1934

POINT-TO-POINT

RESISTANCE

ANALYSIS

Theory — and Application

of This Modern Test Procedure

to Every-day Radio Service Problems

by Bertram M. Freed

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FOR SERVICE MEN

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RADCRAFT PUBLICATIONS, Inc.
PUBLISHERS

99 HUDSON STREET • **NEW YORK, N. Y.**

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POINT-TO-POINT RESISTANCE ANALYSIS

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CHAPTER 1

Value of Resistance Method of Servicing

Up to a few years ago, the only testing equipment available for analysis of the tube circuits in a radio receiver was the set analyzer, whereby voltage and currents were read. Although a means for resistance measurements or continuity testing was usually included as part of the set analyzer, the instrument became limited in its extent and was inadequate for obtaining a complete circuit analysis of a tube stage for the reason that the analyzer did not provide, nor was capable, for many new indications made necessary by advanced tube and circuit design.

These limitations, however, were minor considerations, since they were more or less overcome by incorporating certain changes in the analyzer, and re-marking the panel indications. The most serious handicap of the set analyzer lay in the fact that a voltmeter was utilized for measurements. With the introduction of circuits employing high resistance values, such as are found in automatic volume control, push-pull resistance-coupled amplifiers and high gain audio circuits, true voltage readings cannot be taken, because a voltmeter, regardless of its sensitivity, requires power for its operation. In many circuits, the energy consumed by the average voltmeter exceeds or is almost equal to the energy in that circuit during normal operation. This is true, even of the more sensitive voltmeters, which require only 50 microamperes for their operation, although voltage measurements are more accurate. Furthermore, voltage readings vary with different ranges of the voltmeter.

To illustrate, a voltage analysis chart supplied by a receiver manufacturer designates a 17 volt grid-bias reading for an output tube employed in a resistance-coupled class A audio stage, shown in Fig. 1. There is a 100,000 ohm resistor in the grid circuit of the tube. In a class A amplifier, because of negative grid bias, little or no current will flow in the grid circuit, and consequently, there will be no voltage drop across the grid leak.
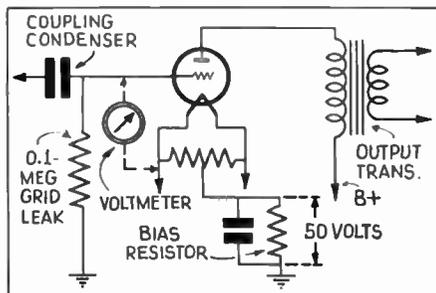
Fig. 1. Customary method of measuring grid bias voltage.

Measuring grid-bias voltage, in the usual manner of the set analyzer, from grid to filament or cathode of the tube with the 0-100 volt scale of the voltmeter, a reading of 25 volts is obtained. These measurements are being made with a meter of 1000 ohms-per-volt sensitivity. With the 0-250 volt scale, 36 volts is indicated.

The reason for this apparent discrepancy may be seen in Fig. 2. The voltmeter has been placed in series with the 50 volt drop across the bias resistor, and the grid leak. Current will therefore

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flow in the circuit, producing a voltage drop across the grid leak. The voltage drop indicated upon the meter will be equal to the voltage drop across the grid leak subtracted from the actual grid-bias voltage. Grid-bias voltage readings with a high resistance in the grid circuit depend upon the resistance value of the grid leak and the resistance of the indicating instrument. Thus, it may be noted that the same meter range and sensitivity as that used by the manufacturer of the receiver must be employed, when comparing the results of a voltage analysis.

When one is diagnosing or analyzing troubles in a radio receiver with a set analyzer or voltmeter, it is essential that line voltage be considered. Coupled with the fact that voltmeter indications are not accurate in high resistance circuits because of the multiplier effects of the resistances, where the supply line voltage differs from that specified by the receiver manufacturer, voltage analysis charts are without value, unless these differences enter into our calculations. All this is confusing and time-consuming. In order

to carry through a circuit analysis with a set analyzer, there must be a source of line or supply voltage. The voltmeter is useless without a source of supply voltage. In some instances, additional damage may result when a receiver is set up for voltage measurements. This may be readily seen in the case of a short-circuited filter condenser in the power supply. Operating the receiver for any length of time to obtain voltage measurements, would, almost invariably, produce rectifier or power transformer failure.

To overcome these objectionable features encountered through the use of the voltmeter in the set analyzer, the resistance method of servicing radio receivers has been advanced. There is nothing new about point-to-point resistance analysis, but its development and application to complex modern radio receivers has grown immeasurably important. The advantages of point-to-point resistance servicing are many-fold, since the method depends entirely upon a few fundamental and elementary principles and a working knowledge of Ohm's law. A comprehensive picture of the condition of a radio receiver may be secured without consideration for line voltage or tube merit. With a set analyzer, the voltage obtained at the plate of a tube would depend largely upon tube emission, where a high resistance was located in that plate circuit, due to the voltage drop across this load. No such factors enter into a resistance analysis. Voltage measurements indicate a discrepancy from the normal or expected value, but do not disclose the reason for this discrepancy. When a receiver becomes inoperative for some reason, discounting defective tubes, misalignment of tuned circuits or reproducers, the inoperative condition or incorrect operation is almost invariably due to the failure of the *resistance* in some circuits. Fundamentally, every radio receiver is composed of conductors and non-conductors of electricity. The amount of opposition offered to the flow of direct current by these components is termed resistance. Each component, normally, possesses a definite, fixed resistance. Due to some breakdown, rupture or decomposition, this resistance or opposition to direct current may vary. Any instrument, or group of instruments, which will disclose this failure or discrepancy in normal expected values, in
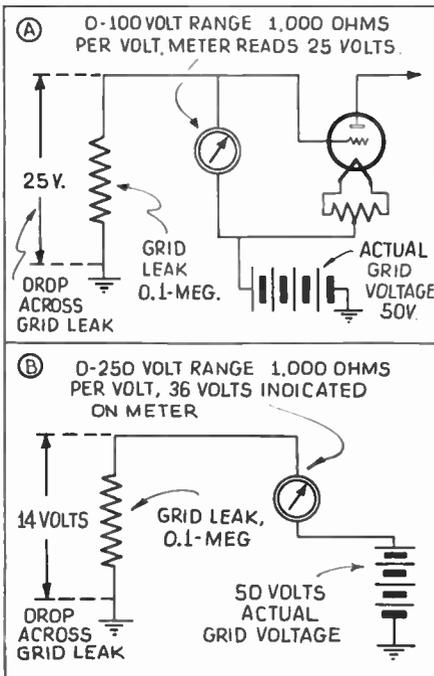
Fig. 2. Illustrating the reason for incorrect grid bias voltage readings obtained with a voltmeter.

terms of ohms, is all that is essential in resistance analysis.

The current flowing or voltage drop in any circuit has no place in point-to-point resistance servicing. Only the receiver, with its associated components and their d-c resistance, enters into our calculations. A circuit shown in Fig. 3, in which are located a 150 ohm i-f transformer primary coil and a 500 ohm carbon resistor should produce a reading of approximately 650 ohms upon the
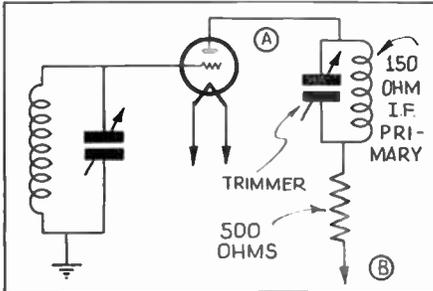
Fig. 3. A resistance reading other than 650 ohms obtained A to B indicates trouble in this circuit.

measuring instrument. An incorrect reading from A to B designates trouble in that circuit. In the event the primary coil were short-circuited, as would be possible with a short-circuited trimmer or tuning condenser shunted across that winding, the set analyzer or voltmeter could not disclose the condition, under normal circumstances. By point-to-point resistance analysis, the trouble becomes quickly localized. As another instance, an inoperative receiver is encountered where all voltages and currents are correct within expected values. A point-to-point check on the output tube circuit reveals a zero resistance reading between plate and screen of the output pentode tube, Fig. 4, which is employed here as a pentode Class "A" amplifier. Since a by-pass condenser is connected across the output transformer primary winding, it would be most reasonable to suspect a short-circuited condenser. A voltage analysis of the tube circuit did not disclose the failure, because the lack of the normal voltage drop, probably 10 or 15 volts, across the output transformer primary could not be readily discerned.

These few illustrations are mentioned only to point out the ease, rapidity and simplicity with which causes for radio receiver symptoms may be diagnosed. In radio servicing, time is of the essence, and point-to-point resistance analysis enables the most perplexing job to be completed in the least possible time. Heretofore, one of the reasons for the lack of popularity of the resistance analysis method was the fact that, in many instances, a point-to-point test could not be made unless the chassis were removed from the cabinet, because of the inaccessibility of some of the tube sockets. It is also true that service men were limited to some extent because ohmmeters of sufficiently high or low range were not easily available.

Manufacturers of testing equipment quickly saw the need for instruments capable of measuring both very high and low resistance values, and also for some simple device that would enable each tube circuit in a radio receiver to be conveniently checked. As a result, the multi-range ohmmeters and free reference point-to-point testers appeared. Some representative instruments for this service and purpose will be discussed in Chapter 4.

Despite the ever-increasing importance of resistance measurement analysis in modern radio receivers, we must not lose sight of the fact that voltage measurements are essential, and that both methods must be combined, one to sup-
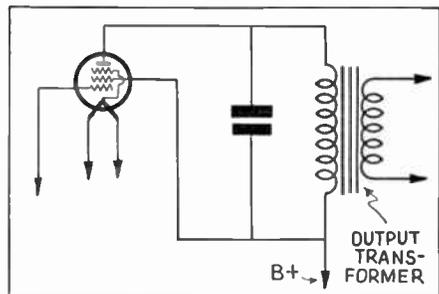
Fig. 4. Failure of the bypass condenser not readily disclosed with a voltage analysis.

plement the other for the diagnosis of receiver troubles. It is only that resistance measurement offers a practical solution for the short-comings of a voltage analysis. Although a voltage analysis may disclose the inoperative or faulty circuit, a resistance measurement will almost always disclose the reason for such failure.

CHAPTER 2

Basic Principles Involved
in Point-to-Point Analysis

To correctly apply the point-to-point resistance method of servicing receivers and to derive all possible benefits, it is vitally essential that a thorough understanding of the various combinations of resistors and resistances employed in radio receivers be possessed, in order to analyze the measurements obtained from various points in a tube circuit. This requires some knowledge of the fundamental and elementary principles of electricity so far as series, parallel and series-parallel circuits are concerned. Since Ohm's law is involved in this study, it may be well to review this important principle.

OHM'S LAW

The discovery of simple definite relationships between the amount of current that would flow in a circuit having a certain resistance, and the voltage or e.m.f. applied to the circuit, is credited to Dr. George Simon Ohm, a physicist, and is known as Ohm's law. The amount of current flowing in a circuit depends upon the amount of e.m.f. applied to the circuit, but since the current flow is limited by the resistance of the circuit, it follows that current flowing in a circuit *increases* directly with an increase in voltage or e.m.f., and *decreases* directly with an increase in resistance. Ohm's law may be expressed as: The intensity or magnitude of current in any circuit is equal to the electromotive force divided by the resistance of the circuit; or

$$I = \frac{E}{R}$$

Where I = Current in Amperes.
E = E.M.F. in Volts.
R = Resistance in Ohms.

From this equation, it will be seen that when any two quantities or values are known, the third may be determined.

PROBLEM: A resistor of 5000 ohms is connected in the plate circuit of a tube (Fig. 5A). There is a voltage drop of 20 volts across the resistor. What current is flowing through this resistor?

SOLUTION: Substituting 20 for E, and 5,000 for R,

$$I = \frac{20}{5000} = .004 \text{ Amp. or 4 Ma.}$$
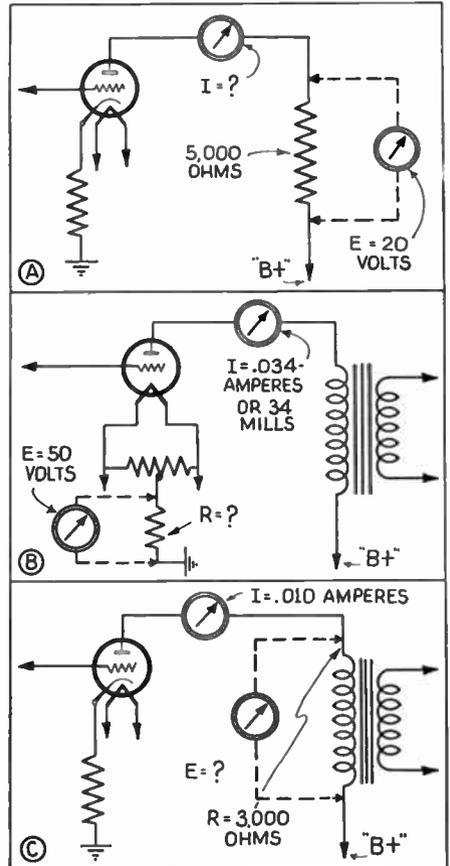
Fig. 5. Simple problems illustrating the three equations of Ohm's law.

In like manner, when the current and voltage are known, the resistance may be

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determined. Since

$$I = \frac{E}{R} \text{ then } R = \frac{E}{I}$$

PROBLEM: The bias resistor for a type 45 output tube has open-circuited. The bias voltage for correct operation is 50 volts at a current of 34 milliamperes. In Fig. 5B, what is the value of the bias resistor?

SOLUTION:

$$R = \frac{E}{I} = \frac{50}{.034} = 1470 \text{ ohms}$$
$$\text{approx.}$$

The third equation comprised in Ohm's law is one in which the value of the resistance, and the current through it are known, and the voltage required to maintain this current flow must be determined. This may be computed from the relation

$$V = R \times I.$$

PROBLEM: Referring to Fig. 5C, the resistance of the primary of an audio transformer connected in the plate circuit of a tube is 3000 ohms. The current fllow is 10 milliamperes. What is the voltage drop across the primary winding of the transformer?

SOLUTION: Substituting 3000 for R and .01 for I, then
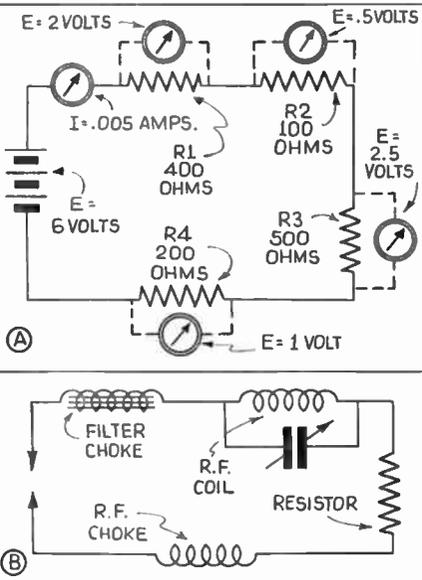
$$V = 3000 \times .01 = 30 \text{ volts.}$$

SERIES CIRCUITS

When electrical conductors are connected in such a way that all the current flowing in the circuit passes through each conductor, we have what is termed a series circuit. When resistors are connected in series, the current has but one path; and the total resistance of the circuit is the sum of all resistors embracing the series circuit. As may be seen in Fig 6A, the total resistance of the combination is 1200 ohms. Here four resistors are connected in a series circuit. Since

$$R = R_1 + R_2 + R_3 + R_4, \text{ then}$$
$$R = 400 + 100 + 500 + 200 =$$
$$1200 \text{ ohms.}$$

Although four resistors comprise the series circuit shown in Fig. 6A, the resistors may, just as readily, be filter chokes or r-f coils, so long as they possess some definite d-c resistance, since we are not concerned with a-c characteristics of units. These resistors may be represented as shown in Fig. 6B. Upon examination of Fig. 6A, it will be noted that in
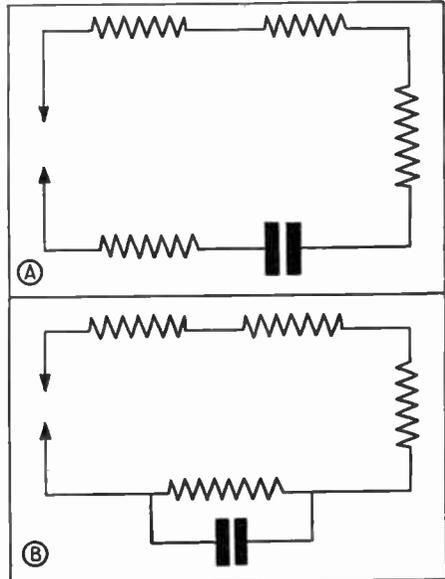
Fig. 7. The circuit in A is not a series circuit due to the presence of the condenser.

series circuits, the current is the same through all the resistances. The voltage drop across each resistance will depend upon the value of each resistance, but the sum of the voltage drops across each resistance in a series circuit is equal to the total voltage applied to it.

A rather apparent conclusion can therefore be deduced that if a series circuit is broken or open at some point, the current stops flowing. Thus, if a perfect solid dielectric condenser were connected into the circuit as shown at Fig. 7A, there would no longer be a series circuit, since direct current cannot flow through a perfect condenser. Should the condenser, however, be connected across one of the units in the series circuit, as at Fig. 7B, the flow of current will not be disturbed
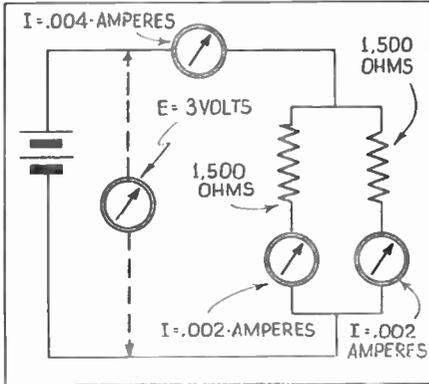
Fig. 8. A parallel circuit of equal resistances. The conductance is equal to the value of one resistance divided by the number of resistances.

and the resistance of the circuit will remain unchanged, namely, the sum of the separate resistances, unless the condenser is of the electrolytic type wherein a definite direct current leakage may be encountered. This will be discussed later. The presence of the condenser at Fig. 7A removes the circuit from the category of series circuits. If such is the case, should a resistance reading be obtained, it can only be due to the fact that the condenser is partially or completely short-circuited. Similarly, when the shunt condenser in Fig. 7B is short-circuited, the current flowing in the circuit will increase because the total resistance of the circuit has decreased.

PARALLEL CIRCUITS

A parallel circuit is one in which the flow of current may divide through two or more paths. This circuit is also known as a multiple or shunt circuit. The total voltage applied exists across each part of a parallel circuit, but since the current may follow several paths, only a portion of the current flowing in the circuit passes through each part. The total current flow-

ing in a parallel circuit is the sum of the currents through each branch.

When a resistance of 1500 ohms is connected across, or in shunt with, another resistance of 1500 ohms, and connected as shown in Fig. 8, the current through each resistor, by solving with Ohm's law, will be 2 milliamperes. Thus the total current flowing in the parallel circuit is 4 milliamperes. To determine the effective resistance or conductance of the two resistances in parallel, we again apply Ohm's law to find the resistance of the parallel circuit as 750 ohms. This example illustrates the parallel circuit in which the resistances are equal. In these cases, the value of the combined resistances is the value of one resistance divided by the number of resistances, since the current divides equally among the various resistances.

PROBLEM: A parallel circuit is composed of 4 resistors, each of 7500 ohms. What is the value of their combined resistance?

SOLUTION: In parallel circuits, where the resistances are equal, the effective resistance is equal to the value of one resistance divided by the number of resistances. Then dividing 7500 by 4, we obtain 1875 ohms.

A different situation is presented when the resistances in a parallel circuit are
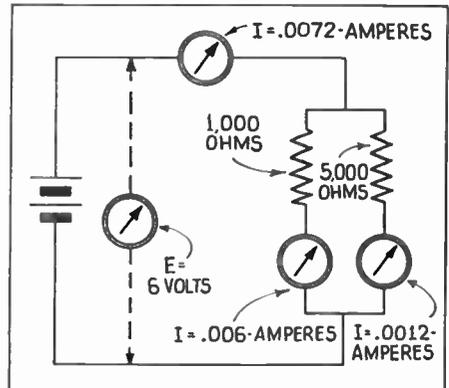
Fig. 9. The conductance of a parallel circuit with two unequal resistances is equivalent to the product of both divided by their sum.

unequal. In the circuit shown at Fig. 9, resistances of 1000 ohms and 5000 ohms are connected in parallel. The current which flows in each branch is equal to the applied voltage divided by the resistance of each branch. This is shown in the diagram. Although the combined resistance

may be calculated by adding the currents in each branch and solving by Ohm's law, the following formula may be used to compute the effective resistance of a parallel connection of resistances, without knowledge of the currents or voltages involved. When there are only *two unequal* resistances in a parallel circuit, such as is shown in Fig. 9, the combined resistance may be calculated by dividing the product of the two resistances by their sum.

$$R = \frac{r_1 \times r_2}{r_1 + r_2}$$

$$R = \frac{1000 \times 5000}{6000} = 833.3 \text{ ohms}$$

With problems in which *more than two unequal* resistances are encountered, the combined resistance is obtained by solving for the reciprocal of the sum of the reciprocals. This is expressed as

$$R = \frac{1}{\dfrac{1}{r_1} + \dfrac{1}{r_2} + \dfrac{1}{r_3} + \dfrac{1}{r_4} + \text{etc.}}$$

Where R = combined resistance.
r = value of branches of parallel circuit.
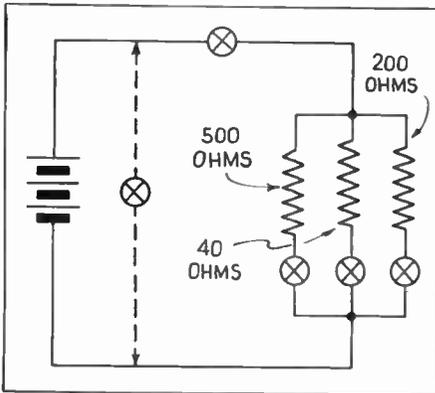
Fig. 10. An example of a parallel circuit with three or more unequal resistances. The effective resistance is obtained by solving for the reciprocal of the sum of the reciprocals.

Fig. 10 shows a circuit in which there are three resistors in parallel and unequal in value. *Without considering voltages or currents,* we may substitute the values of each branch in the parallel circuit in the foregoing formula.

Thus:

$$R = \frac{1}{\dfrac{1}{500} + \dfrac{1}{40} + \dfrac{1}{200}}$$

$$R = \frac{1}{.002 + .025 + .005} =$$

$$\frac{1}{.032} = 31.25 \text{ ohms}$$

From the above, we may sum up the conditions existing in parallel circuits as follows:

The combined resistance is less than the resistance of any branch of the circuit.

The total current is equal to the sum of the currents through all the branches.

The voltage is equal across all branches of a parallel circuit.

SERIES-PARALLEL CIRCUITS

In radio receivers and other electrical equipment, circuits are encountered which are a combination of series and parallel circuits. Here, resistances are so connected that some are in parallel with each other, and some in series with each other and with the parallel circuits. Reference is usually made to circuits of this type as series-parallel circuits, since they are composed of simple series and parallel circuits. The total effective resistance of any series-parallel circuit, no matter how complicated, may be found by solving each portion consisting of parallel circuits and resolving them into simple series circuits. The sum total of the value of the series circuits is the effective or combined resistance of the circuit.

