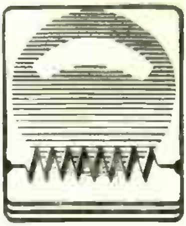

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by means of
Resistance Measurement

by

John F. Rider

This volume originally written in 1932 is somewhat behind the times in 1949. However there are many servicemen who are not thoroughly familiar with the various resistance networks used in radio receivers and this volume will be found of value in explaining the numerous combinations.

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Servicing Receivers
by means of
Resistance Measurement

BY

JOHN F. RIDER

Author of:
Perpetual Trouble Shooter's AM-FM
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AUTHOR'S FOREWORD

"SERVICING Receivers By Means Of Resistance Measurement" is intended to expound a revision in radio service analysis. For years past the radio service industry has been "voltage conscious"; predicating all service work upon tube operating voltages and currents.

Modern receiver design requires a change. For that matter, such a change should have been instituted quite some ago. It is said that the satisfactory operation of a radio receiver or kindred system is dependent upon the correct operating potentials. This statement is subject to revision, for even if the correct operating voltages are available from their basic source, the power line or rectifier system, the application of these values to the tube elements is dependent upon correct resistance in the various systems. This is particularly true when we realize the fact that radio receiver and amplifier circuit structure is such that correct operating voltages are possible with incorrect resistance values between tube elements. Because of the incorrect resistance and not the operating voltages, the circuit is inoperative. On these grounds, although there are many other supplementary facts, we make the statement that the service industry must become "resistance conscious" and predicate service analysis upon resistance rather than voltage measurement.

It is a definitely established fact that the ultimate test in a receiver or amplifier, after the operating voltage test indicates some sort of a defect, is resistance measurement to locate the exact fault. If resistance measurement is the final test, why not make it the primary test and thus remove the need for the preliminary test. If we analyse the original sources of the operating voltages, we can very readily appreciate that the tube operating potentials must be correct if the resistance of the respective circuits is correct and the voltage at the point or origin is correct.

In a-c receivers, this point of origin is the line voltage, the a-c voltage applied to the rectifiers and the filament voltage. In d-c receivers, it is the line voltage. In battery receivers it is the battery voltage. The remainder of the systems in a-c, d-c and battery receivers, with the exception of the tubes, is a matter of resistance only. Because of this need for voltage measurement at certain points, resistance measurement methods of service analysis do not wholly supersede voltage measurement.

The tubes are considered as items entirely foreign to the receiver or amplifier. They must be checked separately and there are definite advantages accruing through such operation. In the first place, a multiplicity of circuits must be handled when a tube is checked in a receiver. For every tube in the receiver, the tube must be removed from its socket. The tester plug is inserted in its stead. Then the tube is inserted into the tester socket and four or five separate observations must be made, each of which involves the manipulation of one or more switches. Then the process of handling the tube and the tester plug is reversed. The total handling without counting the switch manipulation upon the tester during the tube test, is about six operations per tube. This means quite a good deal of work and time in an eight or ten tube receiver.

On the other hand, if the tubes are tested in a tube checker independent of the receiver, the handling is less and the number of operations required to show whether the tube is good or bad are much less. Furthermore, the indication shown upon the tube checker is more readily interpreted into tube condition.

If it so happens that the defect within the receiver interferes with the operating potentials, tubes cannot be tested.

When a separate tube test is made in an independent tube checker, the condition of the voltages in the receiver is of no consequence.

A man operating a tube checker can function much more rapidly, because of the standard voltages applied and because of the uniformity of indication with tubes which are good. When working with receiver voltages, each test is separate and requires individual comparison with a reference table. There can be no memorizing of indications to be expected in receivers. Tube checkers can be arranged with self-indicating meters.

Certain tubes in receivers cannot be checked because operating voltages are available only upon some of the elements. These tubes as tubes, can be tested in tube checkers. Examples are various types of AVC tubes.

Tubes cannot be tested in a receiver unless everything is perfect, hence there is need for a repeat test after the supposed defect has been remedied.

To attempt to operate a receiver which is in a defective state is jeopardizing the tubes, in the event that the nature of the defect is such as to apply incorrect operating voltages to the tubes.

There are many more reasons, which become self evident upon an analysis of tube testing in receivers.

We recognize that certain forms of service work have no bearing upon resistance or voltage measurement methods of operation. Such operations are neutralization, realignment of trimmers, adjustment of speakers, placement of leads, etc. Accordingly, these operations can be dismissed with the statement that they are necessary as heretofore. However, condenser testing, as outlined in this book, becomes a part of resistance measurement and in many cases is of great aid in diagnosing those troubles which may exist yet not influence either voltage or resistance values. While it is true that condenser testing is possible when voltage measurement methods are used, it must become an entirely separate test, because a test of a condenser is impossible during the time the receiver is operative. This reference to a test does not mean the substitution test, wherein a good condenser is connected in parallel with the suspected unit.

Resistance measurement method of analysis is by no means new. It is strange to reconcile the prevalent use of point-to-point measurement of resistance in the receiver manufacturing plants during production and inspection work and the lack of such tactics in the field. If the manufacturer of the receiver finds the system suitable for his needs, there can be no doubt about the fact that it is suitable for the field.

To give credit where credit is due, let it be known that such methods referred to as continuity testing and in many cases as definitely established resistance measurement have been employed by some few service men and organizations.

Voltage measurement involves complete circuits, with a defect in any one of the units which comprise the circuit. Resistance measurement when combined with condenser testing allows individual unit measurement and complete isolation of the majority of units to be found in a radio receiver.

Resistance measurement method of service analysis offers the possibility of operating through the sockets and thus determining the defective unit without removing the chassis from the cabinet. This is of great value in the attempt to stabilize service procedure, because servicing can be placed upon a businesslike basis. You can estimate the cost of the repair after a diagnosis and before the chassis is removed. There are times, when the problem at hand requires the removal of the chassis from the cabinet, but the data which can be secured before the chassis is pulled serves as a guide in estimating costs.

Resistance measurement reduces all types of receivers and circuits to a common servicing level. This is so because the most complicated of receivers or amplifiers becomes a simple resistance network when the operating voltages are removed from the receivers and the tubes removed from the chassis. Thus, receivers which were not serviceable by means of voltage measurement, become serviceable by means of resistance measurement.

The use of a wiring diagram is essential during resistance measurement and it can be said that electrical values of resistance and possibly of the windings are essential. The same is true in the case of receivers which are checked by means of voltage measurements for the simple reason that a defect as indicated by a voltage test requires that the circuit and component values be available for guidance and comparison. Even if the operating voltages are correct, a wiring diagram is required for guidance and for indicating the components of the circuit. In this respect, it is possible to check a receiver by means of resistance measurement if the electrical values of the components are furnished and if the sum total of all of the voltages given is that of the line voltage and the a-c voltage applied to the rectifiers. If these voltages are standard and the circuit resistances are correct and the tubes are in good condition as determined by a separate test, the voltages applied to the tubes in the receiver will be normal in every respect. In d-c and battery receivers, the required voltages are the line voltage and the battery voltages respectively.

If it is a matter of tabulation, a point-to-point resistance tabulation is far more valuable than a tube operating voltage tabulation, particularly when a wiring diagram is not available. If a diagram is available, there is no comparison between the two systems. The resistance measurement arrangement is vastly superior.

There are of course certain limitations in connection with resistance measurement. However, these limitations exist only when the resistance measurement method of analysis is applied through the sockets. When the chassis is pulled, all units are accessible. The oscillator in the superheterodyne presents somewhat of a problem, but it is not native only to resistance measurement methods. It is to be found in connection with voltage tests as well. In this case, correct operating voltages or correct resistance of the various circuits does not mean that the system will function as an oscillator. Other factors, beyond voltage and d-c resistance, may serve to prevent its function as an oscillator. In such cases, the local test oscillator, which is a part of the average service kit, comes into play.

Predicating service analysis upon resistance measurement serves to stimulate systematic operation. In contrast to voltage measurement, when a resistance test is made, one knows whether the resistance of the circuit is correct or incorrect and can progress to the next step. In the case of voltage measurement, one is not certain that the circuit resistance is right or wrong, because of possibility of incorrect resistance and correct operating potentials.

Once again we wish to comment upon the fact that point-to-point resistance measurement is not new. It has been recommended in manufacturer's service manuals time and again. In the past, men in the field, not allied with manufacturers, considered such work as supplementary to voltage measurement. The process has been reversed. The conventional voltage test shall become secondary to resistance measurement, if used at all.

As we write these lines we hear rumblings of changes in service equipment. The modern set tester will be built around the ohmmeter. We hazard the guess that the future service kit will contain an elaborate ohmmeter, a combination a-c and d-c voltmeter, a self-contained tube checker with its own power, a combination high-frequency, radio-frequency and intermediate-frequency oscillator, a condenser tester and an output meter. One of the important changes being effected in testing equipment is that in connection with ohmmeters or combination volt-ohmmeters. The modern instrument is designed to be plugged into the tube socket in the receiver and give access to the various circuits at the load socket so that the ohmmeter can be switched between any two elements of that tube system. In combination instruments, a voltmeter instead of the ohmmeter can be connected across any two contacts of the tube system to check the voltage if desired.

If the contents of this book will help you as a service man to work more rapidly and more effectively; make the service industry "resistance conscious" and in any way help stabilize the industry, its purpose will be fulfilled.

June, 1932. *John F. Rider*

CHAPTER I

RESISTANCE; TYPES, VALUES AND WATTAGE

IN as much as this book is not intended as a course of instruction in the general art of radio, but rather as an exposition of a modern method of servicing, written for the men in the servicing profession, there is no need for general theory. Consequently, we can immediately embark upon those items which are pertinent to our subject.

RESISTANCE.

The average reader of these pages is fully familiar with the action of what is generally known as a resistance or resistor. Common usage has resulted in the interchange of terms to signify a unit which is included into a circuit in order to limit the magnitude of current flow, produce a definite voltage drop, definitely establish the path of certain currents, introduce certain losses into systems, etc. Each of these units is referred to in a definite manner as for example, "filament control," "voltage divider," "bleeder," "filter," "suppressor," "volume control," etc.

Past practice has established that one routine test after the presence of a defect has been indicated, is the measurement or determination of the ohmic value of these units. This routine remains unchanged in all respects other than the time of test. This shall be discussed at greater length later in this volume.

Now, the units to be found in a receiver or amplifier and which possess the property of resistance as related to the method of servicing as outlined in this book, are not only units definitely established as resistors of any type. The scope of what is understood to represent resistance must be greatly broadened. Every unit found in a receiver or amplifier which contains wire of any size or any number of turns possesses resistance. This means that every r-f transformer, i-f transformer, a-f transformer, output transformer, power transformer, r-f choke, a-f choke, filter choke, etc., must come under observation. These units utilized in circuits of one manner or other constitute the items which enable us to make the required resistance tests. The manner in which the winding is used, its function as far as the operation of the receiver or amplifier is concerned, the location of the unit, are items of no consequence with respect to the test. The fact to be borne uppermost in mind, is that each of these windings possesses resistance and because they, singularly or in connection with some other device, constitute a circuit, represent a system which must be tested for resistance.

Generally speaking, many service men have overlooked the fact that the various transformers in the system constitute resistances and while it is true that the usual form of resistors have undergone rigid tests, the transformers as a rule have been considered apart and tested in devious ways without regard to the ohmic value of the windings. The service industry must become "resistance conscious" as applied to all units utilized in a receiving or amplifying system.

It is possible to find an excuse for such little regard in connection with transformer windings. When speaking of resistors in the past, the term was invariably associated with current-carrying systems, that is, systems which were related to direct currents and d-c voltages. Such ideas are no longer true in modern receivers and amplifiers. Quite a few resistors are used in parts of systems where they do not carry direct currents. However, they serve as paths whereby the operating potential (d-c) is applied to some tube element. In other instances, they serve only as a means of isolating one circuit from another, thus controlling the paths of certain currents.

Our basis of operation, that is the servicing of a receiver or amplifier by measurement of the resistance, is built around any unit which affords a continuous path for the flow of direct current and possesses a finite value of resistance expressed in ohms. Naturally this includes every resistor irrespective of type and function and every winding of wire, irrespective of type and function. It is necessary to make this statement in connection with coils, windings, etc., because in many instances certain transformers are used in such a manner that direct current does not flow through the winding during the normal application of the unit and because the utility of the winding may be related to some part of the receiver or amplifier far remote from anything which is associated with direct current.

As far as the service process is concerned, there is no distinction between a resistor of the carbon type and a transformer winding. Of course, we realize that the two units are greatly different in appearance and function. But again we state that when the test is the measurement of the ohmic value of resistance possessed by the two types of units named, there is no distinction between the two units, either in method of measurement or final decision. We are after resistance values and both possess resistance. As to what may be done after the test has been made, that is something else. Because of the difference in function, the two units may be associated with different parts of the receiver and referred to differently in order to distinguish between the parts of the system.

While it may be apropos at this time to consider possible variations in methods of applying test instruments because of the different location of resistors and transformer windings, we deem it best to reserve that discussion for a subsequent chapter.

Types of Resistances.

It is possible that the caption at the head of this paragraph may not be considered technically accurate, in as much as "resistance" is a property rather than a physical unit, consequently the association with "types" is likewise incorrect. However, in view of the fact that it has been common practice to employ "resistance" and "resistor" to designate units which possess the property of resistance, we feel free to employ such a heading.

RESISTANCE; TYPES, VALUES AND WATTAGE

As far as types are concerned, we have several. If we start with those units usually designated as "resistors," we have

1. Wire wound
2. Carbon
3. Metallic coatings
4. Composition

These may take various shapes, be available as fixed or variable units and be available for any number of applications. The major consideration is that a resistor remains a resistor irrespective of type. As far as resistance measurement method of analysis is concerned, there is no occasion for distinguishing between the types of resistors. It is of course true that certain forms of troubles may be native to one type of resistor in particular, but we are not so much concerned with the form of trouble as we are with the fact that the final consequence is a variation from normal ohmic value. Once the condition has been established, the correction is the restoration of the receiver or amplifier to its normal state, either by replacement of the defective unit or by remedying some associated fault.

It is unnecessary at this time to make particular reference to the operating characteristics of these various types. The same is true of the relation between type and mode of utility in the system. The latter is indeed needless in view of the fact that there is no definite form of standardization relative to type and utility. This statement is made in the face of the fact that certain types of resistors are most commonly employed in a certain manner. Yet there are to be found sufficient instances of differences to completely nullify any possible standardized list. As a matter of fact, confusion rather than clarity may be the result.

The other form of resistance in receivers and amplifiers is the winding of wire, as stated before. Repetition of the types of windings is not necessary. Let it be understood that any and every type of winding, used in any part of the system at hand represents resistance, and as such can be checked. The property of resistance possessed by these windings is inherent. Let it be understood that with very few exceptions, the fact that the winding possesses the property of resistance and can be measured in ohms is something related to the wire used and not to the utility of the winding. Were it not for cost of manufacture and physical dimensions, some of the units used in receivers and amplifiers would have much lower values of resistance. However, in order that the resistance of the winding be low, fairly heavy wire is required and this involves increased expenditure for the wire and also increased dimensions for the unit. In some few instances, as for example the filter chokes in power packs, the resistance of the winding serves as a voltage-reducing unit, but even here, there is no doubt about the fact that if a choke of very low resistance were economically available, it would be preferred.

Values of Resistance.

As far as resistance values in receivers and amplifiers are concerned, they cover a range of from .2 ohm to about 10,000,000 ohms. Once more it is not possible to quote a table of resistance values as applied to resistors and to correlate these values with types or function. However, in the case of windings, some sort of a table is possible. It should be understood that this table is approximate and represents a cross-section of receiver and amplifier design. Consider the following.

R-f transformer primaries	5.	to	75 ohms
R-f transformer secondaries	0.5	to	5 ohms
I-f transformer primaries	25.	to	200 ohms
I-f transformer secondaries	25.	to	200 ohms
A-f transformer primaries	500.	to	3000 ohms*
A-f transformer secondaries	1100.	to	8000 ohms*
Output transformer primaries	300.	to	1000 ohms*
Output transformer secondaries	0.2	to	10 ohms*
Power transformer plate windings	200.	to	600 ohms**
Power transformer primary windings	1.	to	15 ohms
Power pack filter chokes	150.	to	800 ohms
Speaker field windings	800.	to	2500 ohms

R-f chokes	10. to 150 ohms
A-f chokes	100. to 1000 ohms

* May be total resistance of split winding or resistance of each half.
** In the majority of instances, represents total resistance of rectifier plate winding.

It is very possible that some few receivers or amplifiers employ units (windings, such as chokes or transformers) which possess resistance values less or greater than the lower and upper limits quoted. The above table has been prepared with the idea of offering a picture and that is all.

Up until a short time ago, resistors were usually rated at higher than .2 ohm and this low value was as a rule to be found only in windings of various types, such as filament transformer secondaries or windings, voice coils, output transformer secondaries, etc. However, times have changed and such low values are to be found among the filament current control resistors, particularly in systems which employ low voltage, high current tubes.

Resistors cover the resistance range stated, whereas windings, whether individual or split, seldom exceed 15,000 ohms. This high value is as a rule, the total resistance of a high quality audio-frequency transformer secondary.

Tolerance Values During Resistance Measurement.

This item is one of great importance. In the first place it represents the major normal discrepancy during the measurement and it is essential that the operator realize that such tolerance values exist. We have often seen advertisements concerning resistors, which name percentages of accuracy as high as a fraction of 1 percent. The manufacture of such resistors is possible, but when made are intended for precision apparatus and not standard receivers or amplifiers. Such high precision costs money and is uncalled for and rarely required in radio receivers. There is sufficient latitude of operation available with a receiver without impairing its efficiency, so that a precision resistor is not desired. We make this statement without any intent to disparage receiver design.

Investigation among engineers associated with resistor manufacturers and design engineers employed by receiver manufacturers shows that the average tolerance for the ordinary run of resistors employed in a receiver or amplifier is about 10-15 percent. However, we hasten to qualify this statement as follows. In the recently developed air-cell type battery receiver a very high order of accuracy is desired and 10 percent would be radically excessive and undesired. As a matter of fact filament current control resistors are made to within 2 to 5 percent of the rated value. This does not of course represent the skill of the resistor manufacturer. He can work to much closer values where they are desired.

A determining factor in connection with tolerance values of resistors is the intended function of the unit. If it carries current and serves to produce a predetermined voltage drop, then the usual tolerance employed in quantity manufacture, such as found in radio receivers is about 10 percent. In some instances as high as 15 percent depending entirely upon whether or not the circuit is critical. An example of this is the grid bias resistor. A tolerance values of from 10 to 15 percent is quite alright for the ordinary run of bias resistors in r-f, i-f and intermediate a-f stages. However, close observance of a 10 percent tolerance is required in pentode circuits because the value of the control-grid bias applied to that tube is quite critical.

From 10 to 15 percent tolerance is allowed for voltage divider and bleeder resistors. Also plate-coupling resistors. In the majority of cases, tolerance limits are held closer to the 10 percent than the higher figure.

In the case of grid filters (to be shown later), grid leaks and even suppressors, as high as 20 percent plus or minus is allowed. Wherever the function of the unit is to isolate one circuit from the other or to curb regeneration or to guide the path of certain currents, then the item of importance is to have resistance present at the prescribed point and a 20 percent tolerance is allowable.

Now, it might be well to state during this discussion of tolerance values, that we have two conditions, both of which are normal. The variation from the rated value may represent an excess or a deficiency. Thus all tolerances are plus or minus, which means that if a unit is rated at 100,000 ohms and its tolerance limit is 15 percent, that unit, to be classed as normal, may possess some value of resistance ranging from 85,000 ohms to 115,000 ohms. Naturally the closer the measured value to the rated value (not tolerance limits) the more suited is that resistor for the function intended and the more remote is the need for replacement.

The resistance of windings is held to a much closer tolerance because the usual consequence of a departure from rating during manufacture means a departure from the inductance of the winding. In r-f systems a very close tolerance is maintained and values of resistance are usually quoted to the fraction. The same is true in i-f systems. In a-f units a tolerance of from 1 to 2 percent is observed and in some instances as high as 3 or 4 percent. Such tolerances must be allowed despite the fact that the coils are machine-wound and the turns are accurately counted. Undue stretching of the fine wire used, during a fraction of a minute of winding, may cause sufficient increase in resistance to require a tolerance. Considering the fine wire used in such windings and the closeness of the turns, as for example in a-f transformers, it is possible that a few adjacent turns may be shorted, and thus lower the resistance of the unit, yet not impair its operation.

DISCREPANCIES IN RESISTANCE VALUES.

It is necessary during the reading of these pages that you bear in mind the fact that resistors or windings employed in receivers and amplifiers are not always employed as individual units. In very many instances other units, such as a condenser in shunt with a resistor or transformer winding or a resistor in shunt with a transformer winding, may develop a defect and create a discrepancy during measurement. This mention is brief and by no means the completion of the subject. Thus a discrepancy between the measured value and the rated value requires discretion before judgment is rendered. The difference may be greater than the tolerance value, but not because of a defect in the resistor. Instead the defect may be in the associated unit. A complete discussion of this subject appears in a subsequent chapter.

Another item which will be discussed in brief at this time, with more extended discussion later, is the possibility of a discrepancy because the operator does not realize the possibility of two widely-separated resistors which are electrically in parallel with each other. Of course where a complete table of "point-to-point" resistance data is furnished, such errors cannot occur, in view of the fact that paralleled circuits are given due cognizance during the preparation of the table. But where the test is made from an ordinary diagram showing electrical values, such errors may occur.

Another significant item relative to discrepancies between measured and quoted values is related to the operating characteristics of resistors and resistor materials. Temperature and age have an effect upon resistance. The exact effect depends upon the constituency of the unit and its method of application. Generally speaking, wire-wound resistors are constant in value over very long periods. Now, this statement should not be construed to mean that all other types of resistors are not satisfactory, for such is not the case. Every one will admit that a wire-wound resistor is preferred where size and cost will allow its use. However, wire-wound resistors are out of the question in high values. First because of the bulk and second because of the very high cost. Thus the metallic coating, carbon and composition units find application.

