FM LIMITER

FIGURE 2-3
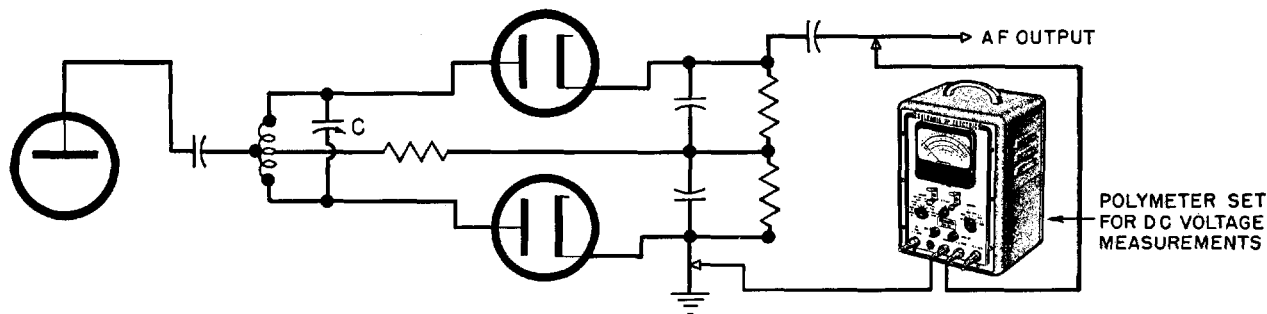
BALANCED DISCRIMINATOR
FIGURE 2-4

justment. Trimmer C in the discriminator input trans-former then is adjusted to give exact *zero* reading of the Polymeter. If C is incorrectly adjusted, the meter will read some definite value of voltage—positive on one side of perfect balance, and negative on the other side. Zero voltage indicates perfect balance. For convenience, the zero set panel knob on the Polymeter may be adjusted to make the meter needle read "zero" on the small zero center scale provided for use during discriminator alignment.

Connections of the Polymeter to a ratio detector circuit are shown in Figure 2-5. The method of adjusting the ratio detector is the same as for the discriminator. Tune the trimmers (C_1 and C_2) of the ratio detector transformer to give exact zero reading of the meter. Any voltage indication, positive or negative, shows the ratio detector to be out of adjustment. Use an unmodulated test signal injected ahead of the ratio detector circuit.

2.7 BANDWIDTH (SELECTIVITY) MEASUREMENTS

Sharpness of tuning, or *selectivity*, is measured by checking the actual bandwidth of a receiver. For this purpose, the Polymeter may be set to AC VOLTS and connected across the loudspeaker voice coil or across a substitution resistor (See Figure 2-2), or it may be set to DC VOLTS and connected across the 2nd detector load resistor in a superheterodyne or the normal detector load resistor in a tuned rf receiver. n amplitude-modulated signal will be required when the ac meter arrangement is used, but the signal may be unmodulated when the dc meter is employed. In either setup, the meter acts as an output indicator.

The procedure in checking selectivity is to tune-in the signal for peak deflection of the vacuum-tube voltmeter. The voltage at resonance is noted and recorded. Then, the signal generator is de-tuned successively to a number of equally-spaced frequencies on each side of the resonant frequency. The voltmeter reading is recorded for each of these frequencies. The signal generator output must be held to a constant value. When the results are plotted as a graph, selectivity (bandwidth) curves are obtained similar to those given in Figure 2-6.

An alternate method is to leave the signal generator tuned to the center frequency (that is, the frequency to which the receiver normally is set) and
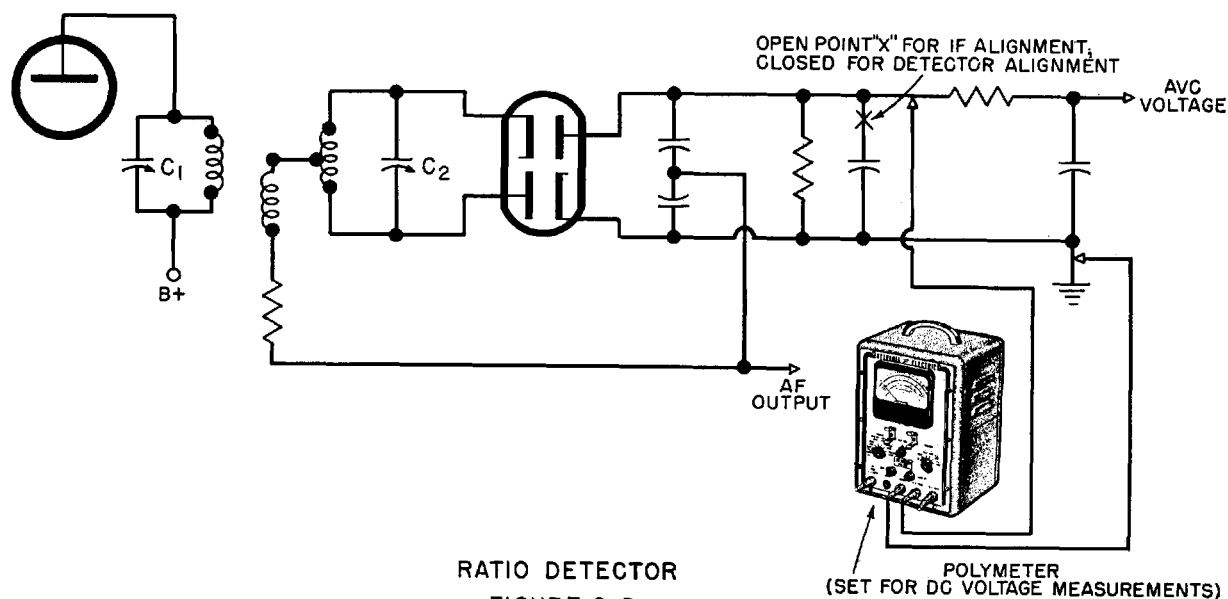
RATIO DETECTOR
FIGURE 2-5

21

then to de-tune the receiver in equal frequency steps above and below the center frequency. The voltmeter readings, recorded against the frequency settings, will give selectivity curves of the same sort described in the preceding paragraph.

If desired, the voltmeter readings may be converted into decibels in the following manner:

$$db = 20 \log_{10} \frac{E_1}{E_2}.$$

E_1 is the voltage at resonance (center frequency), and E_2 the voltage at any particular frequency off resonance.

The curve shown in Figure 2-6(A) is the type generally obtained with a sharply-tuned and aligned superhet. .Curves (B) and (C) indicate broader tuning (wider bandwidth) and are characteristic of high-fidelity receivers which intentionally are tuned more broadly than conventional receivers and of trf sets.

The bandwidth of an FM receiver may be inspected in a similar manner. Connect the Polymeter, set to DC VOLTS, across the limiter resistor (See Figure 2-3) in a set employing the limiter-discriminator arrangement. In a ratio detector setup, connect the Polymeter in the manner shown in Figure 2-5 and open point "X" temporarily. Use an unmodulated signal generator. The selectivity curve of an FM receiver will approach the shapes given in Figures 2-6(B) and (C).

Bandwidth measurements should be made at several points in each frequency band covered by the receiver —preferably at the high and low ends and in the middle.

2.8 AVC CHECKING

The effectiveness of the automatic volume control (avc) system in a receiver may be checked in two ways. One way is to measure the actual dc bias voltage produced by the avc system as the signal input to the receiver is varied. The other way is to measure the audio output voltage as the signal input to the receiver is varied.

The first method requires an unmodulated input signal, applied to the antenna input terminals of the receiver. The signal must be tuned in carefully, as indicated by peak upswing of a vacuum-tube voltmeter, set to DC VOLTS, connected across the 2nd detector load resistor. Referring to the receiver circuit diagram in Figure 2-1, avc voltage then may be checked between the following circuit points: 4-5, 5-17, 5-23, and 5-30. The signal generator output should be varied, while the operator watches the corresponding changes in the avc voltage. In the ratio detector circuit of an FM receiver (See Figure 2-5), avc voltage may be checked between ground (B-minus) and the point labeled "avc voltage."

The second method requires a modulated signal, applied to the antenna input terminals of the receiver. The Polymeter (set to AC VOLTS) is connected across the loudspeaker voice coil (or across a substitution resistor, as shown in Figure 2-2). The signal is
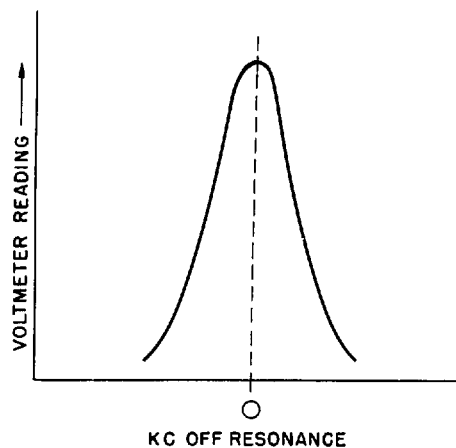
(A) SHARP TUNING
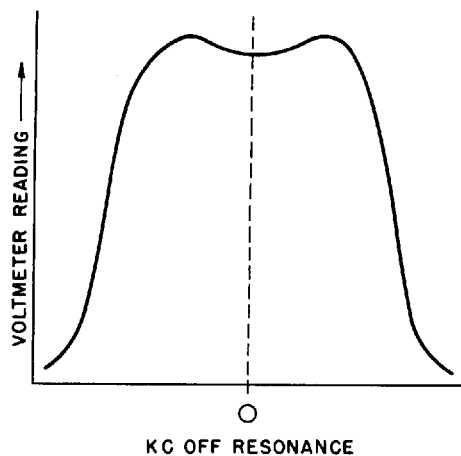
(B)"DOUBLE-HUMP"TUNING
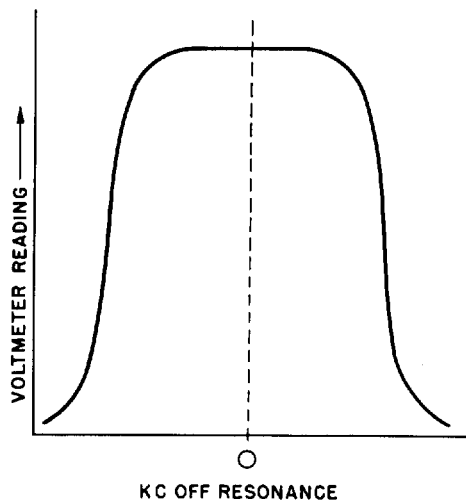
(C) FLAT-TOP TUNING

SELECTIVITY CURVES OBTAINED IN
BANDWIDTH MEASUREMENTS

FIGURE 2-6

tuned in carefully, as indicated by peak upswing of the meter. The signal generator output then is varied, while the operator observes the effectiveness with which the avc system keeps the meter reading *constant*. With a good avc system, the input signal voltage may be varied over a considerable range without a substantial change occurring in the meter reading.

2.9 AFC CHECKING

The discriminator stage in an automatic frequency control (afc) circuit may be checked (at the intermediate frequency of the receiver) in the same manner as explained for FM discriminator checking in Section 2.6 of this Chapter. The discriminator voltage may be checked at the discriminator in the conventional manner or at the grid of the control tube.

2.10 USE OF THE VACUUM-TUBE VOLTMETER IN RECEIVER ALIGNMENT

The vacuum-tube voltmeter may be used in several different ways as an accurate and sensitive resonance indicator in receiver alignment. In fact, this visual method is to be preferred to aural alignment methods.

One of the following procedures should be followed: (1) Set the Polymeter to DC VOLTS and connect it across the the avc voltage string (points 2-5, 2-17, or 2-23 in Figure 2-1). Apply an unmodulated signal to the antenna input terminals. Use the lowest signal strength which will give an accurately readable meter deflection. Tune in the signal carefully, and adjust each of the alignment trimmers and padders in each stage for peak deflection of the meter. Go through the complete series of adjustments a second time, for close adjustment.

The second method involves the following steps: (2) Set the Polymeter to AC VOLTS and connect it across the loudspeaker voice coil (or across a substitution resistor, as shown in Figure 2-2). Supply a modulated signal to the antenna input terminals. Use the lowest possible signal generator output which will

give a good, readable deflection of the meter—otherwise the avc system will have to be put temporarily out of commission. Tune in the signal sharply, as indicated by peak deflection of the meter. (This assumes, of course, that the receiver is not too far out of alignment, and that some output voltage can be obtained). Adjust the trimmers and padders in each stage for peak deflection of the meter. Reduce the signal generator output, as required, when closer alignment brings up the output indication. After going carefully through the receiver, repeat the complete series of adjustments, for closer final alignment.

The third method utilizes the rf voltmeter arrangement of the Polymeter. (3) Apply an unmodulated signal to the antenna input terminals of the receiver. Use a low signal level. Touch the contact pin of the rf probe successively to the control grids of the rf amplifier, 1st detector (or converter), if amplifiers, and 2nd detector stages, while adjusting the trimmers and padders in each preceding transformer for peak deflection of the meter. If the receiver employs diode 2nd detection, touch the rf probe to the detector (not avc) plate terminal. It may be necessary to use the high output of the signal generator when aligning the rf amplifier stage, since no amplification is present at the grid of this tube.

2.11 PEAK VOLTAGE MEASUREMENTS IN THE POWER SUPPLY

Excessive peak voltages across the filter capacitors in power supplies often are responsible for repeated failure of these capacitors in service. These peak voltages may be measured with an ac vacuum-tube voltmeter, provided the meter utilizes a peak-actuated input circuit.