An example of a simple series-parallel circuit is shown in Fig. 11. We have three parallel combinations of resistances in series with each other and with a single resistance. This series combination is in parallel with two paralleled resistances. Resistances R1, R2, and R3 are in parallel with each other. The combined resistance of this parallel combination is 40 ohms since each resistance is 120 ohms. The parallel resistances R4, R5, and R6 are 10, 20, and 10 ohms respectively. This circuit has a resistance of 4 ohms. The parallel circuit of R7 and R8 is equal to 10 ohms, each resistance having a value of 20 ohms. Since R9 is 15 ohms, the circuit comprising R1, R2, R3, R4, R5, R6, R7, R8, and R9 is equivalent to 69 ohms. However,

these resistances are in shunt with R10 and R11, which are each 100 ohms, and connected across the voltage source. Substituting 50 ohms, the effective resistance of R10 and R11, for that of R1, and 69 ohms, the effective resistance of the first combination or resistances for that of r2 in the formula,

$$R = \frac{r_1 \times r_2}{r_1 + r_2}$$

then

$$R = \frac{69 \times 50}{69 + 50} = \frac{3450}{119} = 28.9 \text{ ohms}$$
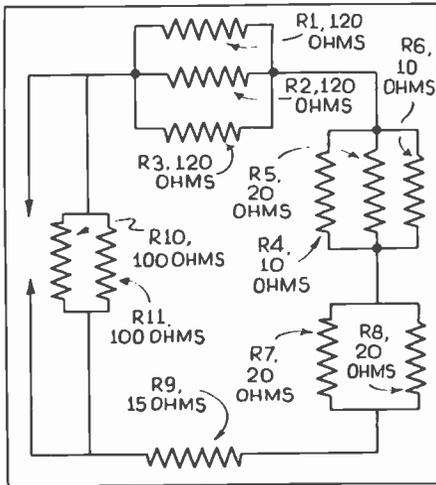
Fig. 11. A series-parallel circuit. The effective resistance of the entire circuit is obtained by resolving each parallel circuit into a series circuit.

An intimate knowledge of series-parallel circuits is very essential in point-to-point resistance measurements, so that an intelligent analysis of conditions in a radio receiver may be made. At first observation of a receiver circuit, it may be difficult to work out the seemingly complex combination of resistances, but by breaking up each parallel or series-parallel circuit into simple series circuits, diagnosis is clarified. We shall see the relation between series and parallel circuits and the circuits in a radio receiver discussed at some length in Chapter 6.

RESISTANCE

Resistance may be defined as the natural opposition offered to the flow of current by any substance. The length, cross-sectional area, and the material of which a conductor is composed, determines the resistance. The resistance of a conductor is directly proportional to its length. A conductor, which may be a wire 10 ft. long, has greater resistance to the flow of current than a 1 ft. length of the same piece of wire. The larger the cross-sectional area of a conductor, the greater the number of electrons that may flow past a given point every second, signifying a greater current flow, and consequently a lower resistance. The resistance of a conductor is inversely proportional to its cross-sectional area or diameter.

The length of a conductor is usually expressed in feet, while the cross-sectional area is expressed in circular mils. (One mil is equal to .001 inches). The resistance of circular conductors is equivalent to the diameter of the conductor in mils, squared.

Composition or material is the third factor which determines the resistance of a conductor. Due to the varying electronic structure of materials, the amount of current which will flow, differs. As an example, it has been found that copper is a better conductor, (has lower resistance for a given length and cross-sectional area) than any of the forms of iron or steel, and for this reason is employed so universally in electrical wiring and devices.

EFFECT OF TEMPERATURE ON RESISTANCE

The resistance of almost all pure metal conductors *increases* with an *increase* in temperature. The resistance of carbon conductors as well as electrolytes *decreases* with an increase in temperature. These facts are important in radio service work since the resistance of a conductor or substance may vary under "hot" or "cold" conditions. The rise in temperature may be occasioned by the heat generated in the conductor by the flow of current through it, or by the heat developed and transferred by adjacent objects. The increase in resistance for each change of one degree in temperature of a substance whose resistance is one ohm is known as the "temperature coefficient". For all pure metals, the temperature coefficient is approximately .0023 ohms per degree Fahrenheit.

The effect of temperature upon resistance and its relation to point-to-point resistance analysis shall be discussed further in a later chapter.

CHAPTER 3

Methods and Instruments Employed
in Resistance Measurements

The accurate determination of the d-c resistance of components employed in radio equipment is one of the most important and essential measurements to be performed by radio service men. Accurate resistance measurement is attained through the proper and correct use of good indicating instruments. The degree of accuracy of any measuring instrument is, primarily, an inherent function and characteristic of the instrument and is usually dependent upon the price paid in dollars and cents. To maintain this initial accuracy, the instrument must of necessity be carefully handled to prevent damage to delicate working parts through abuse and overload. For most practical purposes, an accuracy of 2% is considered adequate.

Because of the construction of most indicating instruments, wherein the needle of the meter does not touch the surface of the meter scale, the initial accuracy of the meter may be voided, due to observational errors. Indicating instruments should be read by looking directly down upon or in front of the needle and never from at an angle. The shadow cast by the needle upon the scale is not the indication. Some high grade instruments are equipped with "mirror" scales. The exact position of the needle is reflected upon the scale, so that the meter may be read from any position. One point to be borne in mind, when concerned with accuracy in radio measurements, is the fact that meters are most accurate between two-fifths to four-fifths scale deflection. Due to initial starting torque and because the moving coil of the meter at "zero" position is almost out of the field of the permanent magnet, an appreciable error may be encountered on the first portion of the meter scale. For this reason, when making resistance measurements, employ the "ohms" scale of the indicating instrument in which the resistance being measured falls past the center of the scale.

There are various methods of measuring resistance values. The ohmmeter, which is calibrated to read resistance values

directly in ohms, has become universal in its application to radio servicing for its simplicity, convenience and ease of operation. For the greatest accuracy, some form of Wheatstone bridge is employed. Probably the oldest simple method of determining resistance values is that using a d-c voltmeter and ammeter or only a d-c voltmeter.

VOLT-AMMETER METHOD

When determining resistance values with a d-c voltmeter and ammeter, the resistance to be measured is connected in series with an ammeter and steady source voltage as shown in Fig. 12. The voltmeter is connected across the unknown resistance to determine the voltage applied to the resistance. By Ohm's law, since the current flowing through the resistance and voltage
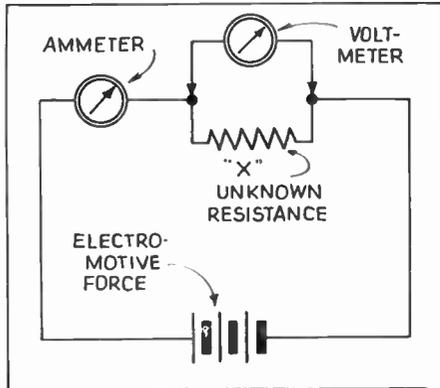
Fig. 12. The volt-ohmmeter method of measuring low values of resistance. The value of X is obtained through Ohm's law.

applied to it are known, the value of "X" is found. This mode of connection is applicable to low resistance values only, to effect a low percentage of error. In this case, the ammeter indicates the sum of the currents through the resistance and the voltmeter. Since the resistance of the average voltmeter is high compared to the low resistance, the current through the voltmeter is small. The percentage of error is dependent upon the resistance of

the voltmeter. The higher the ohms-per-volt value of the voltmeter, the less current consumed by the meter and the more accurate the measurement, as most of the current passing through the circuit is through the unknown resistance.

For high resistances, connecting the voltmeter across the unknown resistance introduces such large percentage of error as to render the measurement worthless, since the resistance of the voltmeter will be small compared to the high resistance
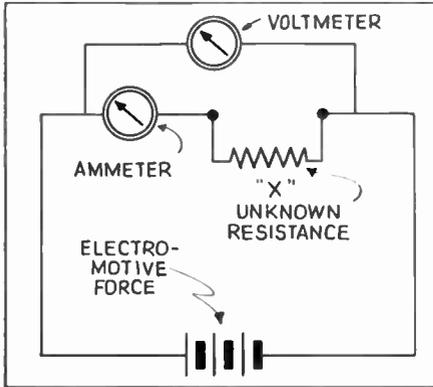
Fig. 13. Measuring high values of resistance with the volt-ammeter method.

and the current passing through the voltmeter greater than that through the resistance. For this reason, the voltmeter is connected across both the resistance and the ammeter as shown in Fig. 13. Here, the voltmeter indicates the voltage applied to both the resistance and ammeter, but the percentage of error is slight because the additional resistance of the ammeter will be so very small compared to the high resistance. As before, the value of the unknown resistance is equal to the voltage applied to the resistance divided by the current passing through the resistance, as indicated upon the ammeter.

The range of the voltmeter employed in these measurements depends upon the voltage of the voltage source. Thus, a voltmeter with a range of 0-7 volts is sufficient where one to three dry cells are used as the source of voltage. High resistance voltmeters are preferable. On the other hand, the range of the ammeter depends not only upon the voltage source but also the value of the resistance to be measured. For example, resistances whose value is 5 to 10 ohms will require an ammeter with a 0-5 ampere range when the

voltage source is 6 volts. An ammeter with a range of 0-100 milliamperes is required for resistances of approximately 100 ohms, etc. It is best to approximate the value of the unknown resistance and employ an ammeter or the range of the ammeter which will safely indicate the current.

VOLTMETER METHOD

A voltmeter may be employed to measure resistance values when the exact internal resistance of the meter is known. The resistance to be measured is connected in series with the voltmeter across a steady voltage source. This is shown in Fig. 14. To obtain the value of "X", the voltage read upon the meter with the resistance in the circuit is subtracted from the reading without the resistance. This difference is then divided by the first reading (with resistance), and the quotient multiplied by the known resistance of the meter. This may be expressed as:

$$R = \frac{Em-Er}{Er} \text{ x } Rm$$

Where R = value of unknown resistance in ohms.

Em = reading upon meter without series resistance.

Er = reading upon meter with unknown resistance in circuit.

Rm = voltmeter resistance.

For example, assume we have a 0-5 voltmeter with a resistance of 1000 ohms-per-volt, to be used to measure the value of an unknown high resistance. The total resistance of the meter is then 5000 ohms
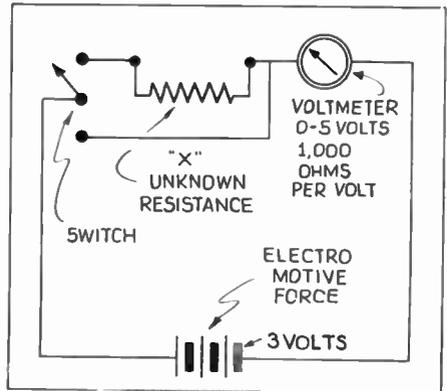
Fig. 14. The voltmeter method of determining resistance values.

The d-c voltage source is 3 volts. The reading upon the meter with the resistance in the circuit is 1 volt. Without the resistance, the meter reading is of course, 3 volts. Then the unknown resistance

$$R = \frac{3-1}{1} \times 5000 = 10,000 \text{ ohms.}$$

This method of resistance measurement is not applicable to the determination of low resistances, for in this case the difference between the two readings would be too small to be accurately discerned, and the percentage of error too great for practical purposes. A meter with a low ohms-per-volt rating may be adapted to this service.

THE OHMMETER

The ohmmeter is a measuring instrument whose scale is either calibrated directly in ohms or which indicates the resistance of a component by comparing meter readings with those upon a prepared table, chart, or graph. By employing Ohm's law, we find that if a current measuring instrument is connected in a circuit with a constant voltage, the meter reading will be inversely proportional to the resistance in the circuit. In this way, it is possible to calibrate the meter directly

Fig. 15. A typical series type ohmmeter.

in ohms. Essentially, the ohmmeter consists of a milliameter of suitable range, a calibrating resistance, and a voltage source, connected in a circuit as shown at Fig. 15. The calibrating resistance serves, both to limit the current through the meter and to provide a means for establishing full scale deflection of the meter when the

test terminals are closed, to compensate for depreciation in battery or cell voltage.

Let us assume that the meter in Fig. 15 is a 0-1 milliammeter. The calibrating or limiting resistance, from Ohm's law, to obtain full scale deflection, with a voltage source of 4.5 volts, is then 4500 ohms. Any resistance connected across the test terminals of the instrument will produce a reading which is inversely proportional to the resistance in the circuit. We have

Fig. 16. To measure lower values of resistance with the series ohmmeter, a shunt is employed across the meter.

seen that when the applied voltage is constant, the current through a circuit is inversely proportional to the value of the resistance in the circuit. In other words, the higher the value of the resistance connected across the test terminals, the lower the meter indication. Thus, a 4500 ohm resistor connected across the test terminals will produce half-scale deflection upon the meter for now there is 9000 ohms in the circuit. In the same manner, other settings of the meter may be determined and the points marked directly upon the dial scale, or a suitable chart or graph prepared from which meter readings may be compared.

The range of any ohmmeter depends upon the meter sensitivity and the value of the voltage source. To increase the "ohms" range, either a more sensitive meter or a greater voltage or both must be employed. In either case, the value of the limiting resistance is higher. To measure low values of resistance, a less sensitive meter, or the same meter to enable greater currents to be read, may be used. In this case, the value of the limiting resistance must be lower. An example of this is shown at Fig. 16. Here, the

same 0-1 range milliammeter is used but with a parallel resistance which may be connected across the meter by means of the switch. Assuming the internal resistance of the meter to be 27 ohms, the value of the parallel resistor would be 3 ohms to divide the ohms scale by 10. The limiting resistor would have to be adjusted lower in value to obtain full scale deflection. The current flowing in the circuit now is 10 milliamperes.

The ohmmeter discussed above is known as the *series* type, in which the resistance to be measured is connected in series with the meter. There is another type of ohmmeter, used principally to measure low resistance values with small current consumption, called the *"shunt"* ohmmeter. In this case, the unknown resistance is connected in shunt with the meter, as shown in Fig. 17. It can be seen that an 0-1 d-c milliammeter is connected in series with a limiting or calibrating resistance and a battery or voltage source of 4.5 volts. The test terminals are across the meter. The calibrating resistance is adjusted so that the meter reads full scale. When a resistance is connected across the test terminals, the meter indication will be less, since the current in the circuit will divide, part through the meter and part through the unknown shunt resistance.

In the series type ohmmeter, when low values of resistance are measured, in the
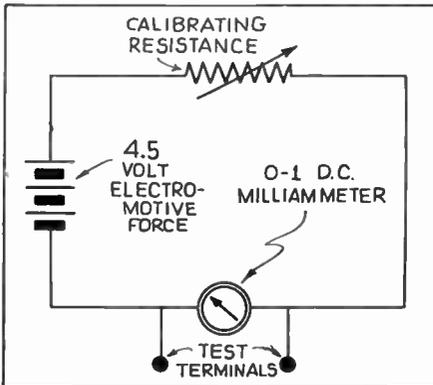
Fig. 17. The shunt-type ohmmeter. The resistance to be measured is shunted across the meter.

manner illustrated in Fig. 16, the current drawn from the voltage source is increased ten times or 10 milliamperes. With the shunt type ohmmeter, the current consumption is practically the same, regardless of the resistance value connected

across the meter. The scale of a series type ohmmeter increases with a decrease in current, that is, the higher the resistance, the less the meter deflection. "Zero" ohms is at the full scale deflection of the meter. In the shunt type ohmmeter, the reverse is true, since the deflection of the meter is less with lower resistance values, as then most of the current in the circuit is passing through the resistance to be measured.

WHEATSTONE BRIDGE

When resistance values are to be determined with the greatest possible accuracy, the Wheatstone bridge, in one of its several forms, is usually employed. Developments in design of the Wheatstone bridge in recent years have produced a means whereby measurement of resistance may not only be accomplished accurately, but quickly.

The Wheatstone bridge, essentially, consists of three *known* resistors, and a fourth resistance whose value is to be de-
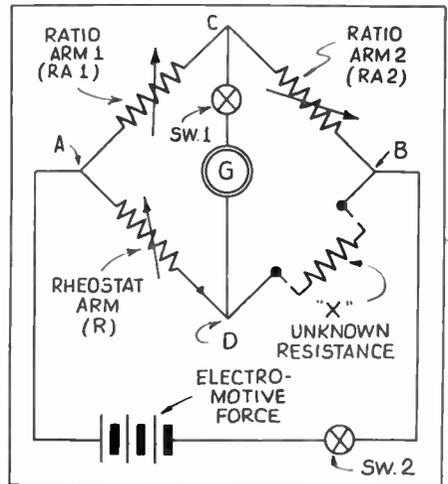
Fig. 18. The Wheatstone bridge.

termined, connected in a closed circuit as in Fig. 18. A battery and switch are connected between points A and B. A galvanometer is connected into the circuit by means of a switch between C and D. The resistors AC and CB are called "ratio arms" and are usually so designed that the resistance of one arm with respect to the other may be adjusted in multiples or submultiples of 10, in such manner that the resistance of one ratio arm may be 10, 100

or 1000 times greater than that of the other or 1/10, 1/100 or 1/1000 times as great. The rheostat arm AD is a calibrated variable resistance.

The value of the unknown resistance "X" is found by "balancing the bridge" This condition is accomplished when the galvanometer needle indicates zero as switch 2 is closed momentarily. To balance

Fig. 19. The slide-wire bridge. A simplified version of the Wheatstone bridge.

the bridge, the battery switch is closed. Current then flows from point A to B The battery current divides between two paths, through ACB, and ADB. The galvanometer will indicate zero only when points C and D are at the same potential, indicating that the voltage drop across ratio arm 1 is equal to that across the rheostat arm AD. In like manner, the voltage drop across ratio arm 2 must be equal to that across the unknown X. The resistance of the ratio arms and the rheostat are adjusted to obtain this result. When C and D are at the same potential, no current will flow through the galvanometer when the switch is closed.

Since the voltage drop across ratio arm 1 is equal to that across the rheostat, it follows that the current through AC is equal to that through AD. Likewise, when the bridge is balanced, the current through CB is equal to that through DB, since the voltage drop across ratio arm 2 is equal to that across X. In other words, the resistance of the ratio arm 1 (or A_1) is to the value of the rheostat (or R), as ratio

arm 2 (or A_2) is to the unknown X. This may be expressed as

$$A_1 : R :: A_2 : X$$

From this relation, then,

$$A_1 X = RA_2$$

or

$$X = \frac{RA_2}{A_1}$$

The values of the ratio arms and the rheostat are obtained when the bridge is balanced, and X is found by substituting these values in the formula.

EXAMPLE: The value of ratio arm 1, ratio arm 2, and rheostat, respectively, have been found to be 10, 4 and 30 ohms, respectively, after the bridge has been balanced. What is the value of X?

SOLUTION:

$$X = \frac{RA_2}{A_1}$$

$$X = \frac{30 \times 4}{10} = 12 \text{ ohms}$$

SLIDE-WIRE BRIDGE

A simplified version of the Wheatstone Bridge is the slide-wire type, shown in Fig. 19. In this type of bridge, a wire of uniform resistance along its length, stretched over a uniformly marked scale, takes the place of the ratio arms in the Wheatstone bridge. The slide-wire scale is marked off in units, for example, 0-100, so that the position of the contact "C" on the slide wire may be expressed as a ratio of the length, that is the relation of the AC to CB or A_1 to A_2. The rheostat R is a calibrated resistance. The bridge is balanced when the galvanometer indicates zero, as a result of adjusting the slide-wire contact and the rheostat R. The value of X is found from the formula.

Let us assume that when the bridge is balanced, we find that the value of the rheostat R is 15 ohms and the slide-wire contact is at 75 on the uniform slide-wire scale which is graduated 0-100. Then AC, (A1), and CB, (A2), may be expressed in terms of 3 and 1, since A1 is three times that of A2. The value of X is found from the formula

$$X = \frac{RA_2}{A_1}$$

$$X = \frac{15 \times 1}{3} = 5 \text{ ohms}$$

Although the slide-wire bridge does not possess the accuracy of the Wheatstone bridge, it has received great popularity because of the ease with which it is balanced.

VOLT-OHMMETER

Since the meter employed in most ohmmeters is usually a sensitive low range d-c movement, such as a 0-50, 0-100, 0-200, 0-500 microammeter, or a 0-1 milliammeter, it may readily be made to serve as a multi-range voltmeter by the addition of
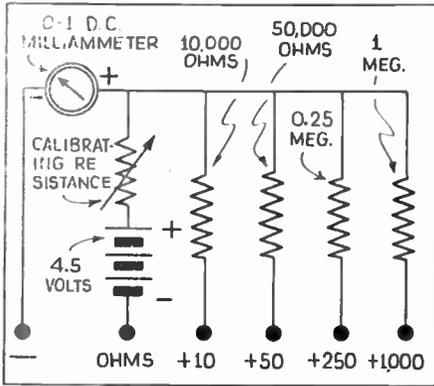
Fig. 20.   A simple volt-ohmmeter.

the necessary multiplier resistances, properly connected to the meter. Any number of voltage ranges may be secured by the correct selection of resistor values, and a suitable switching arrangement. The value of the multiplier or series resistances depends upon the current required for full scale deflection of the meter, and the voltage ranges desired.

Where the meter employed is a 0-1 d-c milliammeter, a voltmeter with ranges of 10, 50, 250 and 1000 d-c volts, as shown in Fig. 20, may be constructed by connecting resistances in series with the meter. The value of these resistances are determined simply by Ohm's law, $R = E \div I$. For the 10 volt range, a 10,000 ohm series resistance is required, since $10 / .001 = 10,000$. A 50,000 ohm resistance will serve as the 50 volt series resistance, etc. The sensitivity of the voltmeter will therefore be 1000 ohms-per-volt. For practical purposes, the d-c resistance of the 0-1 milliammeter may be disregarded.

In like manner, by the addition of the proper shunt resistances, low range microammeters and milliammeters may be con-

verted into multi-range current-measuring instruments. For example, in Fig. 21, a 0-1 d-c milliammeter is connected in a circuit with three shunt resistances and a three-position rotary-type switch, to enable current values of 10, 100 and 500 milliamperes to be read. The resistance of any meter shunt resistor is easily calculated from the formula

$$R = \frac{Rm}{N-1}$$

Where R = value of shunt resistor
Rm = internal resistance of meter
N = factor by which the meter range is to be multiplied.

Assuming the internal resistance of the 0-1 d-c milliammeter to be 27 ohms, for the 10 milliampere range, the shunt resistance will be

$$R = \frac{27}{10-1} = 3 \text{ ohms}$$

Similarly, the 100 and 500 milliampere shunt resistances are computed from the formula and found as approximately .27 and .05 ohms, respectively. These shunt resistors may be constructed when suitable resistance wire and an accurate means of determining low resistance values are at hand. High-grade, inexpensive meter "shunts" are available
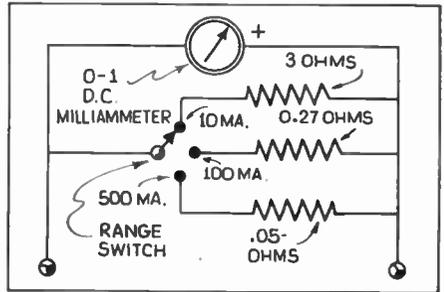
Fig. 21.   Extending the range of a milliameter by the addition of suitable shunt resistors.

commercially so that almost any low-range milliammeter or microammeter may read current values to 5 amperes, as desired.

In this way, one meter is made to function or do the work of several. A description of several typical commercial instruments of this type will be discussed.

CHAPTER 4

Point-to-Point Testing Equipment

Rapid and accurate point-to-point testing depends largely upon the accuracy and versatility of the testing instruments employed for the measurements. The correct diagnosis of the indications obtained, on the other hand, is dependent entirely upon the individual making the tests, in each case. There are available many instruments suitable for point-to-point testing, from simple ohmmeters and combination volt-ohmmeters to elaborate dual instruments combining the functions of

Fig. 22. Weston Model 772. Volt-ohmmeter.

the volt-ohmmeter with that of a point-to-point tester.

These point-to-point testers are equipped with a test plug, adapters, sockets, switches or tip-jacks, so that a voltmeter or ohmmeter may be quickly and easily connected between any two desired circuits of any tube stage in a receiver, or from any point to ground or chassis. Some do not incorporate meters of any kind, enabling the use of the meter functions of the set analyzer or indicating instrument at hand. A number of manu-

facturers have designed their point-to-point testers in two units for convenience and freedom from obsolescence.

In addition to many resistance, d-c voltage and current ranges, most test instruments include facilities for making a-c voltage and output measurements. With others, capacity, inductance and power level tests may be performed. Batteries supply the operating potential for resistance measurements in most cases. Some instruments employ an a-c line-operated d-c power supply to provide higher voltages so that extremely high resistance ranges may be obtained. Several of these point-to-point testers and muti-range instruments will be described.

WESTON MODEL 772

The Weston Model 772 volt-ohmmeter, shown in the illustration at Fig. 22, is a typical example of the accurate and dependable apparatus produced for resistance and voltage measurement.