Now, some substances offer varying resistance per unit length and mass with temperature: Some substances increase in resistance with an increase in temperature and others decrease in resistance with increase in temperature. The former substance is said to possess a positive temperature co-efficient of resistance and the latter is said to possess a negative temperature co-efficient of resistance. Metal, pure or alloys, increase and carbon, graphite and composition generally decrease. Up until a short time ago, it was thought that all conductors other than metals had negative temperature co-efficients of resistance. Recently there have been announcements of resistors which can be manufactured to have either positive or negative temperature co-efficients of resistance and to vary in whatever manner is desired.

The fact that we mention these details is because of the variation in resistance and possible discrepancy when resistors are measured hot or cold. The measurement of resistance requires that current flow through the unit, that is, the current required by the indicating instrument. However, this current is in nearly every case much less than that normally flowing through the unit when it is in use. Thus this measurement is the equivalent of a "cold" test. However, if the test is made soon after the resistor has been removed from active use, or immediately after the power supply system has been disconnected, the heat developed in the unit during operation may cause a discrepancy because of the temperature co-efficient of resistance, which would augment the possible variation due to tolerance in manufacture. It is therefore suggested that a few minutes cooling time be allowed, before resistance measurements are made. This is particularly true in the case of carbon, graphite, metallic film or composition resistors which are normally operated in confines where the temperature is quite high. If this precaution is not exercised, it is highly probable that confusing conditions will ensue in the form of continually changing resistance value during measurement. Voltage co-efficient is mentioned elsewhere in this book.

WATTAGE RATING OF RESISTORS.

This subject is of greater importance in connection with replacement than with the actual testing. This is so because the usual method of checking the resistance of a resistor or coil winding is such that the current flowing through the unit during the testing process is very small, invariably so small as to obviate any possibility of damaging the unit. However, mention must be made of the necessity for working in this manner. It is simple to damage a resistor by passing an excessive amount of current through it during the test.

The current-carrying capacity of all conductors, irrespective of type, is definitely limited. Some will carry more current than others, but by observing the precautionary measure of limiting the current flow to a maximum of .001 ampere (1.0 milliampere) safe operation will be obtained. As a general rule, wire-wound units will carry more current than either metallic coatings, carbon or composition units.

The current-carrying ability of a unit of fixed or definite resistance is usually expressed in wattage. This term expresses the relation between the voltage which may be impressed across that unit, the resistance of the unit and the resultant current flow. The higher the wattage rating of a resistor of fixed value, the greater may be the voltage impressed across that resistor and the greater is the current-carrying capacity. However, it must be understood that the wattage rating applies to the entire resistor or winding and NOT to a part.

A complete resumé of Ohm's law as applied to conventional d-c circuits, wattage rating and its various relations to current, voltage and resistance, is to be found in Appendix 1.

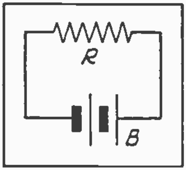
CHAPTER II

SERIES, PARALLEL AND SERIES-PARALLEL RESISTANCES

THE major requisite for operation along the lines set forth in this book is a thorough understanding of the various combinations of resistors employed in receivers and the manner in which it is possible to determine the value of the individual units in a network and the effect of making resistance measurements from various points. In any combination of several individual resistors or units representing resistance, the resultant value is dependent upon the distribution of the units and the equivalent network. Just how this condition exists will be shown in subsequent paragraphs.

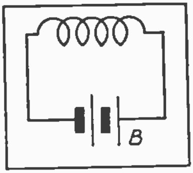
SERIES CIRCUITS.

The definition of a series circuit is "one in which the current has but one path." This is shown in figure 1, representing a simple battery connected across a resistor. Whatever the value of current (determinable by Ohm's law), that current has but one continuous path in the system. Now, it is not necessary that R be a resistor. It may be a transformer winding possessed of a value of resistance R, as shown in figure 2. If the potential of the battery B is the same in figures 1 and 2 and the value of R in figure 1 is equal to the d-c resistance of the winding, then the same value of current will flow through the two circuits. If you recall, we specified the d-c resistance of the winding. Its a-c characteristics are of no interest, in as much as our method of testing entails only d-c measurements. Furthermore, we are not concerned with signal input, the turns ratio of the transformer, its a-c impedance, etc. We are desirous of determining if its d-c resistance is correct, and by comparing the measured and rated values, determine if the unit is still in its original perfect condition.



Left, Fig. 1. Simple series circuit

Right, Fig. 2. Simple series circuit with winding in place of resistor



The winding shown in figure 2, need not be a transformer primary or secondary. It may be a choke of some kind, a speaker winding, field coil, voice coil, etc. Each of these units bears some d-c resistance rating and as far as resistance measurement is concerned, is nothing more than a resistor equal in value to the d-c resistance rating of the winding.

According to the original definition of a series circuit, the circuit is not limited to one unit. Any number of units may be employed and they may be of any type, pure resistors, transformer windings, choke coils, etc., providing that they allow the flow of continuous current and that they are arranged in such fashion that only one path is available for the flow of the current in the circuit. An example of a number of individual resistors connected in series is shown in figure 3. The number of resistors and the individual values (in ohms) of R, R1, R2 and R3 is a matter entirely in the hand of the man who assembled the circuit and the conditions he desires to attain. All of these resistors are in series and it is easily to understand that there is only one continuous path, for the flow of current which would circulate in this system. Once more, application of Ohm's law enables the determination of the total value of current, dependent of course upon the voltage of the battery B and the sum of the individual resistors. Whatever the value of current as governed by the factors stated, that value of current will be the same in all parts of this system. This must be so because there is but one path for the current.

Now, each of the resistors represents a current-limiting agency and the total limiting agency is representative or the equivalent of the total resistance in the system, exclusive of the internal resistance of the battery. Thus, in a series circuit, the total resistance is the sum of the individual resistances. In figure 3, the total resistance is the sum of R, R1, R2 and R3 when each is expressed in ohms. If for example, R is 100 ohms, R1 is 35 ohms, R2 is 1,098 ohms and R3 is 76 ohms, the total resistance is the sum of these four figures, or 1,309 ohms.

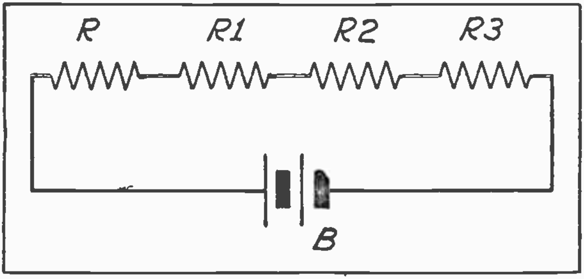


Fig. 3. Series circuit consisting of four separate resistors

Now, it is possible that the number of resistors which constitute a series circuit are not located adjacent to each other. They may be located at remote points, but if they are so connected electrically that they constitute a series circuit with respect to a potential source, the statements previously made are applicable in their entirety.

The four resistances shown in figure 3, need not be four resistors. The entire circuit may include resistors, coil windings, transformer windings, etc. This is shown in figure 4. Here we find a combination of two resistors R and R1, connected in series with two inductances L and L1. The electrical circuit structures shown in figures 3 and 4 are identical, although the actual units used to constitute the circuit are not of identical type. Both are series circuits. If we assume the values of resistance shown in figure 4, to be those of the units illustrated, the total resistance

of the series combination is 1,309 ohms. Once again, let it be said that when measuring resistance, the exact character of the unit or the exact function of the unit are items of little consequence. If the voltage of B in figure 4 is the same as that shown in figure 3, the total current flowing is the same in both systems.

Electrical circuits need not always consist of resistors. Neither are series circuits limited to the presence of one or four units. Any number greater than one, may be employed. The fact that one of the units in the system is a winding, does not alter the circuit and distinguish it from a series circuit which consists solely of resistors.

Naturally such circuits cannot have a capacity in the path of the current. A condenser so used, shown in figure 5, immediately interferes with the flow of the current. While it is electrically true, that the combination shown in figure 5 is a series circuit, in as much as there is only one path for the flow of the current, the circuit is out of the d-c category, because the condenser impedes the flow of direct current. The circuit would function as a series system when subjected to an alternating voltage, but when checked with direct current, the resistance of the system would be the equivalent of infinity, assuming a good condenser. This is so because of the location of the condenser; also because we are concerned with a conducting path for direct currents.

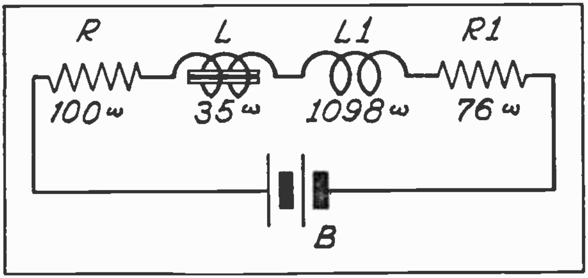
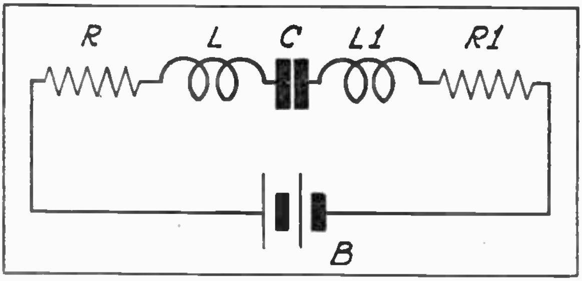


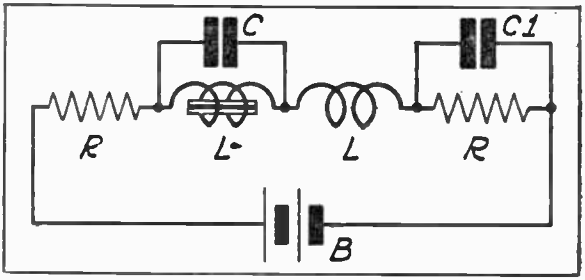
Fig. 4. Series circuit of resistors and coil windings

If a condenser is connected in parallel with a resistor or a winding, as in figure 6, it does not interfere with the structure of the system as far as



Above, Fig. 5. Condenser in the circuit does not allow direct current flow

Below, Fig. 6. Condenser in shunt with winding does not interfere with direct current flow



direct current is concerned. Since the condenser does not offer a path for the direct current, the balance of the system with respect to d-c continuity, remains unchanged. We still have but one continuous path for the direct current and the total resistance present in the system is the sum of the individual resistances, as in figure 4.

At all times, it is of greatest importance to remember that we are working with direct current and as such are concerned solely with the various paths which are presented to the flow of direct current. While it is true that the circuit shown in figure 6 is capable of functioning in a certain manner when connected across a source of alternating voltage and while it is true that the presence of the condensers C and C1 must be recognized in a-c systems, their presence may be ignored in d-c systems. Of course, this is true only in the event that the capacities are perfect. In the event of a defect within this unit, so that it is short circuited, then its presence must be recognized in d-c systems, because when shorted, it offers a path for direct current flow and influences the total resistance of the system.

This fact is given definite consideration in the method of service analysis outlined within this book, because by so doing we have a means of determining condenser defects of this type. The fact that a punctured or shorted condenser does offer a conducting path for direct currents is our key when working with a circuit such as shown in figure 6 and to be considered in greater detail later in this book. The usual receiver or amplifier network involves condensers shunted across resistors or windings. These condensers develop defects. By means of resistance measurement, as outlined herein, these defects are located.

Let us now consider a few practical examples of such series circuits, bearing in mind the possibility that the various components of the circuit may be located at different points in the system and that by correct selection of the test points it is possible to make up a complete series circuit out of what appears to be a chaotic assortment of units. What is to follow is by no means intended as the explanation of how resistors and windings are employed in receivers. This information is presented for the purpose of leading up to what is contained in subsequent chapters.

Brief reference was made to the fact that the nature of a circuit is dependent to a great extent upon the location of the voltage source. During resistance measurement, the voltage source is represented by the test instrument, the ohmmeter. The fact that the test instrument is only a part of a complete system is of no consequence. The fact that the voltage source required to operate the resistance-measuring device is separate from the indication device, is likewise of no importance, at least as far as the actual testing is concerned. The voltage source and the resistance-indicating instrument are considered to be one and the same unit. With this in mind, let us proceed to a few practical examples of series circuits as shown in figures 1 to 6 inclusive.

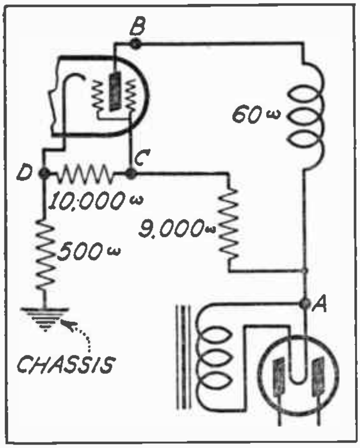


Fig. 7. Voltage distribution in a part of a receiver illustrating a series circuit formed by the units present in the circuit

Examine figure 7. This shows the distribution of voltage to some of the tube elements in a single stage. The plate of the tube secures its voltage through the r-f transformer winding rated at 60 ohms. The screen secures its voltage through a 9,000-ohm resistor. A bleeder unit of 10,000 ohms is connected between the screen and the cathode. The cathode returns to ground (grid bias resistor) through a resistor rated at 500 ohms. The basic source for the voltage is the rectifier filament system. The complete rectifier and filter system need not be shown for what we have in mind.

Let us break down the circuit shown. It is always advantageous to select a common reference point. As it happens any point in the system may be classed as common, since some value of resistance is present between that point and any other. However the point decided upon must be that which affords greatest versatility, which is reached with greatest ease and which will obviate the necessity of changing connections for the measurement of other stages in the receiver.

We shall designate one of the rectifier socket filament terminals as A and trace from that point on. Point A is one of the connections to the indicating instrument, therefore one connection to the ficticious voltage source. The plate circuit contains the transformer winding rated at 60 ohms and if we trace this circuit, starting at A, we have the equivalent in 7-A. The plate of the tube is the other junction for the indicating instrument, or B. Accordingly, this circuit is a series system which is the identical of that shown in figure 1. The dotted lines in figure 7-A show the connections to the combination voltage source and indicating instrument. The last two named items are shown within one circle to indicate that they are related and independent of the circuit being checked.

The circuit between the point A and the screen, point C, contains the 9,000-ohm resistor. If we apply a voltage between points A and C, there is only one path for the current, hence the system is of the series type. It is identical to that shown in figure 7-A, except for the presence of a 9,000-ohm resistor rather than the resistance of 60 ohms represented by the transformer winding.

The circuit from A to the cathode of the tube is through the 9,000-ohm resistance and through the 10,000-ohm resistance to point D. This circuit is shown in simplified form in figure 7-B. A voltage source connected across points A and D will result in the flow of current through the two resistors, but there is only one path for this current flow, and the two resistors are in series. The total resistance between A and D is the sum of the two resistances in the system. Because of the location of the 60-ohm transformer winding, connecting a voltage source across A and D, will cause no current through the winding. Consequently it is entirely out of the circuit as far as the system between points A and D is concerned.

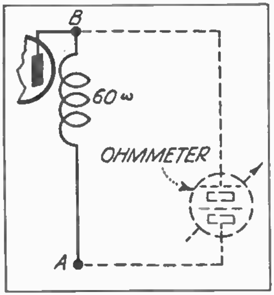


Fig. 7-A. Equivalent circuit between A and B

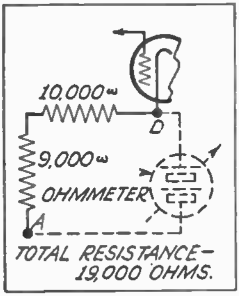


Fig. 7-B. Equivalent circuit between A and D

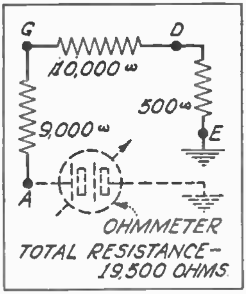


Fig. 7-C. Equivalent circuit between A and E

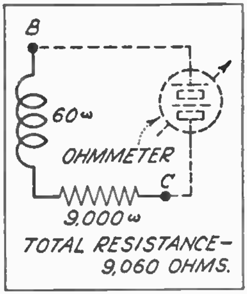


Fig. 7-D. Equivalent circuit between B and C

A still greater extension of the series circuit involves the inclusion of the grid-bias resistor of 500 ohms. With A as one point and the chassis as the other, or point E, we have the equivalent circuit shown in figure 7-C. With a voltage source connected across point A and the chassis, current will flow in one continuous path through the 9,000, 10,000 and 500-ohm resistors. These three resistors are in series.

Now, if we desire to employ some point other than A as the common connection, as for example the plate of the tube, point B, the circuit structure does not change, although it is true that between points B and C we now have a series combination of the 60-ohm transformer winding and the 9,000-ohm resistor. This is shown in figure 7-D. If a voltage source is connected across B and C, the current has but one path, as indicated. With the exception of the actual number of units entailed, figures 7-B, 7-C and 7-D are the equivalent of the series system shown in figure 4. By making B in figure 7 the common connection, and making point E, the chassis, the other, we develop a series circuit as shown in figure 7-E. The total resistance is 19,560 ohms, the sum of the individual values of resistance for each unit in the circuit.

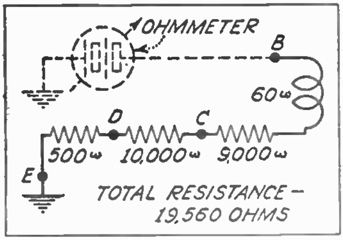


Fig. 7-E. Equivalent circuit between B and E

There are of course many more arrangements of coils and resistors as used in receivers or amplifiers, but if these units are so connected electrically that there is but one continuous d-c electrical path, the circuit is a series system, irrespective of the types and functions of the units present.

Figure 8 illustrates another circuit arrangement. Various series combinations are to be found in this circuit. By proper location of the test instrument it is possible to isolate the different resistors and to encompass many units. No matter where the testing instrument (voltage source) is located, the system is always a series circuit. No matter where the voltage source is located, the same value of test current flows through each unit. With what has been shown in figures 7 to 7-E inclusive, it is unnecessary to break down figure 8 in similar fashion. You should be capable of locating the various units which constitute the series circuits between:

A and B with a total of 20,150 ohms
A and C with a total of 5,000 ohms
A and D with a total of 21,000 ohms
A and E with a total of 46,150 ohms*
A and E with a total of 21,150 ohms**
A and G with a total of 20,000 ohms
A and H with a total of 20,050 ohms
B and G with a total of 150 ohms
B and D with a total of 41,150 ohms

D is the cathode of tube 1.
* With variable resistance adjusted for full resistance.
** With variable resistance adjusted for zero resistance.

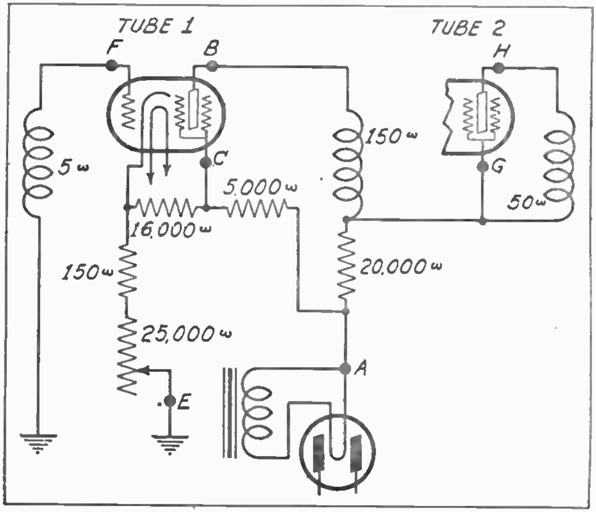


Fig. 8. Illustrates a number of different series circuits and isolation of certain units

There are numerous other combinations which can be suggested, but the material shown in figures 7 and 8 should suffice to show the practical structure of a series circuit by means of a number of different kinds of units.

As we progress in this discussion of resistance measurement method of servicing, you will note how it is possible to select certain points for the location of the test instrument and thus isolate the various units comprising the system. At first glance at the circuit in figure 8 one would naturally be struck with the problem of checking the resistance of the winding in the plate circuit of tube 1. However, closer examination shows that by properly connecting the test instrument between the plate of tube 1 and the screen grid of tube 2, the desired winding is isolated.

During the process of resistance measurement, one must exercise one great precaution. This is critical examination of the system to locate paralleled circuits. What may appear to be a series circuit is, because of some not too obvious resistor or winding, a parallel circuit and the final determination will be very confusing. Of course, when a point-to-point resistance table is furnished, wherein specific test points and the correct resistance values are given, there is no occasion for critical inspection. However, in many instances, you will make such tests by working from a wiring diagram. When so doing you must be familiar with series, parallel and series-parallel circuits; so much so as to be able to immediatley distinguish the presence of some unit which changes one combination into another. It is for this reason that we illustrate the various circuit combinations in this chapter. At no time can you know too much about such circuits. You will find that a series-parallel combination, when tested between two certain points presents one condition; when tested between two other points, it presents another condition.

A similar situation exists in series systems. The exact resistance; the exact units in the circuit depend upon the location of the test points. To us this is important, as shall be shown later, because we are interested in checking the receiver by measuring resistance without removing the chassis from the cabinet.

The suggestion to check units by working between tubes, as for example between points B and G in the table previously quoted, is of definite value. It shall be shown later in this text, that working from the rectifier filament to the various amplifier and detector tube elements offers a tangible and uniform basis of operation and that the tube-to-tube tests are supplementary and so arranged as to offer greatest speed of operation and greatest accuracy and total coverage. An elaborate discussion of the isolation of units shall follow immediately after parallel and series-parallel resistance combinations have been dealt with.

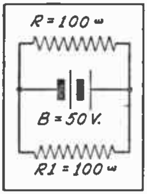
PARALLEL CIRCUITS.

Basically, all electrical circuits are series circuits. Actually, however, such is not the case. The reason for making these two statements is that any combination of units can be evolved into an equivalent system of a single or fewer units. That is, with respect to the actual amount of current caused to flow through the system when a fixed voltage is applied.