Figure 2-7 shows how the Polymeter (set to AC VOLTS) may be used to check the peak voltage across each filter capacitor in a power supply. Since the ac voltage scales of the Polymeter read rms values, it will be necessary to multiply each reading by 1.414 to ob-

POLYMETER SET FOR AC VOLTAGE MEASUREMENTS (MULTIPLY READING BY 1.414 TO OBTAIN PEAK VOLTAGE VALUES)

CHECKING PEAK VOLTAGES IN POWER SUPPLY

FIGURE 2-7
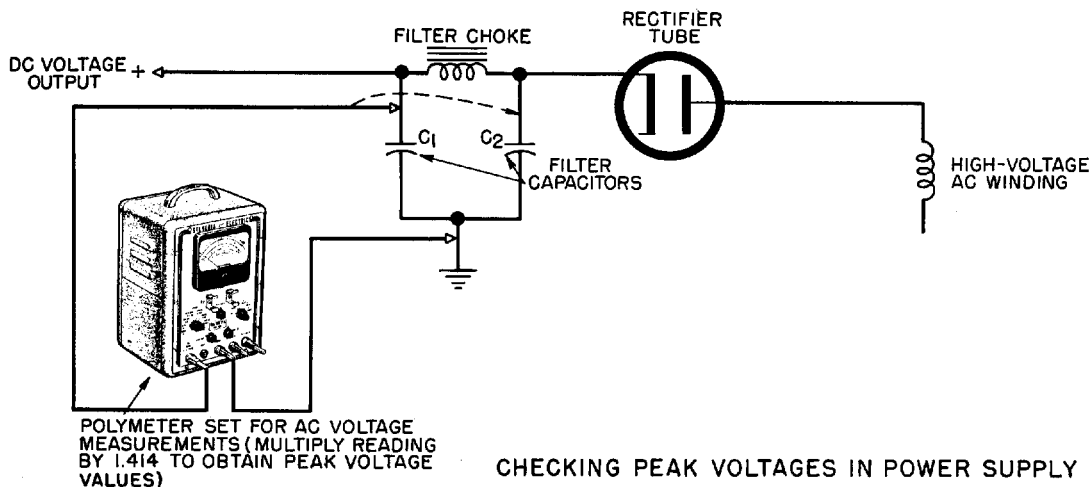
tain the peak voltage value. The peak voltage across the rectifier tube likewise can be measured.

The Polymeter will not be damaged by the dc voltage also present in the power supply circuit, since this instrument is provided with an isolating input capacitor which effectively blocks the dc.

2.12 CHECKING OSCILLATOR ACTIVITY

The vacuum-tube voltmeter may be used in two different ways to check receiver oscillator intensity. These two methods are illustrated in Figure 2-8.

In the first scheme (See Figure 2-8A), the Polymeter is set to DC VOLTS and is used to read the oscillator grid voltage. This voltage is proportional to the strength of oscillation, being highest when oscillation is strongest. A provocative test is to touch the grid terminal with the finger. If the stage was oscillating, the meter reading will dip toward zero due to oscillation being stopped.

The second scheme (See Figure 2-8B) uses the Polymeter, set to RF VOLTS, to measure the actual rf output voltage of the oscillator.

2.13 HIGH-FIDELITY AM RECEIVER ALIGNMENT

High-fidelity am receivers may be either superheterodyne or tuned rf sets. Faithful reproduction in the rf stages is obtained by means of wide bandwidth. The relatively broad selectivity curve required in these receivers is obtained by means of either stagger tuning in the stages or by resistance-loading the coupling coils. Sometimes, both systems are employed.

The vacuum-tube voltmeter is used in aligning high-fidelity am receivers in the same manner as when aligning conventional sets (See Sections 2.7 and 2.10 of this Chapter), except that the technician must seek deliberately to obtain the flat-topped type of selectivity curve shown in Figure 2-6(C).

POLYMETER SET FOR
DC VOLTAGE
MEASUREMENTS

(A) DC BIAS VOLTAGE METHOD

R.F. PROBE

POLYMETER SET FOR
RF VOLTAGE
MEASUREMENTS

(B) RF OUTPUT VOLTAGE METHOD
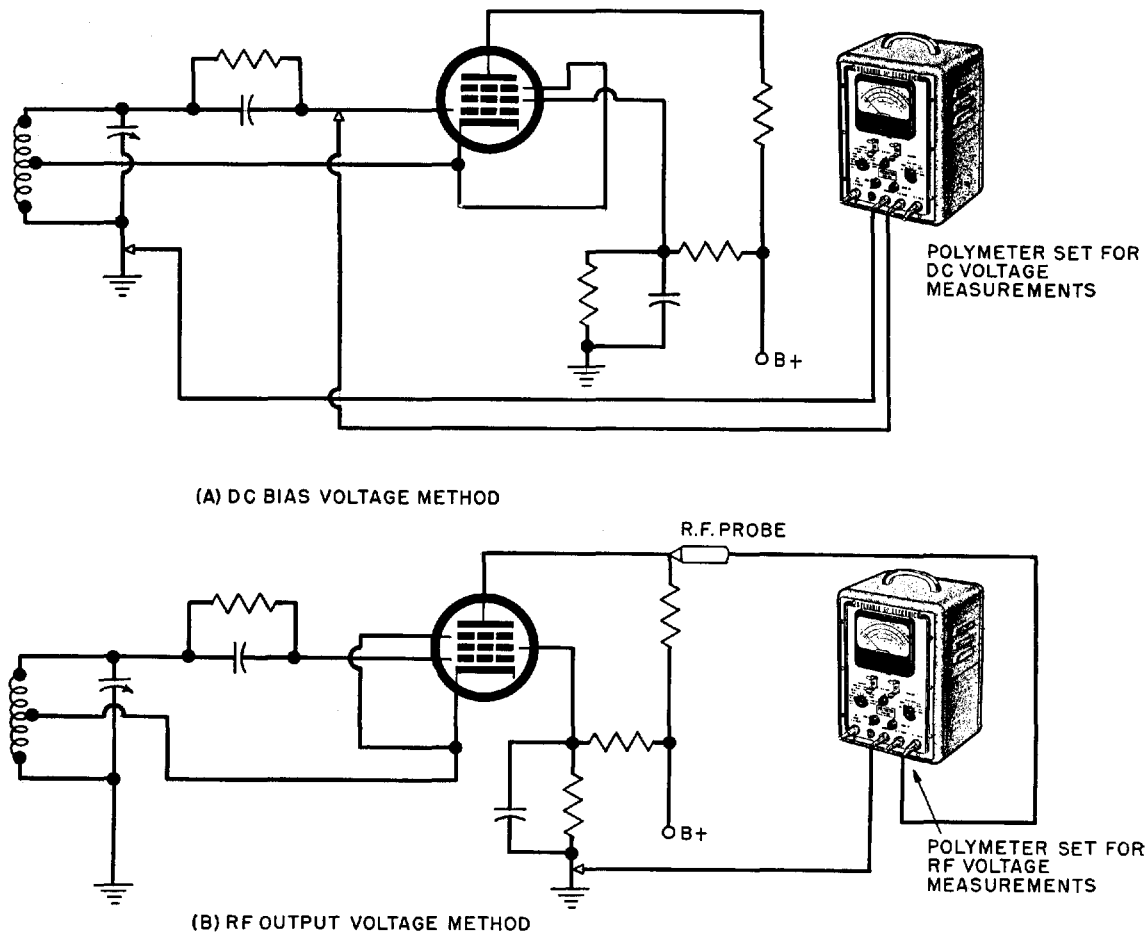
CHECKING RECIEVER OSCILLATOR INTENSITY

FIGURE 2-8

CHAPTER 3

AUDIO AMPLIFIER TESTS
AND MEASUREMENTS

3.1 DC VOLTAGE MEASUREMENTS IN AUDIO AMPLIFIERS

Resistance-coupled stages are widely used in audio amplifiers. The coupling resistances often have values ranging from several hundred thousand ohms to several megohms. The voltage drops across these resistors are important in determining amplifier performance and shooting trouble. The vacuum-tube voltmeter is the only instrument which will permit rapid and accurate voltage measurements without disturbing operation of the high-resistance circuits.

Figure 3-1 shows the circuit of a typical high-gain audio amplifier with degenerative feedback in the output stage. In this schematic, there are 41 numbered points for tests with a vacuum-tube voltmeter. We will list first the routine dc voltage tests and will discuss the ac tests in Section 3.2.

To prepare the Polymeter for dc voltage measurements in the amplifier, set its function switch to DC VOLTS, and polarity switch to positive $(+)$. Connect the COMMON test lead to point 2. Unless otherwise directed, all measurements will be made with the negative terminal of the instrument connected to point 2 and with the dc probe travelling to the numbered circuit points. When the abbreviation *NEG* appears after a number in the following discussion, the probe will contact a negative circuit point. For this test point only, therefore, throw the polarity switch to its negative $(-)$ position. The volume control of the amplifier should be set to its position of maximum output. No signal is to be applied to the amplifier during the dc tests.

Following are the circuit points to be contacted by the travelling dc probe, together with the significance of the indicated voltages. 3 (NEG), grid voltage tube V_1. 4, cathode voltage tube V_1 (should be same value as voltage at 3). 5, plate voltage tube V_1. 6, screen voltage tube V_1. 7, B-voltage 1st stage (voltage here and no voltage at 5 indicates open plate resistor R_3; voltage here and no voltage at 6 indicates open screen resistor R_2 or shorted bypass capacitor C_3). 8, main supply voltage for low-level stages (voltage here and no voltage at 7 indicates open decoupling resistor R_5, or shorted decoupling capacitor C_5). 10 (NEG), grid voltage tube V_2. 11, cathode voltage tube V_2. 13, B-voltage 2nd stage (voltage here and no voltage at 12 indicates open plate resistor R_7). 14 (NEG), grid voltage tube V_3. 15, cathode voltage V_3 (should have same value as voltage at 14). 16, plate voltage tube V_3. 17, B-voltage 3rd stage (voltage here and no voltage at

16 indicates open primary, transformer T_1). 18, to K (NEG), grid voltage tube V_4. 20, zero dc voltage (voltage here indicates leaky capacitor C_{10}). 21, same as 20. 22, zero dc voltage (voltage here indicates leaky capacitor C_{13}). 23, K (NEG) grid voltage tube V_5. 24, same as 23. 25, plate voltage tube V_4. 26, plate voltage tube V_5. 27, B-voltage output stage (voltage here and no voltage at 25 or 26 indicates corresponding open half of transformer T_2 primary. 32, dc output of rectifier tube V_6. Voltage at 27 and no voltage at 8, 13, or 17 indicates open resistor R_{15}. Voltage at 32 (usually excessively high) and no voltage at 27 indicates open filter choke CH or shorted output filter capacitor C_{15}.

In determining the operating condition of the amplifier, the voltages measured at these various points should be compared with those listed by the amplifier manufacturer or found in a service manual. Voltage variations of the order of plus or minus 10 percent from rated values generally are not considered detrimental. Excessively high grid voltages (points 3, 10, 14, 18, and 23) usually indicate oscillation, grid current, or a gassy tube in the stage under test.

Positive voltages at points 9 or 14 indicate leaky coupling capacitors (C_4 or C_7).

3.2 AC VOLTAGE MEASUREMENTS IN AUDIO AMPLIFIERS

Set the Polymeter to AC VOLTS. The ac test leads have no particular polarity; however, to prevent "pinning" of the meter, the COMMON probe should be touched to the circuit *first*. After taking the voltage reading, the COMMON probe then should be held in contact with the circuit point, and the ac probe removed *first*.

Following are the circuit points between which ac voltages must be checked to determine operating condition of the amplifier. 33-34, amplifier tube heater voltage. 35-36, rectifier tube filament voltage. 37-38, voltage of top half of high-voltage secondary, power transformer T_3. 38-39, voltage of lower half of high-voltage secondary. 37-39, voltage of entire secondary. 40-41, power-line voltage, and action of ON-OFF switch S.

The ac voltages measured at the foregoing points should be compared with the values given in the amplifier manufacturer's data or found in amplifier service manuals. The Sylvania Tube Manual should be consulted regarding permissible variations and heater voltages in the particular tubes used.
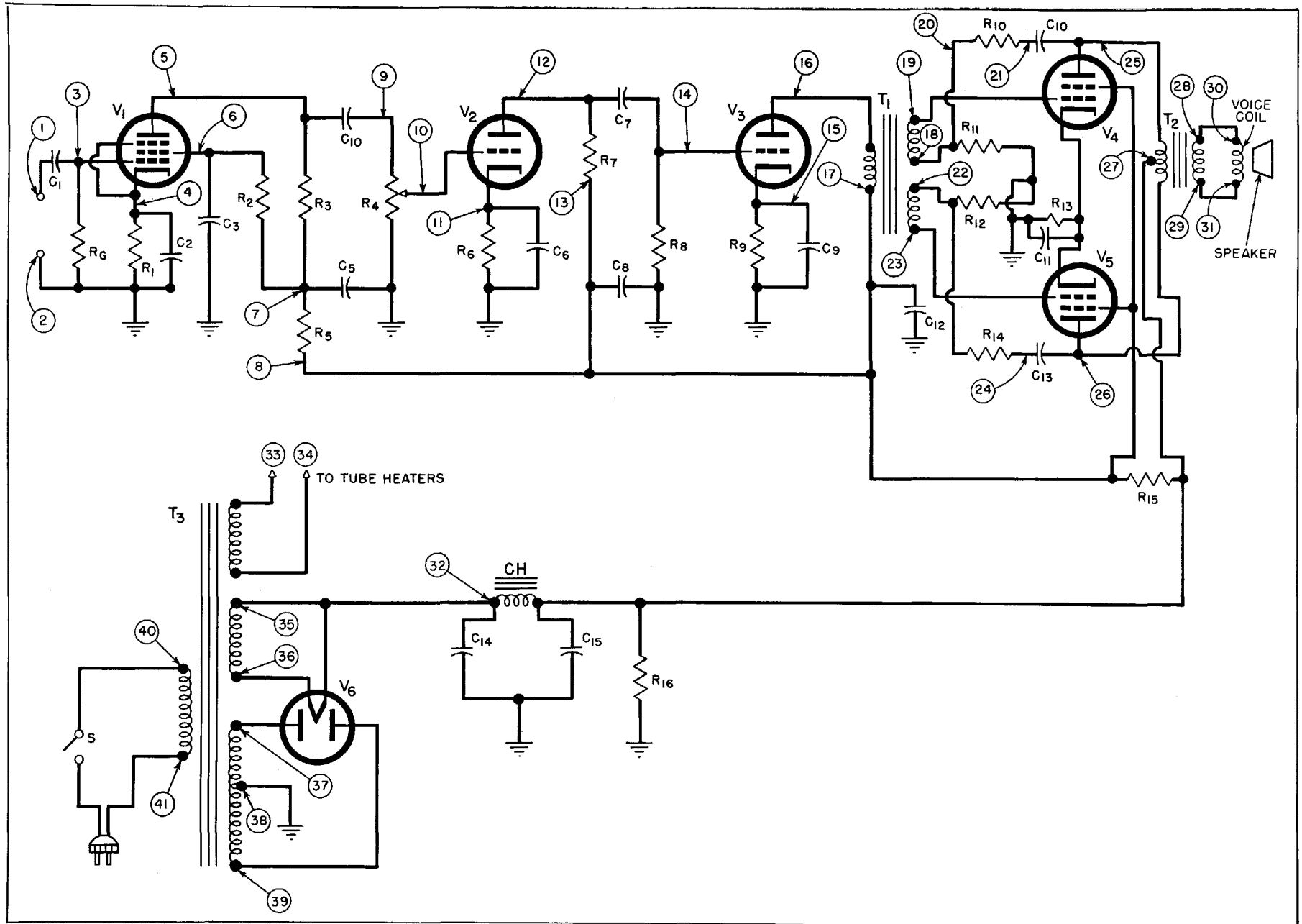
FIGURE 3-1   TYPICAL AUDIO AMPLIFIER, WITH TEST POINTS