Built around a large 50 microampere movement equipped with an easily-read 5-inch scale, a sensitivity of 20,000 ohms-per-volt is obtained. This sensitivity is required to make possible the high resistance range of 30 megohms through the use of only two small 7.5 volt batteries. In all, four resistance ranges are provided. The "ohms" scale of the meter extends from 0-3000 ohms, and is laid out so that the first ten divisions of the scale permit resistance values as low as one ohm to be accurately determined. By means of the rotary switch, this resistance range may be multiplied by 10, 1000 and 10,000. The 30 megohm range enables the value of the highest resistances employed in radio receivers to be checked most accurately.

At the two tip-jacks provided for ohms connection, five d-c voltage ranges of 2.5, 10, 50, 250 and 1000 volts are available, at the proper setting of the rotary switch,

17
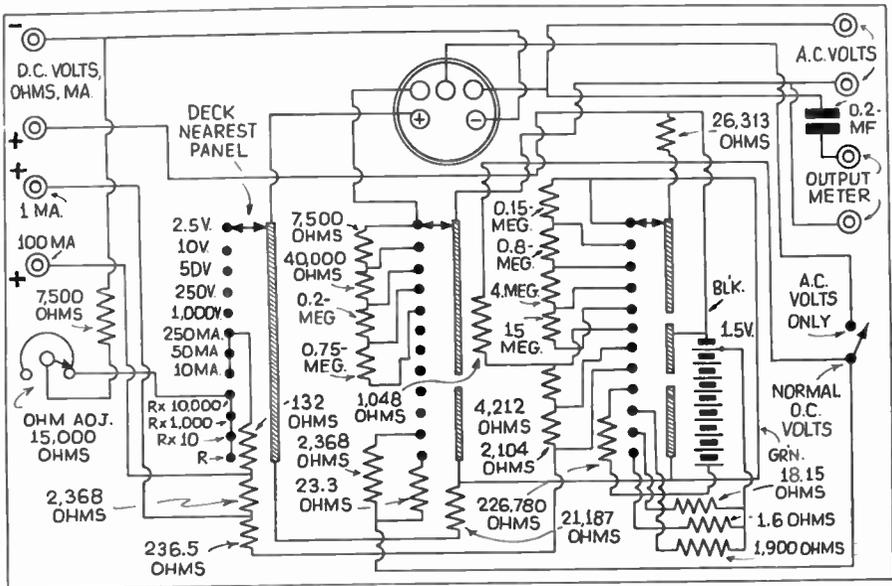
Fig. 23. Schematic circuit diagram. Weston 772 volt-ohmmeter.

all at a sensitivity of 20,000 ohms-per-volt.

By means of this same rotary switch, and an a-c—d-c switch, five a-c voltage ranges of 2.5, 10, 50, 250 and 1000 volts may be obtained at a sensitivity of 1000 ohms-per-volt. As an output meter, these a-c voltage ranges are available through a series condenser, as may be seen from the schematic circuit diagram of the instrument at Fig. 23.

Facilities for measurements of direct current values are also provided in three ranges of 10, 50, and 250 milliamperes. Two additional current ranges of 100 microamperes and 1 milliampere are also obtainable, but only at two independent pin-jacks on the panel to safeguard the meter.

To simplify the taking of accurate measurements, the d-c voltage and current scale consists of an arc of 100 divisions. The a-c scales are calibrated in red and are entirely independent from the d-c scale.

By means of a one megohm resistor and from 50 to 70 volts of "B" battery, connected externally, the 30 megohm "ohms" scale may be increased to 150 megohms. This extremely high range is valuable in testing paper dielectric condensers for excessive leakage.

A chart supplied with the instrument

permits decibel readings to be taken by referring a-c voltage measurements across a 500 or 600 ohm line with .006 watts (6 milliwatts) as the reference level for zero D.B. Power ratio to zero D.B. or actual power in watts may be determined from the table.

TRIPLETT MODEL 1220-A

The Triplett Model 1220-A, illustrated at Fig. 24, typifies the point-to-point testers available, which may be employed with any volt-ohmmeter or with the meter functions of a set analyzer.

Resistance and voltage tests are made through a test-plug and cord terminating in a small seven prong base, which, with the aid of any of the five adapters supplied with the instrument, is inserted into the socket of the tube stage to be analyzed. Thus, the tube circuits of any tube, glass or octal type, are brought out to a panel where resistance or voltage measurements may be taken conveniently and quickly.

The eight-wire test-plug terminates in the five sockets on the panel. The standard RMA tube pin numbering system is used to designate the terminals of the 4, 5, 6 and 7 hole sockets. For the octal type socket, the eight pin numbering system is indicated in red. A lead and clip for connection to the chassis provides a

means for measuring resistance and voltages from any point, using the chassis as reference point. An ohmmeter or voltmeter may be connected across any two

Fig. 24.   Triplett Model 1220-A. Point-to-Point Tester.

circuits, or between any circuit and chassis, through the ten black tip-jacks. The red tip-jacks of corresponding numbers are wired together through a jack switch which open-circuits when a test lead tip is inserted in the red jack. In this way, current measurements in any circuit may be taken by connecting a milliammeter in the proper red and black tip-jacks. This system of open-circuiting jacks provides a means for connecting phonograph pickups, headphones, etc., to a receiver for test purposes. By inserting a small battery in the control grid red and black tip-jacks, with the test plug in the receiver socket and the tube in place on the panel, tubes may be tested by the grid-shift method.

The circuit diagram of the Triplett Model 1220-A is shown at Fig. 25.

TRIPLETT MODEL 666

This instrument is representative of the many pocket-size volt-ohmmeters that have made their appearance recently. Despite miniature proportions, a fair degree of accuracy is attained. As shown in Fig. 26, the Triplett Model 666 is built around a square-type meter with four scales, two for "ohms" readings, one for direct current and voltage, and another for a-c voltages.

A 0-400 microammeter is employed to secure five d-c voltage ranges of 10, 50 250, 500, and 1000 volts, at a sensitivity of 1000 ohms-per-volt. Four direct current ranges of 1, 10, 50, and 250 milliamperes are also provided. A compensate copper-oxide rectifier used in conjunction with the sensitive d-c meter enables a-c voltages of 10, 50, 250, 500, and 1000 volts to be read at 1000 ohms-per-volt.

Two resistance ranges of 0-300 ohms and 0-250,000 ohms are included. A single small flash-light cell (1½ volts) provides the motivating power for the ohmmeter. The low "ohms" range makes use of the now familiar "back-up" scale, in which the resistance to be measured acts as a shunt directly across the meter movement.
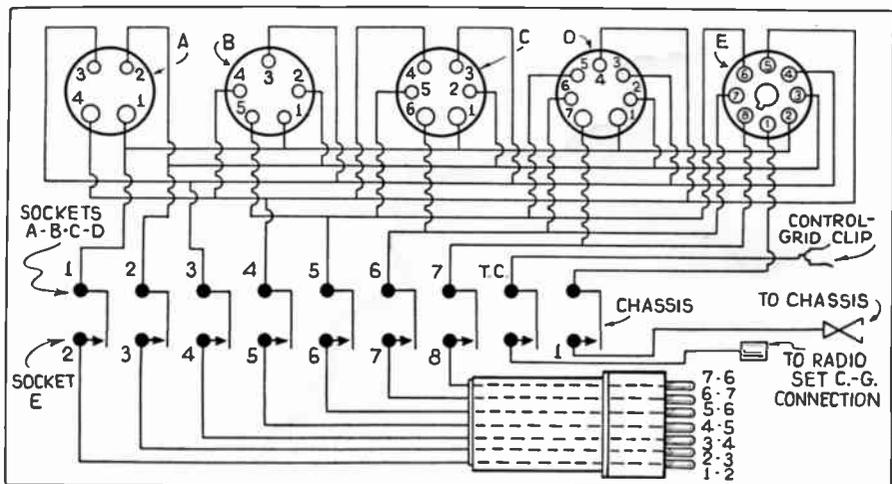
Fig. 25.   Schematic circuit diagram of Triplett 1220-A.

Fig. 26. Triplett volt-ohmmeter model 666.

A rotary range selector provides the necessary switching, with a toggle switch for a-c or d-c volts. "Zero ohms" is obtained through use of a rheostat in series with the flashlight cell and meter, as shown in the schematic circuit diagram at Fig. 27.

WESTON MODEL 666-1B

A means for modernizing or converting any good volt-ohmmeter into a complete point-to-point testing instrument is furnished by this simple but effective "socket selector set," shown at Fig. 28.

Instead of bringing the socket terminals through the plug to the inside of a complex instrument, as was the case with most former set analyzers, they are brought out to a small rectangular block unit carrying a tube socket and a group of pin-jacks. These analyzer units have two small fixed pins on the underside which fit into corresponding blank pin-jacks for mechanically mounting it on the Weston Model 772, 665 or 663 volt-ohmmeters. Any volt-ohmmeter may be fitted with similar tip jacks, so that the blocks may be firmly anchored by means of the fixed pins during the test procedure.

By fitting the block into position and using the small jumper leads supplied with the block, resistance voltage, current, and output readings can be taken with ease and rapidity, on any type of tube base regardless of pin arrangement or electrode position. A set of skirted adapters used with the block carry over the tube pin numbering on each type of base in accord with RMA standards.
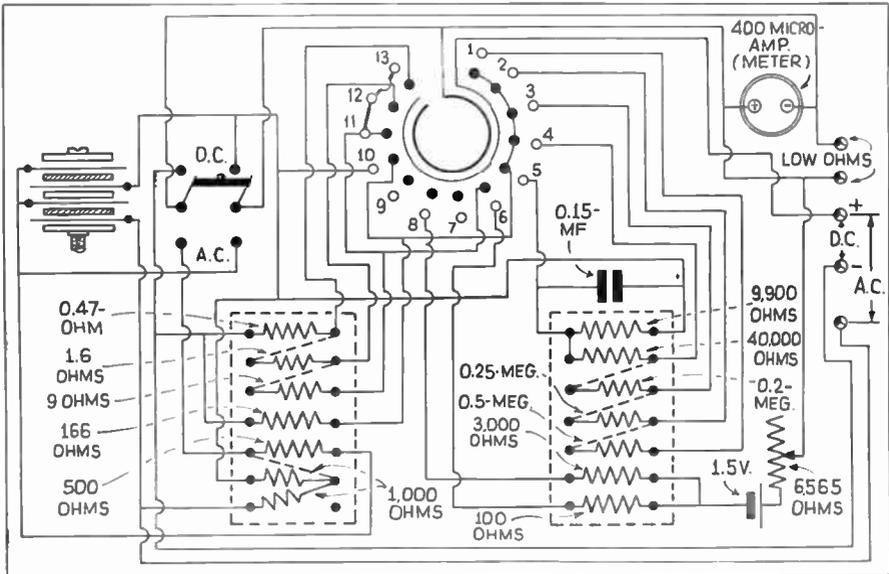
Fig. 27. Schematic diagram Triplett 666.

To obtain readings, the adapter that has the base corresponding to the tube under test is selected and placed on the analyzer block. The test plug is fitted with the correct plug adapter. The tube is removed from its socket in the receiver and placed into the skirted adapter socket. The test plug is then inserted into the receiver socket under test. Charts are furnished to aid those who are unfamiliar with tube electrode positions. These charts tie any tube base to the numbers on the selector block. A circuit-breaking jack in each circuit (except heater) permits insertion of any milliampere range of the volt-ohmmeter so that current readings may be taken.

SHALLCROSS MODEL 611 UNIVERSAL TESTER

The Shallcross Universal Tester, pictured at Fig. 29, embodies the necessary facilities for taking resistance, voltage and current measurements in conjunction with a suitable point-to-point tester. In addition to these fundamental tests, both capacity and inductance values may be determined.

With this one instrument, a wide coverage of ranges is possible, as follows:

5, 25, 100, 250, and 1000 d-c volts at 1000 ohms-per-volt.

1-10-100, and 1000 d-c milliamperes.

5, 25, 100, 250 and 1000 a-c volts at 1000 ohms-per-volt.

0-500, 0-5000, 0-50,000 ohms, and 0-5 megohms (d-c resistance).

0-30,000, 0-300,000 ohms and 0-3 megohms (a-c resistance).

0-100, 0-1000, and 0-10,000 henrys (inductance).

.001-.1, .01-1.0, and .1-10 microfarads (capacity).

Voltage and current measurements are made in the usual manner by adjusting the range selector switch to the desired voltage or current range. Both d-c and a-c resistance tests are incorporated. For d-c resistance measurements, the range switch is set at "R" and the correct scale factor button is pressed. When all buttons are up, the scale factor is 100. Resistance values as low as ½ ohm may be accurately adjudged. For resistance val-
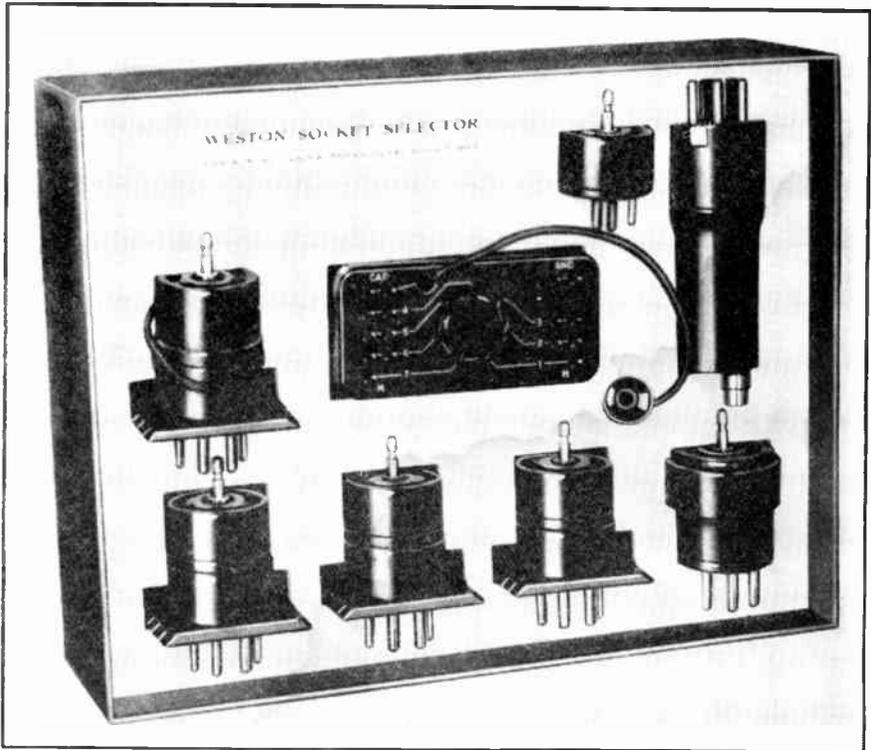
Fig. 28. Weston Model 666-1B. Point-to-Point Tester.

Fig. 29. Shallcross Model 611. Universal Tester.

ues to 5 megohms, the instrument is connected to the a-c supply line and the range selector turned to "Z" position. The 10,000 factor button is pressed for this range.

An auxiliary scale is supplied for a-c resistance and inductance tests. The a-c resistance or impedance may be capacity, inductance or resistance. The instrument is connected to a 110 volt a-c supply line with the range switch at Z, but the a-c d-c switch is turned to a-c position.

Electrolytic condensers may be tested, in addition to paper and mica condensers, for capacity and d-c leakage. D-c leakage tests are made by setting up the instrument to test high resistances, with the range switch at Z, the factor button 10,000 pressed down, the a-c—d-c switch on d-c and the instrument connected to 110 volts a-c. Condenser polarity must be observed by connecting the positive condenser terminal to the positive test pin-jack on the panel.

Both the d-c and a-c functions of the meter are fused for protection against overloads. The wiring diagram for the model 611 tester which may be obtained completely assembled or in kit form is shown at Fig. 30. No values are supplied or available.
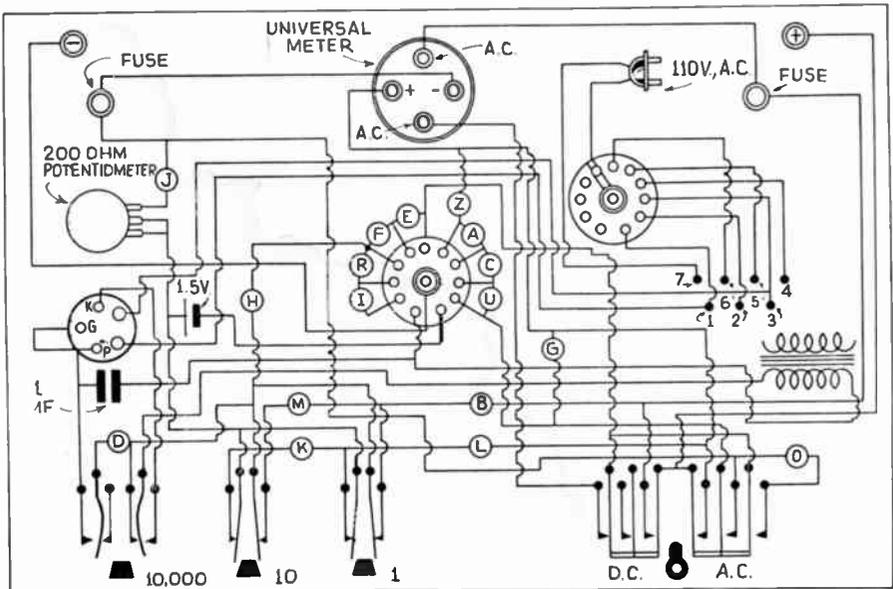
Fig. 30. Schematic diagram. Shallcross Model 611. Component values unavailable.

SUPREME MODEL 550

The Supreme model 550 radio tester, shown at Fig. 31, is an excellent example of a combination point-to-point test instrument, in which a free reference point analyzer is incorporated with a multi-range volt-ohmmeter. Full facilities are provided for making a complete circuit analysis of any tube stage, enabling resistance, voltage and current measurements. In addition, leakage current of electrolytic condensers and the capacity of paper or mica condensers may be determined without reference to external charts.

The instrument utilizes a newly designed meter, called the "Quadrimeter", with dual viewing windows and a centrally balanced bi-indicating pointer. In this way, greater scale space is available thus avoiding needless crowding of dial markings. A total of thirty-five meter ranges is made possible by a complex switching arrangement as follows:

0-2000, 0-20,000, 0-200,000 ohms, 0-2 megohms and 0-20 megohms.

7, 35, 140, 350, 700, and 1400 d-c volts at 1000 ohms-per-volt.

7, 35, 140, 350, 700, and 1400 d-c milliamperes; 14 d-c amperes.

7, 35, 140, 350, 700 and 1400 a-c volts at 1000 ohms-per-volt.

.002—.07, .01—.35, .04—1.4, .1—3.5, .2—7.0 and .4—14.0 mfd.

—10 to +6 D.B., 0 to + 16 D.B., + 10 to + 26 D.B., + 20 to + 36 D.B., and + 30 to + 46 D.B.

The scales on the illuminated quadrimeter show three sets of markings. The scale in the lower window is associated with the ohmmeter and megohmmeter circuits and is read directly for the 2000 ohm range, and multiplied by 10, 100, 1000 and 10,000 to obtain readings for the other resistance ranges. Values to 35 ohms are read on the first half of the low ohms scale. A type 71-A tube is employed as a rectifier in conjunction with
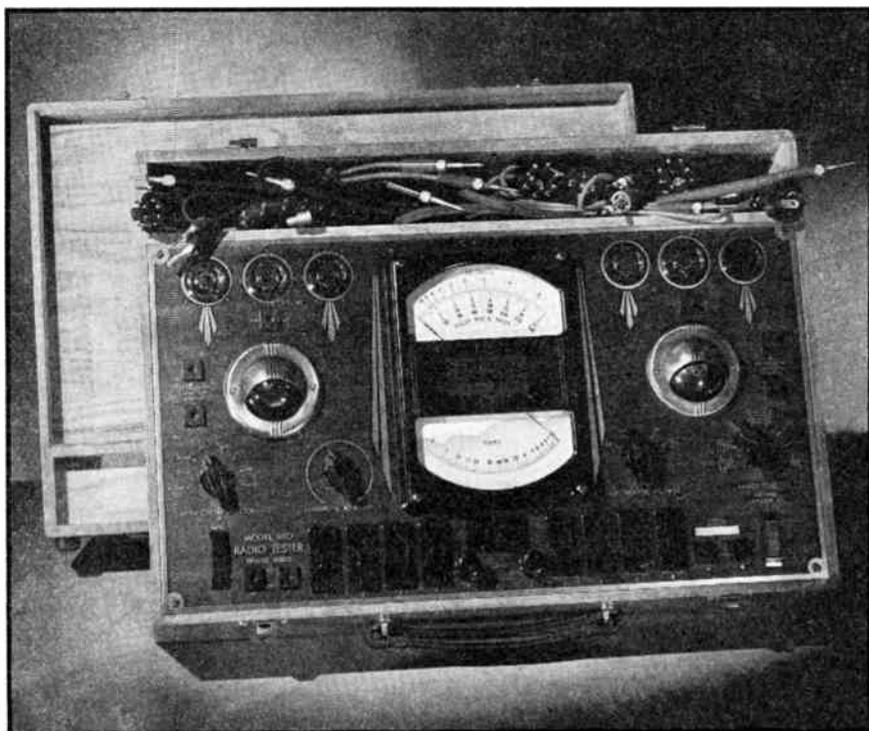
Fig. 31. Supreme Model 550. Radio Tester.
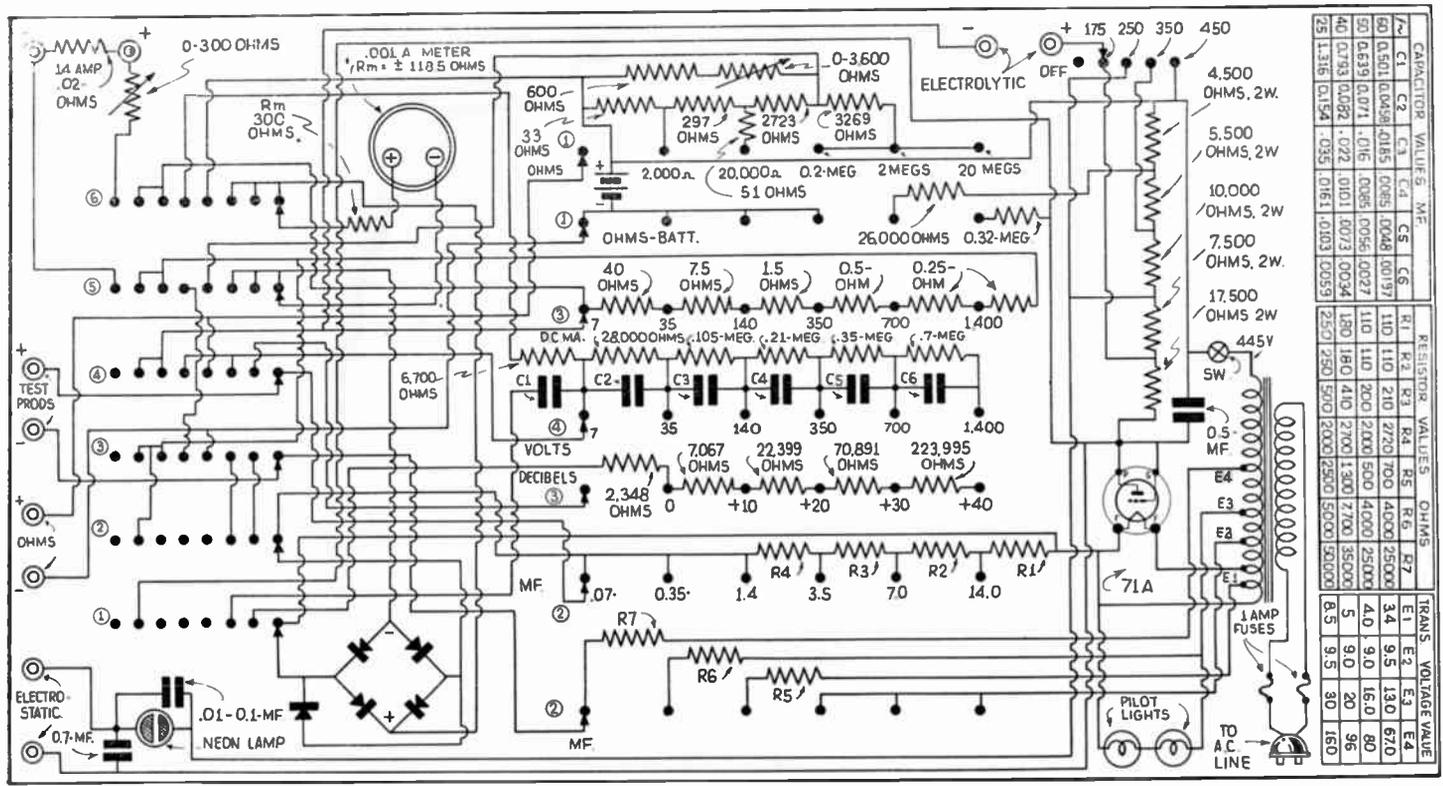
Fig. 32. Supreme 550. Schematic circuit diagram of meter functions.
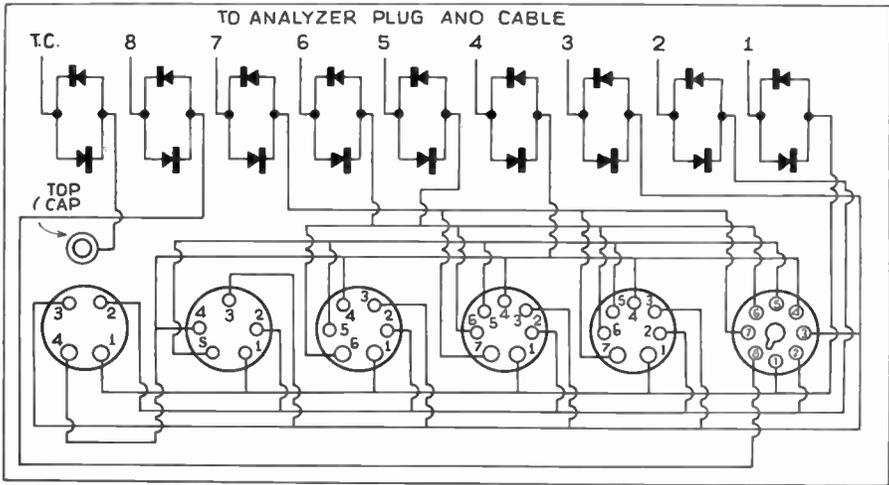
Fig. 33. Schematic circuit diagram of Supreme 550. Point-to-Point Analyzer.

a suitable transformer to obtain the necessary d-c voltages for the 2 and 20 megohm resistance ranges, and to supply the operating potential for testing condensers for leakage at their rated working voltage. When making resistance measurements using the megohmmeter or electrostatic leakage tester, the instrument is connected to an a-c supply line of specified voltage.