Whereas a series circuit offers but a single path for the flow of the current, a parallel circuit may offer any number of paths for the flow of current, providing that it is greater than one. The previously made statement that any circuit can be evolved into a series circuit, refers to the magnitude of the current and not to the distribution of the current. While we are not actually interested in the distribution of the current, we are interested in the fact that a group of resistors are employed in such fashion as to distribute the current or voltage as the case may be. Accordingly, we consider parallel circuits as parallel systems, without any effort to simplify the system into a single equivalent resistance. This is so because our concern is with the individual checking of the component parts of the parallel circuit. Once more we must mention that we are interested solely in d-c circuits. How an a-c circuit, when defective, becomes a part of our d-c system, shall be described in due time.

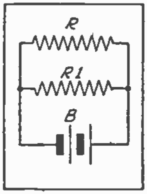
If a parallel circuit offers more than one path for the flow of current, it stands to reason that the current paths must be so arranged that the voltage source may act independently upon each. Consider figure 9. Here we have a battery which causes current to flow through two resistances, R and R1. The current flowing through R is dependent primarily upon the value of R and the voltage of B. A similar condition exists in the R1 circuit. The value of R1 and the voltage of B determines the current in that branch. If resistor R, were removed, it would not interfere with current flow through R1 and the same is true with respect to R if only R1 is removed. In each case, the branch currents assuming fixed voltage, depend upon the resistance of the branches. According to the values quoted, the current through R is (according to Ohm's law as quoted in Appendix 1) .5 ampere (500 milliamperes) and through R1, it is .5 ampere (500 milliamperes). The total current flowing out of the battery is naturally the sum of the branch currents or 1.0 ampere (1,000 milliamperes). If we were concerned with total current only, we could determine the value of a single resistance which, when connected across a battery of 50 volts, causes the flow of 1. ampere. According to Ohm's law, this resistor would have a value of 50 ohms.

Now, according to the original definition of a parallel circuit, two units are in parallel when they are connected between the same two points of the circuit. According to this definition R and R1 in figure 9 are connected in parallel, since they are connected between the same two points in the circuit. (Two units are also in parallel when they are connected in shunt with each other. The term "shunt" while actually related to "additional path" in connection with meters has become to be understood as signifying a parallel connection.) It is therefore possible to show R and R1 as in figure 9-A, which is more typical of a parallel circuit arrangement, at least as far as illustrations are concerned.



Left, Fig. 9. Two resistors connected across a battery

Right, Fig. 9-A. The equivalent circuit showing re-arrangement of the resistors



According to previous statements, current flows in each branch of the parallel circuit, and in each instance its magnitude is dependent upon the resistance of the branch. The total current is the sum of the branch currents, and no matter what the value of the branch currents, the total current must be greater than any one individual branch current. It is therefore easy to understand that the resultant resistance of any parallel combination is less than the resistance of any one of the units in the parallel combination; actually, less than the resistance of the lowest resistance in the combination. The combined resistance must be less than the smallest resistance in the combination because the current flow through this branch is only one part of the total current. No matter how small the current in the other branch or other branches, as the case may be, the total current must of necessity be greater than the current through the branch which carries the most current of the group. Consequently the total resistance is less than the resistance of the branch which carries the maximum current. This data is of great importance when determining the total resistance of a parallel combination. In many instances it saves a great deal of computation, as for example when the ohmic value of one branch is many times the ohmic value of the other branch. Suppose that we consider a few examples.

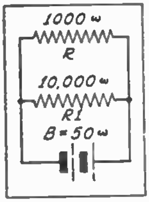
Referring to figures 9 and 9-A, the total current is 1. ampere. If the battery voltage is 50 volts, the combined resistance of R and R1 is 50 ohms, despite the fact that each individually has an ohmic value of 100 ohms. Examine figure 10. R has a resistance of 1,000 ohms and R1 of 10,000 ohms. The battery is rated at 50 volts. The current through R is .05 ampere and through R1, it is .005 ampere. The total current is the sum of the branch currents, or .055 ampere. Now, .055 ampere is greater than .05 ampere. Further, the lowest resistance in this parallel combination is the branch which allows the greatest current flow, namely through R, rated at 1,000 ohms. Therefore, if the total current is .055 ampere and this current is greater than the current flow through the branch with the lowest resistance, the combined resistance of the combination must be less than the lowest resistance in the parallel system. According to Ohm's law for resistance (see Appendix 1), the combined resistance of the units shown in figure 10, considering the current and voltage shown, is:

$$R = \frac{50}{.055}$$

$$= 909.09 \text{ ohms}$$

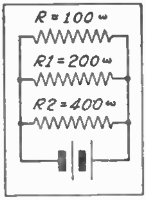
which is less than R, representative of the lowest resistance branch.

Bearing the above in mind we can consider the relation between parallel connected resistors or other units which bear d-c resistance ratings. In the first place, parallel-connected units are not limited to two in number. Any quantity of units can be connected in parallel. Also any values of resistance can be connected in parallel. Thus, two, three, four, five or more resistors may be connected in parallel and there is no limitation to the exact ohmic values of the units which must be connected in parallel. Parallel connections are used for several reasons. One of these is to provide a resultant value of resistance which is not available with a single unit. Another is to distribute current flow in such fashion that the current through the various units does not exceed the current-carrying capacity of the units. A third is to distribute current flow in order to achieve a certain purpose. Illustrations of each of these shall follow in due course.



Left, Fig. 10

Right, Fig. 11. Three resistors connected in parallel



When working with paralleled circuits, it is not customary to go through the routine of determining branch currents, adding these currents and then solving for the total resistance by applying Ohm's law. There are certain laws governing parallel circuits which are put into use. These are as follows:

PARALLEL AND SERIES-PARALLEL RESISTANCES

When all the units in a parallel combination have similar values of d-c resistance, the combined or resultant resistance is the value of one of the units divided by the number of units connected in parallel. Figure 9-A shows two 100-ohm resistors connected in parallel. The resultant resistance of this combination is:

$$\frac{100}{2} = 50 \text{ ohms}$$

The expression is R/n where R is the value of one of the units and "n" is the number of units connected in parallel. If figure 9-A contained ten such units, the resultant resistance would be 10 ohms.

When the units connected in parallel have unlike values of resistance, and the number of units is greater than two, then we invoke the basic law related to parallel circuits, namely; "The resultant or combined resistance of a parallel combination is equal to the reciprocal of the sum of the reciprocals of the resistances of the branches."

The reciprocal of a number is 1 divided by that number. Therefore, the reciprocal of a resistance R is 1/R. If R is one branch of a parallel circuit and has a value of 100 ohms, the reciprocal of that branch is 1/100 or .01. If we have a number of branch circuits, as in figure 11, the resultant resistance is:

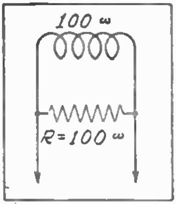
$$\frac{1}{\frac{1}{R}+\frac{1}{R1}+\frac{1}{R2}} = \frac{1}{\frac{1}{100}+\frac{1}{200}+\frac{1}{400}} = \frac{1}{.01+.005+.0025} = \frac{1}{.0175} = 57.1 \text{ ohms}$$

When only two resistors are involved, the resultant value is equal to the product divided by the sum. Thus, in figure 10, the combined resistance of R and R1 is:

$$R = \frac{R \times R1}{R + R1} = \frac{10{,}000 \times 1{,}000}{10{,}000 + 1{,}000} = \frac{10{,}000{,}000}{11{,}000} = 909.0909 \text{ ohms}$$

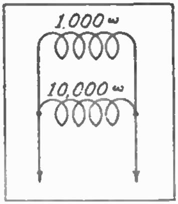
The product and sum method can be applied to any number of resistances connected in parallel, by solving for two at a time. Thus in figure 11, we show three resistors R, R1 and R2. The product and sum method can be first applied to determine the joint resistance of R and R1. When this figure has been determined, it is combined with R2. If we imagine a fourth resistance R3 in figure 11, the joint resistance of R and R1 is determined first. Then separately, the joint resistance of R2 and R3 is determined. Then the resultant of R and R1 is combined with the resultant of R2 and R3.

Now, there is nothing which limits parallel combinations to resistors only. It is possible to connect a resistor in parallel with a winding and to determine the d-c resistance of the combination, as shown in figure 12. As far as resistance is concerned, this circuit is identical to that shown in figures 9 and 9-A. By the same token, it is possible to connect two windings in parallel, as shown in figure 13. The determination of the d-c resistance of these windings is identical to that employed for resistors, as shown in figure 10. The joint resistance of the two windings shown in figure 13,



Left, Fig. 12. Coil connected in parallel with resistor

Right, Fig. 13. Two coils connected in parallel



based upon the d-c resistance values quoted in the illustration, is 909.0909 ohms. (Of course there is no need for carrying decimals to four places. It is done to enable proving the odd numbers and to arrive at the correct figure. If in the case of such odd figures, the decimals were carried to two places only, proving would result in a discrepancy and possible confusion.)

Let us now consider a few practical examples of parallel circuits with respect to circuit checking. Examine figure 14. This illustration shows a single r-f amplifying stage including the antenna system. If you examine the input of this system, you note the use of the 25,000-ohm resistor in the antenna circuit as a sort of voltage divider with the r-f primary connected to ground and to the moving arm of the divider. Two values of resistance may be determined by connecting the ohmmeter across the aerial and ground posts A and B. The value depends upon the position of the moving arm. If the arm is adjusted for zero input, that is, grounded, then the resistance across A and B is 25,000 ohms.

However, if the arm is adjusted for maximum volume, the r-f primary of 50 ohms is connected in parallel with the resistor of 25,000 ohms and the joint resistance of the combination has some value less than 50 ohms, that is, if the moving arm is making good contact and the r-f primary is perfect.

When the moving arm is adjusted for maximum volume, the parallel combination is the identical of that shown in figure 12, except for a difference in ohmic values. If we now use the rectifier filament as the common reference point, designated as C in figure 14, we can repeat the process of checking the various series circuits between C and D, E, F and G. (The grid winding is checked separately between F and H, or G and H. If desired it may be checked between C and H). Now, working between C and D, we have a series circuit through the r-f transformer winding of 50 ohms with the switch S open. In this way the condition of the

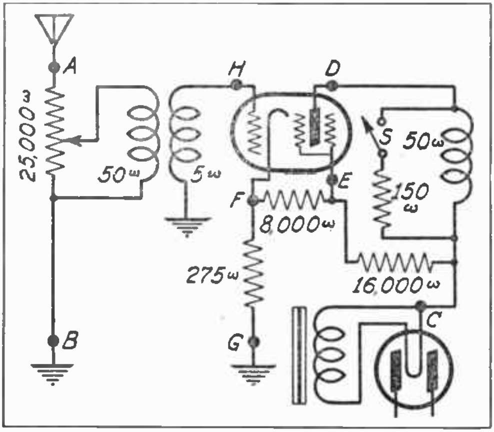


Fig. 14. Examples of series and parallel circuits to be found in a receiver

transformer winding may be determined. However, the shunting resistance of 150 ohms must also be checked. If S is closed, the 150-ohm resistance is placed in shunt with the 50-ohm winding and the two are in parallel. When S is closed the plate system is identical to the circuit shown in figure 12. With S open, the resistance between C and D is 50 ohms. With S closed, the resistance between C and D is 37.5 ohms.

The presence of a parallel circuit in any system is of consequence even when point-to-point data is given, because it is of importance in connection with the location of the defect. The significance of paralleled systems must be realized. The possible differences to be experienced under certain conditions must be thoroughly understood. Without any attempt to include trouble shooting information in this chapter, let us consider the following data contained in a point-to-point resistance tabulation. It is purported to apply to the r-f system shown in figure 14.

Aerial to Ground (Volume control minimum).....	25,000 ohms
Aerial to Ground (Volume control maximum)....	50 ohms

Suppose that the first test is made and found correct. But when the second test is made the resistance indicated is 25,000 ohms The complaint is no signal, consequently no control. According to the rated and measured values, the trouble is localized to the antenna volume control and native to the moving-arm circuit, or to the r-f primary; maybe it is open within the winding, maybe the connection to the control moving arm is open or the ground connection is open.

Another practical example of a parallel system of simple nature is shown in figure 15. This circuit is very significant of the difference between resistance measurement methods of analysis and voltage measurement methods. As far as the screen-grid and plate systems are concerned, this system is like the others shown before. However, the cathode circuit is different. Two resistors, each of 200 ohms, are connected in parallel. A resistance measurement from cathode to chassis would under normal conditions show a correct value of 100 ohms, although each of the units is of 200 ohms. If either one is defective, open in this case, the measurement between cathode and ground would show the supposedly correct value; namely, 200 ohms. While it is true that each is of 200 ohms, a resistance of 200 ohms between cathode and chassis is an indication of a defect, rather than a correct condition. During routine voltage testing one would be very prone, if the bias voltage appeared excessive, to check the two bias resistors, without giving heed to their possible parallel connection. Whichever one were open and responsible for the high bias, connecting the ohmmeter across the cathode-ground system would show the ohmic value indicated for each of the units. When presenting point-to-point

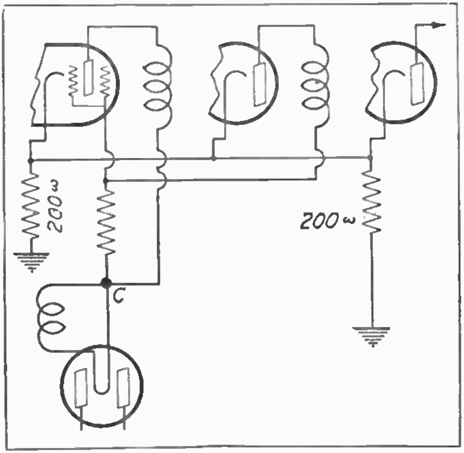


Fig. 15. Two resistors connected in parallel as used in a popular receiver

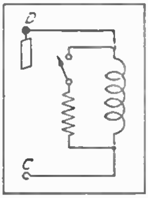
resistance data, it is possible to definitely specify that the resistance between points X and X is that of two parallel resistors.

There are of course other combinations of parallel circuits, but it is unnecessary to illustrate them at this time. They shall follow in subsequent chapters.

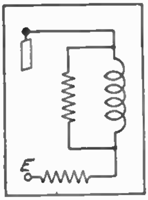
If you examine the circuit between points C and D in figure 14, you will find that it is the equivalent of that shown in figure 16. However, if point D, the plate of the r-f tube, is the common reference point, checking between D and E, introduces a circuit which we have not mentioned thus far. It is the series-parallel combination shown in figure 17.

SERIES-PARALLEL CIRCUITS.

The series-parallel system is a combination of the two individual arrangements mentioned thus far. The solution of these systems is the application of the laws governing series circuits and parallel circuits. The exact method depends entirely upon the circuit arrangement. Of series-parallel combinations there are many and they find extensive application in resistance measurement method of service analysis.

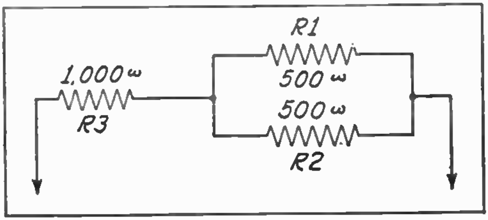


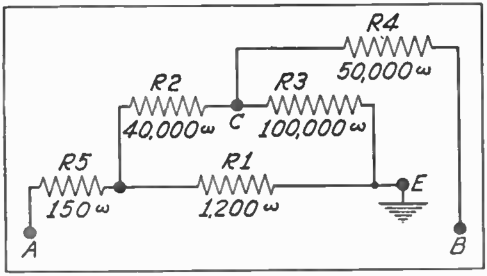
Left, Fig. 16. Switch controlled resistor connected in parallel with transformer winding



Right, Fig. 17. Same as figure 16 but permanently connected or with switch closed

Starting with a single resistor connected in series with a parallel combination of two resistors we have the circuit shown in figure 18. When working with such combinations, it is customary to first solve for the joint value of the resistors in parallel and then combine this resultant value with the series unit. Working along such lines the total resistance is 1,250 ohms. The joint resistance of R1 and R2 is 250 ohms, which added to the series resistor R3, totals 1,250 ohms. The arrangement shown in figure 18 is one of the simplest. A more complicated arrangement is shown in figure 19. Not that the actual solution is complex, but its appearance is apt to be confusing. Here we find the resistor R1, connected in parallel with two series resistors R2 and R3. The connection between R2 and R3 joins another resistor R4. The other series resistor is R5. This circuit is a true representation of systems employed in receivers and which will be encountered during resistance measurement. It is true that as far as actual practice is concerned, some of the resistors shown in figure 19 are replaced by windings. However, these windings have resistance, consequently resistor method of representation is satisfactory. Example of such circuits will be shown as our subject unfolds. We have shown five reference points, A, B, C, D and E. The ohmic values of the various resistors are as designated. The total resistance between any two points depends entirely upon the type of resistance structure between those two points. In many instances, it is





Upper, Fig. 18. Series-parallel combination of resistors

Lower, Fig. 19. Series-parallel combination of resistors with reference points for testing necessary to reconstruct the network in order to fully comprehend the arrangement present. A close examination of the arrangement of resistors R1, R2 and R3 with respect to points E and C, shows that two combinations are available. If the resistance check is between A and E, the circuit is as shown in figure 20. But if the resistance test is between A and C, then the circuit becomes as shown in figure 21. As you will note, figure 20 shows R1 in parallel with the series combination of R2 and R3. However, in figure 21, R2 is in parallel with the series combination of R1 and R3. As far as illustration is concerned, these two systems, appear alike, but as far as the resistance between A and E, and A and C is concerned, the values are markedly different.

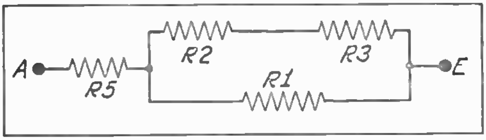


Fig. 20. The equivalent of figure 19 when testing between points A and E

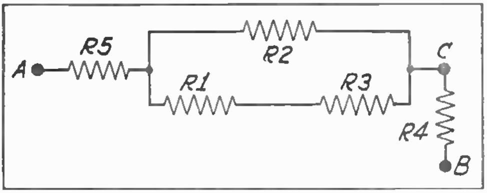


Fig. 21. The equivalent of figure 19 when testing between points A and C

Full comprehension of such network changes according to the test points is of great importance, because the occasion will arise when it will be necessary to switch from point to point in order to include all units.

Suppose that we solve for the various values present in the system shown in figure 19. Resistors R4 and R5 are always series units, consequently, very little thought need be given to them. Resistors R1, R2 and R3 require attention. Let us start between points A and B. The two series resistors R4 and R5 can be immediately added, making an initial total of 50,150 ohms. Now for the parallel combination. According to the figures shown, a resistor of 40,000 ohms (R2) is in shunt with a series combination of 1,200 and 100,000 ohms (R1 and R3) or 101,200 ohms. Thus the parallel combination has a joint value of

$$\frac{R2 \times (R1 + R3)}{R2 + (R1 + R3)} = \frac{4{,}048{,}000{,}000}{141{,}200} = 28{,}668 \text{ ohms}$$

The final value between A and B is 28,668 + 50,150 = 78,818 ohms. This is the solution of the arrangement shown in figure 21. Let us now compare the figure with that secured when checking between points A and E. All of the units involved in the original parallel combination are still present, but the arrangement is different. Also R4 has been omitted. R5 is the individual series resistor. The parallel combination now consists of one branch total of 140,000 ohms in shunt with the other branch of 1,200 ohms, or

$$\frac{140{,}000 \times 1{,}200}{140{,}000 + 1{,}200} = \frac{168{,}000{,}000}{141{,}200} = 1{,}189 \text{ ohms}$$

The total resistance then is 1,189 + 150 = 1,339 ohms. Quite a difference from the first example.

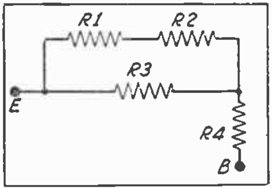


Fig. 22. The equivalent of figure 19 when testing between the points B and E

Now there is another arrangement of these units, representing point B as the reference and working between B and E. Here we find a series combination of R1 and R2 in parallel with R3 or a total of 41,200 in parallel with 100,000 ohms. The external series resistor R4 enters after the joint resistance of the parallel combination has been solved. The parallel combination is determinable as follows:

$$\frac{41{,}200 \times 100{,}000}{41{,}200 + 100{,}000} = \frac{4{,}120{,}000{,}000}{141{,}200} = 29{,}107 \text{ ohms}$$

The total resistance between B and E is 29,107 + 50,000 = 79,107 ohms.

In some practical applications of such series-parallel systems, calculation is simplified in many ways. One example is the case where R1 in figure 19 represents the speaker field winding. If this is connected into the chassis by means of a plug and the plug is withdrawn, the balance of the system becomes a simple series combination. Then again, if the resistance is definitely specified between certain points, there is no cause of calculation. Let us consider a practical application of a series-parallel combination. Examine figure 23.

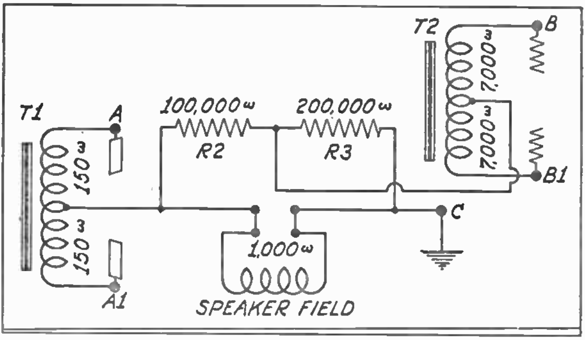


Fig. 23. A typical circuit which is the equivalent of figure 19 except for a change in values and the presence of coils

It is the equivalent of the circuit shown in figure 19, except for a change in values and that some of the resistors are coil windings. This shows the circuit between the rectifier tube plates, through the speaker field to the grids of the output tubes. The voltage developed across the speaker field is apportioned and applied to the output tubes in the form of control-grid bias. T1 is the power-transformer plate winding and T2 is the audio-transformer grid winding. The resistance values specified apply to each half of these windings. The speaker field is attached to a plug so that it may be removed from the filter circuit. Working between points A or A1, and B or B1, with the field coil plugged into the system, we have the arrangement shown in figures 19 and 21. Working between A or A′ and C, we have the arrangement shown in figure 21, from A to C. If the speaker field plug is removed, the circuit between any two points becomes a simple series combination.