3.3 SIGNAL LEVEL MEASUREMENTS IN AUDIO AMPLIFIERS

The actual value of the audio signal voltage in various stages of an amplifier may be measured with the ac vacuum-tube voltmeter. Amplifier operation is not disturbed when the Polymeter is used for this purpose. For signal level measurements, an input signal of approximately 1 millivolt will be required in high-gain amplifiers. This test signal may be obtained by means of the arrangement shown in Figure 3-2. A simple 100:1 voltage divider, consisting of a 100,000- and 100-ohm resistor in series, is connected to the output terminals of the audio oscillator. Set the oscillator to 1000 cycles, and connect the Polymeter temporarily to points A and B. Adjust the oscillator output to give 1 volt deflection of the meter. The output terminals of the resistor network now will deliver 1 millivolt. Connect the system to the amplifier input terminals. Remove the Polymeter from points A and B. Switch on the amplifier.

With the 1-millivolt signal fed into the amplifier, set the amplifier volume control for maximum output. If a noiseless test is desired, disconnect the loudspeaker voice coil and substitute for it a resistor having the same resistance value as the voice coil impedance. The wattage of this resistor must equal twice the rated power output of the amplifier.

The Polymeter now may be used to check the signal voltage value at selected points throughout the amplifier (See Figure 3-1). Connect the COMMON test lead to point 2, and touch the AC probe successively to the following numbered circuit points. 9, signal output of 1st stage (this voltage will indicate the amplification of the 1st stage—thus; if the amplification is 100, the 1-millivolt signal will be stepped up to 100 mv., or 0.1 volt at point 9). 14, signal output of 2nd stage (the ratio of this voltage to that at point 9 will indicate the amplification in the 2nd stage). Run the volume control R_4 up and down while watching its effect upon the signal voltage at point 14. Return the volume control to maximum. Transfer the ac probes to points 19 and 23 to check signal voltage applied by
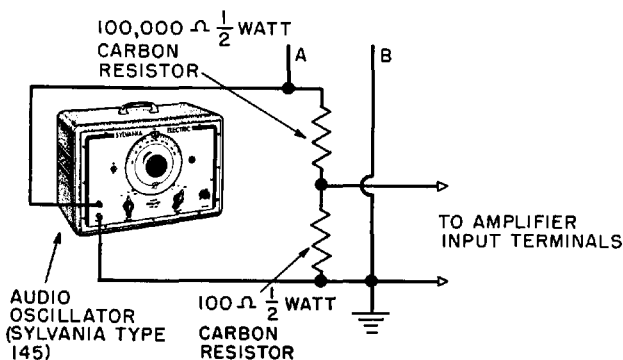
the 3rd stage and transformer T_1. The signal voltage between 2 and 19, and between 2 and 23 should be equal. The signal voltage between 2 and 20, and between 2 and 23 likewise should be equal. They indicate the level of degenerative feedback voltage applied to the grids of V_4 and V_5. Transfer the AC probes to points 28 and 29, or 30 and 31 to check the signal output voltage of the entire amplifier.

The entire test should be repeated at a low and high frequency (such as 100 and 10,000 cycles), in addition to the 1000-cycle frequency employed in the foregoing series. This will enable the technician to determine whether amplification is uniform throughout the audio spectrum. If the amplifier has a tone control, separate tests should be made at various settings of that control.

A stage-by-stage signal voltage measurement of this kind is a dynamic test of the amplifier and should follow the complete dc and ac voltage measurements described in Sections 3.1 and 3.2 of this Chapter. The signal voltage test will isolate defective stages quickly and will even disclose bad tubes. The whole series of voltage measurements described thus far in this Chapter form the basis of a complete trouble shooting procedure. They may appear unnecessarily laborious, but after a reasonable amount of practice, they may be performed in a routine manner with complete ease.

3.4 TONE CONTROL TESTS

Connect the Polymeter, set to AC VOLTS, across the speaker voice coil or across a substitution load resistor (as described in Section 3.3). Set the amplifier volume control at about $\frac{1}{2}$ maximum. Connect an audio oscillator to the amplifier input terminals, as shown in Figure 3-2. If the amplifier is a low-gain unit, dispense with the signal voltage divider and use the oscillator output control to adjust the input signal to a comfortable level. Adjust the *maximum* input signal to approximately 1 millivolt if the amplifier is high-gain.

Set the tone control to its bass position. Starting at about 50 cycles, increase the oscillator frequency in regular steps up to 10,000 cycles, recording the output voltage (as indicated by the Polymeter) at each frequency setting. *Keep the input signal voltage constant.* Draw a *frequency-vs-output* voltage curve from the data obtained. Next, set the tone control to its middle position and repeat the frequency run as before. Finally, set the tone control to its treble position and repeat the frequency run. The three curves obtained will show completely the performance of the amplifier in each position of the tone control. The technician will be able to see at a glance which band of frequencies is emphasized and which is muted by the tone control, also where cutoff points are located.

3.5 FIDELITY TESTS

Fidelity of an audio amplifier, that is its ability to reproduce faithfully all frequencies in the useful audio spectrum, is checked in the same manner de-

100,000 Ω $\frac{1}{2}$ WATT CARBON RESISTOR

A B

TO AMPLIFIER INPUT TERMINALS

AUDIO OSCILLATOR (SYLVANIA TYPE 145)

100 Ω $\frac{1}{2}$ WATT CARBON RESISTOR

INPUT SIGNAL DIVIDER FOR AMPLIFIER TESTS

FIGURE 3-2

scribed in Section 3.4. A true high-fidelity amplifier would give a straight-line frequency resonance curve.

The tone control preferably should be removed from the circuit temporarily when making a fidelity test, since this control is operated intentionally to modify the response curve.

A fidelity test serves to reveal faulty circuit components and, in newly-constructed amplifiers, poor design as well. Dropping off of fidelity, due to distortion resulting from overloading, can be localized by checking dc grid voltages. These voltages will show up as positive, instead of negative, at points 3, 9, 14, 18, and 23 (Figure 3-1) if overloading is present. This assumes, of course, that the amplifier stages are biased class-A throughout. Class-B and class AB_2 grids normally are driven somewhat positive.
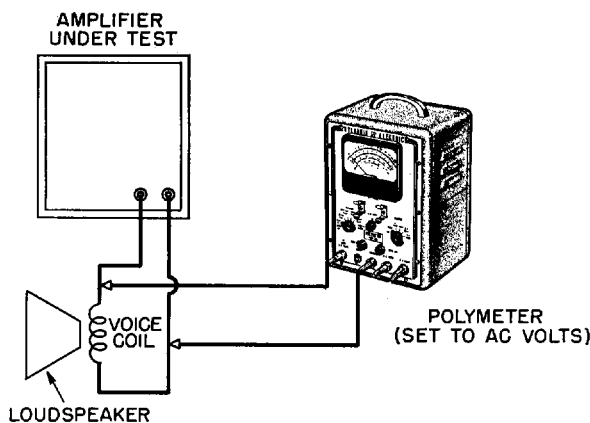
3.6 GAIN TESTS

Voltage gain is an indication of amplification. Gain measurements are made very simply by applying a signal voltage of known value to the input of an amplifier or amplifier stage and measuring the amplified output voltage. The output voltage divided by the input voltage expresses the voltage gain. Thus, an input of 10 millivolts and output of 1 volt shows a gain of 100. The voltage gain of the 2nd stage in Figure 3-1 may be checked, for example, by applying a known signal voltage to point 9 (volume control set for maximum output) and checking the output signal voltage at point 14. Point 2 is common to both input and output voltages. In addition to per-stage gain (or loss), the gain of an entire amplifier also may be checked by feeding a known signal voltage into the input and measuring the output voltage.

Gain often is expressed in decibels. Voltage gains obtained in the manner just described may be converted to db by means of the following calculation:

$$db = 20 \log_{10} \frac{E_1}{E_2}$$

Here E_1 is the measured output voltage, and E_2 the measured input voltage. For accurate determinations,

the impedance of input and output circuits must be taken into consideration.

Gain tests should be made at several frequencies in the audio spectrum and at several settings of the volume and tone controls of the amplifier.

3.7 HUM LEVEL MEASUREMENTS

Figure 3-3 shows the arrangement of equipment for checking amplifier hum level with the Polymeter, used as a high-input resistance ac voltmeter. The amplifier volume control must be set for maximum output; and the tone control must be set to its bass position, in order to transmit hum frequencies. There should be no signal input to the amplifier. The Polymeter, connected across the loudspeaker voice coil, will indicate the hum voltage directly. This voltage may be compared to the voltage measured with normal signal output, to determine the ratio of hum to maximum signal voltage. Thus; the hum voltage may be expressed as a percentage of the maximum signal output voltage, or it may be shown to be a certain number of db below maximum signal.

The technician must determine, by means of a listening test, that the voltage being measured actually is due to hum and not to noise or oscillation.

3.8 NOISE LEVEL MEASUREMENT

Noise level, detected in amplifiers having very high gain, is measured with the Polymeter in the same way described for hum measurements (See Section 3.7). A listening test will decide that the phenomenon under test is noise and not hum or oscillation.

3.9 POWER OUTPUT MEASUREMENT

Figure 3-4 shows the setup for measuring the power output of an amplifier.

The loudspeaker voice coil is disconnected temporarily and, in its place, is connected a load resistor. The latter must be equal in ohms to the voice coil impedance at the frequency used. The minimum wattage of this resistor must be equal to twice the rated power output of the amplifier. Thus; for temporary replacement of a 16-ohm voice coil in a 20-watt amplifier, the load resistor must be 16 ohms, 40 watts minimum.

To make the test, set the audio oscillator to 1000 cycles and reduce its output to give maximum undistorted amplifier output. (Check the distortion by means of a listening test before disconnecting the speaker voice coil). Read the output voltage as indicated by the Polymeter. Determine the power output in watts by squaring the voltage and dividing by the load resistance. Thus, a measured voltage of 10 v. across a 16-ohm resistor would result in

$$\frac{10^2}{16} = \frac{100}{16} = 6.66 \text{ watts.}$$

Power output should be measured at several frequencies (such as 400, 1000, and 5000 cycles) and at several selected settings of the volume and tone controls.

SETUP FOR HUM AND NOISE TESTS
FIGURE 3-3
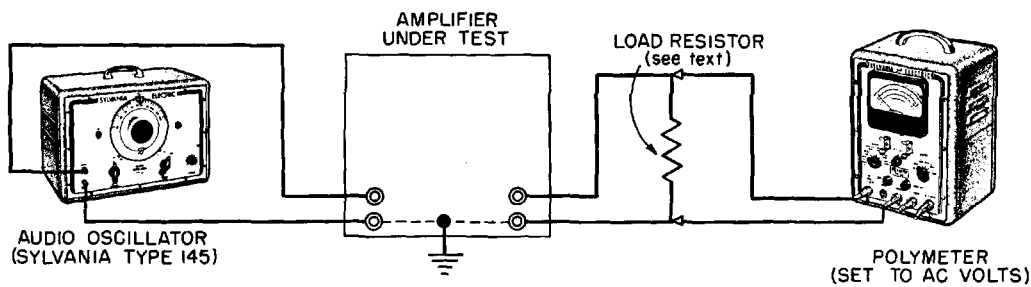
SETUP FOR POWER OUTPUT MEASUREMENT

FIGURE 3-4

3.10 SIGNAL TRACING IN AUDIO AMPLIFIERS

Section 3.3, *Signal Level Measurements in Audio Amplifiers*, covers the procedure to be followed in signal tracing. This dynamic method, using the signal itself as the common denominator, permits rapid localization of trouble in amplifiers.

3.11 DISTORTION MEASUREMENT

Figure 3-5 shows how a bridged-T network and Polymeter, set to AC VOLTS, can be connected to the output of an audio amplifier for measurement of distortion percentage. The bridged-T network can be built by an experimenter.