The lower scale in the upper window is used for all d-c voltage and current readings; a-c voltages and capacity in microfarads. There is no correction scale or markings for these a-c or d-c indications since a compensated rectifier circuit is employed for a-c measurements. The upper scale in the upper window is used for reading audio power directly in decibels. By means of the range selector, measurements from minus 10 D.B. to plus 46 D.B. are obtained in a 500 ohm line, with respect to a zero D.B. level of 6 milliwatts (.006 watts).

By reference to the schematic circuit diagram of the meter functions of the instrument in Fig. 32, it may be seen that a capacitor, employed for scale correction of the low a-c range, serves to isolate the a-c from the d-c measuring functions of the tester, so that the meter will not register d-c values on a-c circuits inadvertently. For this reason, comparative output measurements are possible, without the usual series condenser, from the plates of output power tubes.

The analyzing circuits of the instrument, shown at Fig. 33, consist of a 9-wire analyzing cable terminating in a 7-pin test-plug. This plug is provided with a center contact for 8-pin tubes, and a thumb-catch so that adapters supplied may be plugged into position when tube circuits having other base arrangements are to be tested. This cable is connected to six sockets through twin-jacks on the panel. When two leads are connected to any twin-jack, the circuit is automatically opened. This permits insertion of any milliampere range of the tester for measuring plate current, cathode current, etc., when the test plug is in position in the radio receiver and the tube inserted in the proper socket on the instrument panel. By connecting the test probes between the twin jacks of any two circuits, and switching the meter circuit and range selectors to the desired position and range, resistance or voltage values between any two circuits may be determined.

CHAPTER 5

Easily Constructed Multi-Range Volt-Ohmmeter

In designing and constructing a volt-ohmmeter to be used in point-to-point testing, certain requirements must be fulfilled to obtain the maximum benefits. The instrument must be capable of measuring, with some degree of accuracy, those values of voltage, resistance, and current most likely to be encountered in servicing radio receivers, and yet be relatively inexpensive to construct. Compactness, portability, and ease of operation are further requisites. To satisfy these conditions, the volt-ohmmeter described below is presented for those who prefer to build their own test equipment.

The instrument is constructed around a single low-cost 0-1 m.a. d-c milliammeter, used in conjunction with a full-wave copper-oxide type rectifier, connected in a simple circuit shown at Fig. 34. Only two terminals are employed to obtain any of the voltage, resistance or current ranges. A 12-position bi-polar switch, S2, is incorporated as a "range selector". By means of the triple-pole double-throw switch S1, a-c or d-c voltage ranges of 5, 50, 250, 500, and 1000 volts, at a sensitivity of 1000 ohms per volt are possible, when the range selector is rotated to the voltage range required. Current measurements of 1, 10, 100, and 500 d-c milliamperes may be made by setting the range selector to the proper position. Four resistance ranges are also included, two of which are battery-operated for resistance measurement of 0-1000 and 0-100,000 ohms. A built-in line-operated voltage supply enables resistance values of 0-1 megohm and 0-4 megohms to be read.

A single set of resistors is used as multipliers for the a-c and d-c voltage ranges of the meter. Although one-watt carbon units, chosen for their low cost, served admirably in this particular instrument, standard precision type non-inductive wire-wound multipliers may be substituted should a greater degree of accuracy be desired. Carbon resistors are highly suitable, providing they are care-fully selected and of good quality. Since the required multiplier resistance values are those most commonly used around any service bench, a number of each may be purchased so that the one most closely approaching the specified value may be chosen for the instrument. In this manner, the proper values are obtained for good accuracy and nothing is lost, for the remainder of the resistors can always be put to use. The value of the multiplier resistors are as follows: 5,000, 50,000, 250,000, 500,000 ohms and one megohm, R1, R2, R3, R4, and R5, respectively. It may be seen that no multiplier is used for the 5 volt a-c range.

The value of the shunt resistors required for current measurements depends entirely upon the internal resistance of the individual meter. A Weston type 301 meter of 27 ohms resistance was employed in this instrument. Thus, three shunts of 3, .27, and .05 ohms, R6, R7 and R8, for the 10, 100 and 500 d-c milliampere ranges, respectively, were constructed. Resistance wire from old filament type resistors was used for the purpose. The values were carefully adjusted on a Wheatstone bridge. When such facilities are unavailable, although resistance wire of specified ohms per foot, obtainable from any good supply house, may be used, it is suggested that these shunt resistors be purchased as they are quite inexpensive. Values for almost any current range for meters of various internal resistance are available.

A suitable dial scale must be used to compensate for the "average" a-c values indicated by the copper-oxide rectifier used with the d-c meter to read a-c voltages. Since no complicated compensating circuit is employed, the dial scale must supply the correction factor when a-c voltages are measured. Usually, the manufacturers of copper-oxide meter-rectifiers provide, also, a dial scale printed upon bristol board to be used in conjunction with the rectifier unit. In almost every case, these dial scales contain voltages and current scales, and a single resistance
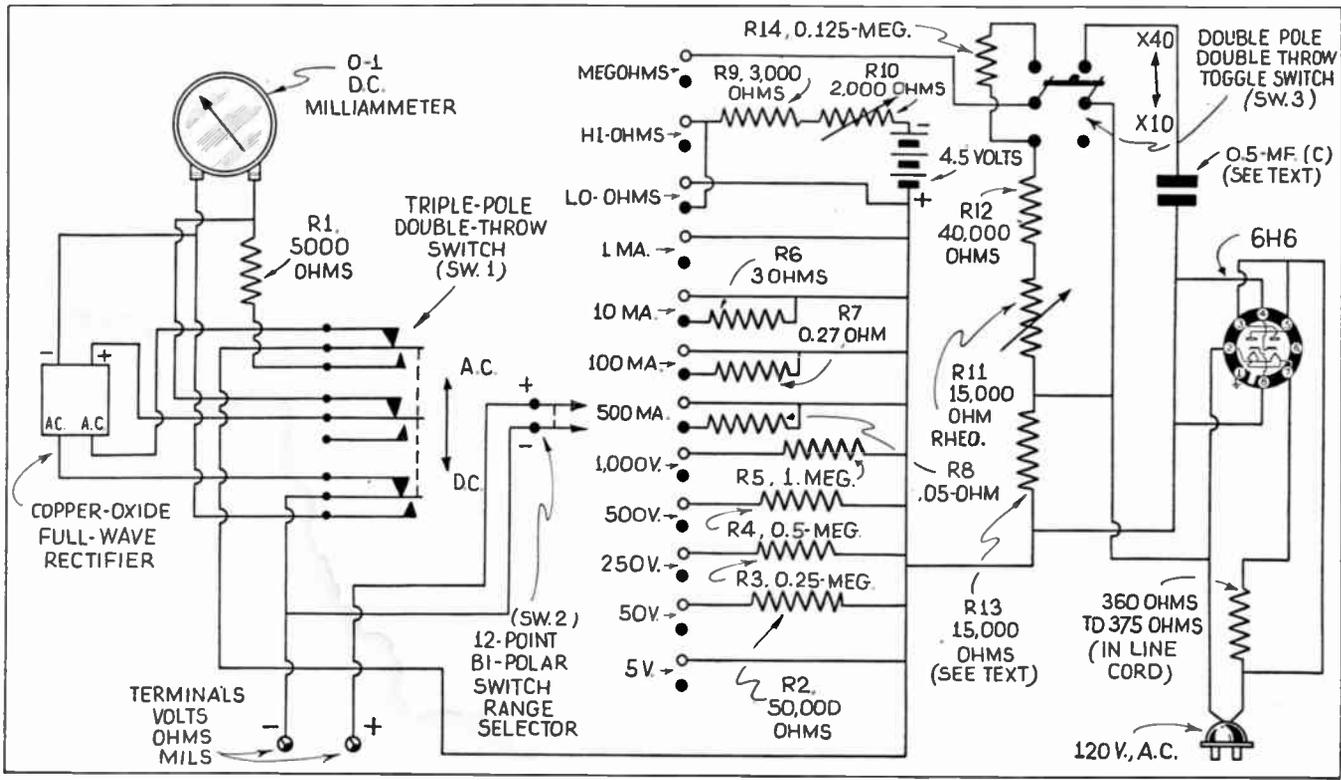
Fig 34. A versatile, compact, inexpensive, easy-to-build volt-ohmmeter.

scale of 0-100,000 ohms. Individual a-c scales are provided, or a single a-c scale with correction markings. These voltage, current and resistance ranges meet the requirements of our instrument. The scale is easily substituted for the dial scale on the milliammeter by removing the case of the meter.

The low ohms range is of the shunt type, in which the resistance to be measured is connected across the meter, and is employed for the measurement of resistance values from 0-1000 ohms. Values as low as ½ ohm may be accurately adjudged. One advantage of the shunt type ohmmeter is the fact that only one milliampere is drawn from the voltage source during operation. Since a "reverse" scale is necessary, the regular ohms scale on the meter cannot be used. Individual markings, therefore, must be plotted on the meter dial for low ohms measurement. This is done by employing

known resistances of 5, 10, 25 and 50 ohms etc., and noting the meter indications. A curve may be plotted on semi-logarithmic graph paper against these meter indications. For convenience, the graph may then be pasted in the lid of the volt-ohmmeter case. In Fig. 35, low ohm scale curves for the 27 ohm Weston type 301 (used here) and 50 ohm Weston universal meters may be seen. The internal resistance of most 0-1 m.a. d-c milliammeters fall within these two values, so that this graph may be employed with good accuracy. Resistance indications are plotted against markings on the 1000 volt d-c scale.

The limiting resistor R9, of 3000 ohms, a carbon unit, is used with the zero ohms adjusting rheostat R10, a 2000 ohm wirewound control, and a 4.5 volt battery for the low and high ohm ranges. Two positions on the bi-polar switch make these ranges available at the terminal posts.
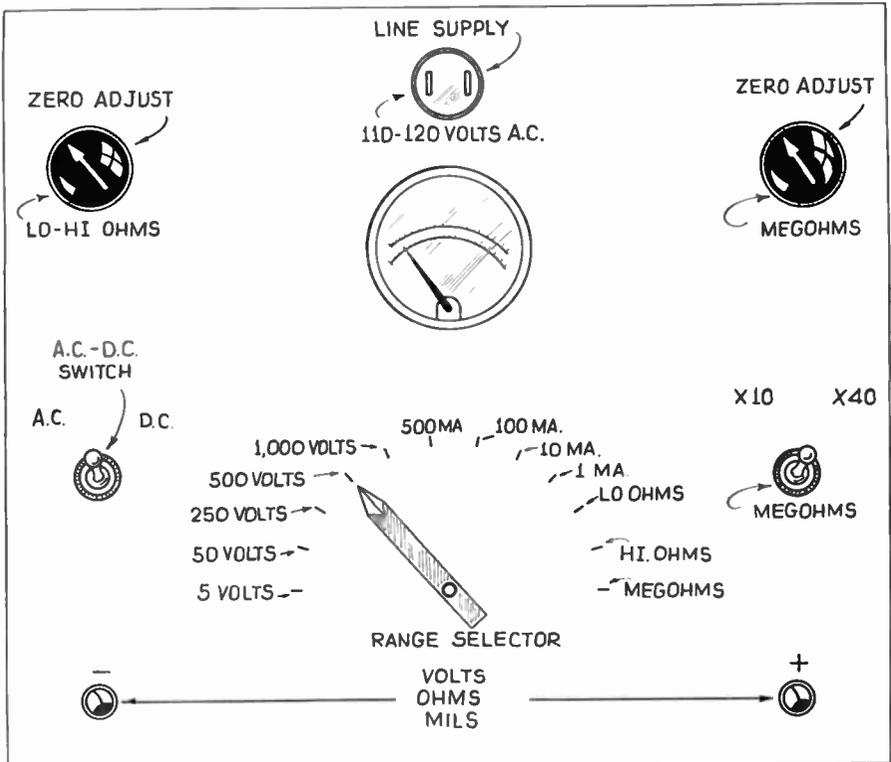

Fig. 36. A suggested panel layout for the volt-ohmmeter.
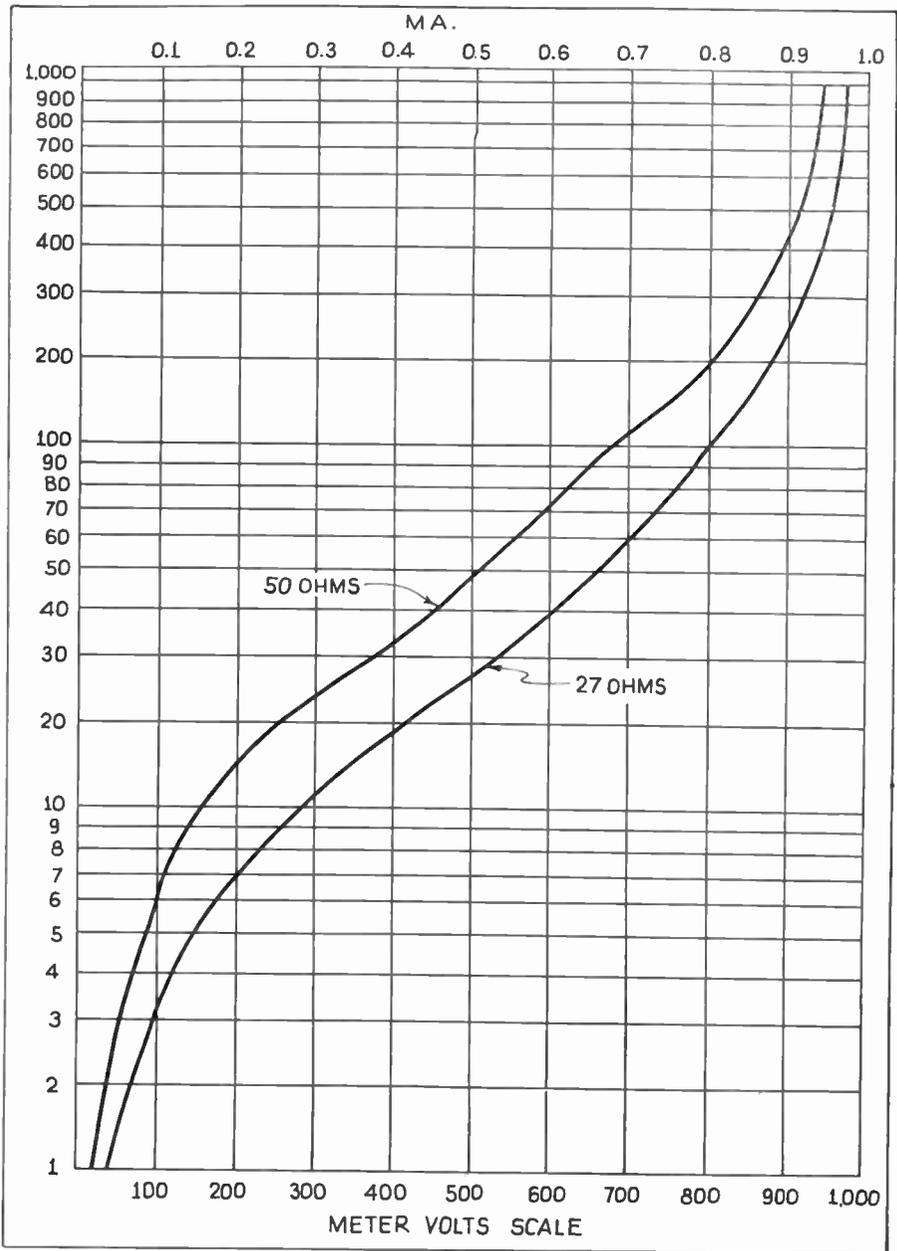
Fig. 35. A graph for use in measurement of low resistance values with the low ohms range of the volt-ohmmeter. The curve is plotted against the 1000 volt range of the meter. Curves for 27 and 50 ohm meters are shown.

For zero ohms adjustment, it is unnecessary to short-circuit the test prods or instrument terminals. Simply rotate the range selector to "Lo" ohms and adjust the rheostat R10. for zero ohms.

An exceedingly simple and compact power supply, consisting of a 6H6 metal octal-type tube, a filament limiting resistor R15, 360 ohms, the bleeder resistor R13, 15,000 ohms, and a .5 microfarad paper condenser, is employed to increase the "high" 100,000 ohm range by 10 and 40 in two steps, using 45 and 180 volts, respectively, so that resistance values to one and four megohms may be read. The 6H6 filament limiting resistor may be of the type contained within a line cord, such as is used in a-c—d-c midget receivers, or a separate resistor of 35 watts rating may be utilized. The line cord type resistor was selected for this instrument for reasons of economy, compactness, and ready heat dissipation.

The d-c voltage available from the power supply was 45 volts with the 15,000 ohm 10 watt bleeder resistor connected across the d-c output. The bleeder resistor should be of the adjustable slide type so that more or less resistance may be introduced to compensate for various line voltages in different communities and thus maintain the 45 volts. A d-c voltmeter of 1000 ohms-per-volt must be used to measure this voltage. In this way, a one milliampere load is placed across the voltage supply, the same current load of the meter used in the volt-ohmmeter. The 15,000 ohm rheostat R11 serves as the zero ohms adjustment for this range as well as the 4 megohm range. When the double-pole double-throw switch S3 is thrown to the "X40" position, the .5 mfd. condenser is connected across the d-c voltage output to increase the available voltage to 180 volts, so that the four megohm resistance range may be obtained. The same switch introduces an additional current limiting resistor R14, into the circuit, to compensate for the added d-c voltage. If it is found that the output voltage of the power supply is slight] higher or lower than 180 volts, the capacity of the charging condenser C, must be decreased or increased as the case may be, until the specified voltage is obtained.

A suggested layout for the panel of the instrument may be seen at Fig. 36. Any other arrangement may be equally de-sirable in accordance with individual requirements. The socket of the 6H6 rectifier may be placed upon the panel to expedite tube renewals, but these will be few and far between. No dimensions for the panel or carrying case are given. These also are left to the individual.

USING THE VOLT-OHMMETER

For d-c voltage or current measurements, the a-c—d-c switch must be thrown to the d-c position. The range selector is then placed upon the voltage or current range required. A-c voltages are read with the a-c—d-c switch in the a-c setting. Any of the a-c voltage ranges may be used as an output meter for making comparative tests by connecting the terminals of the instrument across the voice coil of a moving coil type reproducer or a transmission line. When the instrument is connected across the plates of output tubes or between one plate and chassis for output measurements, a series condenser must be used. This may be a .25 mfd. or .5 mfd. unit whose working voltage is sufficiently high to withstand the voltage in the circuit across which it is connected.

Resistance measurements of 0-1000 and 0-100,000 ohms are made with the range selector in either "low" or "high" ohms position. Zero ohms must be established before making tests by means of the battery "zero adjuster" as previously described. For resistance values to one megohm, connect the line cord to a 110-120 volt a-c source, after placing the range selector in the "megohms" position and the factor switch in the "X10" position. Allow time for the rectifier to heat. Adjust the megohm "zero adjuster" for zero ohms with the instrument terminals or test leads short-circuited. Multiply the 0-100,000 ohm meter scale by 10. For the four megohm range, the same procedure applies. In this case, however, the factor switch is thrown to "X40". Scale readings are now multiplied by 40 to obtain the value of the resistance under test. When the megohm ranges are used, the receiver must be disconnected from the supply line. Also remove antenna and ground leads.

LIST OF PARTS REQUIRED FOR THE VOLT-OHMMETER

One panel and carrying case.
One 0-1 m.a. d-c milliammeter.

One full-wave copper-oxide rectifier.

One dial scale to be used with rectifier.

One triple-pole double-throw switch (S1).

One 12-position bi-polar switch (S2).

One double-pole double-throw toggle switch (S3).

Five carbon resistors, one watt size, plus or minus 2%-5%, 5,000, 50,000, 250,000, 500,000 ohms, and 1 megohm (R1, R2, R3, R4, R5).

Three shunt resistors, 3, .27, and .05 ohms for 27 ohmmeter—(R6, R7, R8).

Three carbon resistors, one watt size, 3,000, 40,000 and 125,000 ohms (R9, R12, R14).

One wire-wound 10 watt resistor, adjustable type, 15,000 ohms (R13).

One rheostat, 2,000 ohms (R10).

One rheostat 15,000 ohms (R11).

One .5 mfd. paper condenser 300 volts (C).

One line cord and resistor, 360 ohms.

One octal type socket.

One type 6H6 metal tube.

One 4.5 volt "C" battery.

Two tip-jacks or binding posts.

Necessary knobs and hardware.

CHAPTER 6

Resistance in Radio Receivers

A study of the schematic diagram of any modern radio receiver will quickly show the very important part that resistance plays in the design of the receiver. One essential point, which should be noted, and which is the entire basis of servicing receivers with point-to-point resistance measurements, is the fact that *a path of electrical resistance exists between the terminals of any tube, and one common point, ground.* Whenever there is an electrical circuit, resistance is present. This resistance may be that of an air-cored or iron-cored inductance, a resistor, or any component through which direct current can flow, or any combination of these components.

Since a certain definite value of resistance exists between the terminal of a tube and ground, the reference point, when this resistance path is destroyed in any manner, the receiver may become inoperative or function improperly. It will be noted, further, that the circuits between these tube elements and ground consist of a network of series and parallel circuits. Only by reducing these series and parallel circuits to terms of simple series circuits may the expected resistance values of any radio circuit be obtained.

In making measurements of this nature,

an important consideration is that of tolerance values. Resistors employed in radio receivers, especially those of the carbon variety, usually have a tolerance of plus or minus 10 per cent. In other words, a carbon resistor, whose specified value is 50,000 ohms may read between 45,000 and 55,000 ohms. Resistors used in voltage divider circuits, or which carry large current values, such as wire-wound units, are held to closer tolerances, from 2 to 5 per cent, plus or minus. In any event, the variation in the value of a resistor, and its effect upon the operation of a radio receiver depends upon its function in the circuit. The stated values of coil windings or inductances, however, should vary only slightly in any case.