Series, parallel, and series-parallel circuits as outlined up to this point cover practically every item to be found in modern receivers and amplifiers. There are of course other combinations of units, such as a fixed and a variable resistance in parallel, functioning as a volume control, shunt resistors across a-f transformers, etc. There are numerous parallel combinations which become of importance only in the event of trouble, because during the perfect state, a condenser is in series with the resistor connected across the transformer. All of these items will receive proper attention in the chapters allotted to the subject.

Technical considerations relative to series, parallel and series-parallel combinations of resistance in the form of various formula are to be found in Appendix 1. It is possible that the presentation of the figures in connection with various resistance combinations have led you to believe that resistance measurement method of analysis requires extensive mathematics. Nothing is more distant from the truth. Resistance measurement methods of service analysis do not require any more tables than voltage measurement systems. True that the character of the tables is different. Instead of quoting voltage data between the cathode and some other point, the d-c resistance in ohms is specified. You will find as you progress into the chapters which outline the actual method of servicing, that resistance measurement affords numerous advantages and that the many service men who have been using this system in the past, have been comparatively alone, but nevertheless upon the right track.

As we write these lines, we are in receipt of communications from men connected with the service industry and they advise that the system has been in use by them for a long time and has stood up under all conditions.

The contents of Chapter 2 while not essential to the actual application of the point-to-point data, when the correct resistance is specified between points, has been included in order to give you an insight into resistance combinations such as you will find in practice. There is no doubt about the fact that you will be called upon to make certain calculations. They are unavoidable becauſe the preparation of point-to-point data is just beginning. We have great hopes of convincing the radio receiver manufacturing industry upon the idea of preparing their service manuals along such lines. As far as certain well known receivers are concerned, point-to-point data has already been prepared by the author of these lines. As far as other receivers are concerned, you will no doubt be called upon to solve for the correct values to be found between certain points as indicated upon the wiring diagrams. The later crop of the wiring diagrams shows the electrical values of parts. If you examine these circuits closely, analyse the various resistor arrangements, you will be able to designate the correct resistance between points and thus prepare your own tables.

The information contained in this chapter should help. You may encounter various combinations not shown. However, by studying the contents of this chapter you will be familiar with the basic circuits, and from these circuits reconstruct and tabulate those which you may find.

CHAPTER III

RESISTANCE IN POWER PACKS

WITH this chapter we start upon the discussion of the elements involved in our process of service analysis.

As you well know, power packs are of two varieties, that used upon a-c circuits and that used upon d-c circuits. In some instances, the d-c arrangement is an inherent part of the receiver and no line of distinction is drawn. This is contrary to a-c systems, and we believe that it will be best to consider d-c receivers as complete units without segregating the power pack and the receiver proper. Accordingly, this chapter will be devoted to a-c power packs of various types.

Resistance in a-c power packs is to be found at points other than the voltage divider. As stated earlier in this book, every coil represents resistance. Consequently, the power transformer windings, field coils and filter chokes, no matter how used, constitute resistance. In view of the fact that the power transformer represents our starting point in many tests, it might be well to consider this subject first.

As far as resistance measurement is concerned, the two vital windings in the power transformer are the primary and the plate winding. Of course the various filament or heater windings are also of import, but because of their connection with the filament or heater terminals upon the tube sockets in the receiver, testing of these windings can be carried out when the receiver is checked.

Figure 24 shows a conventional power pack of the variety

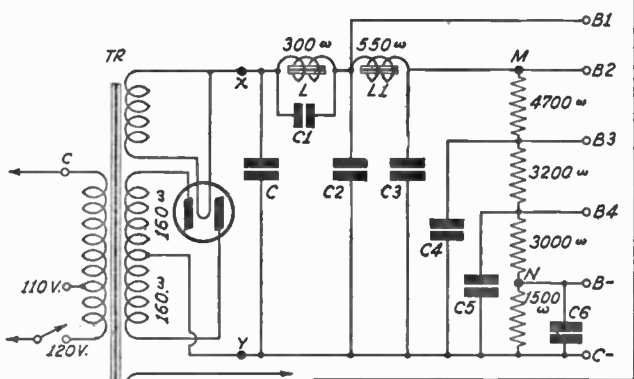


FIG. 24.

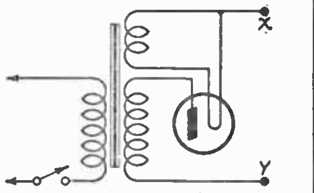


FIG. 24A.

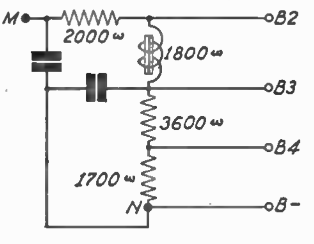


FIG. 24B

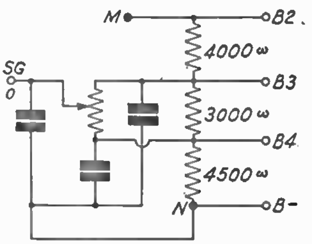


FIG. 24C

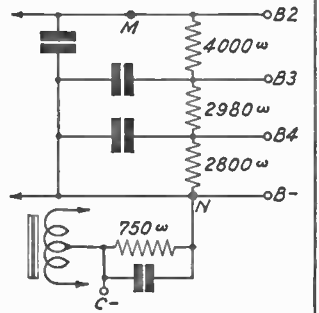


FIG. 24D.

used for quite a few years. Present power packs differ in certain respects, as shall be shown. The arrangement selected for the original discussion is of the kind where it is complete in itself and the voltage divider sections are a part of the pack, the connections terminating in a terminal board to contact strip. A unit such as this can be considered independently of the receiver proper because contact is possible between any two points via the terminal board. With this simple system as the basis, we can elaborate upon the various modifications. No matter what these modifications may be, basically the circuit is similar to that shown in figure 24.

With the exception of the transformer primary, the rectifier filament and anode winding when considered in conjunction with the voltage divider constitute a series circuit. This is so between any two points in the system. Thus, with known values of resistance for the various windings and the voltage divider sections, it is possible to locate the exact position of the defect, by correct interpretation of the measured values.

Let us segregate the various sections of such a power pack. As far as the transformer primary is concerned, two values of resistance are involved if the winding has a single tap to accommodate two voltage ranges. The major portion of the primary resistance is to be found between the common lead and the tap for the lowest voltage. This is shown in the diagram. If the transformer winding is tapped for 110 and 120 volts, the major portion of the resistance is between the point C and the 110 volt tap. The resistance between C and the 120 volt tap includes the entire winding. As a rule the amount of resistance present in the entire winding covers a range of from about 1.5 ohms to perhaps as high as 15 ohms. The most commonly employed range extends from 1.5 to about 5 ohms. Of any total within this range, the tapped section seldom represents more than 20 percent of the total. Connection across the two contacts of the a-c plug places the test instrument across the power transformer primary winding. In some instances a fuse is located in one of the power leads. This unit must be given cognizance with respect to the resistance to be expected across the plug contacts.

Among the output windings, we are concerned primarily with the rectifier plate winding, because it represents resistance, which is a part of the balance of the test circuit. Although the majority of rectifier systems now in use employ the full-wave rectifier (split winding) as shown, there are some systems which employ a half-wave winding, as shown in figure 24-A. This winding is assumed to be connected in place of the full-wave system and joins the filter section at points X and Y. In full-wave systems, the resistance of the plate winding is usually the same both sides of the mid-tap. The range of resistance to be experienced at this point varies from about 120 ohms total to about 440 ohms total. There are a few exceptions where the resistance of the rectifier plate winding is in excess of this maximum but not to a very great degree. If you examine figure 24, you will note, that with one of the anodes as one test terminal, only one-half of the complete winding is in the circuit, when checking to other points in the receiver. Only under one condition is the entire plate winding in the circuit and this is the test between the two anodes. With either rectifier tube anode as one test point, and any one of the B or C terminals as the other point, only one section of the winding is in the system. If one-half has been checked, repetition between the other anode and the B or C terminals is not required. With one-half tested, the conclusive test for the other half of the complete winding is a check between the two tube anodes.

This method is applicable to all types of transformers employed in rectifier systems used in radio receivers or amplifiers. The actual voltage rating of the transformer, that is, whether it is used with type '80, '81 or '82 tubes, is of no consequence, in as much as the tests are made without voltage applied to the rectifiers and the rectifier removed. When working with half-wave systems, the entire rectifier plate winding is in the circuit at all times.

The two chokes L and Ll in figure 24 can be assumed to represent any one of a number of arrangements. The two windings can be two chokes, as shown, intended solely as parts of the filtering system. However, one of these may be the speaker field and the other the filter choke. Of course the speaker field when used as L or L1 also serves as a filter choke. There is nothing to specify which of these two windings is the speaker field. That is a matter of design, but irrespective of the mode of use, these windings have resistance. As far as filter chokes are concerned, resistance values range from 160 to about 800 ohms, with about 400 ohms as the most frequently employed upper limit. However, it is necessary to stipulate that chokes within this resistance range are to be found in a-c systems. Chokes used in d-c systems have very much lower values of resistance in order to keep the voltage drop at a minimum. Speaker field windings employed in a-c receivers have a resistance range from about 800 to as high as 2,500 ohms. However, the higher values are to be found in some of the older receivers only. The more modern receivers use chokes which are as a rule limited to about 1,500 ohms maximum. Speaker fields employed in d-c receivers have an equally wide resistance range, depending upon the mode of application. Where the field current is secured from the filament battery as in some receivers, the resistance is fairly low, but in some instances where the field current is secured from the 110-volt d-c line, the resistance may run as high as 1,000-1,500 ohms, depending entirely upon the amount of current required for excitation.

Perhaps the mention of resistance ranges causes you to wonder about the method of testing if you do not know the resistance value. It is common practice nowadays, and it is daily increasing in popularity, to specify field coil resistance data, also filter choke data. So much so, that you will find no trouble applying resistance measurement methods to your service work. When point-to-point resistance data is available, and it will be in increasing numbers as the system becomes more popular, servicing will become a simple operation. We want to assure you that we shall make every effort to stimulate this type of servicing because it is of definite value to every one concerned—the manufacturer, the service man and the customer.

As far as voltage dividers are concerned, the system illustrated is quite common. There are, of course, certain modifications of this arrangement, but they do not complicate matters. If you example figure 24 and then imagine the application of several modified circuits shown in figures 24-B, 24-C and 24-D, between points M and N, you will have a fair idea of what to expect. Figure 25, illustrates an entirely different method of voltage division. However, before reading on, examine figures 24 to 24-D. Familiarize yourself with these systems. You will realize that checking such circuits is not a difficult matter. In many cases, the method of illustrating the system creates the impression that tracing of the circuits and measurement of the resistance is a complex operation. That is far removed from the truth. If you make an effort to appreciate an ordinary tube circuit and the various simple components of such a circuit, you will soon learn that there can be nothing complicated about the system. Certain points may be common to more than one circuit, but current paths as a rule are made as simple as possible in order to assure stability, and maintain low manufacturing and production costs.

In each of the illustrations we assume that the divider terminals terminate upon a strip, which links the power pack with the chassis. However, in many cases, the power pack is as shown, but without the aforesaid terminal strip, in which event, point-to-point method of testing is carried out along the lines stated in the chapter devoted to that subject.

Where the terminal strip is used, its location is oftentimes in the rear of the chassis, so that it is easily accessible and connection can be made thereto. In some cases the power pack and the receiver are two separate assemblies and it is easy to contact the terminal strip.

Of the many circuits shown, there is one example of a parallel resistance arrangement, that shown in figure 24-C, where the screen-grid voltage is secured by means of a potentiometer connected across one section of the divider, thus giving a variable voltage represented by the minimum and maximum limits of voltage across that section. The data pertaining to parallel circuits given in Chapter 2, with particular reference to the effect of changing the testing points, is applicable in this case. If the terminal O terminates upon the terminal board one value of resistance would be quoted for a minimum position and another for the maximum position, thus indicating the condition of both resistances in the system. If the moving contact does not terminate upon the terminal strip, the same method of test is applied except that one test point is the screen grid of the tube associated with the volume control and the other test point would be terminals B3 or B4, or the tube circuits connected thereto.

All other units shown in figures 24 to 24-D inclusive represent series circuits. The 750-ohm resistor in figure 24-D, utilized to supply the bias for, say, the output tubes, is also in series with any point along the divider or the rectifier winding and the tube filament circuit. The 1,800-ohm choke used as a voltage-divider section in figure 24-B represents a change from conventionalism, but such installations in a-c systems are not very numerous.

If we were working with voltage and current methods of analysis, it would be necessary to consider the individual function of each of these units, since their condition has a definite bearing upon the tube operating voltage. As a matter of fact, several circuits may be affected in devious manner, so that a complete analysis would be required. Being concerned solely with resistance, all that we do is consider this arrangement as purely a series system. With terminal X as one starting point and one of the rectifier socket anode terminals as an alternate starting point, we can locate any defect of a nature which will influence the resistance of the system.

Perhaps you are now wondering about defects in condensers which will not influence resistance. It is true that such defects represent one limitation in connection with resistance measurement, but is this limitation not also present in voltage testing systems? Most certainly it is! However, there exists the possibility of certain testing arrangements which are applicable to determine whether or not a condenser is open circuited. Such tests (not replacement or paralleling) are, however, not applicable if a d-c voltage exists across the associated resistor.

In connection with condensers, the primary test is to determine two types of information. Is the condenser properly connected across the circuit? is the first. The second; is the condition of the condenser with respect to leakage. The first includes the electrical continuity of the unit, such as perfect contact within the can. The second may, in the case of electrolytic condensers, include the capacity test. Now, we want to state that our connection with service work has not shown a very definite need for a test to determine whether or not the capacity of the condenser is up to its rating. This is particularly true in connection with solid dielectric condensers. Failure in these units seldom is of the type which will cause a change in capacity. Leakage may develop, but seldom will the physical condition of the condenser change, so that its capacity will be reduced.

One of our major interests in connection with this method of servicing is to develop or cause to be developed, some means of condenser testing whereby it will become unnecessary to disconnect the condenser in order to test it. As far as a short circuit is concerned, there is no need for such a test when working along resistance measurement lines, because a short-circuited condenser will lower the resistance between points. Ordinary condenser-testing methods now call for paralleling, which is not always satisfactory, or the opening of one condenser connection and checking of the capacity. It is not difficult to imagine the amount of time to be saved if a condenser-testing system is developed whereby it becomes unnecessary to unsolder one condenser lead and then resolder this lead when the condenser is found to be perfect. Condensers should be tested in the fashion employed to check resistances, just as they are in the receiver. Mark my words, such a system will be developed. . . . It must be developed. . . . It is essential to the welfare of the radio service industry.

RESISTANCE MEASUREMENT.

Suppose that we analyse the power pack shown in figure 24 and make a few sample resistance tests. Additional tests will be shown when the power pack is connected to the receiver. In the meantime, we are in a position to consider the power pack as a separate unit, because of the use of a terminal board and because by means of this terminal board the power pack may be isolated from the receiver. In the event that you have been thinking about the effects of the various condensers shown in figure 24, rest assured that they shall receive attention.

Suppose that we start with the rectifier tube filament. How this part of the power pack is contacted shall be shown later. Between the point X (rectifier filament) and the terminal B1, we cover the first filter choke, or field coil, if it so happens that it is used at this point. The resistance between X and B1 is as shown, 300 ohms. You note of course that one side of the choke L and the condensers C and C1 joins the point X. Since we are working with d-c resistance values, an open condenser will have no effect. Shorted condensers will however display some effect. But even here we must take notice of the circuit arrangement of the condensers. If the condenser C is shorted, it will be a shorting link across the test points X and Y, but the circuit between X and B1 has no connection with test point Y, so that even if C is short-circuited, the 300 ohms between X and B1 will be measurable. On the other hand if C is intact, but condenser C1 is shorted, we find another condition. The circuit between X and B1 will have supposedly zero resistance, whereas the circuit between X and Y will be reduced in resistance by the ohmic value of the winding L.

Now, to get to the point M, with X as the start, we must pass through L and if C is shorted the resistance between X and M, would be 550 instead of 850 ohms. But, if the first test is that between X and B1, and it indicates a shorted condenser, the test from X to M is mere supplementary proof. However, such a test must be made for two reasons. First to ascertain if the connection between L and L1 is intact and second to check winding L1. It is true that troubles in receivers are usually singular in number, but there exists the possibility of a dual defect; consequently all tests must be made. Another item is that pertaining to condenser C2. Shorted filter condensers prohibit power-pack tests of any kind with the rectifier in service, due to the unavoidable overload and the possibility of damage to the rectifier.

Operating upon a voltage-measurement basis, short circuit across any one of the three filter condensers C, C2 and C3 will immediately interfere with the presence of a voltage across any terminals along the voltage divider. However, when checking resistance, such a problem does not confront us. By careful selection of the test points we can locate the exact section at fault.

It is possible to continue checking the various sections of the system with X as the start, and thus determine the condition of each and every winding or resistor in that power pack. With X as one test point, the other test points alternately become B1, B2, B3, B4, B-, C1 and both rectifier tube anode terminals. However, simplification is possible, so much so that one test may be sufficient to show the defect, if one is present. If a certain type of trouble exists, then it is necessary to check between points, as will be shown. If you examine the wiring diagram of the power pack, you will note that the total resistance between X and either one of the tube anodes is the sum of the following:

300 ohms, 550 ohms, 4,700 ohms, 3,200 ohms, 3,000 ohms, 1,500 ohms and 160 ohms. The total is 13,410 ohms. This is true if all the windings and resistors are intact and if the condensers are not shorted. Open condensers have no effect. Let us now consider each of the condensers shown with respect to short circuits and the effect upon the total

resistance measurable between X and one of the tube anodes. (The item of resistance tolerance shall be dealt with later.)

1. If C is shorted the resistance between X and the rectifier anode is 160 ohms. The reason for this is obvious, since the shorted condenser short circuits the filter system, but has no bearing upon the d-c resistance of the plate winding.
2. If C1 is shorted, the total resistance becomes 13,110 ohms, showing a decrease of 300 ohms from the required value indicating perfect electrical continuity. Obviously the 300-ohm winding is shorted.
3. If C2 is shorted the total resistance becomes 460 ohms. With the 160-ohm rectifier section being a fixed value, the additional resistance in the circuit to total 460 ohms, is 300, consequently, the short circuit occurs at the junction of the 300-ohm unit and the remainder of the system.
4. If the measured value is 1,010 ohms, the short circuit is in condenser C3, since the total of 1,010 ohms consists of the rectifier winding and the two chokes.
5. If C4 is shorted, the total resistance is 5,710 ohms, since the 1,500-ohm, 3,000-ohm and 3,200-ohm sections are shorted out of the circuit.
6. If C5 is shorted the total resistance is 8,910 ohms, since the 3,000- and 1,500-ohm sections are shorted.
7. If C6 is shorted, the total resistance is 12,910 ohms.

As far as tolerance values are concerned, we must give thought to two facts. In the first place the tolerance limits concerning such resistors vary from about 3 percent to about 10 percent. These tolerance limits are plus or minus, so that it is permissible to imagine that for any one value of tolerance, the possible variation in values, some plus and some minus, will cause a total which will closely approximate the total rating. However, as far as the individual units are concerned, we may find that one may be high and another may be low by an amount equal to the tolerance. A 10 percent tolerance in a unit such as the 4,700-ohm resistor would cause a voltage variation range of about 20 volts with 20 mils flowing through the resistor, between the 10 percent minus and 10 percent plus tolerance limits. This means about 10 volts high or 10 volts low. In a way this is an excessive fluctuation. If this resistor were high by 10 percent and the voltage drop across it would be 10 volts more than required, the remaining voltages (B) available below this point would also be less than required. Thus it is safe to assume that in the majority of modern receivers these units are held to a tolerance of about 5 percent.

Now a tolerance of 5 percent allowed in the case of the 4,700-ohm resistance amounts to a value slightly more than the d-c resistance of the plate winding sections. Thus a normal and allowable discrepancy in the 4,700-ohm unit would complicate definite testing of the plate winding, that is, unless the plate winding resistance was checked between the two anodes. This must be done. When this test is finished and supplemented by the check between X and M, tolerance values in the voltage-divider system cannot cause confusion. Primarily so, because those individual units which represent resistance within the tolerance range of the higher rated units have been determined separately and individually.

One should not think that a service analysis operation of the plan stated, is possible only when the power pack is isolated from the balance of the receiver. Such tests are possible by working in the original manner stated, but operating between the point X and the tube element associated with the circuit joined to one of the B terminals.

Solution of the various types of divider systems shown in figures 24-B, 24-C and 24-D, follows along similar lines. The volume control arrangement shown in figure 24-C comes under the category of parallel circuits and by carefully studying the information relating to such circuits as given in Chapter 2, solution will present no complication.

As far as the checking of fixed condensers is concerned, we are presenting in Appendix 2, a suggestion along such lines. It is intended to be used with the chassis removed from the cabinet. This operation is required at any rate after a thorough routine resistance check shows no resistor at fault. When such a condition is experienced, it usually is necessary to remove the chassis and check the various condensers. The usual condenser test requires that the unit be disconnected from the chassis, at least one lead removed. The system we suggest eliminates the need for disconnecting the condenser to be tested. Instructions are to be found in Appendix 2.

MODIFIED POWER PACKS.

In contrast to the power pack shown in figure 24, there are in use many power packs which contain nothing more than the filter system, a part of which may consist of the voltage-distribution arrangement for the output tube grid bias. An example of this is shown in figure 25. The total plate current flows through L1, which may be the speaker field, and the values of R and R1 apportion the voltage for the output tube. In structure, this arrangement is identical to that shown in figures 19 and 23. For an explanation of the resistance relations in such a system, read the material devoted to parallel resistance circuits contained in Chapter 2.