The bridged-T consists of choke CH, capacitors C_1 and C_2, and rheostat R. The capacitors are selected to resonate the choke to the test frequency (supplied by the oscillator), say 400 or 1000 cycles. This combination must be worked out experimentally for the particular choke which is available to the technician. The choke must have low resistance (high Q). The bridged-T network is a null circuit. It *removes* the test frequency and allows all other frequencies to pass through. Switch S short-circuits the network during initial adjustments.

Replace the loudspeaker voice coil with a load re-

sistor (for directions, see Section 3.9). Supply a signal to the amplifier input terminals at the frequency of the bridged-T network. Close switch S, and read the signal output voltage with the Polymeter. Record this voltage as E_1. Open switch S, noting that the meter reading drops to a lower value. Adjust the oscillator frequency for lowest dip (null) in voltage reading. Adjust rheostat R for still lower null. Record the small null voltage as E_2. The total distortion percentage (in terms of the fundamental) equals E_2/E_1 times 100.

The theory of this method of measurement is simple. The network removes the fundamental test frequency. Any voltage then remaining at its output terminals is due to total harmonics (distortion) present.

Distortion measurements should be made at several selected settings of the volume and tone controls and also at several values of input signal voltage. For a complete examination of an amplifier, distortion also should be checked with the loudspeaker voice coil in place of the substitution load resistor.

3.12 LOUDSPEAKER MATCHING

When no information is available regarding the impedance values of the various taps of a universal output transformer, the transformer can be matched to the loudspeaker voice coil with the aid of an ac
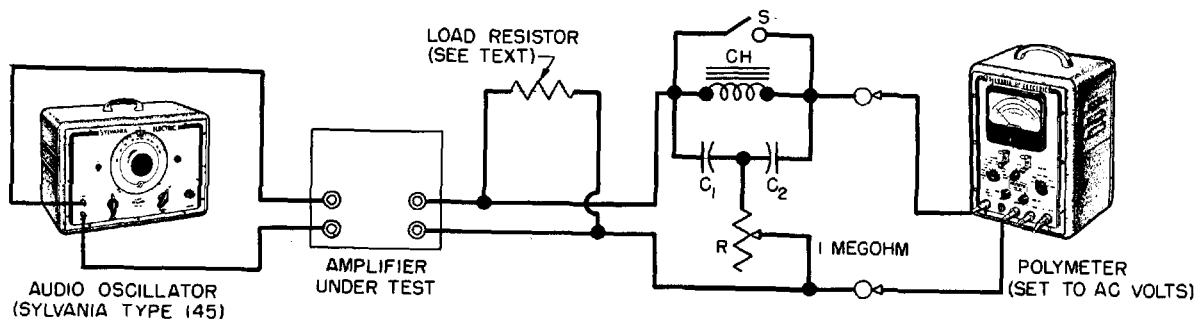
SETUP FOR DISTORTION MEASUREMENT

FIGURE 3-5

vacuum-tube voltmeter. Figure 3-6 shows how the Polymeter is used in this operation.

Feed a steady-voltage signal at 400 or 1000 cycles into the amplifier. Connect the Polymeter, set to AC VOLTS, across the loudspeaker voice coil, as shown in Figure 3-6. Connect the speaker successively across each pair of output taps on the transformer secondary, and record the voltage obtained with each combination.

The highest voltage indicates the most favorable impedance match, as far as transferring maximum power is concerned. However, this will not always be the connection affording least distortion. For this reason, the technician should supplement his observations of voltage with listening tests. In some amplifier-speaker combinations, it will be necessary to select a pair of taps which, although not affording *maximum* voltage, give the minimum of distortion and hum. Usually, there will be more than one such combination, and the one chosen should be the one affording highest voltage.

3.13 SCRATCH OR WHISTLE FILTER ADJUSTMENT

Some amplifiers are provided with simple filters for attenuating phonograph scratch or heterodyne whistles. To determine the effectiveness with which these filters operate, the Polymeter may be used to measure output voltage of the amplifier with and without the filter. A good frequency for this test is 10,000 cycles, which may be supplied to the amplifier input terminals by an audio oscillator, such as Sylvania Type 145.

Check the output voltage (E_1) with the Polymeter set to AC VOLTS, with the filter disconnected. Insert the filter and read the output voltage (E_2). The relationship $\frac{E_2}{E_1} \times 100$ shows what percentage of scratch or whistle is transmitted by the filter.
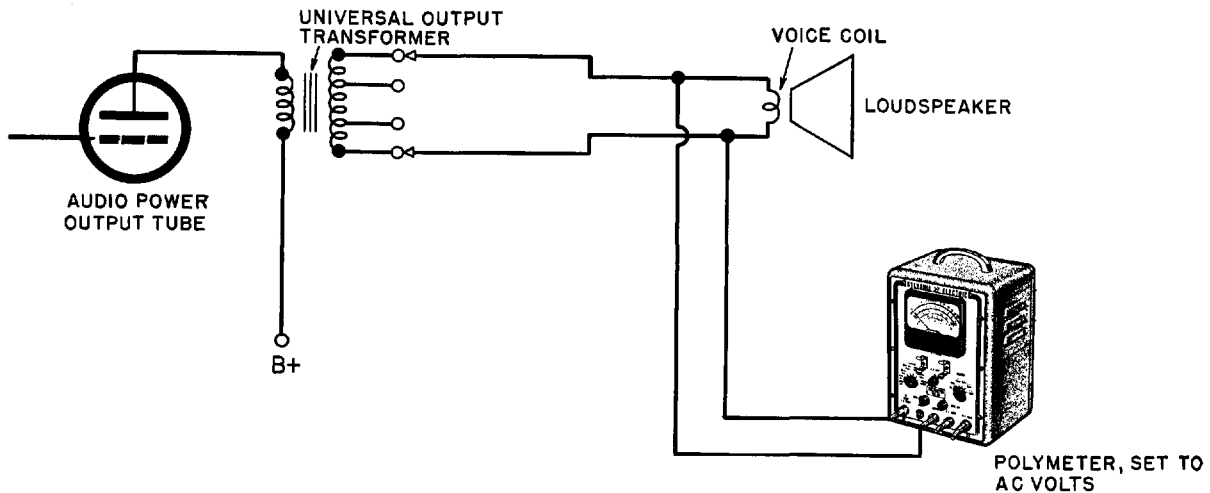
SETUP FOR LOUDSPEAKER MATCHING

FIGURE 3-6

CHAPTER 4

TELEVISION RECEIVER TESTS

Many of the signals appearing at various points in a television receiver circuit are of complex waveform. It is not sufficient to know the *values* of these voltages; their wave shape also must be checked for compliance with proper shapes. Correct operation of the television receiver depends upon maintaining proper waveshape, magnitude, and phase relations of these signals. Obviously, all such complex signal voltages must be examined with a cathode ray oscilloscope, such as Sylvania Type 132Z or Sylvania Type 400. The oscilloscope will show the actual wave shapes. The oscilloscope screen may be calibrated, as explained in Chapter 5, also to indicate the peak value of all complex waves and pulses.

Aside from the presence of complex signals, there are numerous points in a television receiver circuit where dc and ac sine wave voltages are present and must be measured. As in other types of radio receivers, these operating voltages must be maintained at prescribed levels. Serious variations indicate faulty components or misadjustment of circuits. In the general run of servicing, voltage tests alone often localize the cause of circuit trouble. In the television receiver, simple voltages usually are associated with high-resistance and high-impedance circuits and cannot be measured successfully with ordinary voltmeters. The vacuum-tube voltmeter is a necessity in television servicing. Oscilloscope tests must be supplemented by use of the meter.

This chapter is devoted to a discussion of the uses of the universal vacuum tube voltmeter, such as Sylvania Polymeter Type 221Z, in television servicing. Since there are many types of television receiver circuits, just as there are numerous variations of the superheterodyne circuit in radio receivers, we cannot cover all possible applications on these pages. We believe that our discussion will serve to clarify the whole general subject and will give the television service technician basic grounding in the role of the vacuum tube voltmeter in television adjustment and trouble shooting.

4.1 LOW-LEVEL AC AND DC VOLTAGE MEASUREMENTS

The low-level ac and dc voltages (up to 500 volts) employed in a television receiver are similar to those found in a radio receiver. Included in this category are plate, screen, grid, cathode, heater, and low-voltage power supply voltages. These potentials are measured with the Polymeter in the same manner as the corresponding voltages in a radio receiver (See Sec-

tions 2.1 and 2.2 Capter 2). The same procedures are employed as those described previously for ac and dc voltage measurements in receivers and amplifiers. However, the technician must be extremely careful when making these measurements not to come into accidental contact with the high-voltage points in the television circuit.

When checking low-level voltages in the television circuit, do not feed a signal of any kind into the receiver input terminals. Disconnect the antenna completely from the set. Make a complete check of all low-level ac and dc voltages in each receiver stage, and compare the readings with those given in the set manufacturer's service data or found in service manuals. These measurements often will reveal troubles quickly, by turning up open or short-circuited capacitors, resistors, chokes, transformers, and similar components. Study the circuit diagram of the receiver before starting to make voltage tests. Note carefully the various components connected to a particular test point, in order best to interpret abnormal variations in voltage.

4.2 HIGH-VOLTAGE MEASUREMENTS

The high dc anode voltages of television picture tubes may be measured with the Polymeter by means of the safety type dc voltage multiplier probes obtainable as accessories for this instrument.
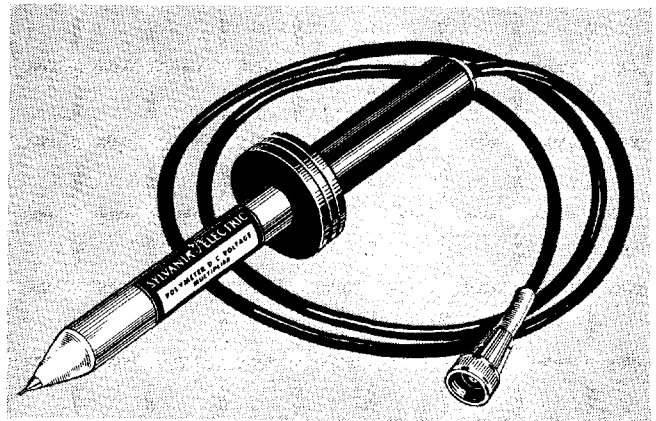
Type 225 30-kilovolt external probe
Figure 4-1

Two dc voltage multiplier probes are available. Type 223 converts the 1000-volt dc range of the Polymeter into a 10,000-volt range. Type 225 converts the 1000-volt range into a 30,000 volt range, or the 300-volt range to 9000 volts. Both multiplier probes are

provided with flexible safety-type high-voltage cable terminated by microphone-type connectors which are screwed into the DC VOLTS connector on the Polymeter front panel. The Type 225 30-kilovolt dc multiplier is shown in Figure 4-1. Both high-voltage multipliers may be seen in front of the instrument in Figure 1-11.

The following procedure is recommended in checking the high dc anode voltage of a picture tube, or the dc output of a high-voltage power supply: (1) *All high voltages are dangerous*, regardless of the type of power supply used. The picture tube anode potential is high enough to be dangerous to life. Avoid shocks. Use more than ordinary caution when checking this voltage. (2) Do not switch the television receiver on until all connections first have been made to the meter. (3) Connect the COMMON lead of the Polymeter firmly to the television chassis (or to the high-voltage negative terminal if the chassis is not at B-minus potential). If the television receiver is operated by a transformerless type of power supply, use a 1:1 isolating transformer between the set and the power line. (4) Screw the voltage multiplier probe cable connector firmly to the DC VOLTS connector on the meter panel. (5) Set the meter range switch to 1000 volts. (6) Set the function switch to its positive (+) position. (7) Place the voltage multiplier probe firmly into contact with the positive high-voltage test point in the circuit. (8) After the Polymeter has been zeroed, switch on the television receiver and turn its brightness control down to minimum so that the tube screen is dark. (9) Read the dc voltage on the 1000-volt scale. Multiply by 10 if the Type 223 probe is used, or by 30 for the Type 225. (10) Switch off the receiver and wait for the meter pointer to fall fully to zero. Then, disconnect the meter leads, multiplier leads first.

By making the high-voltage dc measurement with the picture tube darkened, a more accurate reading is obtained. The Polymeter drain from the power supply will be equal approximately to that of the picture tube when bright. The instrument will check the dc output voltage of rf, fly-back, and power-frequency-type high-voltage power supplies. However, do not attempt to check the high ac voltage ahead of the rectifier tube, since the external probe may not be used with the ac range of the instrument.

If it becomes necessary to hold the high-voltage probe while making a test, grip the handle firmly and keep the fingers back of the safety flange. Do not remove the safety flange from the handle. Keep the cable out of contact with the body and do not touch the metal case of the meter. It is a good rule of safety during high-voltage measurements to keep one hand in your pocket.

4.3 MEASUREMENT OF OSCILLATOR STRENGTH

The superheterodyne oscillator (or the oscillator portion of the converter stage) may be checked for

| Channel Number	Channel Freq. (Mc)	Picture Carrier Freq. (Mc)	Sound Carrier Freq. (Mc)
2	54–60	55.25	59.75
3	60–66	61.25	65.75
4	66–72	67.25	71.75
5	76–82	77.25	81.75
6	82–88	83.25	87.75
7	174–180	175.25	179.75
8	180–186	181.25	185.75
9	186–192	187.25	191.75
10	192–198	193.25	197.75
11	198–204	199.25	203.75
12	204–210	205.25	209.75
13	210–216	211.25	215.75

Television Frequency Data.
Figure 4-2.

activity by (1) measuring the rf output voltage delivered by this stage, or (2) checking the dc grid bias of the oscillator.