In Fig. 37, the r-f stage of the Stromberg Carlson model 55 receiver is presented as an example to illustrate series and parallel circuits that are so typical of recent radio receivers. From the diagram, we find the resistance of the path between the plate of the 78 tube and ground is 26,050 ohms. This value represents the d-c resistance of the r-f coil primary winding, 50 ohms, and the bleeder network composed of the 16,000 ohm resistor and 10,000 ohm volume control. However, when considering the entire receiver

Fig. 37. The r-f stage of Stromberg-Carlson Model 55 receiver. Notice the series-parallel circuits.

circuit, an ohmmeter test from plate to ground would result in a reading of approximately 4200 ohms, since the power supply of this receiver, shown in Fig. 38, has a bleeder resistor of 5000 ohms, connected

Fig. 38. Stromberg-Carlson Model 55. Power supply circuit.

across the d-c output of the power supply, which is in shunt with the plate to ground circuit of the r-f tube. The circuit 1 to G may be represented as a series parallel circuit, as in Fig. 39. Here, the 16,000 and 10,000 ohms series resistors are in parallel with the two 50 ohm r-f chokes and 5,000 ohm bleeder resistor series circuit, all of which are in series with the 50 ohm r-f primary.

It must be noted that the d-c resistance values of the r-f primary and the r-f chokes mentioned above are not those specified by the manufacturer. The values

Fig. 39. Illustrating the relation of the bleeder resistor in the power supply of Fig. 38 to resistance measurements of the r-f stage in Fig. 37.

shown in the diagram have been selected solely for the purpose of this discussion.

The cathode circuit of the i-f tube in this receiver illustrates a precaution which should be observed in making a point-to-point resistance measurement. The value of the resistance from the cathode of the i-f tube to ground, as can be seen from Fig. 37, will depend upon the setting of the variable volume control. At minimum resistance position of the control, a reading of 650 ohms should be obtained, the value of the limiting resistor and the r-f choke in this circuit. However, at maximum volume position of the control, or when the full resistance is in the circuit, an ohmmeter reading of the circuit 2 to G will be quite different, because of the series circuit consisting of the 16,000 ohm resistor, the two 50 ohm r-f chokes and the 5000 ohm

Fig. 40. The presence of a variable resistance and its position is important in a resistance analysis.

bleeder resistor in the power unit which is in parallel with the volume control resistance. This resistance network is shown at Fig. 40. Therefore, the ohmmeter would indicate a value of approximately 7,000 ohms for circuit 2 to GND. It should be remembered that the reading obtained in this circuit is always dependent upon the setting of the volume control.

In point-to-point resistance measurements, there are various circuit arrangements where erroneous indications may be obtained because consideration is not paid to the possibility of parallel circuits. The RCA-Victor model R-50 receiver furnishes two such examples. The push-pull power stage and power supply is shown at Fig. 41. The type 47 output tubes, in this receiver, are biased by a negative voltage impressed upon the grids, secured by tapping a portion of the voltage drop, by means of the resistors, across
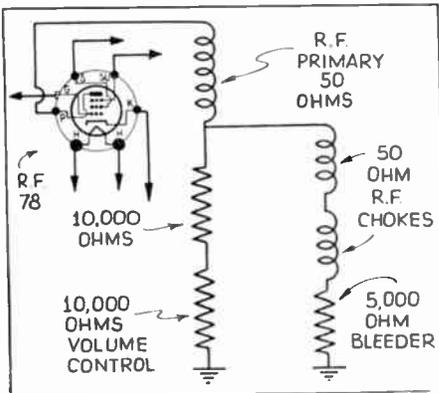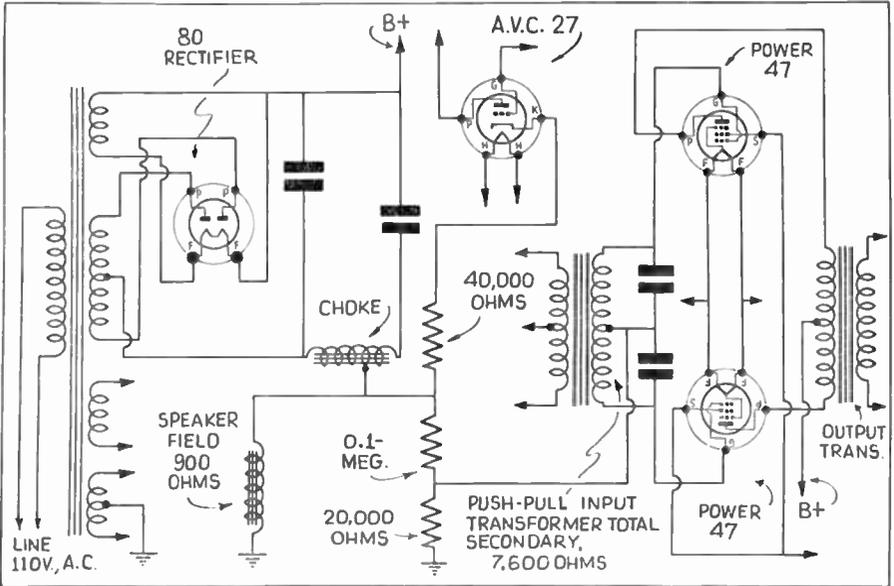
Fig. 41. The power supply output and A.V.C. stage of the RCA-Victor Model R-50 receiver illustrates the possibility of making erroneous calculations because of parallel circuits.

the negative return. Connecting the ohm-meter from the control grid of either 47 power output tube to ground will indicate the presence of a series-parallel circuit, since the series circuit composed of either half winding of the push-pull input transformer, which is 3,800 ohms, and the 20,000 ohm resistor, is shunted by the series circuit composed of the 100,000 ohm resistor and the 900 ohm field coil. Correct resistance values in this series-parallel circuit are especially important, since changes of only 20% will affect receiver operation with regard to tonal quality. This network is shown in Fig. 42.

The resistance path from the cathode

Fig. 43. A series-parallel circuit.
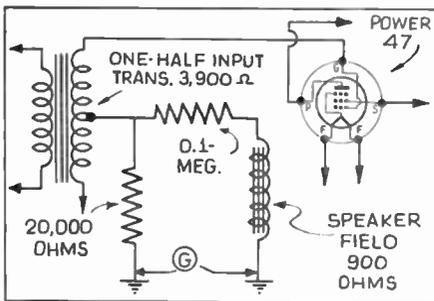
Fig. 42. An example of a series-parallel circuit in the RCA-Victor R-50 receiver.
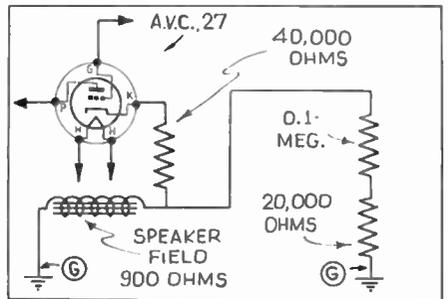
of the AVC tube to ground in this receiver is another instance of a series circuit, part of which is shunted by another series circuit. The 100,000 and 20,000 ohm resistors in series are in parallel with the field coil which is in series with the 40,000 ohm resistor in the cathode circuit, shown at Fig. 43. The combined resistance, when an ohmmeter is connected from the cathode of the AVC tube to ground will be indicated as approximately 30,000 ohms. Those familiar with circuits in which a separate tube is employed as AVC will readily appreciate the critical voltages impressed upon these tubes and the importance of substantially accurate resistance values.

In some receivers, a resistance of usually 30,000 to 50,000 ohms is connected across the primary winding of an audio transformer as in Fig. 44, for the purpose of flattening the audio response. A voltage analysis will not reveal an open-circuited primary, since voltage will be maintained upon the plate of the tube because of the presence of the resistance
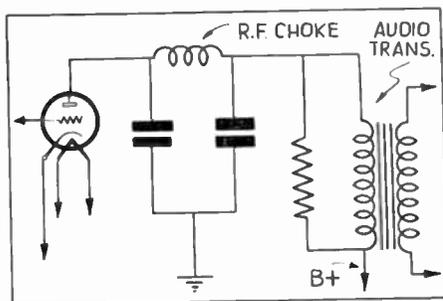
Fig. 44. An open-circuited audio primary is not easily disclosed with a voltage analysis.

in the circuit. (A lower plate voltage will be indicated, however). As a rule, the resistance of audio transformer primaries seldom is more than 5,000 ohms. Due to this wide variance, a point-to-point check of the resistance in the plate circuit will reveal the faulty primary almost immediately.

To compensate for slight differences and to match the output tubes in a radio receiver, so as to minimize hum, some manufacturers utilize a push-pull input
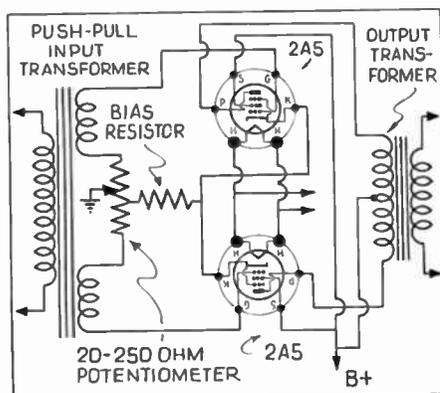
Fig. 45. Resistance measurement in each grid circuit is dependent upon position of potentiometer.

transformer with split secondaries and a potentiometer of 20-250 ohms, connected in the circuit as shown at Fig. 45.

The potentiometer is adjusted to the point where minimum hum level is obtained. Resistance measurements from the grid of either output tube to ground may disclose a higher reading from one grid than the other. The difference may be considerable, in some instances, especially where class AB or B amplifiers are employed with step-down ratio input transformers in which each half of the secondary may be as low as 75 ohms, and a 200 ohm potentiometer has been adjusted to either extreme end of its range.

ELECTROLYTIC CONDENSERS IN RESISTANCE MEASUREMENT

Almost all commercial radio receivers employ electrolytic type condensers for filter and by-pass purposes. These units have a d-c resistance value because of direct current leakage, however small. The interesting point of what effect these condensers may have upon the resistance of circuits in which they are present, when a point-to-point test is carried through, is brought up.

An electrolytic condenser in good condition has been proven to have a negligible effect upon any resistance or circuit across which it is connected, in almost every instance, less than 5%. For this reason, the presence of this type condenser in a circuit ordinarily may be disregarded. In circuits, other than voltage divider circuits, where an electrolytic condenser is connected across a high resistance, the d-c resistance of the condenser is important. This may be seen in the case of an electrolytic by-pass condenser connected across a cathode bias resistor of 50,000 ohms in a power detector stage. Any excessive leakage in the condenser would provide a shunt path for current flowing in the cathode circuit. Leakage of only 50,000 ohms in the electrolytic unit would disturb operating conditions sufficiently to result in distortion and lowered sensitivity.

When making resistance measurements in a circuit in which an electrolytic condenser is connected, the only precaution is that of maintaining the correct polarity of the ohmmeter, that is, connecting the negative side of the ohmmeter to ground, which is usually the reference point, since the negative terminal of an electrolytic condenser is *always* connected to the "negative" side of any receiver circuit.

The polarity of the ohmmeter is determined by the polarity of the battery, which may be one or more cells, contained within. When the ohmmeter is not "poled" correctly, when making resistance measurements in a circuit containing an electrolytic condenser, a low resistance indication, that of the electrolyte, is obtained, and not the normal d-c leakage resistance of the unit. Simply reverse the ohmmeter terminals, in this case, to obtain the correct indication.

STANDARDS OF MEASUREMENTS

In discussing resistance in radio receivers, we have concerned ourselves with the d-c resistance of components employed in the receiver and their effect upon a point-to-point measurement analysis. An appreciable departure from normal expected values in any circuit would suggest trouble in that circuit. When a resistance measurement is taken of a tube circuit, the accuracy of the meter and the allowable tolerance values of the resistances comprising the circuit are important factors. The question of permissible discrepancy from expected values therefore arises. To save undue manipulation and needless waste of time, some standards of measurement should be planned. In other words, what is the maximum permissible discrepancy in the d-c resistance of a circuit, before the operation of that circuit is influenced by the discrepancy?

The principal resistance unit in modern radio receivers is the carbon resistor. Although carbon resistors may be manufactured within very close limits, as already stated they are usually supplied with a tolerance of plus or minus 10%, and often as high as 20%. On the other hand, wire-wound resistors are held to closer tolerances, in some cases better than 5%. Since air-cored or iron-cored coils are wound with a given number of turns of wire, their d-c resistance is more or less fixed and should vary by less than 5% of the expected value. Thus, an antenna coil primary of 50 ohms is probably partially short-circuited when a reading of approximately 35 ohms is indicated.

As a general rule, circuits containing carbon resistors may have a tolerance of plus or minus 20%. When a circuit contains wire-wound units, such as r-f or a-f coils, and wire-wound resistors, a toler-

ance of less than plus or minus 5% should be expected as normal values. Resistance indications in a circuit which vary by an amount greater than these specified tolerances usually spell trouble due to the failure of the d-c resistance of some component in the circuit, or in the insulation resistance between any component in one
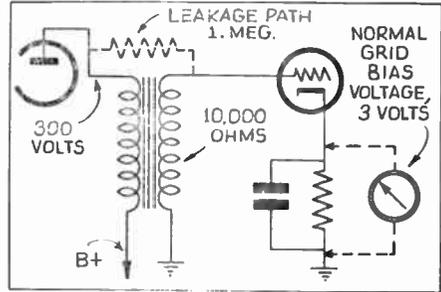
Fig. 46. Leakage between primary and secondary may seriously upset operating potentials.

circuit and a component in another circuit.

There must be a minimum insulation resistance of at least 25 megohms between any pair of windings of an r-f or a-f transformer, or from any winding to the form, core or case of the transformer, at a voltage equal to that applied to the transformer when in use. An insulation resistance less than 25 megohms will often upset circuit conditions and produce faulty operation.
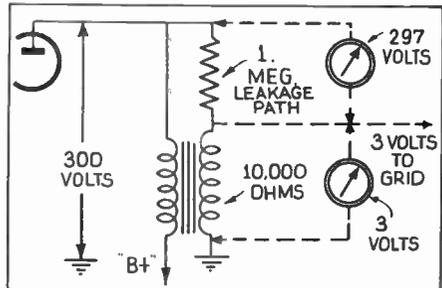
Fig. 47. Effect of leakage from primary to secondary.

To illustrate, let us assume an insulation resistance of only one megohm between primary and secondary of an audio transformer connected in a circuit as shown in Fig. 46. The one megohm leakage path and the secondary winding represents a parallel path to the primary winding. A potential of 300 volts will therefore exist across the one megohm

"leak" and the secondary. This voltage will divide across the "leak" and the secondary winding in direct proportion to their resistance, as shown in Fig. 47. A positive potential at "X" will be sufficient to overcome and cancel the negative bias applied to the tube. A distorted condition therefore will result during operation. Failure of the insulation resistance may have been due to electrolysis between windings, faulty soldering at the terminal

Fig. 48. Excessive leakage or low insulation resistance in any or all bypass condensers may cancel part or all A.V.C. voltage.

board of the transformer or occasioned by moisture. There are many instances where insulation resistance leakage will upset operating conditions. When incorrect voltages are obtained in a voltage analysis of a stage tube and the d-c resistance of the tube circuit is within normal expected values, it is well to check insulation resistance between circuits. Faulty soldering, in which the acid or paste spatters about, is the cause for a great many radio receiver troubles, producing undesired leakage paths.

In connection with insulation resistance and point-to-point resistance measurements, paper or mica dielectric condensers used in radio receiver circuits

should have certain standards of measurement or tolerances, for failure in the insulation resistance will often seriously interfere with normal functioning of a circuit. The tolerance value for paper or mica dielectric condensers with regard to insulation resistance varies with the service which the condenser has to perform. When employed as coupling or blocking-condensers in resistance-coupled amplifier circuits, or as by-pass condensers in AVC circuits, the minimum insulation resistance should not be less than 200 megohms. Where condensers bypass cathode, screen or plate circuits, the requirements are not quite as rigid, but for satisfactory operation, the insulation resistance should be 25 megohms or more.

The reason for this apparently high requirement for condenser insulation resistance, especially in circuits where they are connected in series with relatively high resistance values, may be seen readily in the case of paper condensers connected in a typical A.V.C. circuit as illustrated at Fig. 48. The value of R1, the load resistor, is generally between ½—1 megohm, as is resistor R2. In order to prevent the loss of any developed A.V.C. voltage to the controlled tubes, the insulation resistance of condenser C1 must be much higher than that of the combined resistance of R1 and R2. Assuming this value to be 2 megohms, an insulation resistance as low as 10 megohms in condenser C1 would produce a loss of approximately one-fifth of the available
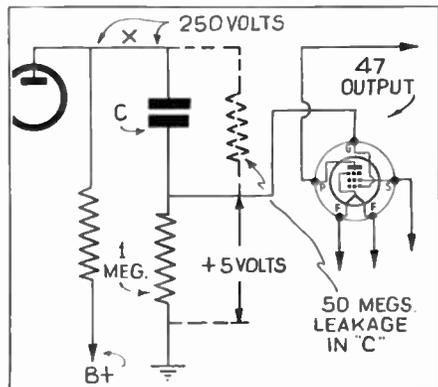
Fig. 49. Poor insulation resistance in an audio coupling or blocking condenser may place a positive potential upon grid of amplifier tube, or cancel part of bias voltage.

A.V.C. voltage. In the event this same low insulation resistance 10 megohms, was present in condensers C2, C3, and C4, each condenser in series with its associated grid filter resistor R3, R4, and R5, would offer further and almost complete reduction in A.V.C. voltage, since each shunts Condenser C1.

In a resistance-coupled amplifier, the insulation resistance of the coupling condenser C1 in Fig. 49, should be more than 200 megohms. It can be shown, that values considerably lower than this tolerance will produce faulty operation. In the circuit illustrated, a coupling condenser with 50 megohms insulation resistance would make possible the presence of a positive potential of 5 volts at the grid of the pentode output tube, in opposition to the normal negative bias. This condition is the result of the 250 volts, existing at point "X", dividing across the condenser and the grid leak, in direct proportion to their resistance values. With an insulation resistance of 200 meg-

ohms, the opposing positive potential at the grid would be 1.25 volts, probably insufficient to affect operation. However, the importance of high insulation resistance in such circuits is apparent.

The facilities of most ohmmeters do not include resistance measurement over several megohms, although some few instruments will indicate as high as 20 or even 40 megohms, using a built-in power supply or an unusually sensitive meter. For the purpose of checking insulation resistance of solid dielectric condensers, an electrostatic tester comprising a neon bulb and a suitable source of high voltage, is utilized.

Power transformer windings, likewise, should have an insulation resistance of at least several megohms between any two windings, or any winding and the core. When separate heater windings on a power transformer are employed for tubes in A.V.C. circuits, as one possible example, the presence of a leakage path may nullify the action of the special circuit.

CHAPTER 7

Typical Point-to-Point Resistance Analysis of a Modern Receiver

In radio servicing, before analyzing the circuits of the receiver with point-to-point resistance measurements, certain preliminary steps are taken to avoid needless manipulation. The tubes in the receiver should all be tested independently to eliminate the possibility of trouble upon this score. Other preliminary tests, such as tapping the detector tube, placing a finger upon the grid of audio amplifiers, applying the aerial lead wire to successive circuits, are all of great value in isolating the seat of the difficulty in an attempt to speed up diagnosis and repair.

The receiver must be disconnected entirely from the power supply and all tubes removed from their sockets when applying the resistance method of servicing receivers. For convenience in making the tests between the various points in the tube circuit, any of the various point-to-point testers, described elsewhere and commercially available may be employed. In conjunction with the point-to-point tester, in order to indicate resistance values likely to be encountered in the analysis of a modern receiver, the ohmmeter should have facilities to measure resistance from 1 ohm to at least 3 megohms.

To illustrate the methods of making a point-to-point resistance test, and to analyze the causes for incorrect indications and their possible effect upon receiver performance, several circuits of the RCA Victor model 8U will be examined. This model whose schematic circuit diagram is shown in Fig. 50, is a three band radio-phonograph combination receiver with metal tubes, and representative of thousands of modern receivers in use today. The wave-band switch, used to connect the long-wave, broadcast or short-wave coils into the circuit, is shown in the broadcast position, in which position the readings are taken.

In making this analysis, a reference point for our readings must be selected. In this case, as with almost every other

receiver, this point is ground, or the metal chassis. The test plug of the point-to-point tester is placed into the r-f 6K7 socket, and the ohmmeter connected to the tester. A reading of approximately 16,680 ohms should be obtained when the switch of the tester connects the ohmmeter between the plate and ground of this stage. This indication represents the series circuit comprising the r-f primary coils, L6, and L8, whose resistance totals 95.2 ohms, and resistors R21, R22 and R24, whose resistance values are 3,500, 13,000 and 85 ohms, respectively.

In the event, a reading of only approximately 3,600 ohms is indicated from the plate to ground, it would be logical to assume that the condenser C2 in the oscillator plate circuit is short-circuited, since then the series circuit from plate to ground consists of L6, L8, and R21. An indication of only about 100 ohms would point to a short-circuited by-pass condenser C25 in the plate circuit. There is also the possibility of a short-circuited tone control condenser, C38, in the plate circuit of the 6F6 output tube, as the cause for a low reading of 470 ohms, but only when the tone control is turned into the circuit. By checking the position of the tone control, this possibility is avoided.

After eliminating the tone control condenser, when the indication of approximately 470 ohms is still obtained, the most probable cause is a short-circuited filter condenser, C40. This value is the resistance of L6, L8, R19, and R20. When the input filter condenser is short-circuited, a reading of approximately 1,000 ohms will be obtained. There is yet another likely cause for trouble. The ohmmeter may register infinity, or an open-circuit between plate and ground. This may be due to a break in the wiring between the B+ terminal of L8 and the power supply, an open-circuited primary winding L6 or L8, or an open-circuited
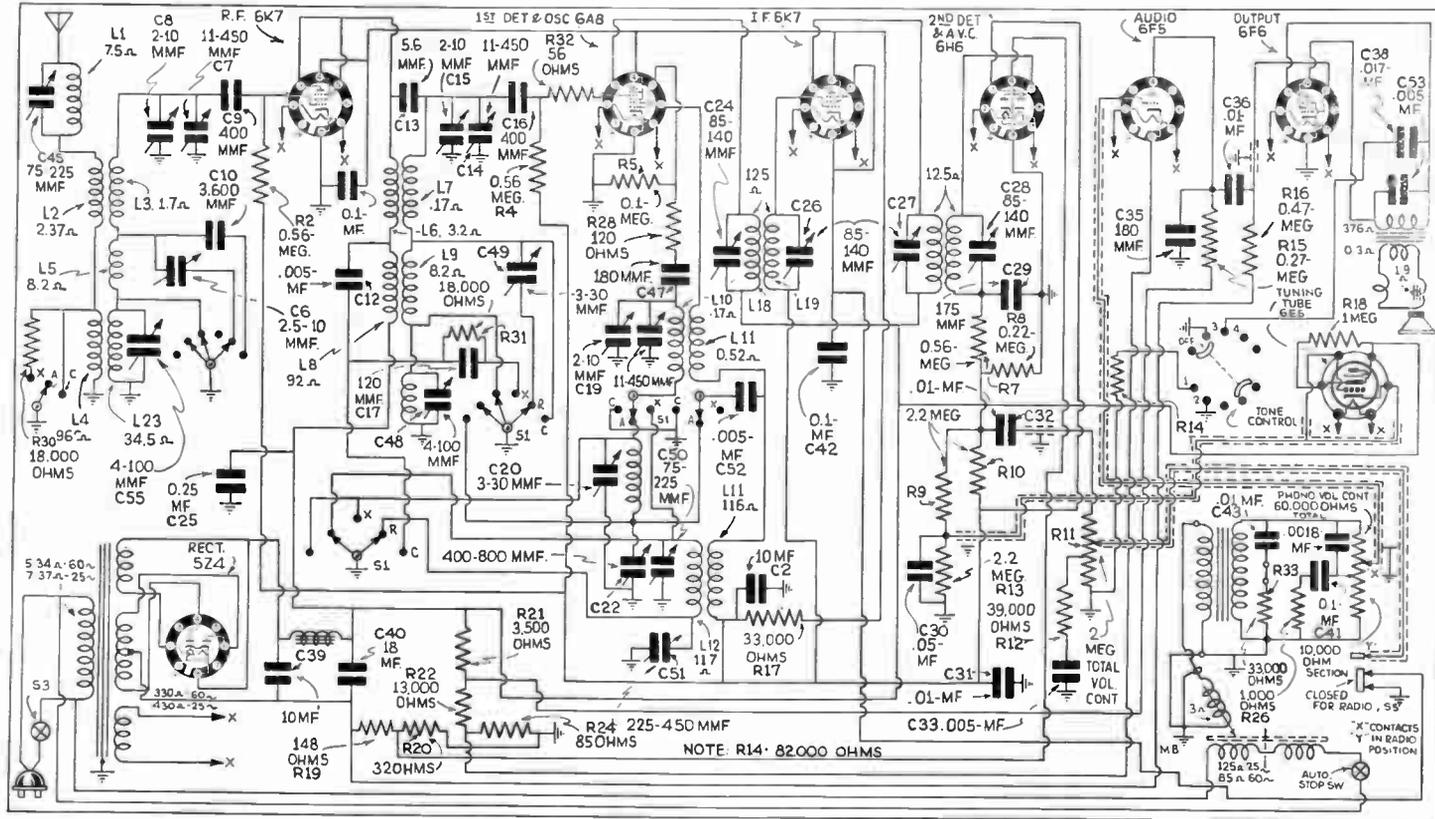
Fig. 50. RCA-Victor Model 8U receiver.

voltage divider R21, R22, R24. Since the short-wave primary, L6, is wound with heavy wire, it would be reasonable to assume that the broadcast and long-wave primary coil L8, is open-circuited, or a section of the voltage divider.