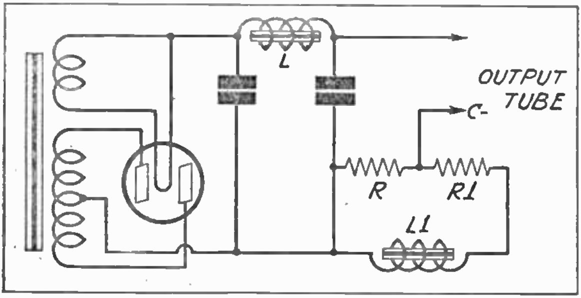


Fig. 25. A practical example of R1, R2 and R3 shown in figure 19

Modern receivers do not differentiate between the power pack and the receiver proper with respect to the arrangement of the resistors in the respective circuits. In a way these systems are very similar to the circuits used in some old time power packs, where individual series voltage-reducing resistors were employed. Such circuit structures did not employ terminal boards. An idea of such an arrangement can be gleaned by referring to figure 26. Here you find a power pack supplying various screen and plate voltages to a system. The various voltage-reducing resistors are individual and are located in the respective circuits associated with them. If the points O and P designate the output of the power pack filter system, an analysis of the circuit will show that the arrangement of resistors R to R3 inclusive, which are individual to the tubes concerned, still constitutes a voltage divider, but because of the arrangement of the resistors, the complete structure is not recognized as a divider. Such a condition may be found in every receiver for the simple reason that no matter what the structure there must be a return path to ground. It is possible to arrange a system which would have its only return to ground through the bias resistors, this return path becoming live only after plate current flows in the various tube circuits. However, such arrangements are not very popular because they do not offer a load upon the power pack during the time that the receiver tubes are being heated to their electronic-emitting condition. Accordingly, as a safety factor and as a means of producing greater stability of operation, the modern receiver employs sufficient bleeder resistors in conjunction with the voltage-reducing resistors to constitute a voltage divider load across the power pack. Thus, if you examine figure 26, you will note that the resistors R, R1, R2 and R3 are in series and electrically constitute a closed circuit across the points O and P.

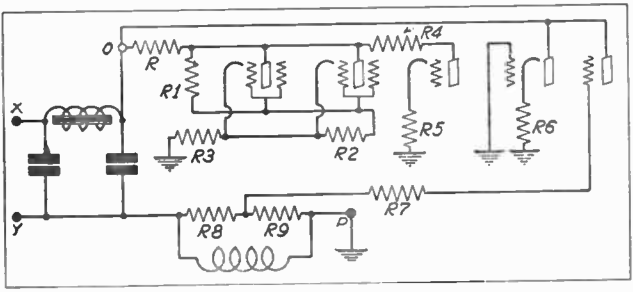


Fig. 26. An example of resistor arrangement in a commercial receiver

This is shown in figure 26A. Another modification in power pack system is shown in figure 27. The resistors R, R1 and R2 are individual series resistors feeding tube circuits. R3 and R4 constitute the voltage divider, but in reality are also series resistors. R3 is the potentiometer-type of bleeder unit connected between one of the plate circuits and the cathode of the tube. R4 is the cathode resistor. An examination of this circuit shows that the various resistors are independent of each other. By the same token a short circuit in the various associated condensers will create an effect only upon that circuit. However, there are several interesting points in connection with the effects to be observed when the test points are changed.

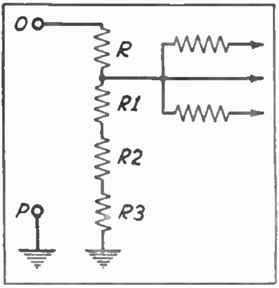


Fig. 26-A. Re-arrangement of the resistors used in figure 26

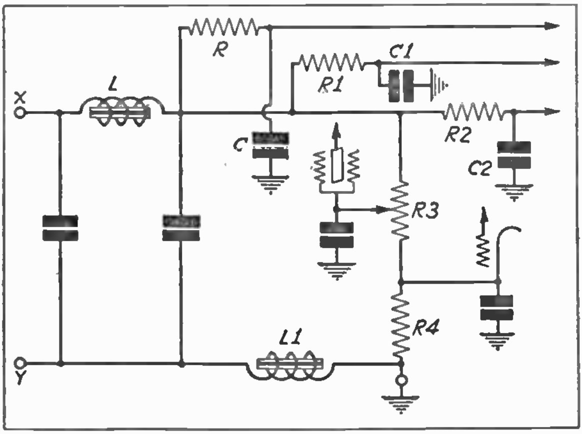


Fig. 27. A modified power pack circuit

With X as the one common test point and with ground as the other, the resistance in the circuit is the sum of the ohmic value of choke L and the two resistors R3 and R4. Now, if one of the condensers bypassing R, R1 or R2 becomes shorted, the associated resistor then is connected in parallel with the combination of R3 and R4. Furthermore if the junction of the arrow associated with R is the plate of the r-f tubes, the resistance between that plate and ground, includes the plate winding (not shown), the resistor R and the R3-R4 combination. But if C becomes shorted, the resistance to ground from that plate is that of only the plate winding. A similar condition is to be found in connection with resistors R1 and R2, condensers C1 and C2 and the tube elements which join the arrows associated with the units named. Thus by properly shifting the test points it is possible to immediately locate the defective unit when it is of the nature which will cause a variation in resistance.

In the case of open resistors or windings, the test between X and ground will show continuity through L, R3 and R4, whereas the test between X and the tube element will show the break in the system. In the event of a break in the R circuit, the test between X and the tube element joined to R is not sufficient. Verification of the condition of L is required, and this is obtained by the test between X and ground.

With known values of resistance to be expected between test points, it is possible to arrange a combination of tests whereby the exact location of the defect may be determined. So much for conventional a-c power packs. Special circuits like the Loftin-White, Triple-Twin and others are reserved for the last chapter in this book.

D.C. Power Packs.

Power packs employed in d-c receivers cannot be considered along the lines employed for a-c systems because the various units in the power pack are inherent parts of the complete tube circuit. As a rule voltage dividers are not to be found in d-c system, although there are a few exceptions. Consequently when working with the conventional d-c receiver, the test is from the d-c power plug to the various tube elements.

Consider figure 28. This circuit is by no means complete, but what is shown is sufficient to illustrate the subject at hand. Although 7 filaments are shown, only 5 plates are illustrated. The balance can be considered as being arranged in similar fashion. Now, one of the first items which is pertinent to the successful application of resistance measurement methods of analysis is that related to the filaments of the tubes employed in the receiver. Resistance measurement is based upon the removal of the tubes from the receiver. That is necessary in a-c systems, but is a disadvantage in d-c systems. Accordingly, we must stipulate that when checking the filament circuit of d-c receivers, that the tubes be left in the receiver. The information to be gleaned in this manner is of value for several reasons. First because it enables a check of the tube filaments. Second, because by removing some of the tubes, (as specified) it is possible to check the condition of the filament shunt resistors. For other tests the tubes are removed.

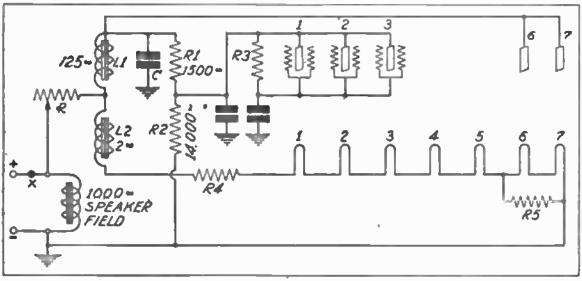


Fig. 28. Resistance network in typical d-c receiver

Returning to the power pack in figure 28, it is difficult to draw the line of demarcation. Just where does the power pack end. We know that it begins with the power plug. One would normally imagine that the parts of the power pack included, the control resistance R, the chokes L1 and L2, the speaker field, the voltage divider R1-R2 and possibly R4. Of course the associated bypass condensers and the plug. It is possible that R1-R2 are parts of the receiver proper and that the aforementioned parts are spread about along the complete receiver chassis, in which event there could be no classification of the parts constituting the power pack.

In d-c systems, one of the power plug cables is the common test point. This is the equivalent of X in figure 24. The plus or positive terminal is used because it affords a means of reaching the various tube contacts with minimum resistance in the circuit. Let us break down the circuit shown. The first significant item is relation of the filament circuit to the balance of the receiver.

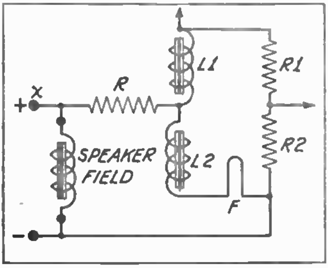


Fig. 28-A. The equivalent of the filament circuit arrangement shown in figure 28

With the tubes remaining in their sockets, the complete network becomes the equivalent of that shown in figure 28-A, wherein the single filament F represents the entire series of filaments. With the system as shown, parallel circuits are involved and when operating between any two points to determine the resistance, as for example between X and the plate of tube 6, which would furnish information concerning R and L1 and some other winding in the plate circuit of tube 6, R1, R2, the filament circuit, L2 and the speaker field must be included. The reason for this is clearly shown by the revised diagram in figure 28-B. It is easy to see that the circuit is quite complex. Simplification is possible by means of one move. Remove the tubes from the receiver and the circuit becomes as shown in figure 28-C. Even now, you are confronted with a parallel network. Further simplification is possible by simply removing the speaker field plug, or by disconnecting one of the speaker leads. In nearly every radio receiver, it is possible to disconnect the speaker field by either a plug or by unsoldering the leads, one of which is sufficient, without requiring that the chassis be removed from the cabinet. When this is done, the circuit becomes as shown in figure 28-D, a simple series system.

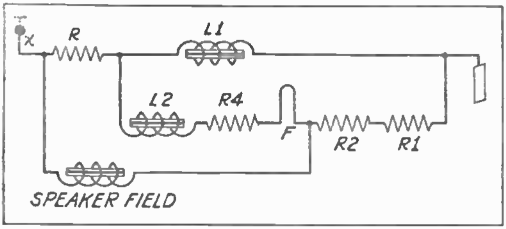


Fig. 28-B. Circuit of figure 28 re-arranged

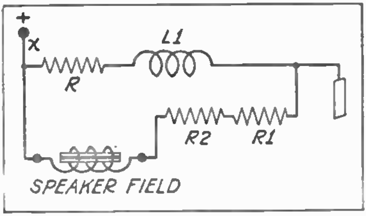


Fig. 28-C. The effect of opening the filament circuit by removing the tubes

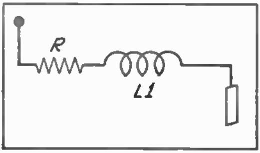


Fig. 28-D. The effect of disconnecting the field coil

With the tube removed and the speaker field out of the circuit, you can check the balance of the system as a series circuit, working from X or by operating between the various tube plates, screen grids and grids.

With the tubes out, R5 is checked by testing across two filament terminals of the output tubes. With the tubes replaced in their sockets and the speaker field out of the circuit and the test between the plus and minus plug terminals, the circuit being tested is as shown in figure 29. Since the filament resistance is comparatively low, R4 is low, L2 is low and R is low, the high resistances represented by L1, R1 and R2 will have very little effect and an accurate test is available. The speaker field is checked separately.

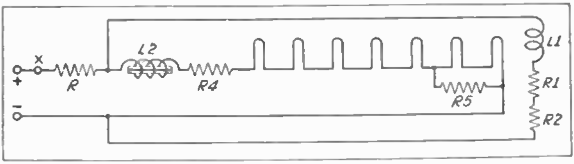


Fig. 29. The circuit when the tubes are replaced but with the speaker field disconnected

Thus a d-c system can be broken down just as easily as any a-c system and offers the advantage that in the event of a defect in the system which causes high filament or heater voltage with the consequent hazard of burnout if voltages are checked during the defective state, testing with the supply voltage "off," removes all possibility of unnecessary tube burnout.

There are of course much simpler d-c systems. The first example we selected contained series-parallel circuits. Consider the diagram in figure 30. This is a commercial d-c receiver using the indirectly-heated cathode type a-c tubes. You will notice that with all the tube filaments in the sockets, the series circuit L, R and R1 is in parallel with the series circuit consisting of the speaker field L2, the resistor R4, the filaments and shunt resistance R5 and R6. However, with the speaker field disconnected or tube 1, 2, 3 or 4 removed from the circuit, all resistors or windings associated with the screen or plate circuits become series circuits and can be tested with X (plus power plug terminal) as the common point. Thus between X and plate 1, we include the resistance of L and R. (Also whatever winding is in the plate circuit of tube 1.) Between X and screen 1, we include L, R and R1. By varying the setting of R1, we can determine its resistance. If we wish to isolate R1, we simply check between screen grid 1 and ground, with R1 set for maximum volume. If we wish to isolate the winding (not shown) connected into the plate circuit of tube 1, we check between plate 1 and screen 1 with the volume control R1 set to maximum. Between plate 1 and plate 2, we can check the plate windings in these two circuits, etc. Between screen 2 and screen 3, we check the resistance R2. Between X and plate 4, we can determine the ohmic value of R3 and whatever unit is in the plate circuit of that tube. With the speaker field plug removed or the field disconnected, we can check the filament circuit by inserting the tubes and checking between one side of the speaker field plug or one of the connections thereto and the minus side of the power plug. If we wish to include R6, we use the chassis as the other test point instead of the minus terminals of the power cable plug. The speaker field can be tested separately. R5 can also be tested separately, by removing the tubes and checking between the correct filament contacts of tubes 5 and 6. Between X and the plates 5 and 6, we can determine the ohmic value of each half of the output transformer primary winding.

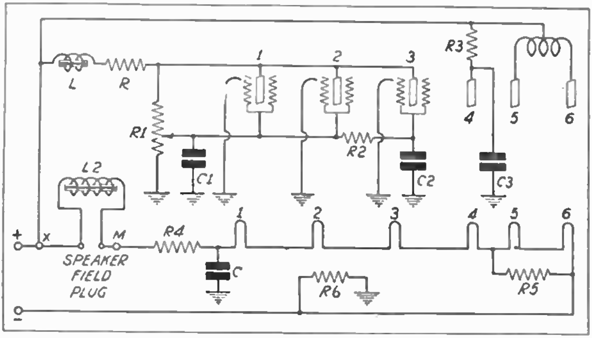


Fig. 30. Another example of a d-c circuit

With resistance tabulations designating the ohmic values to be expected between any two points of the receiver under different conditions, it becomes a very simple matter to locate the defect. While we do not show condensers in the different circuits, their action when shorted means a variation of the resistance between various points. Thus, if C is shorted, the resistance between X and chassis (speaker field in) would be the sum of the resistance of the speaker field and R4 paralleled by L, R and R1. With the speaker field out, and the common test points being one side of the speaker plug and chassis, the resistance present in the circuit between M and the chassis would be that of R4.

To locate a shorted condenser somewhere in the power pack system, the first check is between the plus and minus terminals of the power cable plug, taking into consideration every unit present in the system. Varying the volume control between minimum and maximum volume will indicate the presence of a short-circuited condenser in any one of the screen-grid circuits. Thus, if C1 is shorted, it will have no effect upon the resistance of the network when the control R1 is set for minimum volume, but will show up when it is set for maximum volume, because the shorted condenser short circuits R1. If C2 is shorted, it is the equivalent of a short circuit across R1, with the addition of R2 into the shorting system. In this case a test between screen grid 3 and chassis will show no variation in resistance irrespective of the adjustment of the volume control. If C3 is shorted to the chassis, and a test is made between X and chassis another paralleling circuit is in the system. This is R3 across the series combination of L, R and R1. However, a check between plate 4 and chassis, instead of showing the presence of R3 and the coil winding in that circuit, will show only the resistance of the coil winding. This is so because the junction of C3 is common with the junction of R3 and the coil winding, which is not shown.

At this point we are obliged to bring up an important issue in connection with d-c circuits. Working with the positive terminal of the power cable plug, we can reach the various tube elements and check for resistance with greatest ease. However, in the event of a shorted bypass condenser in one of the tube circuits, it is more easily located by working with the chassis as the common terminal. Suppose that we consider two examples of this. Between chassis and screen 1 we need check only through R1 and if this control is set at minimum signal, the connection is direct. However, if we wish to check the plate circuit of tube 4, with the chassis as the common point, we must work through R1, R, L and R3, (with the plate winding in tube 4 omitted.) With X as the common point, we work directly to plate 4. Now, if a short circuit develops in condensers C1 or C3, working with the chassis as common, will give direct contact with screens 1 and 2 and with the plate circuit of tube 4.

Here we have a choice of operation. In one case, that of test point X, we can more easily locate an open circuit in one of the resistors and more rapidly determine which of the resistors or windings is open. On the other hand, working with the minus terminal of the power plug as the common test point, we can more readily determine shorted bypass condensers. If we base our conclusion upon which troubles are more frequent, we are forced to continue the suggestion that the common testing point be the location designated by X. This is to be followed by tests between tube elements.

When the point-to-point data is given in table form, there is but one choice, namely, to follow the table sequence, but where one operates from a diagram, the suggestion made herein will be found most advantageous.

CHAPTER IV

RESISTANCES IN TUBE CIRCUITS

THE modern receiver contains several hundred percent more individual resistors than was used in years gone by. Many of these resistors are to be found outside of the power pack and employed in the various tube circuits. The functions of these resistors are manifold, depending upon their location. If you will examine the modern receiver you will find resistors used as grid filters, plate filters, grid suppressors, filament controls, voltage reducing units, bleeder units, grid bias sources, stabilizing units across transformer windings, losser units for local-distance operation (sensitivity control), coupling units, grid leaks, etc.

However, resistance as a property of a conductor is not limited to solely these resistors. Resistance is to be found in every r-f transformer, antenna coupling coil, oscillator winding, i-f transformer, a-f transformer, output transformer, detector plate choke, ordinary r-f chokes, etc. Every winding has resistance and as such every tube circuit contains resistance in one form or another. Thus it might be well to realize when checking receivers, that resistance is to be expected in every tube circuit. True that it may be small in one case and great in another, but whatever it may be, it still represents resistance. In order to preclude the possibility of confusion in certain tube circuits, where two or maybe three tube elements are common to one voltage-supply circuit and the resistance is negligible, we want to qualify the previous statement and say that d-c resistance is present in every tube circuit known to contain some unit or winding.

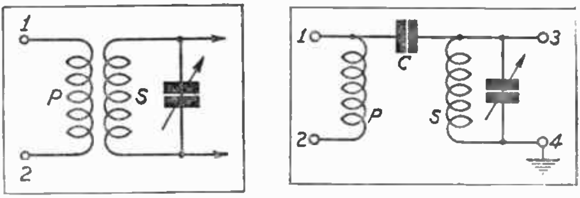
Technically we were correct in the first statement, in as much as the shortest conductor possesses resistance, but it is so low as to be wholly negligible. On the other hand, the various units, (resistors or windings) which are to be found in the various tube circuits do possess finite values of resistance. Accordingly, all future reference to windings of any nature will signify resistance in those units and these windings shall be interpreted in the form of resistance.

In the majority of radio receivers and amplifiers, it is possible to check the d-c resistance of the various windings without removing the chassis from the cabinet. One can very readily comprehend the ease of measuring the d-c resistance of a winding, when it is possible to reach the terminals of that winding and thus avoid continuity through all associated units. But when the chassis is not to be removed, it is necessary to seek such points of contact as will enable closest electrical approach to the coil terminals themselves. This is simple in most instances, but there are cases where such contact is impossible without pulling the chassis. Since we are concerned with the means of testing without removing the chassis from the cabinet, we shall devote the major portion of our discussion to such arrangements. With the information available, you will have no trouble testing units when the chassis is out of the cabinet.

The examples to be used in this chapter are purely hypothetical, but based upon actual circuit structure. Obviously it is impossible to show every type of radio circuit separately. What we shall do is to combine several types into one drawing, allotting one or two tubes, as the case may be, to one particular type of circuit arrangement and the balance of the tubes to other types of circuits.

R.F. TRANSFORMERS.

Transformers used in receivers are of various types, such as radio frequency (r-f), intermediate frequency (i-f), audio frequency (a-f), output, etc. Now, it has become customary to apply the term transformer to various kinds of units, some of which are quite different from the usual concept of what constitutes a transformer. Normally, one considers a transformer to consist of a number of windings wound around a core of some kind, not necessarily iron; sometimes air, as in the case of radio- and intermediate-frequency units. The usual transformer employed in a radio-frequency system, consists of a primary and secondary, as shown in figure 31. The primary winding has some value of resistance and the secondary winding also has some value of resistance. The modern receiver employs an r-f transformer, wherein the primary resistance usually is several times the resistance of the secondary. In older receivers this is not true. The closest approach to a means of stating under what conditions such is true, is to state that in the majority of instances, screen-grid r-f amplifiers employ r-f transformers which have higher primary and secondary resistance values. The old type receivers had few-turn primaries and many-turn secondaries. As a result, the primary resistance was low, with the exception of the transformers which employed special resistance-wire primaries.



Figs. 31 and 32. Two types of radio frequency transformers

Modern practice has accepted the capacity-coupled r-f transformer to be known simply as a transformer without special designation. This is shown in figure 32. In some cases the primary is also inductively coupled to the secondary, but this is of no value to us in connection with our measurements. Another type of r-f transformer consists of two complete windings and one open winding joined to the primary, as shown in figure 33. The open winding is a coupling winding, and as you will note one lead from this winding goes nowhere. Resistance measurement upon this winding is out of the question for several reasons. In the first place, it usually consists of one or two turns with negligible resistance. Second, it has but one common terminal for testing and the other is hidden within the recesses of the transformer.

As far as our testing is concerned, we are interested in the primary and secondary windings. The only time that the capacity concerns us is when it is shorted, and consequently influences either the primary or secondary resistance measurement. Of course the condition of this coupling condenser (C) is of importance with respect to the performance of the receiver, but not with respect to resistance tests.