The wide-band response of the Polymeter RF probe (up to several hundred megacycles) permits measurement of oscillator output voltage even at the highest television channel frequency. (See Figure 4-2 for channel frequencies). For this test, place the RF probe as close as practicable to the point of measurement. Use the contact pin of the probe directly without any connecting leads; and fasten the probe-case ground clip to the chassis, or other ground point, preferably also without any connecting lead whatever. Check the oscillator rf output voltage on each channel. Do not apply a signal of any kind to the receiver input terminals—disconnect the antenna from the set.

The dc grid voltage of the oscillator is checked with the Polymeter set to DC VOLTS. Connect the COMMON test lead firmly to the chassis, and keep the fingers well away from the contact pin of the DC probe. Touch the DC probe directly to the grid terminal of the oscillator tube socket. The bias voltage measured here is negative in polarity and will be directly proportional to the strength of oscillation. If the grid terminal is touched momentarily with the finger tip, the meter reading should decrease sharply, indicating the presence of oscillation. Repeat the grid voltage measurement on each channel.

4.4 BANDWIDTH MEASUREMENT

Bandwidth of the video if amplifier and alignment of this portion of the receiver can be checked by means of an unmodulated signal applied to the converter tube grid, and a Polymeter (set to DC VOLTS) connected across the video detector load resistor as shown in Figure 4-3. If the wide if bandwidth is obtained by stagger tuning, several of the if trimmers are set to a frequency at the lower end of the pass band, and the remainder of the trimmers to a frequency near the top end of the pass band. Generally, the even-numbered trimmers are set to the low fre-
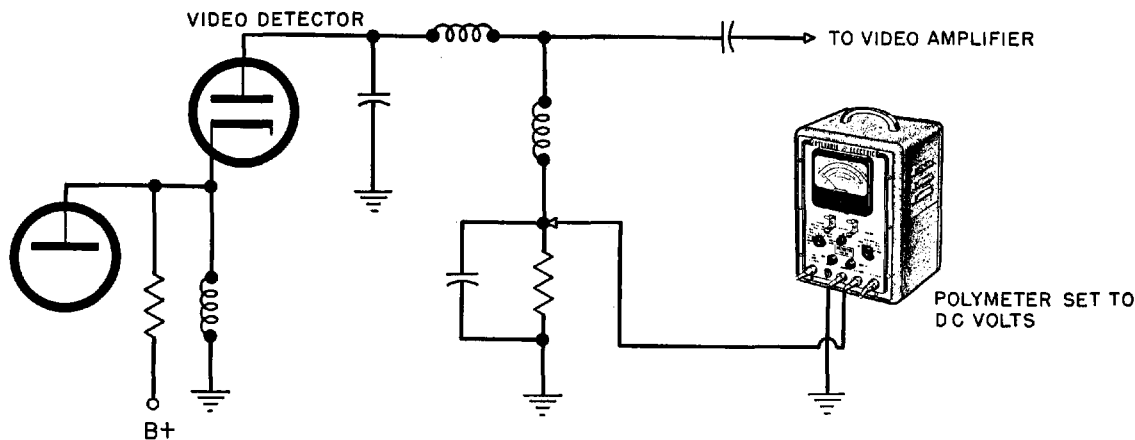
SETUP FOR TELEVISION BANDWIDTH TEST

FIGURE 4-3

quency, and the odd-numbered ones to the high-frequency. Set the signal generator to the lower alignment frequency and adjust the proper if trimmers for peak deflection of the meter. Then switch the generator to the higher alignment frequency and set the other trimmers for peak meter deflection. To check the bandwidth, swing the signal generator tuning in steps through the entire pass band and slightly outside on each end, keeping the generator output constant. Record the meter readings at each frequency setting, and draw a curve band from this information. This curve will show the width and shape of the pass band.

In sets which do not have stagger tuning but obtain wide bandwidth by means of overlapping or loading, set the signal generator to the specified intermediate frequency (See manufacturer's specifications). Adjust each if trimmer for peak meter deflection. Then swing the generator frequency in steps throughout the pass band and slightly outside on each end, keeping the generator output voltage constant. Record the meter reading at each frequency setting. Draw a bandwidth curve from the data obtained.

Bandwidth of the video amplifier can be checked by applying a constant-voltage signal to the input of the video amplifier and checking the amplified signal voltage at the output terminals of the video amplifier. The regular AC probe may be used up to 15 kc with the Polymeter set to AC VOLTS. The RF Probe must be used at frequencies higher than 15 kc, with the Polymeter set to RF VOLTS. Both an audio oscillator (Sylvania Type 145) and unmodulated rf signal generator (Sylvania Type 216) will be required. The frequency coverage afforded by the instruments should be 20 cycles to 4 megacycles. Note the meter reading at each test frequency. Maintain the voltage output of the test generator constant. Draw a bandwidth curve from the data obtained.

4.5 CHECKING WAVETRAP OPERATION

Apply an unmodulated rf signal to the front end of the receiver, ahead of the stage in which the wavetrap is installed. Set the Polymeter to DC VOLTS and connect it across the load resistor of the video detector, as shown in Figure 4-3. Set the signal generator to the frequency to which the trap is to be adjusted. Adjust the wavetrap trimmer for minimum deflection (dip) of the meter if the trap is a rejection unit. Adjust for peak deflection of the meter if the trap is a transmission (pass) unit.

The 4.5 Mc. trap found in intercarrier type television receivers is adjusted by applying a 4.5-Mc. unmodulated signal to the 1st video amplifier tube grid reading the rf voltage at the output terminals of the entire video amplifier, and adjusting the trap for minimum reading (dip) of the meter.

4.6 SOUND CHANNEL TESTS AND ALIGNMENT

The sound channel of a television receiver may be aligned closely by using the Polymeter, set to DC VOLTS, as a resonance indicator. Connect the meter to the discriminator or ratio detector, as shown in Figure 2-3.

4.7 CHECKING PICTURE SIGNAL VOLTAGE

The picture-signal voltage level may be measured with the Polymeter set to RF VOLTS. Touch the contact pin of the rf probe directly to the video grid terminal of the picture tube socket. To convert the readings into approximate *peak* voltage values, multiply by 1.414.

4.8 MEASURING DEFLECTING VOLTAGE

In television receivers employing electrostatic deflection, the voltages at the deflecting plates may be

33

checked with the Polymeter to verify operation of the sweep circuits. Use the rf probe on the horizontal plates, and the AC probe on the vertical plates. It is preferable to use an oscilloscope such as Sylvania Type 400 to check the amplitude and waveform of deflecting coil voltages in receivers employing electromagnetic deflection.

4.9 SIGNAL TRACING IN A TELEVISION RECEIVER

The well-known advantages of signal tracing are available in shooting trouble in television receivers. While the oscilloscope unquestionably must be used to determine the operating condition of several of the stages, the vacuum tube voltmeter may be employed in tracing a signal through most of the receiver. Figure 4-4 is a block diagram of a typical television receiver, showing the points at which signal voltages may be checked advantageously with the Polymeter.

The following procedure is representative of the steps which should be taken in signal tracing in all types of television receivers. (1) First, check dc voltages at points 16 and 17 to determine that the high- and low-level power supplies are operating. Then, make a complete series of ac and dc voltage tests as described in Sections 4.1 and 4.2 of this Chapter. Apply no signal to the antenna input terminals while these tests are being made. (2) With no input signal, check the oscillator rf output voltage at 15. (3) Supply an unmodulated signal to the antenna input terminals of the receiver. The frequency of this signal must be that of the *video* (picture) carrier of the channel to which the receiver tuning is set (See Figure 4-2 for frequencies. (4) Connect the Polymeter, set to RF VOLTS, to 1 and tune-in the signal carefully as indicated by peak deflection of the meter. (5) Check the rf signal voltage successively at points 2, 3, 4, 5, 6, and 11. Lack of signal or weak signal at any of the points between 1 and 11 indicates failure or misalignment of the stage at whose output the voltage

is tested. (6) Amplitude-modulate the test signal and check the signal voltage at points 7, 8, and 9. (7) Change the signal generator tuning to the sound frequency of the channel to which the receiver is tuned (See Figure 4-2). Apply frequency modulation to the generator and check the signal voltage at 12, 13, and 14. Tune the receiver carefully for peak deflection of the meter.

For a complete signal tracing analysis of the receiver, repeat the entire series of tests on each channel covered by the receiver. The signal voltage at all points not numbered in Figure 4-4 must be checked with an oscilloscope, such as Sylvania Type 132Z. This is because the signals at these points have complex waveforms and cannot be measured accurately with a meter.

The Sylvania book *Servicing TV Receivers* gives detailed explanations of use of the picture on the screen, test patterns, the oscilloscope, and wide-band sweep generators (such as the Sylvania Type 500) in those circuit tests which cannot be handled accurately by the vacuum tube voltmeter. The reader is referred also to the article *Checking Television Waveforms with a Cathode Ray Oscilloscope* which appeared in the February 1949 issue (Vol. 16, No. 2) of SYLVANIA NEWS.

4.10 CHECKING TELEVISION RF POWER SUPPLIES

Some television receivers such as 7-inch sets employing electrostatic deflection, use radio-frequency-type high-voltage power supplies. The dc output voltage of this type of power supply may be checked, as described in Section 4.2 of this Chapter, using an external high-voltage probe with the Polymeter. It is not practical to check the high-tension rf voltage ahead of the rectifier tube, however, since this potential is several thousand volts and accordingly is too high for the rf probe. The rf voltage across the primary coil of an rf power supply can be measured, however, if it does not exceed 300 volts rms.
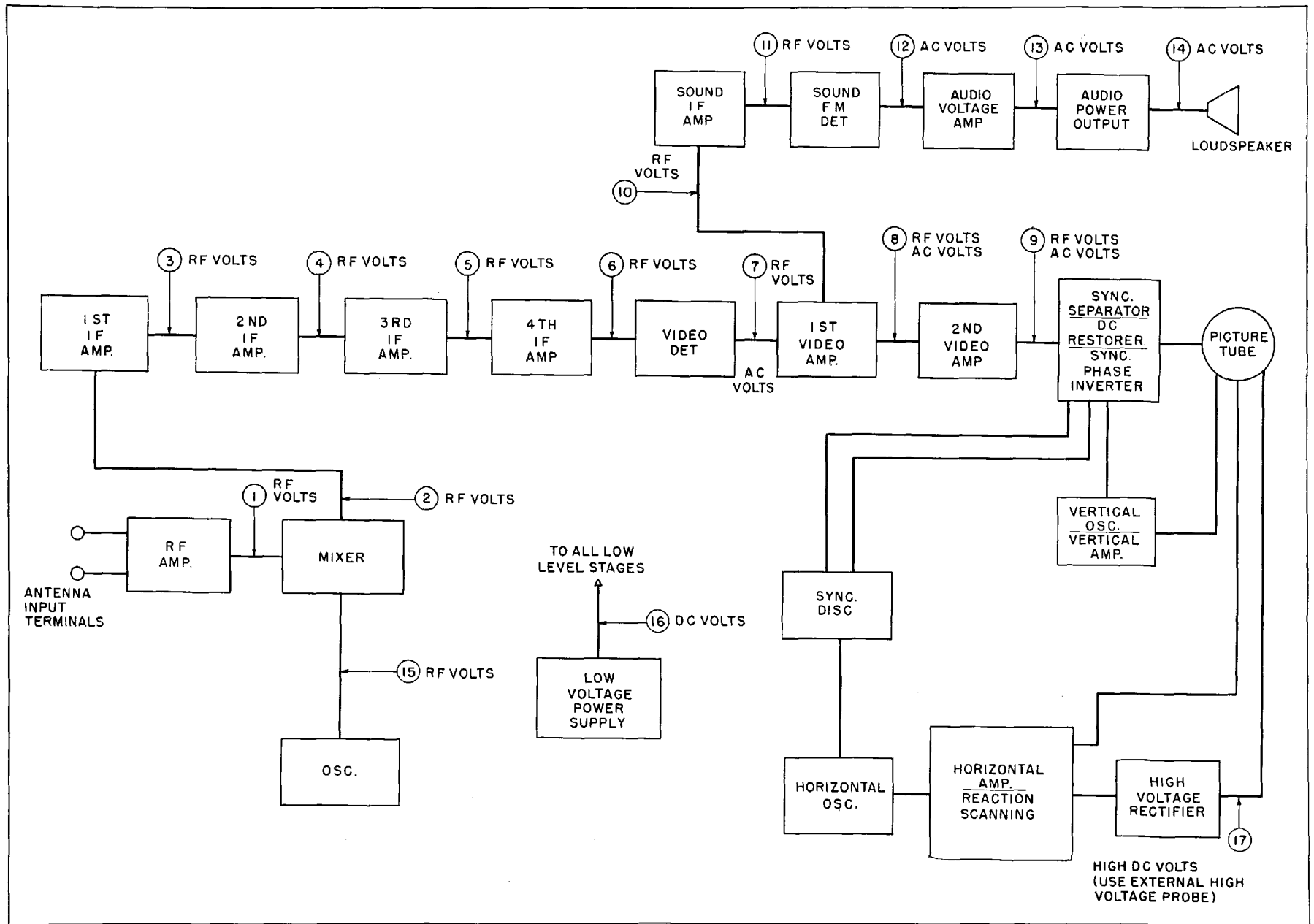
FIGURE 4-4   BLOCK DIAGRAM OF TYPICAL TELEVISION RECEIVER, SHOWING SIGNAL TEST
POINTS FOR VACUUM TUBE VOLTMETER

CHAPTER 5

MISCELLANEOUS APPLICATIONS

5.1 POWER SUPPLY RIPPLE

A measurement of the amount of ripple present in the dc output of a power supply is important in determining how well the filter units perform. Power supplies intended for operation of high-quality receivers, high-gain audio amplifiers, and sensitive test instruments must have low ripple values, under 1 percent. The instrument used to measure the ripple voltage must have negligible loading effect upon the power supply.