Analysis of the r-f screen-grid circuit is carried out in like manner. The point-to-point tester is switched to the screen terminal so that the ohmmeter is connected between screen-grid and ground. A "zero" ohm reading will indicate a short-circuited screen bypass condenser, C21. The correct resistance value that should be obtained between these two points is approximately 46,000 ohms, the resistance of the series circuit consisting of R17, R22 and R24. When the ohmmeter reading is only 33,000 ohms, which is the value of the screen-grid series resistor, then condenser C2 is probably short-circuited, a condition that should have been disclosed when the plate circuit was analyzed. However, this manipulation may be regarded as a check on the condition of C2, when a reading of 3,500 ohms is indicated between the plate and ground of the r-f stage. An infinite resistance reading from screen-grid to ground, points quite definitely to an open-circuited series resistor R17. In connection with the grid circuit, where bypass condenser C21 is found short-circuited, and then replaced, it is well to check the resistance of the series resistor, R17, since excessive current passing through the unit due to

the failure of C21, will in all probability cause it to carbonize and decrease in value. This condition may seriously impair operation.

Although ordinarily connected to the cathode, in this receiver the suppressor grid of the r-f 6K7 is tied to the plate, thus eliminating this circuit from our analysis. Since the cathode is grounded, we may direct our attention to the control grid circuit.

In this receiver, the r-f transformer secondary coils are isolated from the tube control-grid circuit so far as resistance or d-c measurements are concerned, by the grid condenser C9, and therefore do not enter into our calculations at this point. However, these coils may be tested by a point-to-point analysis and shall be treated soon.

The resistance value to be expected, when the point-to-point tester and ohmmeter are connected between the control grid of the r-f tube circuit and ground, is approximately 3 megohms. Any indication at considerable variance from the stated value signifies trouble in the circuit. The resistance path consists of the grid-leak R2, 560,000 ohms, the grid-filter resistance R10, 2.2 megohms, and the load resistor R8, in the 6H6 diode circuit, 220,000 ohms. A reading of approximately 560,000 ohms may indicate a short-circuited grid-filter condenser C31. The effect of such a short-circuit at this point is distortion at resonance due to the
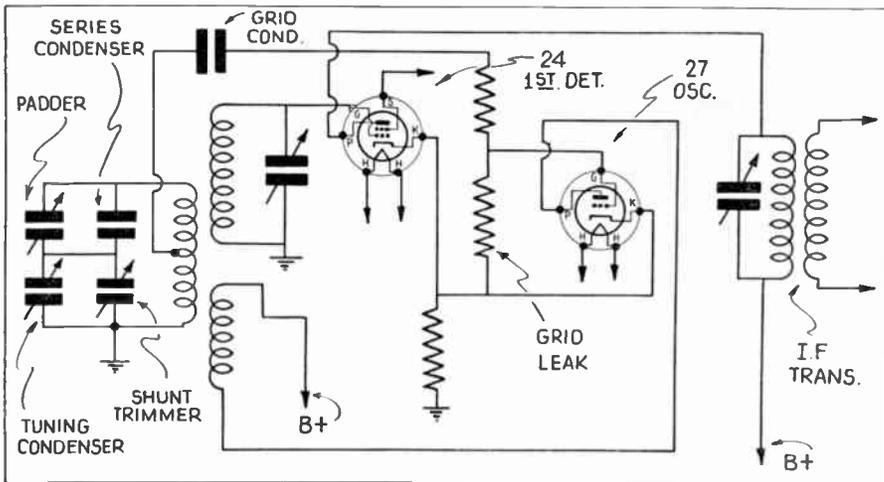
Fig. 51. The tank circuit cannot be checked with a resistance analysis due to the isolating condenser.

lack of A.V.C. voltage, and possibly oscillation in the form of motor-boating. These condensers, however, seldom if ever are found short-circuited. Leakage in secondary return by-pass condensers, such as C31, is common, and will produce similar symptoms. An indication of approximately 10 ohms may be caused by a short-circuited grid condenser C9. Although this failure is not likely, it is possible. An infinite resistance reading may be the result of an open-circuited gridleak, R2, or a broken or loose connection to the control-grid clip.

This completes the analysis of the r-f stage with the exception of the r-f transformer secondary coils. To check these coils without removing the chassis, the ohmmeter terminals are connected from

Fig. 53. The volume control cannot be checked with the usual tube socket resistance analysis.

There are some receiver circuits, however, to which a point-to-point resistance analysis cannot be applied without first removing the receiver chassis from the cabinet. Examples of this are found in some tuned circuits, where an inductance, or a portion thereof, is isolated from the balance of the receiver by a condenser, which may be a series or padding condenser. This inductance may be an r-f coil or oscillator coil as shown in Fig. 51, or an iron-cored choke in an audio or power supply circuit, shown in Fig. 52. In some instances, a resistor, employed as a volume or tone control, Fig. 53, or in some tone filter circuit, shown at Fig. 54, is isolated by a condenser, and therefore cannot be checked through point-to-point resistance measurements, without first removing the chassis of the receiver.

Fig. 52. Another example of an inductance, part of which is isolated by a condenser.

the stator of the r-f section of the gang condenser, to ground. A reading of 10 ohms, the resistance of L3 and L5, should be obtained. A "zero" ohm indication may be due either to a short-circuited r-f tuning condenser section, C7, or trimmer condenser C8 on the section. A short-circuited tuning condenser section is rare, but this may be checked quickly by turning the condenser plates "out-of-mesh". When an indication of less than 10 ohms, but not quite zero-ohms, is obtained, the trimmer condenser C6 may be short-circuited.

Similarly, it is possible to check the circuits of each tube stage, as well as almost every other circuit in the receiver, with a point-to-point resistance measurement, and to analyze the results of these tests. The methods involved are the same.

Fig. 54. To check the resistors in the tone filter circuits, the chassis must be removed from cabinet.

CHAPTER 8

Point-to-Point Resistance Analysis
When Receiver Circuit Diagram
And Values are Unavailable

When the schematic circuit diagram and d-c resistance values of a radio receiver are at hand, there is no problem in carrying through a point-to-point resistance test, since we have the means to an end. However, when a receiver is serviced for which no diagram or values are available, it is quite difficult to make tests of this nature with any degree of accuracy and certainty, unless the particular receiver is well-known. Fortunately, the basic structure of most receivers is such that certain factors can be relied upon to hold true, thus permitting the application of a point-to-point resistance analysis.

The statement that a path of electrical resistance exists between ground, a common reference point, and the terminals of any of the elements of a tube, is synonymous with the fact that an infinite resistance reading should never be obtained between any tube circuit and ground. An infinite resistance reading in any circuit signifies trouble in that circuit.

The plate circuit in most tube stages is inductive or resistive in character, or a combination of both, as shown in Fig. 55. For this reason, it may be stated gen-

Fig. 56. An example of zero resistance between plate and cathode—an exception.

erally since these components possess some d-c resistance, that a "zero" ohm reading will never be indicated between the plate terminal and ground, unless the tube is used as a rectifier with the plate tied to the cathode which is grounded, as in the diode detector at Fig. 56.

A zero ohm reading probably should never be found between the control-grid and ground. The resistance reading in the control grid circuit may vary between a few ohms to several megohms, represented by the resistance of an r-f or a-f coil winding or grid leak as at Fig. 57. Zero resistance should never be indicated between the control grid and any other element, unless the tube is used as a rectifier in a power supply circuit as in Fig. 58, or as a diode detector, with the control grid, tied to the plate (Fig. 59). In perhaps one or two cases, as in a dynatron oscillator, the control grid may be connected to the cathode. Here, a zero resistance indication will be obtained.

In very few instances should zero resistance be indicated between the screen grid and cathode or ground. A "zero" ohms reading should not be obtained between screen grid and plate of the same

Fig. 55. Plate circuit of most tube stages possess d-c resistance.

tube. This does not hold true, however, where a screen grid tube is operated as a triode with the screen grid tied to the plate, as in a power output circuit and some detector and a-f amplifier circuits.
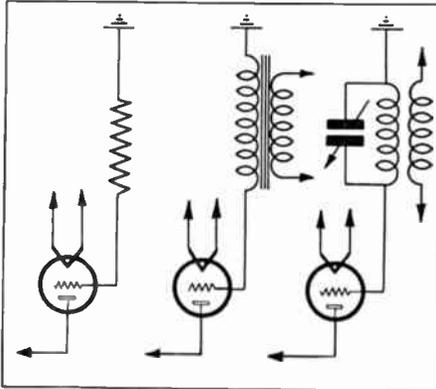
Fig. 57. A resistance reading is almost always obtained between grid and ground of a tube stage.

Some cases may be found in which "zero" ohms is indicated between screen grid,
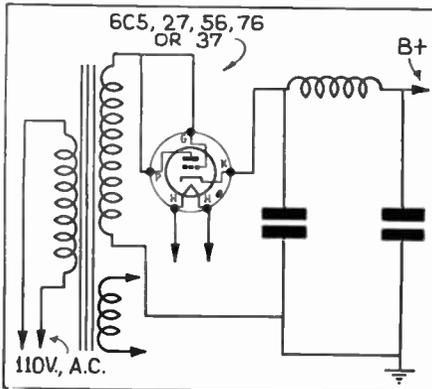
Fig. 58. An exception to the statement that zero resistance is unusual between grid and any other element of a tube stage.

plate and suppressor grid, since these elements are connected together and the tube employed as a power or voltage amplifier, as indicated in Fig. 60.

The resistance value indicated between the screen grid and ground may be either lower or higher than that indicated between plate and ground of the same tube circuit. This value will depend upon whether the screen grid voltage is obtained from a voltage divider circuit
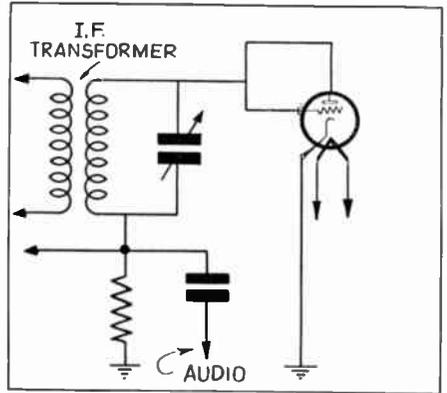
Fig. 59. Another example of zero resistance between grid and another element of a tube stage.
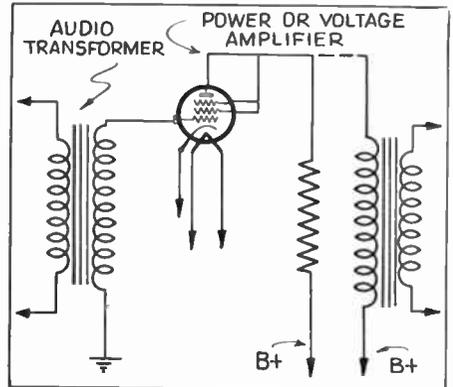
Fig. 60. An instance of zero resistance between screen grid and plate or any other tube element. Not usual.
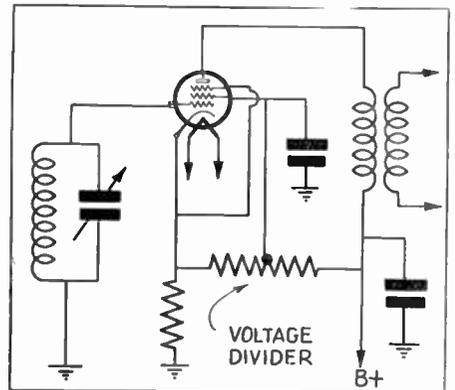
Fig. 61. A lower resistance reading from screen grid to ground than from plate to ground is usual.

as shown in Fig. 61, or through a series resistance of high value, shown at Fig. 62. Only in a direct-coupled amplifier, should "zero" ohms be obtained between the plate of one tube and the grid of a tube in another circuit.
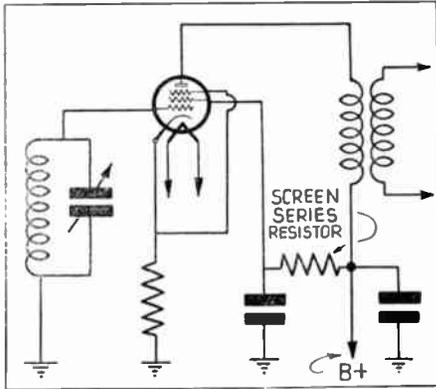
Fig. 62. An exception to the statement that a lower resistance reading is obtained from screen grid to ground than plate to ground.

In rectifier tube circuits, zero resistance should never exist between the filament or cathode terminals and the plate. "Zero" ohms should never be obtained between the cathode or filament terminals and
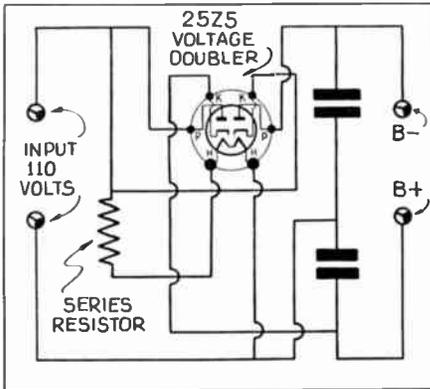
Fig. 63. One case where zero resistance is indicated from plate of a rectifier to B—.
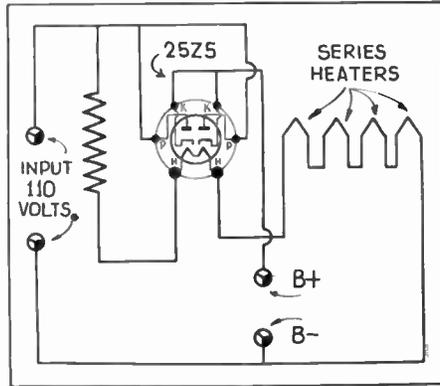
Fig. 64. When rectifier tube is removed, an infinite resistance reading is obtained between plate and ground.

ground of a rectifier. Seldom should zero resistance be indicated between the plates of a rectifier and ground, unless the tube is employed in a voltage-doubler rectifying circuit, in which one plate serves as B—, or ground. This is shown at Fig. 63. Another exception to this statement has already been pointed out in the case of an amplifying tube used as a rectifier with plate connected to cathode which is grounded. When the rectifier tube in the usual a-c, d-c receiver is removed from its socket so that a point-to-point test may be made, an infinite resistance reading will probably be found between the plate terminals and ground or B—, since the resistance path provided by the series filament or heater circuit of the tubes is broken. This is illustrated in Fig. 64.

The foregoing data has been presented with the purpose of providing some means for applying a point-to-point resistance analysis to receivers whose schematic circuit diagram is unavailable. It should be remembered that although these statements are true in most instances, exceptions other than those already pointed out will be found.

CHAPTER 9

Combination Voltage and Resistance Point-to-Point Analysis

In servicing radio receivers and associated equipment, there is one common objective—that of determining and correcting any troubles which may arise, in the most rapid and efficient manner possible. There is no "best" or "only" method of locating these difficulties. The testing procedure that will permit the diagnosing of radio receiver symptoms in the least possible time, and time *is* an important factor, is the best method to employ. Probably the two most common servicing systems are point-to-point voltage and resistance analysis. There is much to be said for both methods, each possessing desirable features, but also some that are disadvantageous.

Voltage and current analysis depends upon the fact that troubles arising in tube circuit will be manifested by a change in the voltage and current in that circuit. In like manner, resistance analysis is dependent upon the departure from the normal d-c resistance in a tube circuit, when trouble exists in that circuit.

The advantages of a point-to-point resistance analysis have been discussed at great length. It must be remembered, however, that resistance measurements take cognizance only of the "cold" resistance of the components in a tube circuit. The d-c resistance of many components in a radio receiver may change appreciably when voltage is applied to their terminals, or current is passing through the unit. In other words, the difference between the "cold" and "hot" resistance values may amount to considerable proportions. Thus, the d-c resistance of a tube circuit, in which a carbon resistor or a condenser is located, may be within normal expected values when the receiver is turned off, but yet another value when the receiver is operating. A by-pass condenser may break down and short-circuit only upon the application of voltage. A coil winding or a wire-wound resistor may open-circuit only upon the
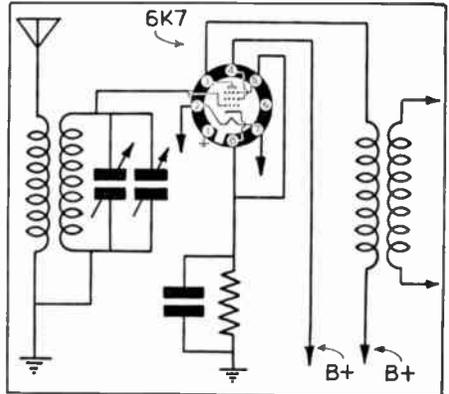
Fig. 65. A voltage analysis will not disclose a short-circuited trimmer condenser.

passage of current or any other cause which may induce heat, and produce a thermostatic action to cause the open-circuit. For these reasons, it may be seen that point-to-point resistance measurements do not always suffice, and that a voltage analysis will serve to better advantage in more quickly locating the faulty circuit.

On the other hand, resistance analysis will disclose the causes for receiver failure or faulty operation where no indication of the nature of the trouble may be obtained with a voltage analysis. There are many circuits in a radio receiver in which the voltages present cannot be read accurately with a voltmeter because of the power consumed by the meter and the multiplier effect of the resistances in the circuit. In other cases, the resistance of a tube circuit may alter considerably without affecting the voltages or currents in that tube circuit.

Assume that a radio receiver is being serviced with the symptom of very weak reception of only one or two powerful broadcast stations. Preliminary tests show that the signal strength is increased

Fig. 66. Combining voltage and resistance analysis quickly pointed to the cathode bypass condenser as to the cause for distortion.

tester to read resistance values. A "zero" ohms reading is obtained in the control-grid circuit. This indication may be the result of a short-circuited secondary of the antenna transformer, which is most unlikely, or a short-circuited section of the gang condenser. To determine whether the tuning condenser section is at fault, the gang is rotated until the plates are "out of mesh". The zero ohms reading is still indicated. The trimmer condenser across the r-f section of the tuning gang is found short-circuited.

Another receiver is encountered for which the complaint is distortion and low sensitivity. The usual preliminary routine tests disclose the fact that the trouble exists in the second detector stage (Fig. 66). The point-to-point tester is employed to obtain voltage and current readings. Plate and screen-grid voltages are found lower than normal, but no cathode voltage is indicated. Both plate and screen grid current readings are higher than normal. Here, the effects of a breakdown are noted, but the direct cause for the trouble is not pointed out. Of course, the experienced Service Man will suspect a short-circuited cathode by-pass condenser.

greatly when the aerial is temporarily connected to the control grid of the 6A8 detector-oscillator tube. The test plug of a point-to-point tester is inserted into the 6K7 socket of the r-f stage whose circuit is shown in Fig. 65. All currents and voltages prove to be normal for the particular receiver. A point-to-point resistance measurement is taken of this stage by manipulating the proper switches or test leads to convert the point-to-point

Fig. 67. An example of an invaluable voltage analysis chart, that of the RCA-Victor Model 10T and 10K receivers.

To prove this assumption, resistance analysis comes into play. Without removing the receiver chassis from the cabinet, the point-to-point tester indicates normal expected d-c resistance values in the plate and screen grid circuits to ground, but a zero ohms reading from cathode to ground. Increased current flow in the plate and screen-grid circuits is caused by the lack of bias voltage occasioned by the short-circuited cathode by-pass condenser. Lowered plate and screen grid voltages are due therefore to the higher voltage drops across the resistors in these circuits.

Many examples to illustrate the importance of both point-to-point voltage and resistance analysis may be shown. It may be seen that there is no one "best" method of analysis and that one method cannot be employed alone in every case. Both voltage and resistance analysis must be used together, so that one may supplement and overcome the short-comings of the other.

Some progressive manufacturers of modern radio receivers are furnishing charts and tables included in the service data for each receiver which are invaluable to the Service Man in locating troubles existing in any circuit. A voltage chart, shown in Fig. 67, is that of the RCA-Victor Model 10T and 10K receivers. Voltages from each tube circuit to chassis, as well as other components are indicated. In some cases, two voltage values are shown for some readings. The value shown in parenthesis with an asterisk (*) indicate operating conditions without voltmeter loading. The other value, which is generally lower, is the actual measured voltage as obtained on a 1000 ohms-per-volt d-c meter, having ranges of 10, 50, 250, 500 and 1000 volts. The nearest range above the specified measured voltage should be used. These voltages have been measured at 115 volts 60 cycle supply. The receiver is tuned to approximately 1000 K.C., with no signal being received. The volume and fidelity controls are both turned in counter-clockwise position.

A point-to-point resistance chart for the same receiver is shown in Fig. 68, in which not only the resistance values of
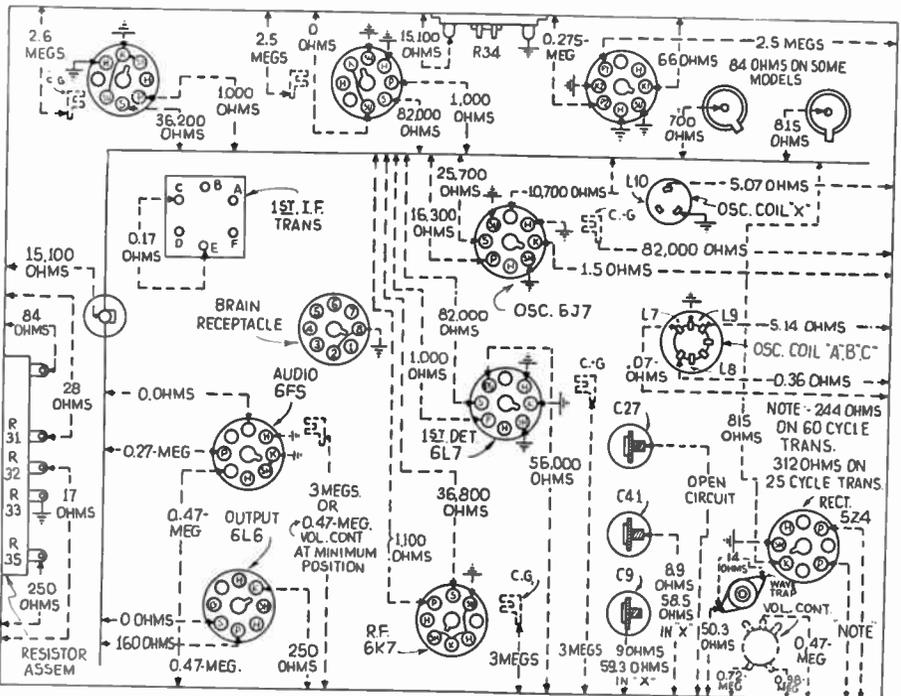

Fig. 68. A resistance analysis chart for the RCA-Victor Model 10T and 10K receivers. Values of all components with respect to chassis are given for point-to-point analysis.

the various circuits are indicated, but also those of other components. These values are obtained with the power supply disconnected and range-selector in "Standard Broadcast" position. The volume control is turned to maximum and the fidelity control is in counter-clockwise position. The negative terminal of the resistance meter must be connected to the receiver chassis when making measurements.