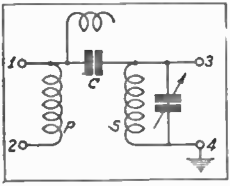


Fig. 33. An r-f transformer with open coupling winding

Still another type of transformer employed in certain receivers consists of the combination shown in figure 34. Still another type of unit is shown in figure 35.

The only reason we have for showing these various types is to illustrate how the windings can be checked and under what conditions special systems must be employed. Picture if you will the transformer shown in figure 31, employed as the input system to a receiver and the connection of the terminals shown in figure 31 to the corresponding terminals marked in figure 36. Figure 36 is a skeleton of the tube circuit, allowing for the use of the r-f transformer primary in the antenna circuit and the secondary in the grid circuit, or the use of the primary in the plate circuit of the r-f tube and the secondary in the grid circuit of the corresponding tube.

You will note upon examination of the diagrams shown in figures 31, 32, 33, 34 and 35, that the primary winding can be checked under any condition, that is, between the aerial and ground, or between the plate of the tube and the B plus terminal, which in many instances joins the filament of the '80 rectifier, or the plate circuit of another tube or the screen circuit of the same or another tube. At any rate, its resistance can be determined.

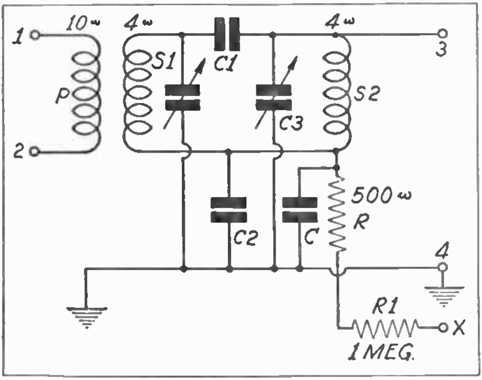


Fig. 34. An r-f transformer. The stator of the condenser across S1 offers the only direct contact with S1

The ease of determining the resistance of the secondary windings in figure 31, 32 and 33 is evident and further discussion is not required. However, when we examine the three winding units, shown in figures 34 and 35, we note certain complexities. To illustrate these complexities we are showing approximate d-c resistance values for the various units. As is evident in figure 34 contact can be made with the second secondary at point 3 (the control-grid), but to check the resistance of this winding of 4 ohms is impossible by contacting ground for several reasons. First, because the winding does not go directly to ground. It reaches ground as far as r-f energy is concerned through the condenser C. The nearest tube contact would be through the series circuit of R and R1, a minimum total of 1,000,500 ohms. When working with such high figures discrepancies in a coil of 4 ohms d-c resistance would certainly pass unnoticed. With respect to secondary 1, there is no tube connection. Neither one of the coupling capacities C1 or C2 can be reached without pulling the chassis. Accordingly, it is necessary to seek some means of contacting these coils so as to measure their resistance. The only method is to utilize the stator plates of the tuning condenser. As a rule this part of the receiver is accessible. In some instances it may be necessary to remove the condenser shield, but this does not necessitate total removal of the chassis from the cabinet. By contacting the stator of the tuning condenser which tunes S1 and the control-grid terminal 3, we can check the resistance of the two

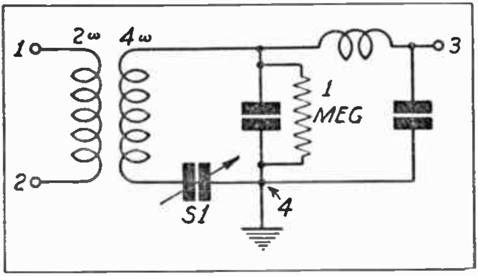


Fig. 35. Another r-f transformer difficult to check

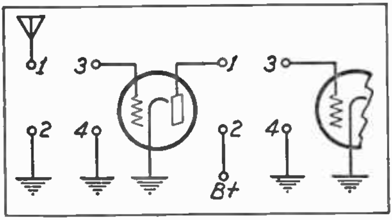
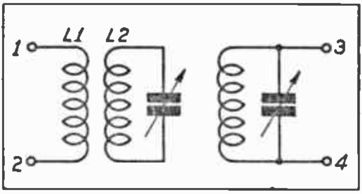


Fig. 36. Common contacts to transformers of different types

windings S1 and S2, connected in series. This test excludes resistors R and R1.

A similar condition exists in the case of the system shown in figure 35. Here too the coils are practically isolated, since a resistance of 4 ohms is of very little effect where 1,000,000 ohms are involved. Consequently, the most logical method of checking is from the control-grid terminal 3 to the stator of the variable condenser which tunes S1. The answer would include both coils in series. The 1,000,000 resistor offers a means of applying the control-grid bias and its resistance can be checked by means of a test between control-grid and ground.

Fig. 37. R-F and i-f transformers with link circuits



Perhaps you have given thought to the possibility that the tuning condenser sections are not available unless the chassis is pulled from the cabinet. How would one check these windings without pulling the chassis. The answer is simple. . . . One would not check them. Not that the information is not desired, but it represents one limitation to service analysis without pulling the chassis. We do not hesitate to admit that there are certain limitations. It is nothing to be ashamed of. In the event of a defect in these coils when checking with voltage, one would be called upon to remove the chassis and hunt for further information. Since resistance measurement offers the means of checking such circuits when the condensers are accessible, and since these condensers are available in the majority of instances, the limitation imposed by those few cases, when they are not accessible, is not half as bad as the numerous limitations which confront voltage measurement under all conditions.

There is still another limitation to be experienced in connection with resistance measurement methods of checking r-f transformer circuits. This applies to the three-winding transformer wherein one winding serves as a tuned link circuit, as shown in figure 37. Windings L1 and L3 can be checked in normal fashion, but since L2 has no common junction, the only means of determining its resistance is contact across the rotor and stator of the tuning condenser. At times, such connections may be very difficult to achieve. Once again, nothing is lost since a similar state of trouble exists if servicing is carried on along voltage-measurement lines and this circuit is bad.

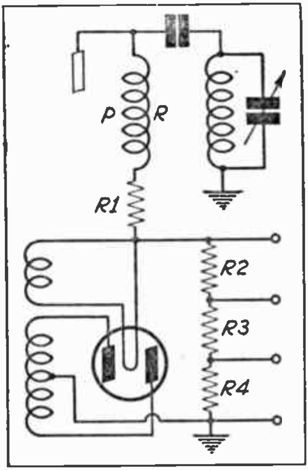


Fig. 38. If the coupling condenser is shorted the secondary winding is shunted across the plate-ground circuit

Where such conditions occur as to require pulling of the chassis in order to allow measurement of one coil, the operator must use his discretion and consider the probability of the trouble being in that part of the receiver as against the many other parts which can be tested without pulling the chassis.

Returning once more to the circuits shown in figures 31 to 33 inclusive, we note that it would be quite simple to locate a shorted tuning condenser, since it would short circuit the secondary winding. A short circuit in the coupling capacity C or its equivalent leak between the primary and secondary windings in figure 31 is detectable after a fashion. Normally the r-f primary in the aerial circuit is measured by checking between aerial and ground. If the coupling capacity is shorted, it means that the secondary is connected in shunt with the primary. If the normal primary resistance is say 30 ohms and the secondary resistance is 4 ohms, the total resistance with these two in shunt would be less than 4 ohms. Verification of the shunt would be secured when the test upon the secondary winding was made. The primary would then be in shunt with the secondary and the final result would be a value of resistance representative of 30 ohms in shunt with 4 ohms.

A similar condition would exist if the primary were located in the plate circuit of the tube. In this case, however, the discrepancy would be even greater than before. See figure 38. The reason for this is found in the fact that the usual check would be a resistance test between the rectifier tube filament and the plate. With the coupling condenser shorted, it would result in the paralleling of a 4-ohm resistor in series with the voltage divider, across the circuit between the rectifier filament and the plate. Now if a test were made between the r-f tube plate and ground, instead of finding some value of resistance equal to the sum of R (primary winding), R1, R2, R3 and R4, the actual value would be slightly less than 4 ohms.

As far as open tuning condensers are concerned, such tests are beyond the pale of the system being outlined herein, just as they are beyond the capabilities ot voltage measurement arrangements.

When working with circuits which involve condensers and the possibility of short circuits in these condensers it is necessary to pay attention to those conditions which will create trouble, yet not be discernible with the routine test. As a concrete example, consider C3 in figure 34. It is perfectly possible that this condenser may become shorted, so that the control-grid terminal 3 would be placed at ground potential. This condition would in no way interfere with the test between the control grid and the stator of the variable unit which tunes S1. However, it would interfere with the operation of the receiver. Accordingly, it is necessary to mention that a test between grid and ground should show a very high resistance, at least more than 1,000,000 ohms (according to the circuit), maybe more, depending upon circuit connections to R1. Then again a short circuit in C or C2 would cause a similar condition, wherein the resistance between control-grid and ground would be of the order of 4 ohms instead of more than 1,000,000. It is therefore essential in connection with such measurements to consider those tests which normally would indicate an open or very high resistance, and when a defect is present would show a marked discrepancy and the presence of the defect. By suitable interpretation of the indication, you would be well fortified to locate the trouble.

Where resistance is involved we must consider the state of conductivity and remember that a finite value of resistance is required. Where capacity is involved, we must also consider the state of conductivity, but instead of finite value of resistance, we desired an infinite value of resistance.

Resistance of R-F Transformers.

The d-c resistance of r-f windings extends over quite a range. There can be no definite stipulation of the extent of these ranges. Approximations mean very little, because a difference of an ohm or two may mean the difference between a perfect and an imperfect unit. Generally speaking, the primaries of r-f transformers vary in resistance from about 1.5 ohms to about 80 ohms. This covers the windings themselves, including those transformers which have two primary windings tuned to different bands. Also the transformers which employ resistance wire for the primary winding. Mind you that these figures apply to tuned transformers. The secondary winding resistance may range from about 2 ohms to about 8 ohms.

In the case of untuned (usually called broad-band) transformers, the primary resistance may run as high as 2,000 ohms. The secondary resistance will approximate about 30 to 70 ohms, in some instances slightly higher.

I-F TRANSFORMERS.

With very few exceptions, intermediate-frequency transformers consist of two windings, as shown in figure 31. The difference is of course the nature of these windings, number of turns, etc. Also that both the primary and the secondary are tuned. One particular type of i-f transformer resembles the circuit shown in figure 37, where L2 is a link winding. As far as application is concerned, the numbers associated with the diagrams in figures 31 and 37 and 36 are equally applicable to i-f and r-f systems. The primary and secondary windings are checked in a similar manner. Of course, because of the location of i-f systems in super-heterodyne receivers, the primary winding of the i-f transformer is never to be found in the aerial system. In every case it is connected between the plate circuit of the mixer (1st detector tube). One exception to this statement is the use of an autodyne detector, in which case the i-f transformer primary is to be found in the screen-grid circuit of the autodyne tube. This information is evident upon the wiring diagram employed when the test is made. Furthermore, if point-to-point data is given, the correct location of the test points to check the different circuits is readily available.

In all discussion such as this we must bear in mind the very great possibility that future wiring diagrams will show the d-c resistance of the various windings. With this information at hand, the service man will be able to select his test points right from the diagram. Furthermore, the test data accompanying the wiring diagram, will be of the point-to-point type.

There is to be found a particular type of i-f transformer in some RCA, Graybar, General Electric and Westinghouse receivers. This is shown in figure 39. The secondary winding consists of two windings L2 and L3. A resistor is so arranged that it can be used as a volume control and by continued movement of the lever, resistance can be inserted into the tuned circuit. As is evident, one end of coil L2 connects to terminal 2 upon the magnetic pickup terminal board. Through a connecting link with terminal 3 upon the pickup board, the circuit is connected to ground through the resistance R. To check the d-c resistance of the major winding L2, one tests between the control grid of the tube and pickup terminal board contact #2. Between terminals #2

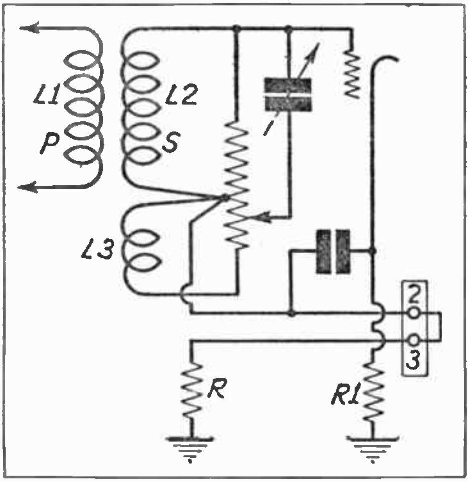


Fig. 39. A special kind of i-f transformer to be found in certain RCA and affiliated companies' receivers

and ♯3, the filter resistance is checked. The variable resistance shown as a part of the transformer cannot be tested unless the i-f transformer shield is removed. Thus a part of the test can be made right through the socket and by contacting the terminal board which is accessible at the rear of the chassis.

Another type of i-f transformer, very similar to that shown in figure 39, yet different, is shown in figure 40. Here L2 and L3 are not connected. The control winding L3 can be tested by checking between ground and the control grid of the i-f amplifier tube. The major winding can be tested only when the chassis is pulled and the shield is removed, or by contacting the control-grid terminal of the AVC tube and the junction between the low end of the secondary winding and the resistor R. The complete circuit can be checked between the control-grid of the AVC tube and the final terminal of the resistor R.

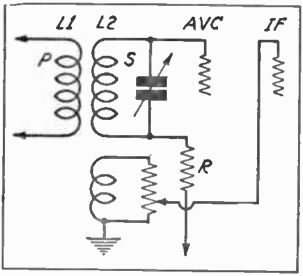


Fig. 40. Another special type of i-f transformers. The three windings are one unit

Resistance of I-F Windings.

The resistance of i-f windings covers a range extending from about 30 ohms to perhaps 150 ohms. These values apply to both primary and secondary windings. One of the peculiar facts about i-f transfromers is that the secondary winding does not always have a d-c resistance rating less than that of the primary. In some instances, the primary and secondary resistance ratings are the same. Once more with point-to-point data at hand, it becomes a simple matter to check right through the socket. The same method is applicable when the wiring diagram shows the electrical values (d-c resistance) of the various windings. While it is not common practice to do so at the present time, every indication points to the fact that this shall become quite common later.

A-F AND OUTPUT TRANSFORMERS.

There is nothing special we can say about audio-frequency and output transformers, which is not to be found in any text book. The only possibe exception to this is the unit to be found in some RCA, General Electric, Graybar and Westinghouse receivers. This is shown in figure 41. A third winding L3, tuned by a fixed condenser is a part of the output transformer. Since this winding does not join any common point it can be checked only when the chassis is pulled from the cabinet.

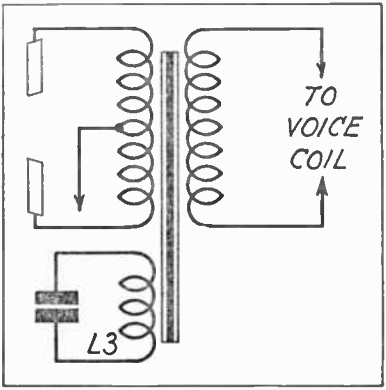


Fig. 41. A special type of output transformer with a tuned winding

Audio-frequency as well as output transformers have values of resistance and parts of a circuit can be checked for resistance, exactly in the

manner employed for the other types of transformers named. You are no doubt sufficiently familiar with such units to realize their construction. With what is to follow in connection with point-to-point resistance measurement there is not need for extended discussion. The illustrations in figures 42 to 48 inclusive show various types of a-f transformers. Figure 42 is a conventional a-f transformer. Figure 43 shows a push-pull secondary. Figure 44 shows push-pull primary and secondary. Figure 45 shows a push-pull primary and conventional secondary. This type of structure is used as an interstage unit and also in push-pull output systems. Figure 46, illustrates a parallel plate feed with a conventional type of transformer. This unit deserves some additional mention because of the fact that the coupling capacity C isolates the primary P. The choke L is the unit which can be checked for resistance right through the sockets, but the primary of the transformer can be checked only when the coupling condenser C is shorted, that is, through the tube sockets. If the chassis pulled, the primary can be checked the same as any other unit, by contacting the proper points as indicated upon the diagram. The secondary of this transformer goes to the control-grid and perhaps cathode, so that it can be checked through the sockets. Figure 47 is similar to figure 46, except for the fact that the secondary is arranged for push-pull operation. Figure 48, shows the use of what is generally termed impedance-capacity coupling with a split choke feeding the output tubes. In circuits such as these both the primary and secondary windings terminate at points which enable definite testing of the d-c resistance of the windings. Fur-

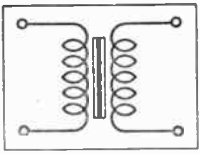


Fig. 42

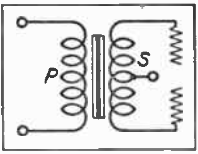


Fig. 43

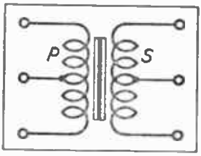


Fig. 44

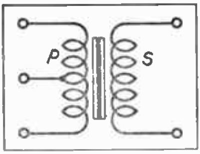


Fig. 45

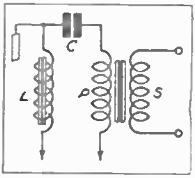


Fig. 46

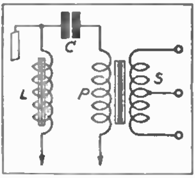


Fig. 47

thermore, definite testing of the condenser C in figure 48 is also possible by contacting the plate of one tube and the control-grid of the other tube, as shown.

RESISTANCE OF A-F AND OUTPUT TRANSFORMERS.

The d-c resistance of these windings runs all over the range. No definite figures can be quoted and as a matter of fact, such quotations are not required at this time because it is becoming common practice to show the d-c resistance of the various windings upon the wiring diagram.

However, it is advantageous to note certain pertinent facts relative to such windings. As a general rule, the d-c resistance of the primary is less than the secondary. There can be no basis of comparison on the grounds of turn ratio or impedance. The total resistance of a push-pull winding is as a rule equal to twice the value of each half, but this is not always the case. In many instances, the windings are not split exactly in the center so that the d-c resistance of one half may be greater than of the other half. This is more common in split secondaries than in split primaries.

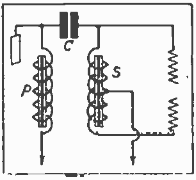


Fig. 48. The coupling capacity C can be reached by checking between the plate and control grid

The d-c resistance of secondary windings of output transformers is very low, some as low as .5 ohm. In every instance, where the output transformer feeds a voice coil, the primary resistance is many times the secondary resistance. In instances where the output transformer feeds a magnetic speaker (not permanent magnet dynamic) as in old receivers, the secondary resistance may be higher than the primary resistance. However, in view of the prevalency of dynamic speakers during the past three or four years, such units will not be encountered in great numbers.

As far as resistance measurement is concerned, you can very readily appreciate that when the chassis is pulled, you can check the d-c resistance of any unit, in as much as you have access to the connections to the unit. In some instances the plate feed choke, L in figures 46 and 47 and P in figure 48, may be a resistor, but this does not introduce any complication, simply because our interest lies in d-c resistance and chokes and resistors possess this property and rating.

RESISTANCE COUPLING.

All receivers do not employ transformer-coupled a-f systems. Quite a large number employ resistance-capacity coupling as shown in figure 49. This circuit illustrates the use of a plate-filter resistor as well as a grid-filter resistor. The units R and R1 are the plate- and grid-coupling resistors, the latter commonly known as the grid leak. R2 is the plate-filter resistor and R3 is the grid-filter resistor. If R2 joins the rectifier filament, then the test from the tube socket plate terminal P to the rectifier filament will include both R and R2 in series. The check between the control-grid G and ground will include R1 and R3 in series. In many instances, plate-filter resistors are not employed, so that the plate coupling unit alone may be checked.

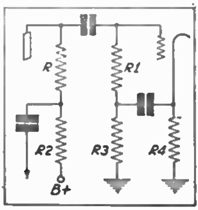


Fig. 49

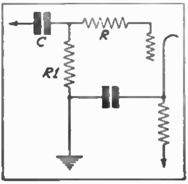


Fig. 50

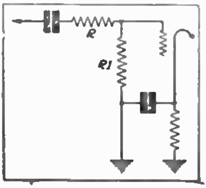


Fig. 51

In a few instances, a separate resistor may be found in some output pentode grid circuits, as shown in figure 50, the resistor being designated as R. In some few cases, position of this resistor was altered as shown in figure 51. It now is connected between the coupling or blocking condenser C and the junction between the control grid and grid leak. When used in this fashion, it cannot be checked by working through the sockets. The chassis must be pulled. As far as resistance-coupling is concerned, figures 49 to 51 should suffice, since they represent the basic systems and there are very few variations.

RESISTORS IN AUTOMATIC VOLUME CONTROL CIRCUITS.

In AVC systems, resistance measurement is the only logical method of service analysis. In view of the operating basis of the system, voltage measurements are out of the question. Such circuits are of varied variety. We have the AVC tube which functions as a detector and automatic volume control, and the AVC tube which functions solely as the volume control tube. Without any attempt to explain the theory underlying the operation of the AVC tube, we wish to make a few references in connection with the operation of this device. It may help in the comprehension of the systems.

The AVC tube is employed as a system whereby the signal voltage causes the flow of plate current through the control tube. During the time that there is no signal being applied, the control-grid bias applied to the control tube is such that there is substantially no plate current. When the signal is applied the effect of the heavy negative bias is overcome and plate current flows. Now, the plate circuit of the control tube is associated with the control-grid circuits of the r-f or i-f amplifying tubes which are to be controlled in the effort to reduce the amplification available with the tubes. This control is secured by increasing the control-grid bias of the r-f or i-f tubes, thus reducing the mutual conductance and consequently the signal output for a certain value of signal input voltage. During the time that there is no signal, a steady control-grid bias is applied to the r-f or i-f tubes. This steady bias represents the minimum bias. When the tube is being controlled, the bias is increased.