To check the amount of ripple, the power supply is conected to its normal load. Check the dc output voltage by means of the Polymeter, set to DC VOLTS, connected across the output terminals of the filter. Record this voltage as E_1. Switch the Polymeter to AC VOLTS and reconnect it across the power supply output (for safety, make all meter connections *before* switching-on the power supply). Read the small ac (ripple) voltage and record it as E_2. The ripple percentage then is determined by dividing E_2 by E_1 and multiplying by 100.

5.2 POWER SUPPLY PEAK VOLTAGES

Figure 5-1 shows test points for measuring peak voltages in a typical ac-operated power supply. The dc output terminals of the power supply must be connected to the normal load device to which the power supply furnishes energy—or, in its absence, to a load resistor (R) which draws the same amount of current.

Set the Polymeter to AC VOLTS. Connect the COMMON test lead to point D. Switch-on the power supply and measure voltages at A, B, and C. Since the Poly-

meter ac voltage scales read in rms values, these readings must be multiplied by 1.414 to obtain peak values. The voltages obtained at B and C indicate peak values across capacitors C_1 and C_2 respectively. The peak voltage across the first filter choke (CH_1) may be read between A and B; and across the second filter choke (CH_2) between B and C.

In power supplies used with radio equipment, amplifiers, and test instruments, peak voltages in the filter section usually rise to high values while the tubes in the external circuit are heating, and gradually decrease as the tubes come up to normal operating temperature. For this reason, peak voltages should be measured from the instant the equipment first is switched on, to detect high initial voltages.

In Figure 5-1, the input filter choke, CH_1, limits the peak voltage across the first filter capacitor C_1. Most simple power supplies omit the input choke. The resulting high peak voltage which accordingly is applied to the input capacitor often is responsible for early failure to the latter. It is important when checking such power supplies to measure this peak voltage and to select an input filter capacitor rated to withstand the full voltage. The peak voltage across the first filter capacitor often is several times the dc output voltage of the filter.

Peak voltages may also be measured between plate and cathode of the rectifier tube or between corresponding elements of a selenium rectifier.

5.3 VIBRATOR PEAK VOLTAGES

High peak voltages are set up across the vibrating contacts in vibrator-type power supplies employed in
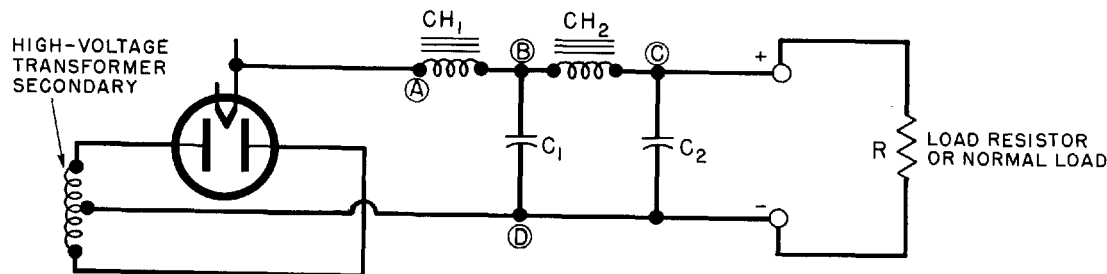
TEST POINTS FOR PEAK VOLTAGE MEASUREMENT
FIGURE 5-1

36

auto radios and other portable electronic equipment. The buffer capacitor connected in parallel with the vibrating contacts for spark suppression must be rated to withstand this high peak voltage. Vibrator peak voltage may be measured by means of an ac vacuum-tube voltmeter connected across the contacts.

The ac range of the Polymeter will handle rms voltages up to 1000 volts only. This corresponds to 1414 peak volts. No attempt should be made to check higher values with this instrument.

5.4 IMPEDANCE CHECKING

Figure 5-2 shows a simple setup for impedance measurement. This arrangement permits checking impedance (in ohms) of inductors, capacitors, chokes, voice coils, transformer windings, etc. The operating principle is simple. The audio oscillator passes current through the unknown impedance (Z) and a calibrated non-inductive variable resistor (R), such as a laboratory decade box, in series. The ac vacuum-tube voltmeter is connected to a spdt switch, S, so that it may be connected to read either the voltage across the impedance (switch position 2) or the voltage across the calibrated resistor (switch position 1). Resistance R is adjusted until the voltage readings are the same for each position of the switch. At this point, R = Z, and the unknown impedance value may be read directly from the calibrated dial of the resistor.

If a calibrated variable resistor is not available, a simple volume-control-type potentiometer may be used. After the control has been adjusted for equal readings of the meter, remove it from the circuit carefully without disturbing its setting. Then, read its resistance setting with the Polymeter set to OHMS. This reading will indicate directly the unknown impedance value.

The impedance of radio and electronic components usually is checked at 400 or 1000 cycles. For this purpose, a good audio oscillator is required in the setup shown in Figure 5-2. When 60-cycle impedance values
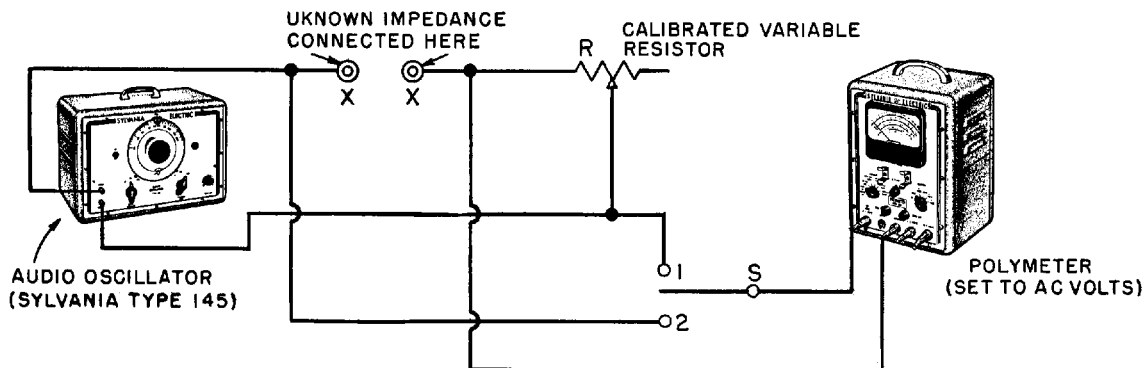
are satisfactory, the test signal can be obtained from the 6.3-volt secondary of a filament transformer.

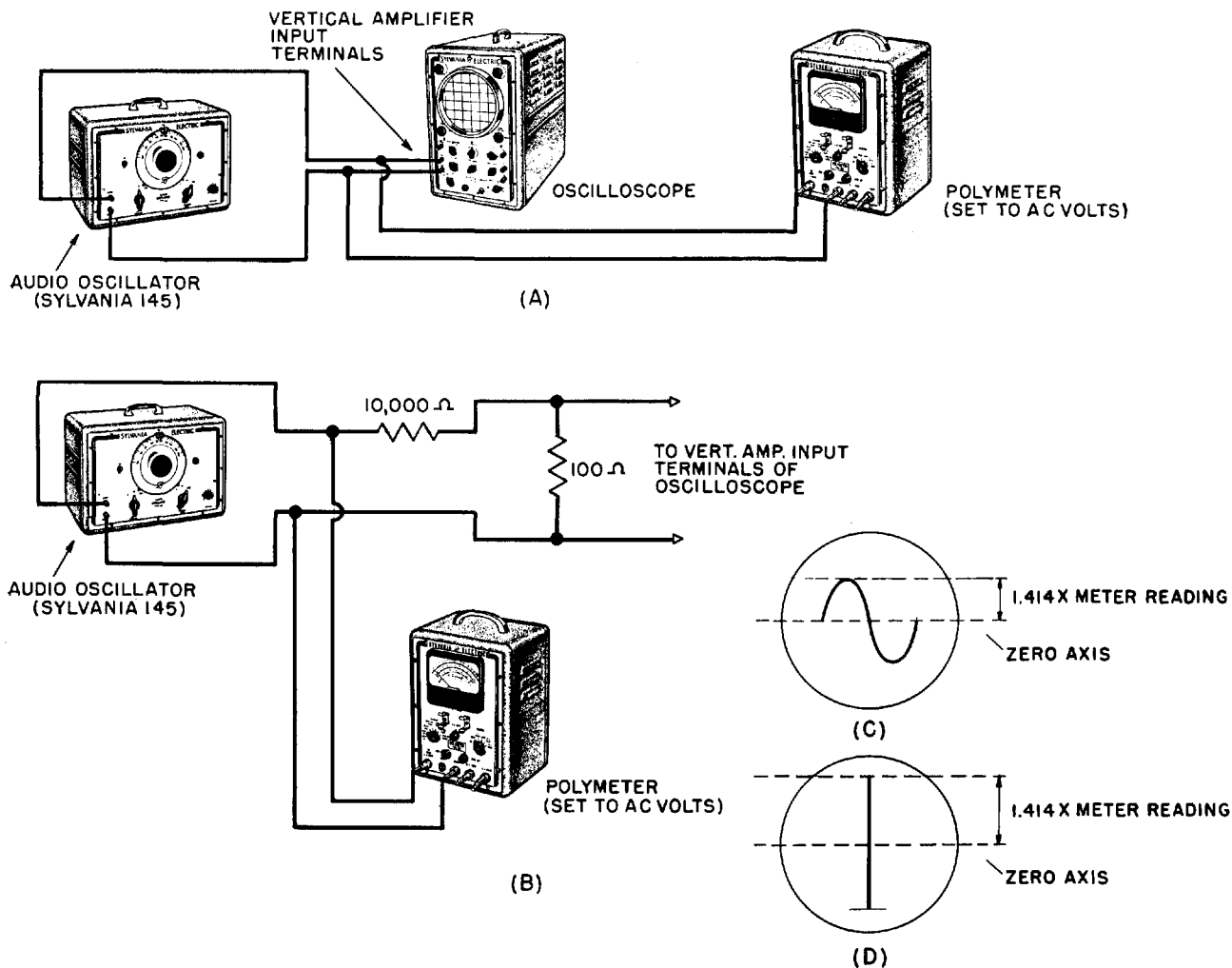## 5.5 CALIBRATION OF OSCILLOSCOPE SCREEN

In order that the height (vertical amplitude) of oscilloscope patterns may be translated readily into voltage values, vertical length along the oscilloscope screen must be calibrated in terms of voltage. Figure 5-5 shows the arrangement of apparatus for making this calibration.

Two types of patterns may be obtained on the oscilloscope screen. These are shown in (C) and (D) in Figure 5-3. Pattern C is obtained by setting the sweep oscillator and sync controls of the oscilloscope to give one complete, *stationary* cycle of the test voltage. For voltage indication, the height of this pattern is measured from the zero axis, as shown in the drawing. The test voltage will produce pattern D when the sweep oscillator of the oscilloscope is switched off, and the horizontal amplifier gain control set to zero. Neither pattern may be said to be superior to the other, although it is somewhat easier to measure length along the single vertical line, D, than from zero to the top of the half-cycle, C. The zero axis for both patterns is the point occupied by the single fluorescent dot before a signal is applied. This point is represented by the dot when the oscilloscope is set to give pattern D, and a horizontal line when set for pattern C.

The Polymeter, set for AC VOLTS, is used for the calibration. The signal voltage should be of 1000-cycle frequency, in order that the test might be made at about the middle of the oscilloscope amplifier response curve. (1) Set the vertical gain control of the oscilloscope to maximum, and the SYNC switch to INTERNAL. (2) Slowly increase the audio oscillator output voltage until the pattern occupies the entire vertical length of the oscilloscope screen. (3) Read the meter voltage indication. (4) Decrease the signal voltage to shorten the pattern by one horizontal divi-

SETUP FOR IMPEDANCE MEASUREMENT
FIGURE 5-2

37

VERTICAL AMPLIFIER
INPUT
TERMINALS

OSCILLOSCOPE

POLYMETER
(SET TO A C VOLTS)

AUDIO OSCILLATOR
(SYLVANIA 145)

(A)

10,000 Ω

100 Ω

TO VERT. AMP. INPUT
TERMINALS OF
OSCILLOSCOPE

AUDIO OSCILLATOR
(SYLVANIA 145)

POLYMETER
(SET TO AC VOLTS)

(B)

1.414 X METER READING

ZERO AXIS

(C)

1.414 X METER READING

ZERO AXIS

(D)

OSCILLOSCOPE SCREEN CALIBRATION
FIGURE 5-3

sion on the screen. (5) Read the corresponding voltage on the meter. (6) Repeat, shortening the pattern one more screen division in each step. (7) If the voltage corresponding to small lengths of the pattern is too small to be read on the 3-volt scale of the meter, set up the circuit shown in Figure 5-3 (B). With this arrangement, the signal voltage applied to the oscilloscope will be 1/100 of the meter reading. (8) The meter reads rms voltage values, while the pattern height on the screen indicates the corresponding peak voltage values. Thus, the true value of a given screen height is equal to 1.414 times the meter reading. Convert the series of test voltage readings by means of this multiplier.

As an example, suppose an input signal of 0.15 volt gives a vertical pattern length (from the zero axis to the tip of the pattern) of 1 inch. This 1-inch deflection then corresponds to 0.15 x 1.414, or 0.212 volt. The sensitivity of the oscilloscope accordingly is expressed as 0.212 peak volts per inch of deflection. For a sym-

metrical sine wave, this sensitivity may be expressed also as 0.424 volts *peak to peak.*

The test should be repeated at several settings of the vertical amplifier gain control, and the voltage calibration recorded for each such setting.