In addition, a table containing the normal cathode current readings obtainable with a milliammeter connected into the cathode circuit, is supplied. This is a decided help in quickly locating with one manipulation the faulty stage in which trouble may exist. Any trouble which will produce a change in voltage in a tube circuit will affect the current in that circuit. This will be reflected by a departure from the normal expected cathode current value shown in the following table.

Radiotron Cathode Current Readings

Measured with Milliammeter Connected at Tube Socket Cathode Terminals under Conditions Similar to Those of Voltage

Measurements

(1)	RCA-6K7—R-F	4.6 ma.
(2)	RCA-6L7—1st Det.	3.0 ma.
(3)	RCA-6J7 —Osc.	6.0 ma.
(4)	RCA-6K7—1st I.F.	5.0 ma.
(5)	RCA-6K7—2nd I.F.	7.0 ma.
(6)	RCA-6H6—2nd Det. —A.V.C.	—
(7)	RCA-6F5—A.F.	0.3 ma.
(8)	RCA-6L6—Power	65 ma.
(9)	RCA-5Z4—Rect.	110 ma.*
(10)	RCA-6E5—Eye	3.0 ma.

(* Cannot be measured at socket)

These voltages and resistance charts are presented by different manufacturers in various forms. Some have seen fit to include only voltage data in table-form or in the more satisfactory point-to-point manner. In Fig. 69, the voltage data chart of the Stromberg Carlson Model 130 receiver may be seen. The various values of voltages listed in the table are obtained by measuring between the various tube socket contacts and the chassis base, with the tubes in their respective sockets. The receiver is, therefore, set up for operation. Fig. 70, shows the terminal layout of the sockets with the proper terminal numbers in accordance with RMA standards. Voltages are given for a line voltage of 120 a-c volts, and allowances

Tube	Circuit	Cap.	Terminals of Sockets								Heater Voltages Between Heater Terminals	
			1	2	3	4	5	6	7	8	Socket Terminal Numbers	Volts
6K7	R. F. Amp.	0	0	0	+ 54	+ 96	+7.6	+4.5	6.3	+7.6	2-7	6.3
6A8	Osc.-Mod.	0	0	0	+222	+ 72	−1.0	+143	6.3	+6.1	2-7	6.3
6K7	I. F. Amp.	0	0	0	+210	+ 96	+7.4	+4.5	6.3	+7.4	2-7	6.3
6H6	Dem.—A.V.C.	—	0	0	0	0	0	—	6.3	+4.5	2-7	6.3
6F5	Audio Amp.	0	0	0	—	+122*	—	—	6.3	+.75	2-7	6.3
6F6	Audio Output	—	0	0	+226	+237	0	0	6.3	+ 15	2-7	6.3
80	Rectifier	—	+330	325	325	+330	—	—	—	—	1-4	4.8
Tri-Focal Tuning Indicator Plug's Socket When Tri-Focal Tuning Unit Is Used			6.3	0	+7.6	+235	+7.8	0	—	—	1-6	6.3
Tri-Focal Tuning Indicator Plug's Socket When Tri-Focal Tuning Unit Is Not Used			6.3	0	+7.6	+237	+7.3	0	—	—	1-6	6.3
Speaker Socket			+327	0	0	+327	+327	0	+237	—	—	—

Fig. 69. A voltage analysis chart in table form. This is for the Stromberg-Carlson Model 130 receiver, to be used with terminal layout illustrated in Fig. 70.

should be made for differences when the line voltage is higher or lower. A meter with a 1000 ohms-per-volt rating is used for measuring the d-c voltage. Voltage values shown are those obtained on the lowest possible scale of a meter having the following ranges: 2.5, 10, 100, 250, 500 and 1000 volts, except when an asterisk appears after any given voltage value, in which case, the 1000 volt scale is used. Receiver is tuned to 1000 K.C., no signal. A-c voltages are indicated by italics.

A resistance chart for the Majestic models 85, 86 and 998 (chassis 800) is shown in Fig. 71, to illustrate another method of presenting service data. All readings are taken from designated points to ground with some exceptions,

Equipped with a voltage and resistance analysis chart of a receiver, similar to those shown at Fig. 67 and Fig. 68, in which the d-c resistance values of all coils and inductances are given, a serviceman may diagnose almost any trouble that may develop in a receiver without the aid of a schematic circuit diagram. The values shown are the actual d-c resistance values from each circuit with respect to ground, and no time is lost in solving parallel and series-parallel circuits. There are instances where these charts may seem to be of little value, as in the case of open-circuiting or intermittent condensers, intermittent or open-circuited coils or wire-wound resistors which are isolated by a condenser, and where some failure
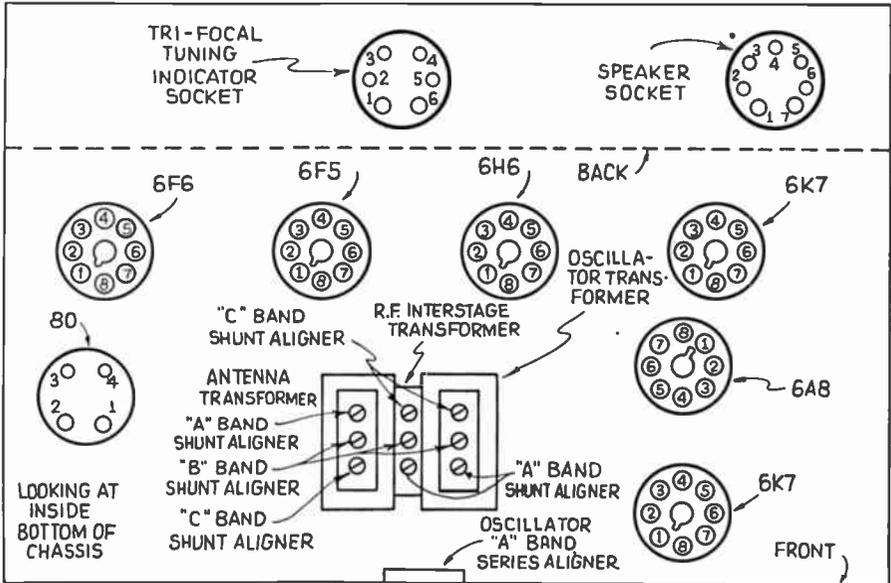
Fig. 70. Socket terminal layout chart, marked in accordance with RMA numbering system, to be used in conjunction with voltage chart shown at Fig. 69. For the Stromberg-Carlson Model 130.

in accordance with the diagram at Fig. 72. This chart, of course, is used only with the schematic circuit diagram of these receivers. All tubes are removed from their respective sockets; the receiver is disconnected from the supply line, but the speaker remains connected in the circuit.

In connection with the chart in Fig. 71, it is interesting to note that in conjunction with the point-to-point data listed, the path of continuity for each circuit or tube terminal is mentioned. It is thus possible to check immediately, in most cases, for the reason for an erroneous indication without recourse to a schematic circuit diagram.

occurs only under load. In the final analysis, however, it is only after a point-to-point resistance check has been made that attention is directed to some particular portion of a circuit or receiver in an effort to locate trouble.

Experience has proven that the servicing procedure productive of the most rapid and efficient results in servicing modern radio receivers, is the combination of both voltage and resistance analysis. Simple preliminary tests aided by voltage measurements to localize the tube stage in which trouble exists, followed by a point-to-point resistance analysis of that circuit, is the "best" method to follow.

Terminal Number	Resistance in Ohms	If resistance differs greatly from value shown, check the following
1	21	Primary of Antenna coil.
2	2,700	R-7 and C-9.
3	300,000	R-9 and C-3.
4	Very high	C-4, C-11, C-13, C-14 and C-15.
*4	1,750	Primary of input transformer and field coil.
5	400,078.3	Secondary of ant. coil, C-2, R-2, C-16, R-10 and R-3.
6	0	Ground connection.
7	0	Ground connection.
8	23,000	R-4, R-5, C-7, C-13, C-1 and C-8.
*8	10,970	R-6, and field coil.
*9	1,112	Primary of R.F. coil and field coil.
10	400,078.3	Secondary of R.F. coil, C-2, R-2, C-16, R-10 and R-3.
11	0	Ground connection.
12	100,000	R-1 and C-17.
*13	10,972.6	Primary of oscillator coil, R-6 and field coil.
14	Same as No. 8	
*14	Same as No. *8	
*15	1,059	Primary of 1st I. F. Transformer and field coil.
16	400,167	Secondary of 1st I. F. Trans., R-2, C-16, R-10 and R-3.
17	0	Ground connection.
18	0	Ground connection.
19	Same as No. 8	
*20	1,110	Primary of 2nd I. F. Transformer and field coil.
21	6,500	R-4 and C-7.
22	300,145	A. V. C. secondary of 2nd I. F. Trans., C-16, R-10 and R-3.
23	0	Ground connection.
24	0	Ground connection.
25	200,155	Audio secondary of 2nd I. F. Trans., R. F. C., C-10, C-12 and R-12.
26	0	Ground connection.
27	Very high	Primary of output trans. for ground, C-13 and C-15.
*27	1,167	Primary of output transformer and field coil.
28	216	Secondary of input transformer and R-3.
29	75	R-3.
30	Same as No. 28	
31	Same as No. 27	
*31	Same as No. *27	
32	Very high	C-15, C-14 and C-13.
33	Same as No. 32	
34	235	Hi-voltage Secondary and R-3.
35	Same as No. 34	
36	Open	C-6, line switch and primary of power transformer.
37	Same as No. 36	

Fig. 71. Another example of a table or chart for point-to-point resistance analysis. This is for Majestic Models 85, 86 and 998 (chassis 800).
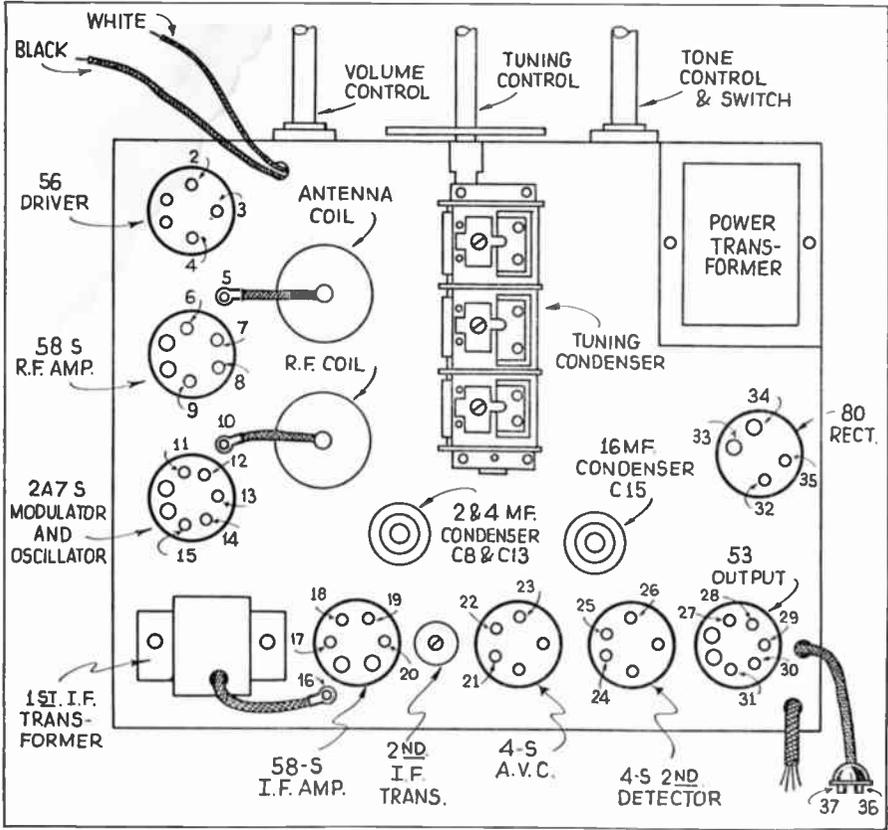
Fig. 72. A socket terminal layout chart to be used with the table illustrated at Fig. 71 for resistance analysis. Note that points other than those of tube terminals are shown also.

CHAPTER 10

Actual Service Problems

To illustrate the ease and rapidity with which causes for radio receiver symptoms may be diagnosed with point-to-point resistance analysis, and to demonstrate methods of procedure, a number of actual service problems encountered with modern receivers will be described. These examples are by no means unusual but only typical of many service problems with which the service man is confronted in his daily routine.

A Stromberg Carlson model 140 receiver was recently serviced for the complaint of very weak reception. It was found that only two or three of the more powerful stations were received, but

6Q7 tube was removed from its socket, the received stations became more audible. Since the tuning eye had operated and the audio amplifier had proven satisfactory, a voltage analysis was performed upon the 6Q7 stage as the probable seat of trouble.This portion of the receiver circuit is shown in Fig. 73. Plate and cathode voltages, measured on the 250 volt scale of the volt-ohmmeter, were normal, approximately 150 and 25 volts, respectively. The voltage impressed upon the 2nd detector diode (in this model, the diodes are used separately, one for detection, the other for A.V.C. purposes) was approximately 25 volts.
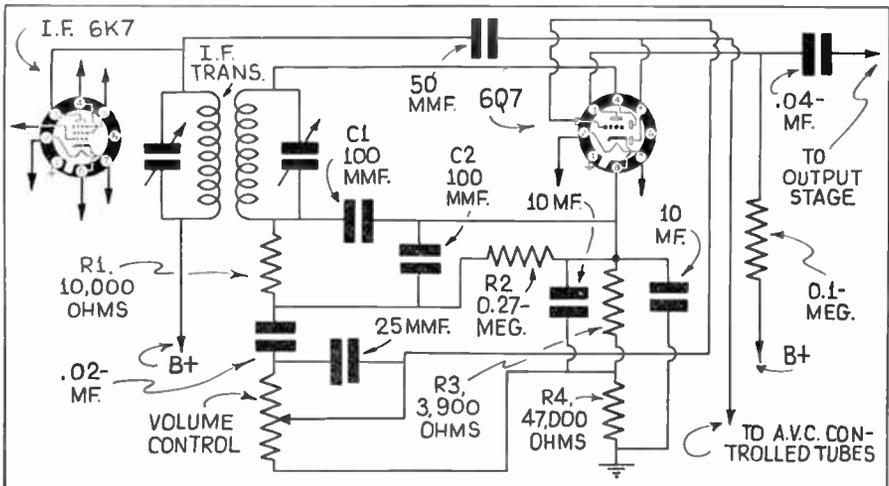
Fig. 73. A short-circuited condenser C1 caused very weak reception in this Stromberg-Carlson Model 140 receiver. Located through a point-to-point resistance analysis.

these were *barely* audible. The "tuning eye" functioned in a manner which appeared normal. A preliminary test of removing the control grid connection to the 6Q7 tube, and placing a finger upon the control grid cap of the tube, produced the characteristic hum. This test removed the audio amplifier from the list of possible causes for the trouble. When the

Although the voltage analysis chart specified 20 volts, as measured on the 1000 volt range of the meter, from detector diode to chassis, the discrepancy was not considered substantial enough to affect operation. However, a point-to-point resistance test after the tube was removed from the receiver, proved otherwise and disclosed the difficulty without removing
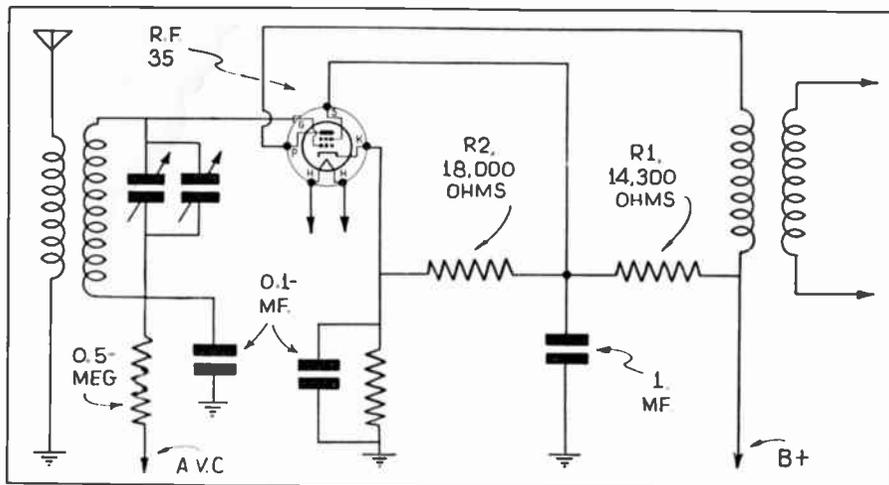
Fig. 74. Distortion and lowered sensitivity in an RCA-Victor Model R-11 was traced to a carbonized voltage divider system. Point-to-Point voltage and resistance analysis disclosed the difficulty in short order.

the chassis from the cabinet. The resistance between the detector diode and ground was found as approximately 50,000 ohms. This reading was the combined resistance of R3 and R4. Apparently, the high resistance R2 had been removed from the circuit by some failure A short-circuited bypass condenser C1 or C2 could produce this result, but were C2 short-circuited, then the resistance between diode and chassis would have read 60,000 ohms. To check this fact, the ohmmeter was connected from detector diode to cathode. A "zero" ohm reading was obtained, pointing to a short-circuited i-f filter condenser C1. This, then, was the reason for the similar voltages from cathode and detector diode, to ground. A new condenser was substituted for C1 to secure normal operation.

Upon another occasion, an RCA-Victor R-11 receiver was serviced for a condition wherein distorted reproduction at any volume level was encountered. Tuning was critical and unstable, and sensitivity lower than normal. Plate voltages on all tubes were found below normal, with excessive screen voltage obtained on the r-f, 1st detector and i-f tubes. A point-to-point resistance check was made of the r-f stage, whose circuit is shown at Fig. 74. Connecting the ohmmeter between the plate and ground indicated only 10,000 ohms, where a correct reading of approximately 33,000 ohms should have been obtained.

Since this erroneous indication may have been due to a short-circuited screen bypass condenser, the ohmmeter was connected from screen to ground. A reading of 4,000 ohms ruled out this assumption. However, when a resistance test was made between plate and screen the ohmmeter read 6000 ohms. Since the resistors R1 and R2, are carbon units, employed as the voltage divider in this receiver, excessive current had caused the resistors to carbonize, and lower appreciably in value, thus upsetting operating potentials. Resistors of higher wattage rating were installed to complete the job.

The symptoms of hum and motor-boating reception of an intermittent character, on an RCA-Victor model C11-I receiver, were remedied by first locating the cause for trouble by a point-to-point resistance analysis. Due to the fact that the complaint was intermittent, clearing up every time the voltmeter was connected across various points, diagnosis was difficult using a voltage analysis.

The difficulty was definitely traced to the 1st audio amplifier, since the symptoms remained even after the r-f, i-f and second detector tubes were removed from the receiver but cleared upon removal of the 1st audio tube. Voltages on the plates of the 1st audio and driver 6C5 tubes were normal, approximately 100 and 200 volts, in each case, but the voltmeter needle fluctuated violently, in step with the motor-boating condition. This was

also evident when cathode voltages were checked. The receiver was turned off while in the motor-boating condition, and the 1st audio and driver tubes removed for the purpose of performing a point-to-point resistance measurement. A reading of approximately 1000 ohms was obtained between the cathode of the 1st audio tube and ground, as well as from the cathode of the driver tube to ground. As shown in Fig. 75, this indication was approximately 50% of the correct value, and much too low taking full cognizance of tolerance values. When the ohmmeter was connected between cathodes of the tube circuits in question, a "zero ohms" reading was indicated. It was found finally

in Chapter 7, in the case of coils in tuned circuits and resistors and volume controls isolated by a condenser.

To illustrate this statement, the case record of an RCA-Victor model 224 receiver may be described. This receiver was serviced for the complaint that only one powerful station was received on the broadcast band, and not at the assigned frequency. No reception on the short wave bands was possible. The usual voltage and point-to-point resistance analysis proved only that all voltages and circuit resistances were intact. However, the very nature of the trouble and the few preliminary tests performed, indicated the probable location for the symptoms
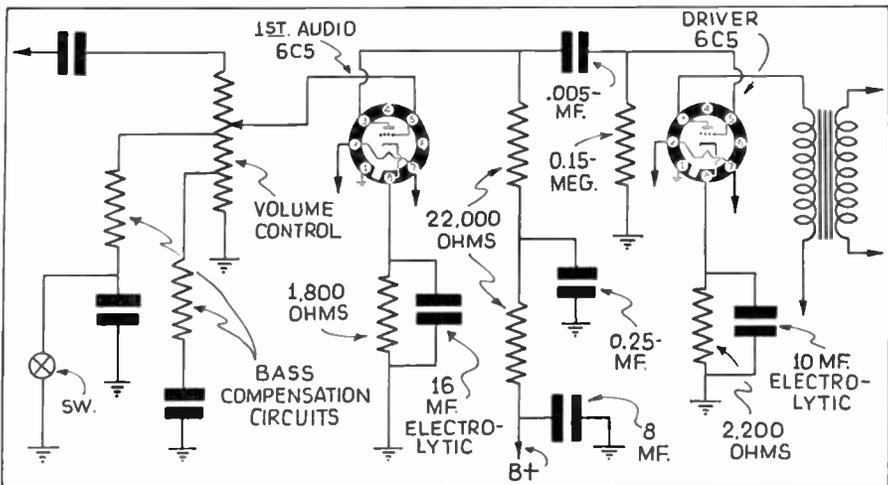

Fig. 75. The very nature of the trouble with this RCA-Victor Model C11-I receiver made diagnosis most difficult through voltage analysis. Only through resistance analysis could a repair be effected.

that the cathode bypass condensers, both electrolytics, and contained within the same bypass block, had short-circuited within the block, virtually connecting the two cathode circuits together, which had produced the oscillation.

Locating receiver troubles with point-to-point resistance measurements does not consist solely of performing tests from the circuits of a tube stage to chassis, or some common point. Many components in a receiver cannot be checked in this manner because of their position in the circuit, but by connecting an ohmmeter between certain other portions of the circuit, the d-c resistance and condition of an isolated component may be determined. This fact was pointed out

described to center around the oscillator stage. A pentagrid converter type 6A7 tube is employed as a 1st detector-oscillator in a circuit shown at Fig. 76. By connecting an ohmmeter from the stator of the oscillator section of the tuning gang condenser to chassis, an infinite ohms reading should be obtained, since the oscillator grid coil for each band is isolated from ground by a series or padding condenser. However, "zero ohms" was indicated.

The only possible cause for this indication was a short-circuited oscillator section of the gang condenser, for a resistance reading of at least one or more ohms would have been obtained, the d-c resistance of the grid coils, had any one of the
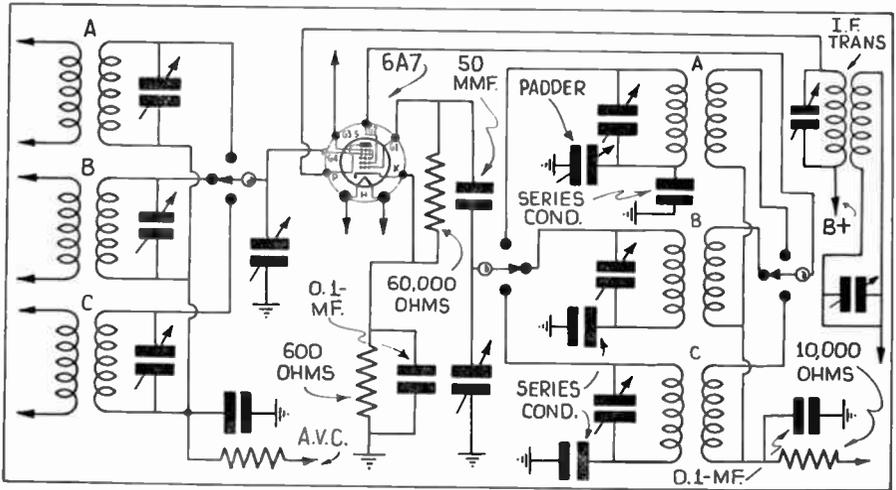
Fig. 76. The first detector-oscillator circuit of the RCA-Victor Model 224 receiver.

series condensers been short-circuited. Upon close inspection, this proved to be the case. One of the braided flexible bonding connectors between the gang assembly and chassis (the gang condenser "floats") was found contacting the stator lug of the oscillator tuning condenser. Clearing the stator lug cleared the condition.