The method of increasing the bias is to tie these control-grid circuits, by means of resistors to the plate circuit of the AVC tube. When the signal is applied to the r-f or i-f tubes and a part of this signal reaches the control tube, plate current flows through the latter. The plate circuit of the control tube contains a series of resistors, which are electrically connected into the control-grid circuits of the r-f or i-f tubes. The flow of plate current through these resistors, causes the development of a voltage across them. The polarity of this voltage is so arranged, by means of circuit structure, that it is additive to the steady minimum bias applied to the r-f or i-f tubes. The final result is that the r-f or i-f tubes, as desired, receive an automatically-controlled variable bias from the control tube. By proper selection of the circuit constants and adjustment of the control tube bias, so as to determine the extent of the signal input required to start operation, the volume output of the r-f or i-f amplifier is kept definitely under control. The greater the signal input into the control tube, the greater is the plate current and consequently, the greater is the bias added to the r-f or i-f tubes and the greater the reduction in the amplification available in the tubes under control. Equilibrium is reached and the signal output of the receiver is kept at a constant level over a range of input signal voltages.

An example of the combination detector and amplifier circuit is shown in figure 52. An i-f stage is shown in front of the control tube. If desired, the controlled action may be applied to the r-f tube, even when the signal fed into the control tube is secured from the i-f tube. The resistors R and R1 represent the voltage divider, through which flows the plate current occasioned by the application of the signal voltage. In a way this type of automatic control differs from that previously stated, that is as far as the bias adjustment of the control tube is concerned. You will note that this circuit is the equivalent of a half-wave rectifier, where the plate and cathode joined represent the electron emitter and the screen is the anode. The i-f transformer (it may be an r-f transformer) is the half-wave rectifier winding. R and R1 represent the voltage divider.

If you will examine the diagram you will also note that contact between the circuit components is possible right through the sockets. The circuit between control grid and cathode or plate is a series system encompassing the transformer secondary S, the resistor R and the resistor R1. Between cathode and plate the resistance is zero, since these are joined. Between i-f control grid and the AVC tube plate, you include the i-f transformer secondary, the filter resistor R2 and the divider resistor R1. Between the a-f tube control grid and the AVC control grid, you include the filter resistor R3 and the transformer winding S.

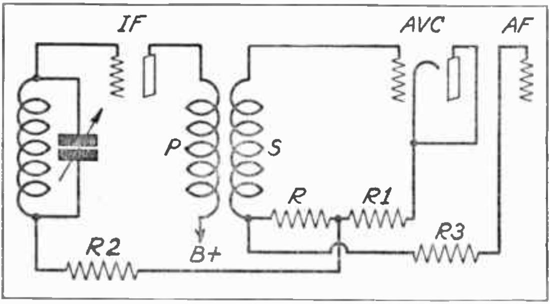


Fig. 52. Combination automatic volume control and detector circuit

The various bypass condensers are not shown. Their influence, when shorted, and further discussion of measurement methods upon such systems is reserved for the next chapter.

The tube used solely for control purposes, is illustrated in figure 53. Here you will note that the signal for the AVC tube is secured from the plate circuit of the i-f tube, through the condenser C. Also that plate current flows through the control tube plate resistor R. Further, that this resistor is tied to the control-grid circuits of the r-f and i-f tubes. In the r-f circuit we find the filter resistance R3. By properly contacting the junctions of these various resistors with associated tube circuits we can check the d-c resistance of the system. In certain instances, such as the r-f stage, it is impossible to isolate the grid winding by working through the sockets. In such cases, the operator must use his discretion in determining the likelihood of the location of the trouble within this r-f winding. The means of applying various tests to overcome such difficulties are mentioned in a later paragraph.

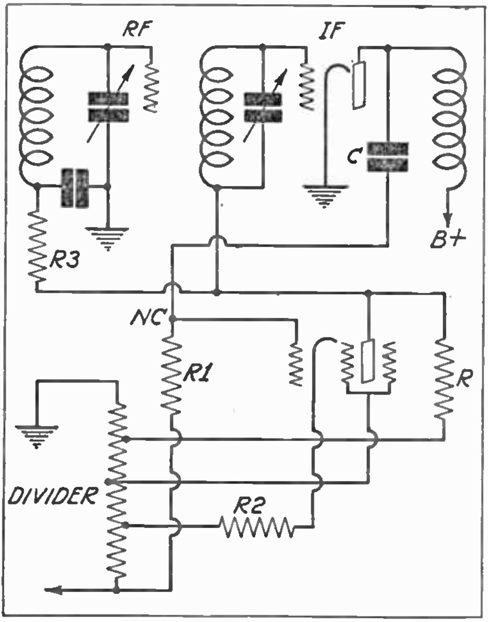


Fig. 53. Screen grid type of automatic volume control only

In many instances, measurement of the d-c resistance of units associated with the automatic control tube involves the power pack, particularly the rectifier anodes. If the power pack voltage divider terminates in a terminal board, so much the better. If not, then it is necessary to consider those tube elements which are common to the junction between the

AVC tube resistors and the voltage divider. In other words, there are other tubes which secure operating potentials from approximately the same point along the divider. By suitable selection of these tube elements, it is a comparatively simple matter to check the resistance of the system and give due consideration to the presence of one or two additional resistors in the system. The tube elements which may secure their operating potentials from various points along the divider are not shown in figure 53. You will however note our suggested method of operation, when we consider receivers as complete units.

Isolation of other component parts not necessarily related to the AVC tube are accomplished by considering the AVC tube socket, just another junction without special thought about the fact that it is a control tube. An example of this is the grid winding in the i-f stage shown in figure 53. Note that connection to the i-f tube control grid and the AVC tube plate enables a d-c resistance check of the grid winding.

As far as condensers are concerned, we do not mean to accord special attention at this time, but if you will note the location of the coupling capacity C in figure 53, you will observe that a d-c resistance check between the i-f tube plate and the AVC tube control grid should result in some ohmic value which would include the AVC tube grid leak, the i-f tube plate winding and whatever other resistors may be in the circuit between the B plus end of the i-f transformer plate winding and the voltage divider junction with R1. However, in the event of a short circuit in C, a test between the i-f plate and the AVC tube control grid would show zero resistance.

Of course an open condenser will not influence the resistance reading, but if a capacity test is made between these two points, it should show the presence of the condenser. We want you to pay particular attention to the fact that such tests must be made with the condenser left in the circuit. If it is removed and tested separately, a supplementary investigation of the leads which join it to the balance of the circuit is required. Furthermore, in order to make such removal, the chassis must be pulled.

RESISTORS USED WITH TRANSFORMERS IN RECEIVERS.

Various types of resistor-transformer combinations are employed. Some of these employ the resistor as a grid filter. In other cases, an r-f choke is used in series with the grid or plate winding. Such r-f or even a-f chokes represent resistance and consequently are considered as resistors. In many instances, the resistors are employed in a manner making them common to more than one circuit, yet it is possible to isolate these units with minimum additional windings involved. Look at figure 54. R, R1, and R2 are grid-filter resistors. You will note that they are connected in series with the transformer windings, r-f and i-f. Also that the common junction for all of these resistors is the AVC tube plate. At first glance it would appear as if the measure-

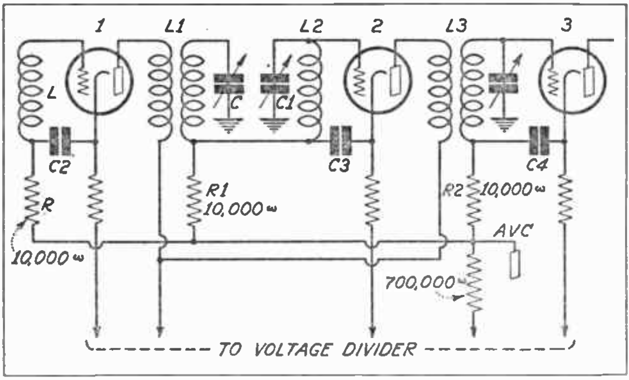


Fig. 54. Grid filter resistors used with transformers

ment of the d-c resistance of the band-pass filter windings L1 and L2 are out of the question. Upon second thought, you can no doubt visualize the use of the tuning condensers C and C1 as test points used in conjunction with control grid of tube 2.

Between the control tube plate and control grid 1, you can check L and R in series. Between the control tube plate and stator of C, you can check R1 and L1. By shifting the lead from the stator of C to control grid of tube 2, you can check R1 and the winding L2. Now, we realize that the resistance of L1 and L2 is low in comparison with the ohmic value of R1. Consequently, by working between the control grid of tube 2 and the stator of C, you can check the total resistance of L1 and L2 in series, thus avoiding R1 entirely. In the case of L3, it will be necessary to include R2 and L3, that is, unless the chassis is removed from the cabinet, in which case, the units may be checked individually. By working between the plate of tube 1 and the plate of tube 2, you can check the ohmic value of the two plate windings in series.

Now, if we wish to pay attention to the bypass condensers C2, C3 and C4, which link the r-f and i-f windings to the cathode and thus provide a path for the signal currents and keep them out of the divider circuits, we are concerned with two things. First, an open circuit and second a short circuit. If these condensers are shorted, they will have an effect upon the resistance test between the AVC tube plate and the divider, since the correct resistance between points is about 700,000 ohms in the case cited. If one of the condensers named is shorted, it will present a parallel path across the AVC tube plate-divider system and thus reduce the resistance. However, this means the calculation of individual parallel circuits and the possibility of three different values, in the event that the circuits between the respective cathodes and the divider possess different values of resistance. A much simpler test is resistance measurement between control grid 1 and cathode 1. Normally this would be a high value, at least 700,000 ohms and no doubt more, because the complete path is through the filter resistance, the control tube plate resistor, through the voltage divider, up into the cathode. But if C2 is shorted, the only resistance in the circuit is that of winding L. A similar condition exists in the case of C3 and C4. We shall have much more to say about such tests later.

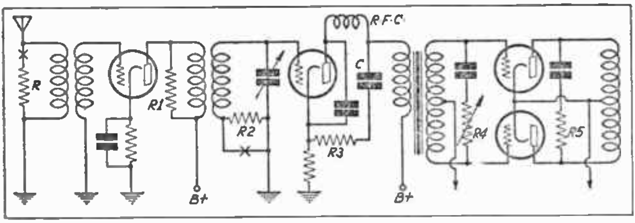


Fig. 55. Resistors used with transformers

Other examples of the use of resistors in connection with transformers of various kinds are illustrated in figures 55, 56 and 57. Figure 55 is a composite picture of how resistance in one shape or other may be encountered in the receiver. There is no special segregation of these tubes as to limit their function as r-f, i-f or a-f amplifiers. R designates the use of a resistor, switch controlled across the input antenna coil. With the switch closed, the resistor R is in parallel with the coil winding, consequently, the two as far as resistance is concerned, are in parallel. A similar situation exists in connection with R1 and the winding that it shunts. This winding may be an r-f, i-f or a-f transformer. Since no switch is provided, the resistor is at all times across the winding and the parallel circuit must be recognized. In the case of R2, this unit is in series with the coil when the switch is open, and shorted out of the circuit when the switch is closed. A resistance test between ground and the control grid with the switch open will give the combined series resistance of the winding and R2. With the switch closed, checking between the same points affords the resistance of the winding only. This type of circuit may be found in both i-f and r-f systems.

R-f chokes are to be found in the majority of the detector plate circuits with the exception of the mixer (1st detector) in superheterodynes. There can be no isolation of this winding in order to determine its resistance, unless the chassis is pulled. The reason for this is that the choke and its consequent resistance is an inherent part of the circuit and entirely disassociated from all other voltage circuits and connections. Thus its resistance is always in series with the coupling unit in the plate circuit, in this case a transformer winding. As a rule, bypass condensers are associated with such chokes and in the event of defects, such as short circuits, the resistance between the plate of the tube and the voltage divider is influenced by the fact that the cathode resistance or cathode circuit is placed in parallel with the plate circuit.

With respect to R3, a filter resistance operated in conjunction with the condenser C, there is no means of checking this resistance without pulling the chassis, as long as the condenser is intact. This is true even if the resistor becomes short circuited, that is between its terminals. It will affect tone quality but will manifest no influence upon either voltage or resistance in the cathode-to-ground or plate-to-divider or common terminal circuit.

A similar condition of no effect is to be found in the case of the tone control resistor R4. As long as the condenser is intact, any condition of R4 will have no ohmic or voltage effect. It may interfere with the control of tone, or the utility of the device, but not with the resistance between the two control grids. This is true if R4 is open or shorted or if the associated condenser is open. In the event of a short circuit in the condenser, then varying R4 will cause a change in resistance between the two grids because this resistor is in parallel with the secondary winding. A similar condition is to be found in connection with R5.

Figure 56 illustrates a combination impedance-capacity-resistance coupled a-f stage. R is the bias resistor, whereas

R1 and R2 are the grid leaks. A test between grid to grid will give the total of the two units in series. A test between filament and one control grid will include the bias resistor. A test between the filament and ground (usually, depending upon the circuit) will give the value of the grid resistor only, neglecting the filament shunt resistor, if this is used instead of a center-tapped transformer winding. The two condensers C and C1 deserve special mention. Short circuits and open circuits in these units are quite common. A short circuit through C will reduce the resistance between the control grid 1 and ground, because the plate circuit and its component parts will then be connected in shunt with the grid circuit. However, this involves the solution of the equivalent resistance and it is a variable depending upon the exact constants in the different brands of receivers. But, a much simpler test is to check the resistance between the plate and control grid 1. Under normal conditions this would be very high because the path involves the grid circuit to ground and from ground, through divider and coupling unit, to the plate. If it is shorted, the resistance indication is zero. With suitable equipment, the condition of the condenser may be checked without removing the condenser from the circuit and operating right through the sockets. This

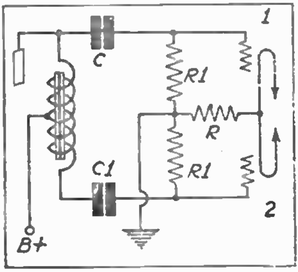


Fig. 56

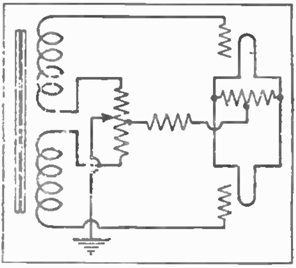


Fig. 57

Push-pull systems

method is shown in Chapter 6 and has been found to function well in practically every instance.

Figure 57 illustrates a split transformer winding with a variable resistor inserted between the two windings. A check between the two grids will give the resistance of the two windings plus the entire resistor. The ohmic value of the circuit between either grid and ground depends upon the position of the tap upon the resistor. Between ground and filament, the exact value of resistance is governed by the position of the tap. If the movable arm joins the junction between the balancing resistor and the bias resistor, then the ohmic value determined is that of the bias resistor. If not, then some portion of the balancing resistor is also in the circuit and the resistance measured represents that portion of the balancing resistor and the bias resistance. To this must be included approximately one-quarter of the total value of the filament shunt resistance, since the two halves are connected in parallel through the filament transformer winding. See next paragraph.

THE EFFECT OF THE FILAMENT SHUNT RESISTANCE.

Quite a large number of receivers make use of a filament shunt resistance across the untapped transformer winding.

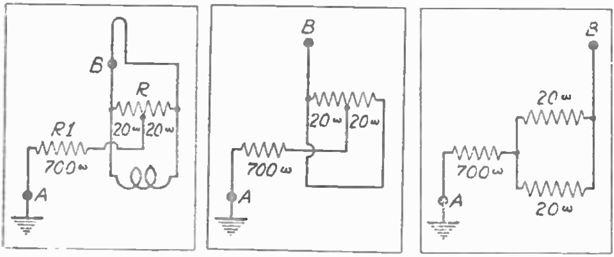


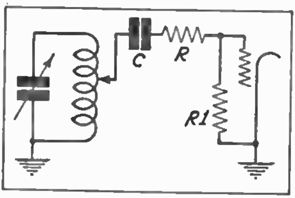
Fig. 58 Fig. 59 Fig. 60

Evolution of the final value of the filament shunt resistor

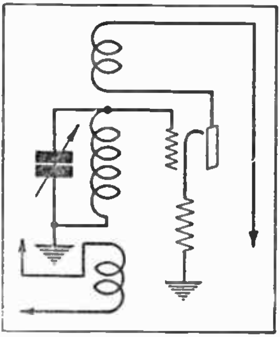
A tap upon this resistance is the return point for the plate current. This is shown in figure 58. It is necessary when checking the ohmic value of a bias resistor connected into the filament circuit, between the filament center tap and ground, to recognize the presence of the filament shunt resistance. R is the center-tapped filament shunt resistance and R1 is the bias resistor. When the resistance test is made between one filament lead (at the tube socket) and the ground, with the tube out of the socket, the actual circuit involved is shown in figure 59. Observe that the two halves of the filament shunt resistance are in parallel. The reason for this is that the path through the filament transformer winding is of such low resistance, as to constitute a direct connection between the two outside terminals of the resistance. This is the equivalent of the circuit shown in figure 60. The total resistance of the filament shunt resistor when considered individually is 40 ohms. But when viewed as shown in figure 60, its equivalent resistance as far as the circuit between the bias resistor and one filament lead is concerned is 10 ohms. The total resistance between A and B then is 710 ohms. Fortunately it is possible to ignore the effect of the filament shunt resistance, because its effective value is quite low and in nearly every case much less than the normal 5 or 10 percent tolerance allowed for bias resistors. Furthermore, in many instances, its normal value (total, when considered alone) is from 6 to 10 ohms, so that its effective value (when considered in conjunction with the bias resistor) is entirely negligible.

RESISTANCE IN OSCILLATORS.

Certain types of oscillator circuits present problems in connection with resistance measurement. We want to stress that this condition is true in certain cases only. An example of such a system is shown in figure 61. We have omitted the multiplicity of tuning condensers used in such circuits because they do not enter into the discussion. The unit which presents the difficulty is the resistor R, located in the grid circuit of the oscillator (when used). Another item is the continuity of the circuit between the oscillator coil and the control grid of the tube, due to the presence of the condenser C. In the normal oscillator system, shown in figure 62, such complications are not present. Accordingly when working with a system such as that shown in figure 61, it is necessary to check as many units as possible and then employ the plate current method of noting a state of oscillation.



Above, Fig. 61. Oscillator system with grid resistor and grid condenser

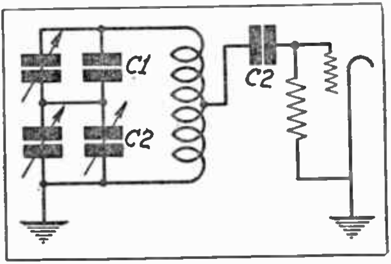


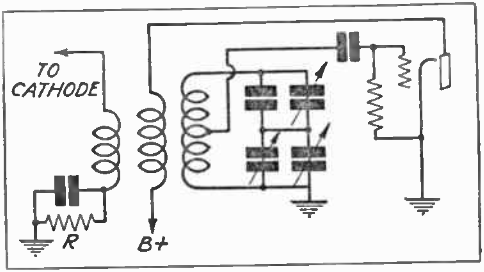
Right, Fig. 62. Conventional oscillator

Check the resistance of the oscillating winding. This is done by working from ground to the stator of the tuning condenser, if a single condenser is used. The system is applicable if a trimmer is used in shunt with the major condenser. When a multiplicity of condensers are used in the oscillator circuit, as shown in figure 63, and condenser C is the main tuning condenser, the test can be made only when the chassis is pulled. If by chance C1 is shorted, (a very infrequent occurrence), then checking between ground and the stator of C will give access to both ends of the winding. A check for a short circuit in condenser C in figure 61 may be made from control grid to ground, providing that you realize the presence of the leak resistor R1. As a rule, the value of R in figure 61 is very much less than that of R1, hence if C is shorted, the resistance between control grid and ground will be less than the value of R, instead of being equal to the value of R1.

A difficult condition is also encountered if the oscillator circuit is like that shown in figure 63. The grid resistor has been omitted. What has been said in connection with the checking of the circuit shown in figure 61 is again applicable, but in this case a short circuit in C2 will cause very low resistance between control grid and ground; being that of a portion of the oscillator winding.

As far as coupling coils are concerned, one type presents





Upper, Fig. 63. Oscillator system as used in many receivers. Note that the oscillator coil cannot be contacted via the tube sockets

Lower, Fig. 64. The resistor R prevents isolation of the coupling winding when working through the sockets a problem, but it is not beyond solution. This is shown in figure 64. The resistor R is in series with the coupling coil and by checking between ground or chassis and the cathode, we must include R as well as the resistance of the coupling coil. The type of defect which cannot be checked by working through the sockets and requires removal of the chassis, is a short circuit directly across the coupling coil terminals or across some of the turns.

These complications as stated in connection with oscillator circuits are no greater than may be experienced with routine voltage tests, because if you refer to figures 61 to 64, you will note that any defect in the oscillator coils, which cannot be determined by means of a resistance test, will have no effect upon the operating voltages applied to the oscillator tube. Furthermore, the attempt to determine an oscillatory state by means of plate current is also beset by the difficulty that the use of the plug-cable arrangement in the oscillator socket will so change the circuit characteristics as to stop oscillation.

One of the best methods of determining a defect in the oscillating system is to feed the required beating signal into the receiver by means of an exploring coil, connected to an unmodulated oscillator d-c operated, to the mixer tube. This system described in greater detail in a subsequent chapter is applicable in all types of superheterodynes.

TAPPED COILS.

Quite a few windings employed in receivers are of the tapped variety. We make mention of this fact in connection with resistance measurements of such windings. Make certain that your finding is that of the winding which you desire and not of only a portion of the winding. What we mean is illustrated in figure 65. You will note two taps upon coil L1. Working from the control grid of the tube to ground covers only a part of the coil. To include coil L as well as the entire winding L1 you must work between the stator of condenser C and the stator of condenser C1.