A voltage calibration can be made also without the vertical amplifier. This is done by applying the measured test signal voltage directly to the vertical deflecting plates of the oscilloscope tube. However, a much higher calibrating voltage will be required in this case.

5.6 CHECKING WAVE FILTERS

The frequency response of wave filters may be checked in the setup shown in Figure 5-4. The signal generator is either an audio oscillator or rf signal generator, depending upon the frequency range of the filter under test. If an rf generator is used, this unit must be able to supply at least 1 volt output.

The filter must be terminated by a non-inductive resistance equal to the rated output impedance. In
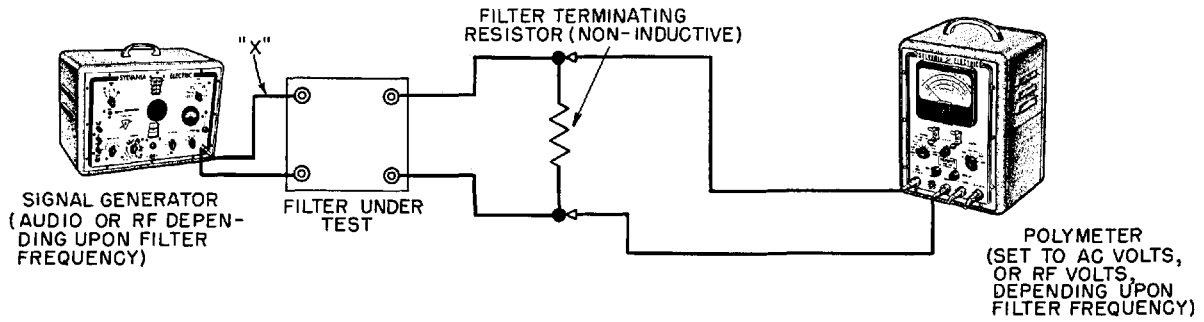
SETUP FOR FILTER CHECKING

FIGURE 5-4

most instances, it will be necessary to connect a second non-inductive resistor, equal to the rated input impedance of the filter, in series with point "x." The ac vacuum-tube voltmeter is connected to read voltage across the output load resistor. The meter is set to AC VOLTS or RF VOLTS, depending upon the frequency range of the filter under test.

The test consists of tuning the signal generator in small steps from a point considerably lower than the specified operating range of the filter to a point considerably higher than the range. The voltage output of the generator must be kept constant. The filter output voltage at each frequency step is read with the meter, and the voltage values plotted against frequency settings to give the filter response curve. Figure 5-5 shows a group of ideal response curves for the four common types of filters.
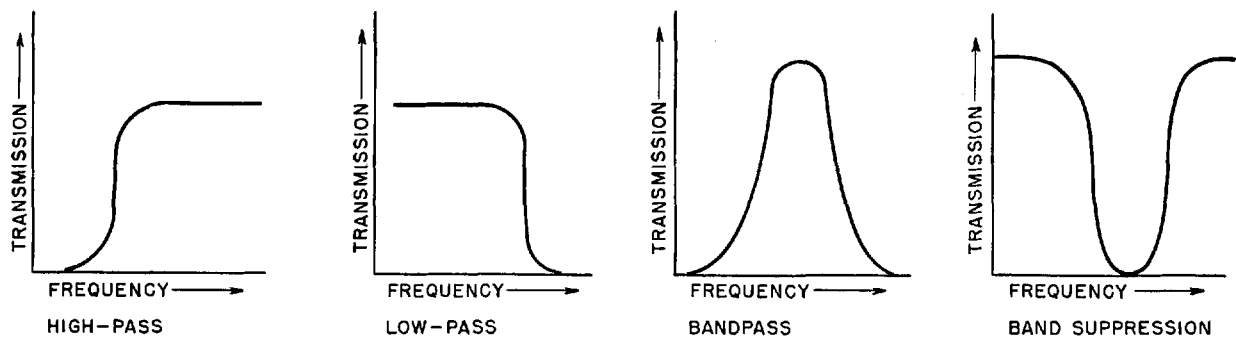
5.7 CAPACITANCE CHECKING

The approximate capacitance of *non-electrolytic* capacitors between 0.01 and 10 microfarads can be checked with the aid of the Polymeter, set to AC VOLTS.

Use the test circuit shown in Figure 5-2. The audio

oscillator is not necessary; a 60-cycle test signal may be obtained from the 6.3-volt secondary of a filament transformer. An ordinary volume-control-type rheostat is used for resistance R. The test procedure is to throw switch S back and forth between positions 1 and 2, while adjusting rheostat R. When the voltmeter reading no longer changes as the switch is thrown, remove the rheostat carefully from the circuit without disturbing its setting. Read the resistance of the rheostat with the Polymeter set to OHMS.
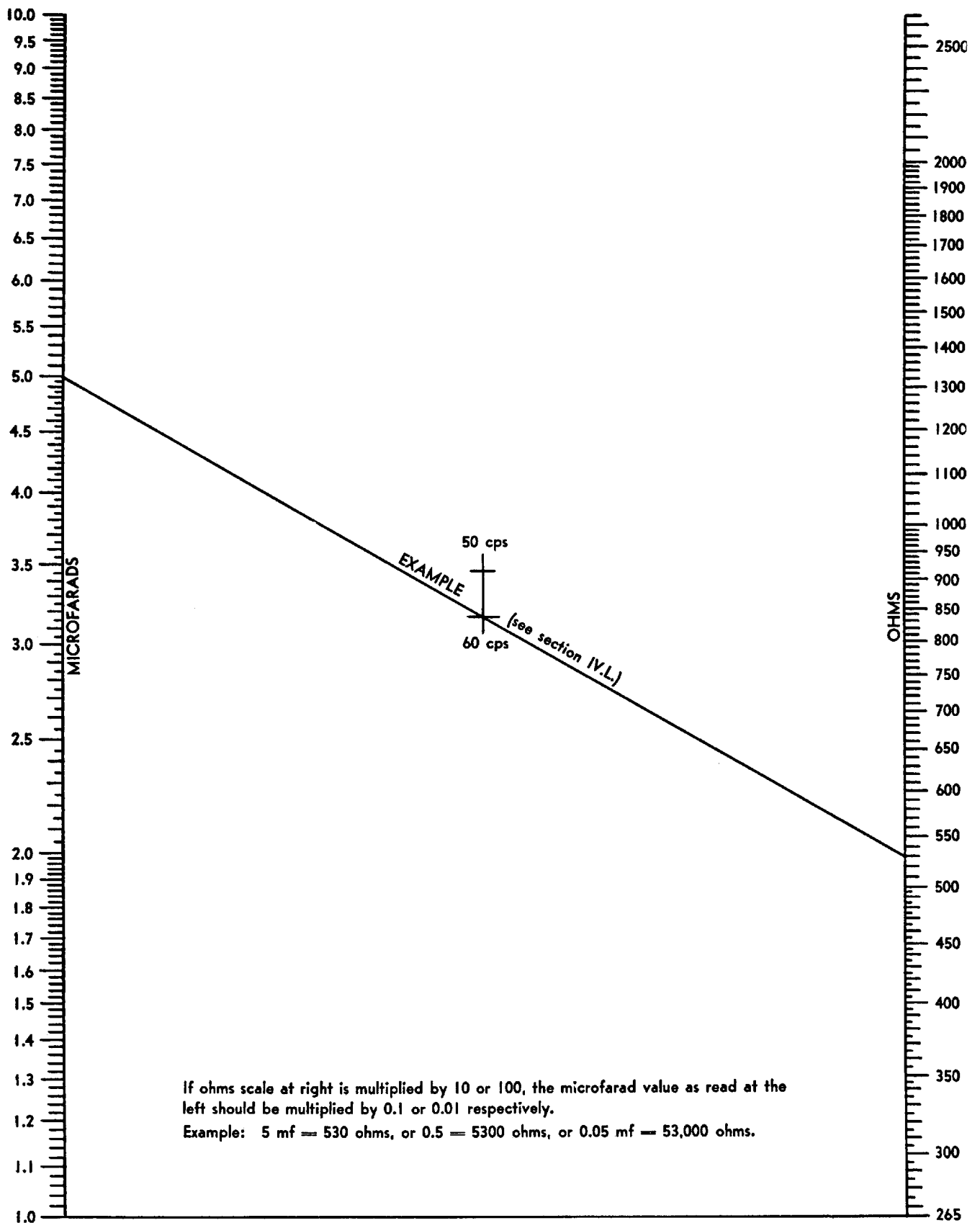
Using the chart given in Figure 5-6, locate this value of resistance on the right-hand scale. Lay a straight edge across the chart so as to connect the resistance point on the right-hand scale with the center of the cross at the center of the chart corresponding to the test frequency used. Both 50- and 60-cycle crosses are given in Figure 5-6. The point of intersection of the straight edge with the left-hand scale indicates the unknown capacitance in microfarads.

A typical example is illustrated in Figure 5-6, the diagonal line across the chart corresponding to the straight edge. The frequency used is 60-cycles. The rheostat setting is 530 ohms. A line thus drawn from this resistance (right-hand scale) through the 60-cycle

IDEAL FILTER RESPONSE CURVES

FIGURE 5-5

REACTANCE CAPACITANCE CHART

FIGURE 5-6

If ohms scale at right is multiplied by 10 or 100, the microfarad value as read at the left should be multiplied by 0.1 or 0.01 respectively.

Example: 5 mf = 530 ohms, or 0.5 = 5300 ohms, or 0.05 mf = 53,000 ohms.
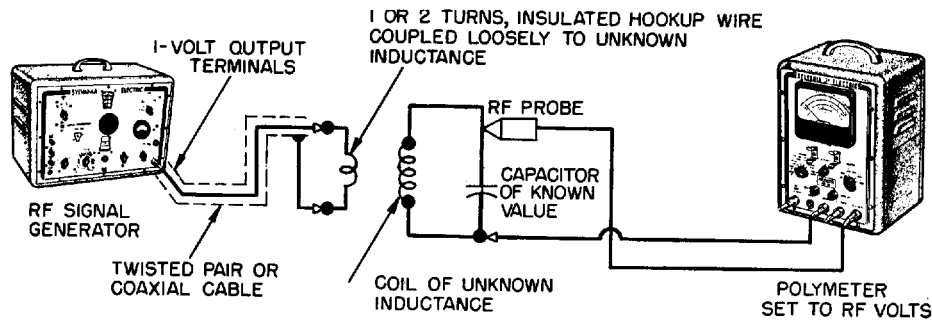
SETUP FOR INDUCTANCE MEASUREMENT

FIGURE 5-7

cross intersects the capacitance (left-hand) scale at 5 microfarads, the unknown capacitance value.

5.8 INDUCTANCE CHECKING

The inductance of coils and chokes from 1 microhenry to several millihenries can be measured with the arrangement shown in Figure 5-7. The essential instruments for this test are an rf signal generator with 1-volt output; a mica, air, or ceramic capacitor of accurately-known capacitance (the actual capacitance is not important, so long as it is not less than 100 $\mu\mu$fd.); and an rf vacuum-tube voltmeter.

The coil of unknown inductance is connected by the shortest possible leads in parallel with the standard capacitance. The vacuum-tube voltmeter then is connected in parallel with this L-C combination. Set the meter to its lowest-voltage range. Energy from the signal generator is coupled into the measuring circuit by means of a small 1- or 2-turn loop, loosely coupled to the unknown coil.

Starting at the *highest* frequency of the signal generator, decrease the frequency slowly through each band until a deflection of the meter is obtained. Increase the separation between the coupling coil and unknown inductance until tuning is smooth, without jumping or "pulling." At the point of peak deflection, read the frequency from the signal generator dial. The unknown inductance then may be calculated from the relationship:

$$L = \frac{25,400}{f^2 C.}$$

L is the unknown inductance in *microhenries*, f the frequency in *megacycles*, and C the standard capacitance in *micromicrofarads*. The accuracy of this method of measurement is governed by the accuracy of calibration of the signal generator and the closeness with which the standard capacitance is known.

For increased accuracy, the capacitance of the rf probe should be subtracted from the value of the standard capacitor, and the answer substituted for C in the preceding formula. Thus; the Polymeter rf probe has a capacitance of 3 $\mu\mu$fd. If a standard

capacitor of 100 $\mu\mu$fd is employed in the setup in Figure 5-7, C in the formula then becomes 100-3, or 97 $\mu\mu$fd. For most ordinary purposes, the accuracy of the measurement will be sufficient without making this subtraction.

5.9 USE OF THE VACUUM-TUBE VOLTMETER AS A BRIDGE NULL DETECTOR

The lowest voltage range of the vacuum-tube voltmeter is useful for visual indications in bridge balancing. When set to its 3-volt dc range, the vacuum-tube voltmeter may be employed as a null detector for dc bridges such as the Wheatstone type. The 3-volt ac range is satisfactory for conventional ac impedance bridges (operated at any frequency up to 15 kc) used for capacitance and inductance measurements.

If "center-zero" operation is desired with the dc null detector, the ZERO SET of the Polymeter 221Z may be adjusted for zero indication on the zero center scale. On other types, connect a 1½-volt dry cell in series with the vacuum-tube voltmeter and bridge. The zero point then will be the 1.5-volt position on the 0-3-volt scale.

5.10 DETECTING GASSY TUBES

Gassy tubes can be detected in non-diode detectors and voltage amplifier stages with the dc vacuum-tube voltmeter by measuring grid bias voltages. These voltages normally are negative with respect to ground or B-minus, but will show up as positive when the tube is gassy. When making this test, the operator must ascertain that the grid is not overdriven by the input signal, or has a leaky coupling condenser since this also will produce a positive grid voltage. This test is not conclusive in power amplifier stages, unless the amplifier is biased class A.