The symptoms of weak and highly distorted reproduction on an Atwater Kent model 328 was diagnosed in the same manner. A voltage and current analysis

produced normal readings for all circuits but with one exception. The plate current of the 1st audio 6F5 tube was almost at the cut-off point. This condition could be due to either a low plate voltage or an increased grid bias, since the tube was perfect. Plate voltage had proven correct. As shown in Fig. 77, the 1st audio 6F5 obtains negative bias voltage from the drop across a 22 ohm resistor in the high voltage secondary return circuit. The cathode of the tube is grounded. Grid bias voltage could not be read cor-
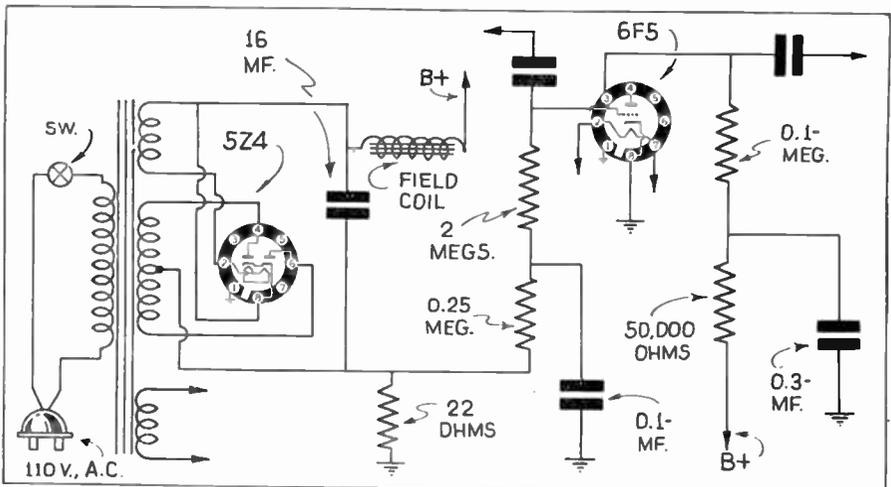
Fig. 77. A point-to-point resistance analysis of this Atwater Kent 328 made correct diagnosis possible without chassis removal.

rectly at the grid of the tube, because of the 2 megohm grid leak.

In this receiver, the negative terminal or can of the input filter condenser is below ground potential. Therefore, the "can" of the electrolytic condenser is insulated by the necessary insulating washers from the chassis. It can be seen that the negative terminal of the condenser is connected to the high voltage secondary return circuit and the same voltage existing across the 22 ohm bias resistor should be present from the can of the input filter condenser to chassis. The voltmeter was connected across these two points to obtain a 4 volt reading, much too high for the bias voltage for a type 6F5 tube, whose normal grid bias

should be approximately 2 volts. By connecting an ohmmeter between the same two points, the "can" and chassis, a resistance of 50 ohms was indicated as the value of the bias resistor. This, then, was the cause for the increased bias voltage and, consequently, the lowered plate current of the 6F5. It must be mentioned that diagnosis to this point was carried out without removal of the chassis.

The bias resistor in this receiver is a flexible wire-wound unit with Wood's metal terminals. Poor contact at the terminals was the reason for the increased resistance value. These terminals were removed and the resistance wire firmly anchored and then soldered to effect a permanent repair.

CHAPTER 11
Appendix

COLOR CODE CHART

Body Color		End Color		Dot Color	
Black	0	Black	0	Brown	0
Brown	1	Brown	1	Red	00
Red	2	Red	2	Orange	000
Orange	3	Orange	3	Yellow	0000
Yellow	4	Yellow	4	Green	00000
Green	5	Green	5	Blue	000000
Blue	6	Blue	6	Purple	0000000
Purple	7	Purple	7	Gray	00000000
Gray	8	Gray	8	White	000000000
White	9	White	9		

The body color of a resistor denotes the first significant figure, the end color the second significant figure and the dot indicates the number of ciphers after the first two significant figures. EXAMPLE: A 350 ohm resistor has an Orange Body, Green End, and Brown Dot. First significant figure is 3 (Orange Body), second significant figure is 5 (Green End) and one cipher following (Brown Dot).


TABLE OF RESISTANCE VALUES
and RMA Standard Color Code

Megohms	Ohms	Body	End	Dot
.0005	500	Green	Black	Brown
.00075	750	Violet	Green	Brown
.001	1,000	Brown	Black	Red
.0015	1,500	Brown	Green	Red
.002	2,000	Brown	Black	Red
.0025	2,500	Red	Green	Red
.003	3,000	Orange	Black	Red
.004	4,000	Yellow	Black	Red
.005	5,000	Green	Black	Red
.006	6,000	Blue	Black	Red
.007	7,000	Violet	Black	Red
.008	8,000	Gray	Black	Red
.009	9,000	White	Black	Red
.01	10,000	Brown	Black	Orange
.012	12,000	Brown	Red	Orange
.015	15,000	Brown	Green	Orange
.02	20,000	Red	Black	Orange
.025	25,000	Red	Green	Orange
.03	30,000	Orange	Black	Orange
.04	40,000	Yellow	Black	Orange
.05	50,000	Green	Black	Orange
.06	60,000	Blue	Black	Orange
.075	75,000	Violet	Green	Orange
.09	90,000	White	Black	Orange
.1	100,000	Brown	Black	Yellow
.15	150,000	Brown	Green	Yellow
.2	200,000	Red	Black	Yellow
.25	250,000	Red	Green	Yellow
.3	300,000	Orange	Black	Yellow
.4	400,000	Yellow	Black	Yellow
.5	500,000	Green	Black	Yellow
.75	750,000	Violet	Green	Yellow
1.	1,000,000	Brown	Black	Green
1.5	1,500,000	Brown	Green	Green
2.	2,000,000	Red	Black	Green
2.5	2,500,000	Red	Green	Green
3.	3,000,000	Orange	Black	Green
4.	4,000,000	Yellow	Black	Green
5.	5,000,000	Green	Black	Green
6.	6,000,000	Blue	Black	Green
7.	7,000,000	Violet	Black	Green
8.	8,000,000	Gray	Black	Green
9.	9,000,000	White	Black	Green
10.	10,000,000	Brown	Black	Blue

TUBE SOCKET CONNECTIONS
(Top and Bottom Views)

Type	Socket	Type	Socket	Type	Socket
00A	16	6D7	27	36	6
01A	16	6D8G	39	37	5
0Z4	60	6E5	12	38	6
1A4	3	6E6	34	39	6
1A6	23	6F5	38	40	16
1B4	3	6F6	51	41	7
1B5	22	6F7	31	42	7
1C6	23	6G5	12	43	7
1C7G	39	6H6	53	44	6
1D5G	55	6J5G	37	45	16
1D7G	39	6J7	52	46	19
1E5G	55	6K5G	50	47	19
1E7G	42	6K6G	51	48	7
1F4	19	6K7	52	49	19
1F5G	56	6L5G	37	50	16
1F6	10	6L6	51	53	34
1F7G	43	6L7	59	55	9
1H4G	57	6N5	48	56	5
1H6G	44	6N7	46	57	21
1J6G	58	6P7	47	58	21
1V	15	6Q7	40	59	29
2A3	16	6R7	40	71	16
2A5	7	6S7G	52	75	9
2A6	9	6X5	52	76	5
2A7	30	6Y5	13	77	21
2B6	40	6Z5	26	78	21
2B7	35	10	16	79	25
2E5	12	11	17	80	2
2F7	31	12	16	81	1
2G5	12	12A5	36	81	1
2S-4S	20	12A7	28	82	2
2Z2-G84	1	12Z3	15	83	3
5V4G	45	15	8	83V	2
5W4	45	18	7	84	20
5Y3	45	19	8	85	9
5Z3	2	20	16	89	21
5Z4	54	22	3	V99	17
6A3	16	24A	6	X99	16
6A4	19	25S	22	182B	16
6A3	34	25A6	51	183	16
6A7	30	25B5	11	485	5
6A8	39	25Y5	24	950	19
6B4G	37	25Z5	24	BA	18
6B5	11	25Z6	53	BH	18
6B6	40	26	16	BR	4
6B7	35	27	5	LA	19
6B8	43	30	16	RK33	32
6C5	37	31	16	12Z5	33
6C6	21	32	3	KR1	15
6C7	14	33	19	KR2	15
6D5	37	34	3	KR98	20
6D6	21	35	6		
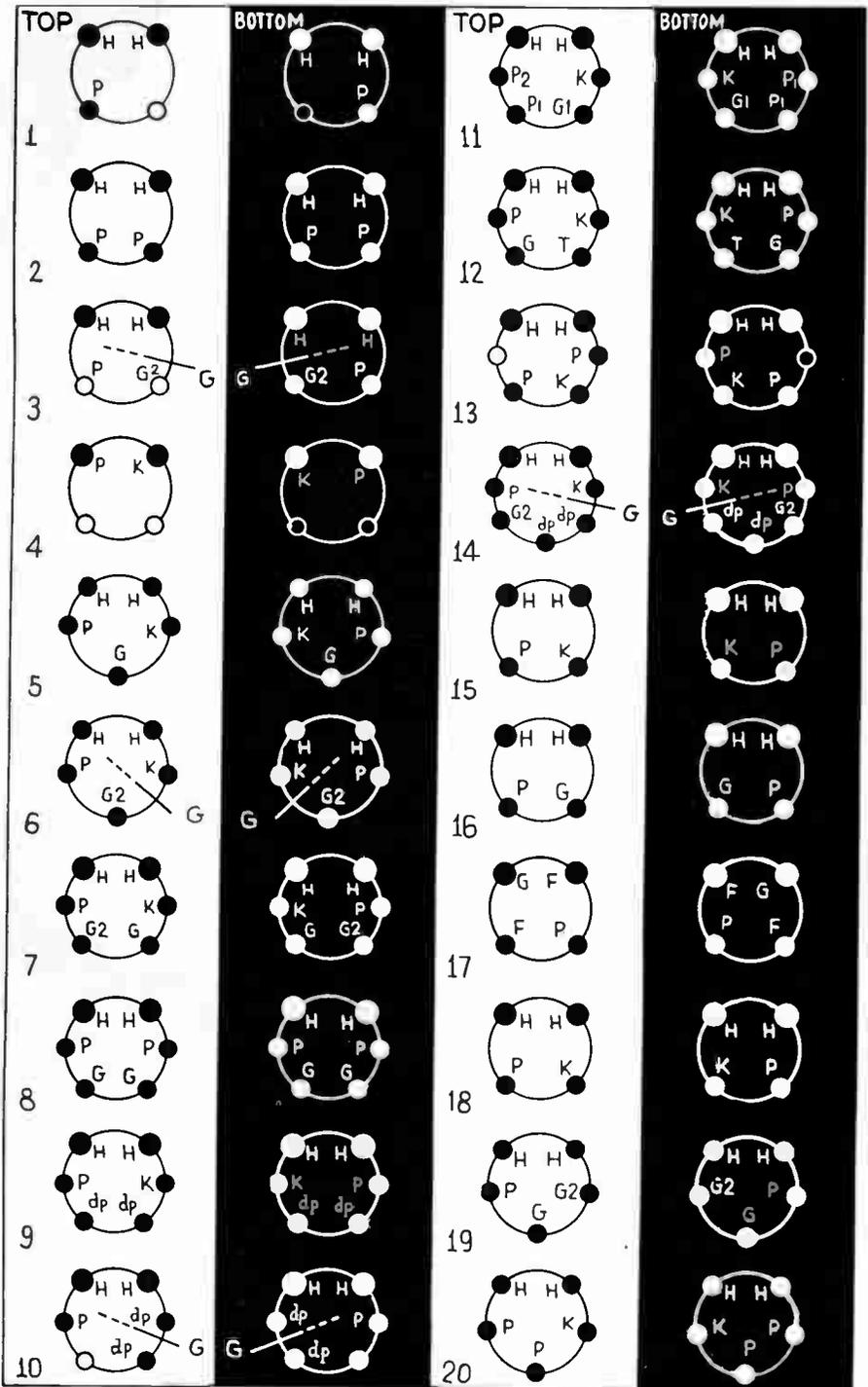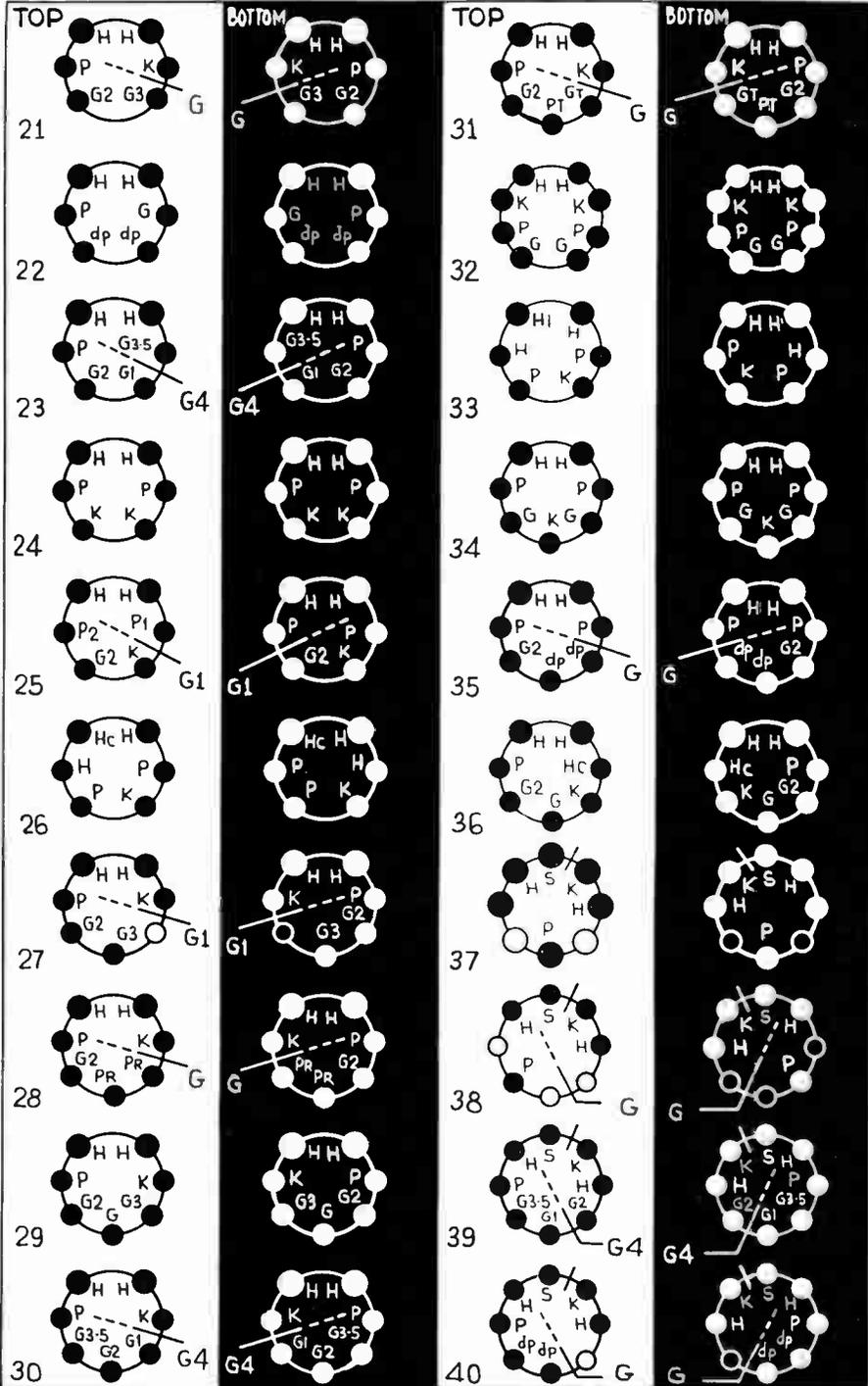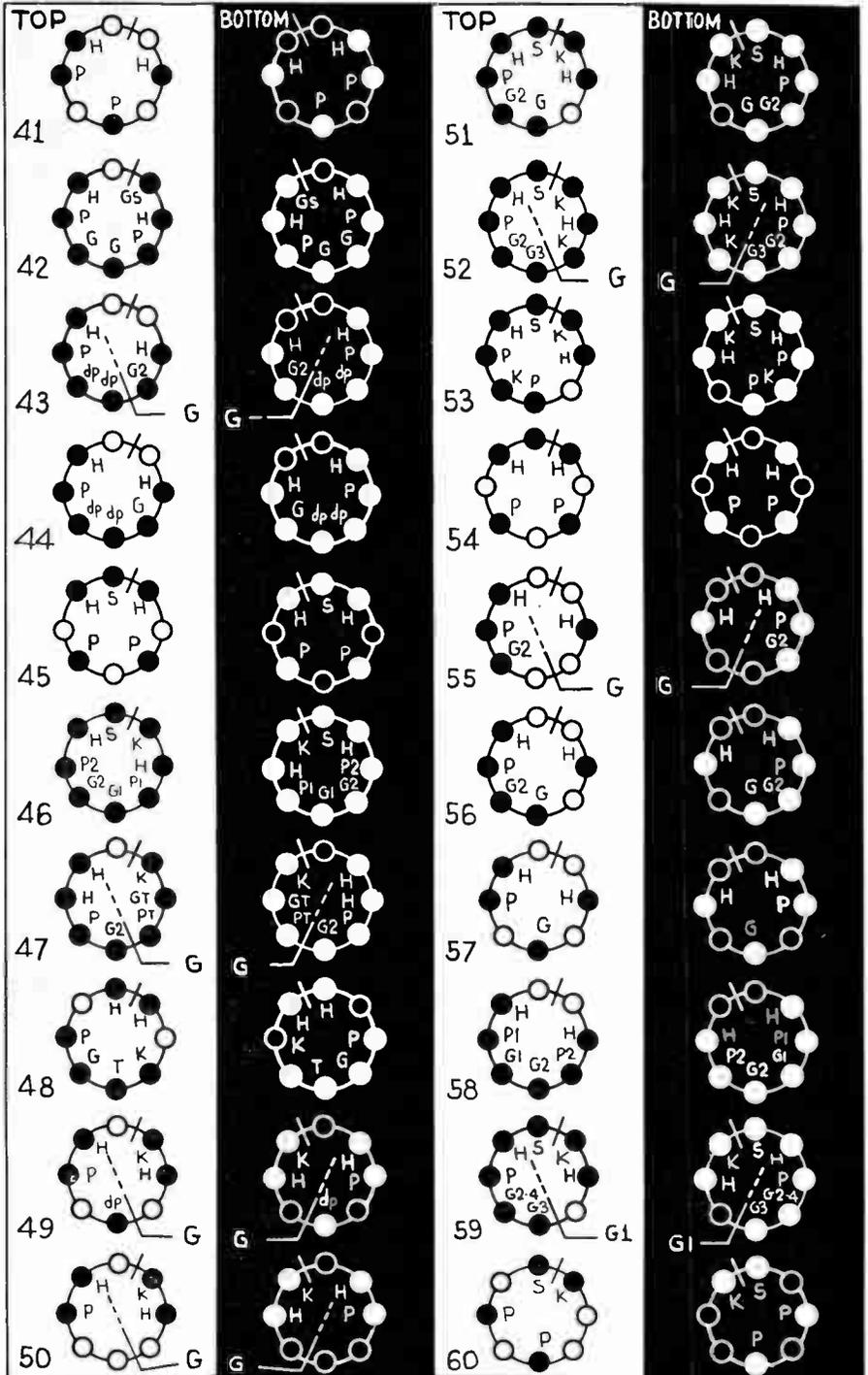
RESISTOR APPLICATION CHART

Current Carrying Capacity and Allowable Voltage that can be
Applied to 3, 10, 25 and 50 Watt Resistors.

Watts........3	3	10	10	25	25	50	50
Res.	Amperes	Volts	Amperes	Volts	Amperes	Volts	Amperes	Volts
1	1.730	1.730	3.163	3.163	5.000	5.000	7.070	7.070
1.5	1.410	2.115	2.572	3.858	4.083	6.124	5.773	8.659
2	1.224	2.448	2.235	4.470	3.420	6.840	5.000	10.000
2.5	1.097	2.742	2.000	5.100	3.154	7.885	4.474	11.185
3	1.000	3.000	1.835	5.505	2.939	8.817	4.083	12.249
3.5	.970	3.395	1.689	5.911	2.672	9.342	3.778	13.223
4	.866	3.440	1.579	6.316	2.500	10.000	3.420	13.680
5	.774	3.870	1.414	7.070	2.236	11.160	3.154	15.770
7.5	.632	4.740	1.154	8.655	1.826	13.695	2.581	19.357
10	.547	5.470	1.000	10.000	1.598	15.980	2.236	22.360
15	.447	6.705	.816	12.240	1.298	19.470	1.829	27.435
20	.389	7.780	.708	14.160	1.119	22.380	1.598	31.960
25	.346	8.650	.632	15.800	1.000	25.000	1.414	35.350
30	.316	9.480	.577	17.310	.912	27.360	1.298	38.940
35	.292	10.220	.534	18.690	.844	29.540	1.197	41.895
40	.274	10.960	.500	20.000	.791	31.640	1.119	44.760
50	.245	12.250	.447	22.350	.700	35.000	1.000	50.000
75	.200	15.000	.365	27.375	.574	43.050	.818	61.350
100	.173	17.300	.316	31.600	.500	50.000	.700	70.000
150	.141	21.150	.258	38.700	.432	64.800	.577	86.550
200	.122	24.400	.223	44.600	.353	70.600	.500	100.000
250	.109	27.250	.200	50.000	.316	79.000	.447	111.750
300	.100	30.000	.182	54.600	.291	87.800	.432	129.600
350	.097	33.950	.169	59.150	.269	94.150	.378	132.300
400	.086	34.400	.158	63.200	.250	100.000	.353	141.200
500	.077	38.500	.141	70.500	.224	112.000	.316	158.000
750	.063	46.650	.115	86.250	.186	139.500	.257	192.650
1,000	.054	54.000	.100	100.000	.158	158.000	.220	220.000
1,500	.044	66.000	.081	121.500	.129	193.500	.182	273.000
2,000	.038	76.000	.070	140.000	.112	224.000	.159	318.000
2,500	.034	85.500	.063	157.000	.100	250.000	.141	352.500
3,000	.031	93.000	.057	171.000	.091	273.000	.129	387.000
3,500	.030	105.000	.053	185.500	.085	297.500	.119	416.500
4,000	.027	108.000	.050	200.000	.079	316.000	.111	444.000
5,000	.024	120.000	.044	220.000	.071	355.000	.100	500.000
7,500	.020	150.000	.036	270.000	.058	445.000	.081	607.500
10,000	.017	170.000	.031	310.000	.050	500.000	.070	700.000
15,000	.014	210.000	.025	375.000	.043	645.000	.057	855.000
20,000	.012	240.000	.022	440.000	.035	700.000	.050	1,000.000
25,000	.011	265.000	.020	500.000	.031	775.000	.044	1,100.000
30,000	.010	300.000	.017	510.000	.029	870.000	.043	1,290.000
35,000	.009	315.000	.015	525.000	.026	910.000	.037	1,290.500
40,000	.008	320.000	.014	560.000	.025	1,000.000	.035	1,400.000
50,000	.007	350.000	.013	650.000	.022	1,100.000	.031	1,550.000
75,000	.006	450.000	.011	825.000	.018	1,350.000	.025	1,875.000
100,000	.005	540.000	.010	1,000.000	.015	1,500.000	.022	2,200.000

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