5.11 DETECTING LEAKY COUPLING CAPACITORS

Leaky coupling capacitors in resistance-capacitance-coupled stages give rise to distortion and shorten tube

41
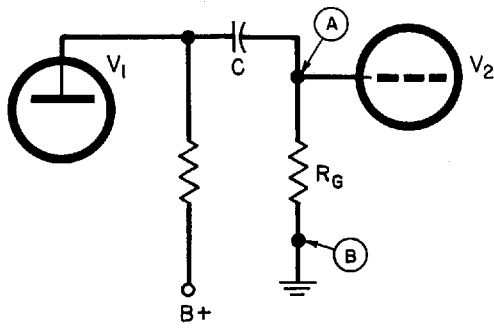
DETECTING LEAKY COUPLING CAPACITOR

FIGURE 5-8

life. A defective capacitor of this kind can be detected easily with the dc vacuum-tube voltmeter.

Figure 5-8 shows two tubes, V_1 and V_2, coupled by means of a resistance-capacitance network. The grid bias voltage of V_2 may be measured between points A and B. Point A normally will be negative. If the insulation resistance of coupling capacitor C is high, the plate voltage of tube V_1 will be blocked from grid resistor R_g, and the grid voltage of V_2 will not be affected by the plate voltage. If capacitor C is leaky, however, its lowered resistance will allow a direct current to flow from the plate of V_2 through grid resistor R_g to ground. If it is known that tube V_2 is not gassy and that the ac signal voltage applied to the grid of V_2 is not excessive, a positive voltage at point A is an indication that capacitor C is leaking.

A conclusive test can be made by disconnecting the grid of V_2 from A. If a voltage then can be measured across R_g, capacitor C unquestionably is leaky.

If a suspected capacitor is removed from the circuit, it may be checked for leakage also by means of the 1000-megohm range of the Polymeter. After connecting the capacitor to the instrument, wait 5 minutes for the capacitor to become fully charged before taking a reading. The ohmmeter test has the disadvantage that the capacitor is tested at a voltage considerably
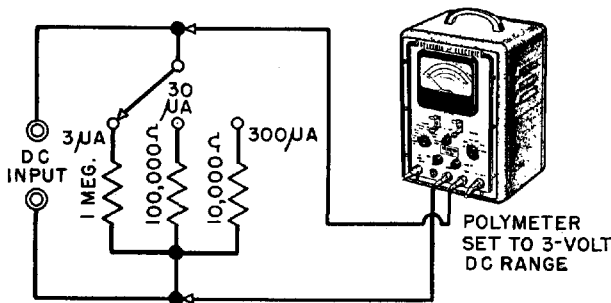
VACUUM TUBE VOLTMETER
AS DC MICROAMMETER
FIGURE 5-9

lower than its normal operating voltage. For this reason, a capacitor may appear better than it will prove to be in its higher voltage circuit.

5.12 DIRECT CURRENT MEASUREMENTS

The 3-volt dc range of the Polymeter may be made the basis of a rugged vacuum-tube type dc microammeter. It is necessary only to provide satisfactory external shunt resistors across which the vacuum-tube voltmeter is connected. The unknown current flowing through the shunt produces a voltage drop which deflects the meter proportionately.

The three shunts shown in Figure 5-9 convert the 3-volt dc scale of the Polymeter to 0-3, 0-30, and 0-300 microamperes. The shunts may be carefully measured 1-watt carbon resistors; or, for highest accuracy, precision wirewound instrument resistors.

5.13 MEASURING VERY HIGH RESISTANCES

Very high resistances, in excess of the 1000-megohm range of the Polymeter, may be checked by means of the setup shown in Figure 5-10. The dc voltage ranges of the instrument are employed. Some of the quantities which can be checked with this arrangement include insulation resistance, leakage component of high-quality capacitors, values of ultra-high instrument resistors, terminal leakage, and high-resistance grounds and faults.

The external test voltage may be any value up to several hundred volts. High voltages are required for the higher values of unknown resistance. The voltage must be supplied by batteries or a well-filtered voltage-regulated power supply.

Connections are made as indicated in Figure 5-10. The external voltage is designated E_1 and the meter reading E_2. The input resistance of the meter plus dc probe is designated R (this is 17 megohms in the Polymeter Type 221Z). The unknown resistance is calculated from:

$$R_x = R \frac{E_1 - E_2}{E_2}$$

As an illustrative example, let us assume that a 500-volt supply (E_1) is used, and that a 1-volt reading (E_2) is obtained with the Polymeter (R of 17 megohms). The unknown resistance then is:
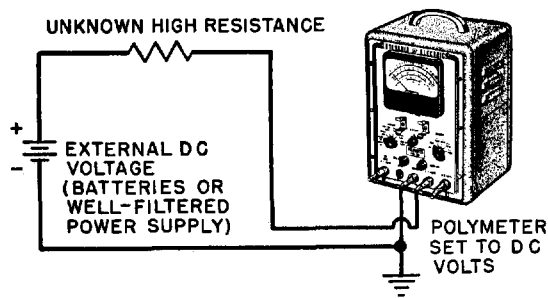
$$R_x = 17,000,000 \frac{499}{1}$$

$$17,000,000 \times 499 \cdot$$

$$8483 \text{ megohms.}$$

5.14 CHECKING BIAS CELLS

The 3-volt dc range of the Polymeter may be used to measure the output voltage of a bias cell directly without injury to the cell. In spite of the low current drawn by the Polymeter (approximately 6 hundredths

42

UNKNOWN HIGH RESISTANCE

EXTERNAL DC VOLTAGE (BATTERIES OR WELL-FILTERED POWER SUPPLY)

POLYMETER SET TO DC VOLTS

CIRCUIT FOR CHECKING ULTRA-HIGH
RESISTANCE

FIGURE 5-10

of a microampere from a 1-volt bias cell), the cell should not be kept in the circuit any longer than is necessary to take the voltage reading accurately.

5.15 MEASUREMENT OF TURNS RATIO

Transformer turns ratio is measured by applying an ac voltage to the primary winding of the transformer, then checking the primary and secondary voltages with an ac vacuum-tube voltmeter. The turns ratio is very nearly the ratio of these two voltages. In a step-up transformer, the secondary voltage is higher than the primary voltage. In a step-down transformer, the reverse is true.

Figure 5-11 shows the setup for measuring turns ratio. Transformers used for audio applications should be checked at 400 or 1000 cycles. An audio oscillator will be needed to supply the test voltage. Power-type transformers may be checked at the power-line frequency, and the test voltage may be obtained from the low-voltage secondary of a filament transformer. An rf signal generator must be used when checking radio-frequency or intermediate-frequency transformers, and an rf vacuum-tube voltmeter must be used to check the voltages with these components.

Use the lowest test voltage which will give an ac-

curately readable primary voltage. In this way, dangerous secondary voltages will be avoided.

The *impedance ratio* of a transformer is equal to the square root of the turns ratio.
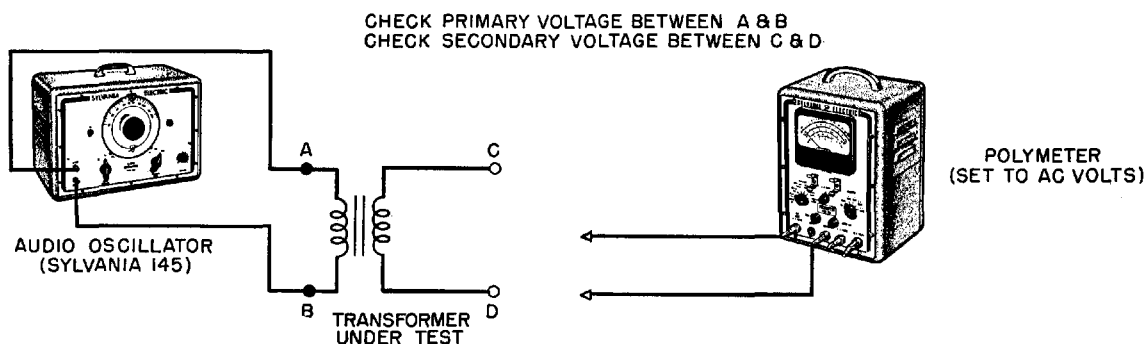
5.16 Q MEASUREMENT

The Q of a radio-frequency or intermediate frequency coil or choke can be measured with the setup shown in Figure 5-12.

The coil under test is connected in parallel with a 350- or 365-$\mu\mu$fd. low-loss variable capacitor. An rf vacuum-tube voltmeter is connected in parallel with this coil-capacitor combination. Energy is coupled from the high output terminals of an unmodulated rf signal generator into the test coil by means of a loosely-coupled coil or loop of 1 or 2 turns of insulated hookup wire. This coupling loop must be mounted in a stationary position near the coil under test.
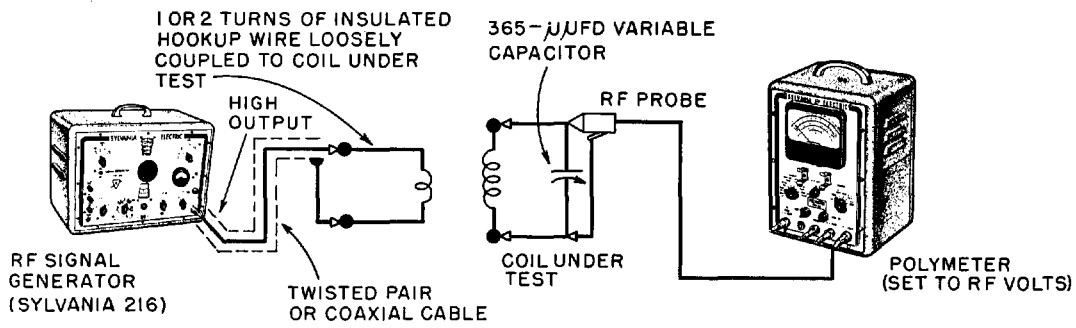
The following procedure is recommended for checking the Q of the coil. (1) Set the rf voltmeter to its 3-volt range. (2) Set the Q tuning capacitor to about half-capacity. (3) Starting at the highest frequency of the signal generator, tune the generator down in frequency through successive bands until a deflection of the meter occurs. (4) Tune the generator (and, if necessary, tuning capacitor as well) for *peak* deflection and record the resonant frequency as f_1. Also, note the voltmeter reading. (5) Tune the signal generator slightly higher in frequency to a point at which the meter deflection falls to 70.7% of the voltage at frequency f_1. Record this second frequency as f_2. (6) Finally, decrease the frequency back through resonance to a point lower than f_1, where the voltage again falls to 70.7% of the meter reading at f_1. Record this frequency as f_3. (7) Compute the Q of the coil with the formula:

$$Q = \frac{f_2 \cdot f_3}{f_1}.$$

The points f_2 and f_3 will be close together for

CHECK PRIMARY VOLTAGE BETWEEN A & B
CHECK SECONDARY VOLTAGE BETWEEN C & D

AUDIO OSCILLATOR
(SYLVANIA 145)

A   C

B TRANSFORMER D
   UNDER TEST

POLYMETER
(SET TO AC VOLTS)

SETUP FOR TURNS—RATIO MEASUREMENT
FIGURE 5-11

SETUP FOR Q MEASUREMENT
FIGURE 5-12

high-Q coils, and more widely separated when the Q value is low. For best accuracy, the loosest practicable coupling should be employed between the signal generator and coil under test. This will minimize critical tuning and "pulling" effects.

5.17 VACUUM-TUBE VOLTMETER AS COMPARISON VOLTMETER

Although not intended as a laboratory standard, a universal vacuum-tube voltmeter, such as Sylvania Polymeter Type 221Z, may be employed by the service technician for checking a wide variety of other meters. Advantages of the vacuum-tube voltmeter in this application are low current drain and a wide frequency response.

5.18 PHOTOELECTRIC TESTS

Because of its high input resistance and consequent low loading effects, the dc vacuum-tube voltmeter may be used for measuring directly the output voltage of photocells and phototubes of all types. Both magnitude and polarity of the output voltage of photoelectric devices may be checked.

## 5.19 CHECKING RECTIFICATION EFFICIENCY OF DIODES

The universal vacuum-tube voltmeter may be employed to measure the rectification efficiency of diode detectors and signal rectifiers of both tube and crystal types. The rf input voltage and dc output voltage are checked separately. Rectification efficiency then is determined from the ratio of the two voltages. Since

the calculation assumes the peak value of the rf voltage, the readings taken from the rms scale of the meter must be multiplied by 1.414.

Figure 5-13 shows a typical diode detector circuit, with test points. With the normal signal being supplied to the diode circuit, rf voltage (E_{rf}) is checked between points A and B, and dc output voltage (E_{dc}) between points C and D. The rectification efficiency (%) equals:

$$\frac{E_{dc}}{1.414\ E_{rf}} \times 100$$

Rectification efficiency increases with applied signal voltage. It also increases with the load resistance and load capacitance values.
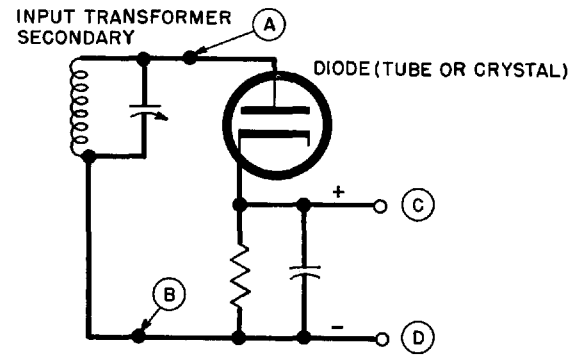
RF VOLTAGE MEASURED BETWEEN A AND B
DC VOLTAGE MEASURED BETWEEN C AND D

DIODE DETECTOR, WITH TEST POINTS
FIGURE 5-13