You may find such conditions in some old type superheterodynes, in the i-f amplifiers. The bias-voltage supply lead joins the secondary windings at a tap upon this winding. Checking between the control grid and the source of the bias voltage includes only one-half of the winding. We are referring to some i-f transformers used in the Radiola 60, 62 and 64. The resistance of the complete secondaries is 100 ohms each, but because of the location of the tap, only 50 ohms is measurable. The other connection terminates at the neutralizing condenser. Incidently, the resistance of the i-f transformer primaries in this series and inclusive of the 66, is 20 ohms. The resistance of the i-f transformer secondaries in the Radiola 66 is also 100 ohms. See figure 66.

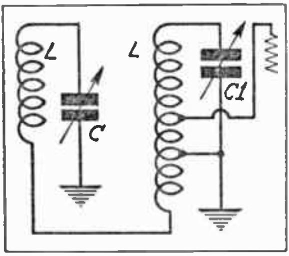


Fig. 65

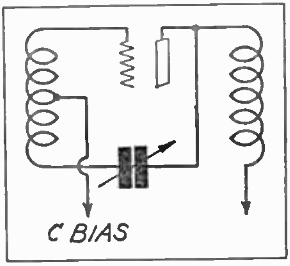


Fig. 66

Fig. 65. Tapped coil L used for image frequency suppression

Fig. 66. Tapped i-f transformer winding and neutralizing condenser used in some intermediate frequency amplifiers

CHAPTER V

POINT-TO-POINT RESISTANCE MEASUREMENT

THIS chapter is not intended as an explanation of service analysis on this basis. Its primary purpose is to show how point-to-point measurement is accomplished and how you can analyse a circuit and pick the most salient testing points, when you have the wiring diagram within your possession. Of course if the data is tabulated for you, so much the better. There is then no need for circuit analysis. However, such information is not very general and you will be called upon to investigate receivers, working solely from the wiring diagram and the electrical values of the resistors perhaps some of the transformer windings.

This is where your knowledge of series, parallel and series-parallel circuits will come to the front. The arrangement of a number of units does not necessarily show its real electrical circuit. That is, as far as the effects of the electrical continuity of the components upon the resultant resistance are concerned. When working with a limited number of resistance values you will be called upon to render certain decisions based upon your better judgment. You will soon learn where to expect a high or low value of resistance. Your knowledge of basic radio circuit structure will be your guiding hand.

There are certain preliminary tests which can be made to determine the approximate location of the defect. The application of these tests shall be described later. In the meantime, we want you to bear in mind that resistance measurement method of servicing does NOT entirely supplant voltage tests. The application of the voltmeter has its time and place. It cannot be entirely neglected.

In order to be able to check the resistance between certain points in the receiver or amplifier, and locate the defect in this manner, we must have some basis to start with. First we must select the test points, and second, we must have the correct values to be expected between the points selected. The wiring diagram gives us this information in many instances. Perhaps a tabulation of some kind quoting the correct values between points will be available from one source or other. There is no doubt that the radio receiver manufacturers are evincing interest in resistance measurement methods of servicing and it is not far-fetched to say that before long, service manuals prepared by manufacturers will contain accurate resistance specifications between different points in the receivers and amplifiers produced by them. Perhaps you as a reader of this page have in your possession certain forms of continuity test data which were parts of manuals published by receiver manufacturers. This type of data appeared in many such publications and we feel certain that its scope and utility will be greatly extended.

CAPACITY VALUES.

The item of importance in connection with resistance measurement is the resistance value in ohms. We are not concerned with capacity ratings in microfarads for anything but replacement. There are very few real occasions for the determination of the capacity of a condenser. The capacity of a fixed dielectric condenser seldom varies during use. The instances when a wrong condenser is incorporated during the production of the receiver likewise is very infrequent. As far as electrolytic condensers are concerned, there is no occasion to check the capacity during service work for the simple reason that such changes are accompanied by definite variations in the resistance of that condenser and if the capacity changes to the extent where it is insufficient for the use at hand, its resistance will have varied sufficiently to be detectable by means of the resistance test.

The primary information required about a condenser is its condition with respect to an open circuit or a short circuit. The short circuit is detectable by means of the resistance test. As far as open circuits are concerned, the condenser should be checked in the circuit. When this is done, it automatically includes the leads connected thereto. This is particularly true if the test is made through the sockets or if the test is made via some points connected to the condenser, but not the immediate terminals. Considered from various angles, it would appear as if there is no real need for capacity meters in connection with service work. If a condenser is bad, open or shorted its capacity cannot be measured. If it is perfect, and its capacity is stipulated, there is no occasion for measurement. In this respect condensers differ from resistors.

By virtue of structure, constituency and the like, resistors will change in ohmic value; consequently they must be checked for resistance. But not so with condensers. As stated earlier in this book, the service industry at large needs a condenser tester applicable directly to the circuit to determine if the condenser is good or bad. As far as the writer knows, the first unit intended for such application is that developed by him and shown in Appendix 2. If anyone else has had a unit of similar type prior to this statement, advice would be appreciated. Let us hope that this unit will serve its purpose, or at least lead to the development of something superior.

ELECTROLYTIC CONDENSERS.

What with the prevalent use of electrolytic condensers in receivers and amplifiers for bypass purposes, we cannot embark upon a discussion of resistance measurement with the condensers in the circuit without referring to these units. No doubt you are familiar with the fact that these units are polarized; that is, one connection or terminal is positive and the other terminal is negative. When used in a radio receiver to bypass a circuit, these units are wired in such fashion as to remain polarized in the proper direction when the operating voltages are applied.

This state of polarization remains an important item in our work, despite the fact that the receiver is not supplied with operating potentials. The reason for this is that the source of voltage required for the ohmmeter supplies voltage which will influence the operation of the electrolytic condenser and its equivalent resistance. Electrolytic condensers are peculiar in the fact that the d-c resistance in one direction (properly polarized) will run into very high figures, whereas the resistance in the other direction will be very low, that of the electrolyte only. Consequently, when measuring the resistance of a resistor shunted by an electrolytic condenser, we are apt to secure an incorrect resistance reading if the polarity of the ohmmeter is incorrect. In order that the shunting effect of the bypass condenser upon the resistor or circuit being measured be minimum, in most cases negligible, it is imperative that the polarity of the ohmmeter be correct. The correct polarity is determinable in two ways. First by an examination of the components of the circuit being checked, to note the presence of an electrolytic condenser. Second by noting the polarity of the terminals of the circuit or resistor to which the condenser is connected. The latter polarity is dependent upon the position of the unit or circuit in the system and its relation to the operating potentials.

At this point you are tempted to say, "How do we know that it is an electrolytic condenser?" Quite true, we do not know. However, you will find that certain circuits do not involve fixed condensers of any type. Furthermore you also know because of your technical training that electrolytic condensers are not used in tuned circuits or oscillating circuits. Third, if the condenser in the system is not of the electrolytic kind, the polarity of the ohmmeter will have no effect, assuming that the circuit is intact. To make certain that the correct value is being determined, it is necessary to make the resistance test with reversed ohmmeter connection. This only in the event that the first measurement shows the equivalent of a short circuit. When a defective condition is indicated, it is always best to recheck the system to be sure of the indication. If the circuit is really defective, the indication will remain unchanged irrespective of the ohmmeter polarity. However, if the indication of a defect is erroneous and due solely to the polarity of the ohmmeter and the presence of an electrolytic condenser, the second check with the polarity of the ohmmeter reversed, will prove this by showing the correct value. Thus nothing is lost.

It is easy to determine how the ohmmeter unit is polarized. Check your ohmmeter and note the plus and minus terminals of the voltage source. The connection of the ohmmeter to the battery determines the polarity of the leads. Follow through to the test prod from one of the battery or voltage source terminals. The prod has the same polarity as the terminal of the battery to which it is directly connected or to which it is connected through some other apparatus. To reverse the polarity of the ohmmeter with respect to the circuit being checked, *you make no changes upon the ohmmeter wiring.* Simply reverse the prods which make contact across the two points you are testing.

The testing voltage applied to a resistor or a circuit shunted by an electrolytic condenser is also of importance. Fortunately however, low values of resistance, normally shunted by electrolytic condensers of low voltage rating, require low testing potentials. Hence it is very unlikely that the condenser will be damaged if the correct testing potentials as determined by the value of resistance to be checked is used. Excessive test voltage will also cause excessive leakage current through the associated electrolytic condenser. Accordingly when the presence of an electrolytic condenser is suspected and the polarity of the test circuit is correct, trouble from the presence of the electrolytic condenser can be minimized by employing the lowest possible test voltage.

POINT-TO-POINT RESISTANCE MEASUREMENT.

Let us take as our first example the wiring diagram of a modern receiver. Figure 67 is the wiring diagram of the RCA Radiola Superette. We have selected this diagram because all electrical values are marked upon the diagram. At the moment we are not attempting to shoot trouble. What is to follow is simply an illustration of how the circuit is broken down. Additional examples of point-to-point measurement working from the sockets and with the chassis removed will follow.

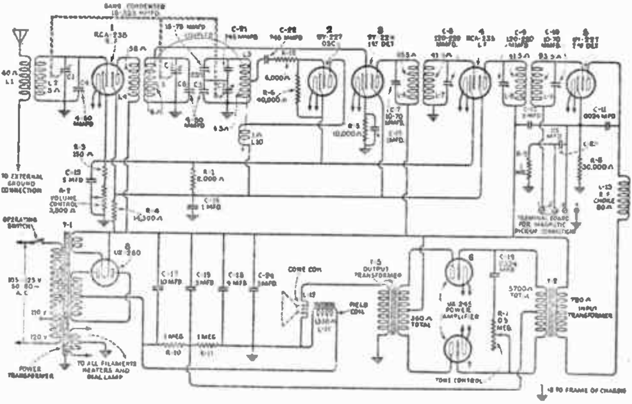


Fig. 67. Circuit diagram of RCA-Victor Superette receiver

(Courtesy RCA-Victor Co.)

Before starting the description, it might be well to make certain general statements relative to ordinary basic circuit structure as may be found in radio receivers and amplifiers. We repeat that these are general statements.

1. There seldom is a direct, presumably zero resistance connection between the plate of a tube and its associated screen grid, if the tube is of the type which has a screen grid.
2. There seldom is a direct, presumably zero resistance connection between a screen grid and the cathode of the same tube.
3. There seldom is a direct, presumably zero resistance connection between the plate and cathode of the same tube. The exception to this is the dual-acting automatic volume control tube (detector and control tubes) such as shown in figure 52.
4. There is seldom a direct, presumably zero resistance connection between the plate of one tube and the control grid of the subsequent tube. The exception to this rule at the present time is the direct-coupled amplifier, of which the Loftin-White system is a commercial example.

5. There seldom is a direct, presumably zero resistance connection between the cathode of one tube and the control grid of the subsequent tube. The exception to this rule at the present time is the Triple-Twin tube.
6. There seldom is a direct, presumably zero resistance connection between the control grid of one tube and the plate of the same tube.
7. There seldom is a direct, presumably zero resistance contact between the filament or electron emitter of a rectifier and its associated anodes.
8. There seldom is a direct, presumably zero resistance connection between the control grid, screen grid, space grid or plate of a tube and ground.

With these facts in mind let us continue. Actually it makes very little difference where we start; whether it is with the ground or chassis of the receiver or the rectifier filament. We shall start with the ground connection and give examples of both. Let it be known that neither affords definite advantages over the other. Each has its fine points and when summed up, both are about on par. Starting with the ground, we follow common practice as used by a large number of service men in the past. However, whichever starting point is used, we shall endeavor to check all of the units associated with the tubes, as each tube is considered. This is preferred by far and is definitely superior to skipping all over the lot.

It is assumed that the tubes have been removed from the receiver, the aerial and ground disconnected and the a-c power plug removed from the power line socket.

THE R-F TUBE.

Between ground and the aerial post, we find the antenna primary winding, having a resistance of 40 ohms. The ground in this case is not the chassis, because the chassis and ground are isolated. Thus the ground connection would be secured at the ground binding post.

Between chassis and the control grid, we check the resistance of the grid winding, at the same time for a short circuit in the tuning and trimmer condensers. An open tuning condenser will not be evident, but a short circuit, will short the grid winding. The condenser test shall be described later.

Between the chassis and the cathode of the r-f tube, we work through the volume control R2 and the cathode fixed bias resistor R3. The amount of resistance in this circuit depends upon the position of the volume control unit. When adjusted for maximum volume, the total resistance is 150 ohms. When the volume control is adjusted for minimum volume, the total resistance is 3950 ohms. This test also indicates whether the bypass condenser C13 is shorted to ground. The test for the open condenser follows later.

Between the chassis and the screen grid, we are called upon to work through R2, R3 and R1, a total of 8150 ohms, if the volume control is set at maximum. Now, if we were working from the rectifier filament to the screen grid, the circuit would involve but one resistor, namely R4 of 14,300 ohms.

Working from chassis to the plate of the tube, we check through, R2, R3, R1 and resistor R4 of 14,300 ohms and the r-f primary winding of 58 ohms, making a total of 26,308 ohms with the volume control set at minimum signal and 22,508 ohms with the control set at maximum signal. There is no need for discussing the effect of a short circuit to chassis through either C13 or C16, because these defects would have been detected during the cathode-to-chassis or screen-grid-to-chassis measurements.

However, it is significant to mention that the resistance of the r-f primary being only 58 ohms is less than the normal tolerance limit of the resistance combination involved. Accordingly it is neccessary to check this winding and the next test is between the r-f plate and the rectifier filament. The correct value is 58 ohms.

With one connection made to the rectifier filament it is natural that we check the d-c resistance of the divider network between the rectifier filament and the chassis. This involves the four resistors R1, R2, R3 and R4. Assuming R2 set for maximum volume, (zero resistance), the total resistance is 22,450 ohms.

Let us now refer back to the original measurement, between chassis and cathode. Rightfully, this should not be the first test of resistance subsequent to the grid winding test. The first test should be from chassis to the rectifier filament in order to remove all doubt of the condition of the two filter condensers C-18 and C-24. The reason for this is that by virtue of their position, a short in either one will influence the resistance between chassis and cathode, chassis and screen grid and chassis and plate. With either C-18 or C-24 shorted, R-1 and R-4 are in parallel with R-3 and R-2 when the test is made between chassis and cathode and when the test is made between chassis and screen grid, the series combination of R-1, R-2 and R-3 is shunted by R-4. However, when data is tabulated, and the initial test is from chassis to cathode, it would show the effect of a short in one of the filter condensers named, because with the volume control set at minimum volume, the resistance between the points named would be 3,355 ohms instead of 3,920 ohms.

Do not be misled by the fact that this discussion appears quite lengthy. Once you become accustomed to operating by means of resistance measurement, and the data is not tabulated, you will soon learn the "ins" and "outs" of the system and to check for those points which should show high resistance and instead show a short circuit. Thus, assuming that you noted the discrepancy when operating between chassis and cathode, but did not realize the cause, you would soon learn what was wrong when you tested between chassis and rectifier filament.

Experience in resistance measurement methods of service analysis will soon teach you the approximate values of resistance which you may expect between different parts of the system. One of these facts is that at least 10,000 or 12,000 ohms should be found between the rectifier filament and ground or chassis. No doubt it will be higher in many cases and perhaps lower in some, but at no time should there be zero resistance.

OSCILLATOR TUBE.

Continuing with the test from the chassis, we note the impossibility of checking the resistance of the oscillator grid winding. However, the cathode of the oscillator tube has a common connection to the r-f tube cathode, hence the resistance experienced between chassis and r-f cathode should be repeated between chassis and oscillator cathode.

Between chassis and oscillator control grid we find the grid leak of 40,000 ohms (R6). If the chassis-oscillator cathode circuit has a resistance of 3,950 ohms with the volume control at minimum signal, then the addition of the 40,000 ohms should make a grand total of 43,950 ohms between chassis and oscillator control grid.

Between chassis and oscillator plate, we must work through R3, R2, R1 and the 1-ohm plate winding. With volume control R3 at maximum signal, the total resistance in the circuit is 8,151 ohms. Now the plate winding has very low resistance with respect to the balance of the circuit. Accordingly, it should be checked separately. Examination of the circuit shows that it joins the screen grid of the r-f tube, so that by checking between the screen grid and the oscillator plate, we can measure the resistance of the oscillator plate winding alone.

THE 1ST DETECTOR TUBE.

The next tube is the mixer or 1st detector. If you trace the control-grid lead you will find that it joins the chassis through the secondary of the r-f transformer, L5 with a resistance of 6 ohms. Hence, between chassis and the mixer control grid the correct resistance is 6 ohms. A short circuit in either the main tuning condenser C3 or the trimmer C6 would show zero resistance between the test points.

Between chassis and mixer cathode, the correct resistance is 10,000 ohms, through resistor R5. A short circuit in

C15 would cause zero resistance. A defect in either of these units would have no effect upon any other part of the complete receiver because the two are isolated from all other units.

The mixer screen grid joins the lead to the r-f screen and also to the oscillator plate coil. Consequently, we have several means of checking the resistance. Actually all we are concerned about is the junction between the common voltage supply lead and the mixer screen. However, since one common test point is the chassis, we repeat the test applied to the r-f screen grid, but test between chassis and mixer screen grid. With the volume control set at maximum signal, the resistance in the circuit is 8,150 ohms.

The mixer plate circuit includes the primary of the i-f transformer, L6, a winding with a resistance of 93.5 ohms. Tracing this circuit we find that it joins the rectifier filament. Between chassis and mixer plate we must pass through R2, R3, R1, R4 and the i-f winding. With the volume control set at maximum signal the total resistance is 22,543.5 ohms. Now, 93.5 ohms represents less than the tolerance value of the balance of the resistance in the circuit, so that it would be well to test the i-f primary by itself. This means a test between the rectifier filament and the mixer plate.

The above is a single example of how the use of the rectifier filament as one common terminal offers an advantage over the use of the chassis as one common terminal. This condition becomes of even greater importance if we recognize the possibility of a shorted i-f tuning condenser (C7) due to too frequent alignment. If this condenser were shorted it would not interfere with the continuity of circuit when testing between chassis and mixer plate, but there is the likelihood that the shorting of the 93.5-ohm winding would pass unnoted. In order to avoid the possibility of an error of this kind, the plate winding alone should be checked. You will find as we get further into this discussion, that the method of operation we shall outline will cause very little loss of time when the common test point is changed from the chassis to the rectifier filament. This is so because we provide a connection to the rectifier filament without interfering with the chassis connection. A push-button switch changes the common contact from the chassis to the rectifier filament. Therefore only one probing contact is used to connect the ohmmeter to the various points in the receiver.

THE I-F TUBE.

Between chassis and control grid, we find the secondary of the i-f transformer. The correct resistance is 41.5 ohms. A short circuit in C8, due to some reason such as that set forth in the preceding paragraph, will short circuit this winding without influencing any other circuit.

The i-f tube cathode is common to the r-f and oscillator cathodes so that the test from chassis to the i-f cathode, with the volume control set at maximum signal should show a resistance of 150 ohms. The reason for adjusting the volume control to maximum signal, is to remove 3,200 ohms from the circuit and thus enable a more accurate check of the low values of resistance which may become part of the circuit as we continue the test. Its value having been determined in the first test, we no longer are interested in it.

The i-f screen voltage supply lead is common to the r-f and mixer tube screens and the resistance between the chassis and the i-f screen should be the same as in the cases cited for the r-f and mixer tube. If this test shows perfect conductivity, there is no need for a supplementary test between the mixer and i-f screens.

The plate of the i-f tube joins the common voltage supply lead for the mixer plate circuit, which is the rectifier filament. Accordingly, we can check between the chassis and i-f plate and find a resistance of 22,491.5 ohms. Once more the value of the i-f primary winding alone should be determined in order to check for a short circuited C9. This means a test between the i-f plate and the rectifier filament. The correct resistance is 41.5 ohms.

THE 2ND DETECTOR TUBE.

This circuit appears a bit more complex but it is fairly simple. With the chassis as one common test point, to reach the control grid we are forced to work through the 1. megohm resistor R9, the link between terminals No. 2 and No. 1 upon the pickup terminal board, and the i-f transformer winding L9. This winding has a resistance of 93.5 ohms. Now, to detect a short circuit across a 93.5-ohm winding when that winding is in series with 1,000,000 ohms is extremely difficult. Therefore, a supplementary measurement, subsequent to the determination that the circuit between chassis and 2nd detector control grid, has a resistance slightly in excess of 1. megohm, is the resistance test between the control grid and pickup board terminal No. 1. This should be 93.5 ohms, if the tuning condenser C10 is not shorted and if the winding is intact.

Between chassis and cathode, we find a 30,000-ohm resistance. Associated with the junction of cathode bias resistor R8 and the tube cathode, are two bypass condensers, C12 and C23. A short circuit in C12 would influence the total resistance between the chassis and the i-f tube plate, for the simple reason that with this defect in the circuit the 30,000-ohm resistor R8 would be shunted across the R2, R3, R1 and R4 series combination. The same value would obtain during the previously stated test between the rectifier filament and ground. By the same token, the resistance between chassis and 2nd detector cathode would be less than 30,000 ohms. To be exact, with the volume control R3 adjusted for maximum signal, the total resistance would be about 12,840 ohms.

Based upon this example, you can very readily appreciate that by solving for the effects of short circuits in various bypass condensers associated with grounded units, we can tabulate a series of ohmic values, which will indicate the condenser shorted. We are not concerned with open circuits in resistors which are isolated from the remainder of the circuit, as in the case of R8, when a bypass condenser (C12) is perfect. When the condenser is perfect, but the resistor is open, it will in no way influence the resistance of another complete circuit which is not normally in parallel with the defective resistor.

You will note that the rectifier filament to chassis resistance is quite high. With C12 shorted, it still remains fairly high, about 12,840 ohms. However, the resistance between the rectifier filament and the 2nd detector cathode would be zero, due to the direct connection via shorted C12. It would not do, although it could be done, to check the resistance between the i-f tube plate and the 2nd detector cathode, because of the presence of the i-f transformer winding. Under normal conditions, the resistance would be high, since it would be necessary to work through L8, R4, R1, R2, R3 and up through R8.

It is significant to note that all of the operations named thus far can be carried out right through the tube sockets. Let us continue.

A short circuit through C23 would manifest its effect in the test between the chassis and the control grid of the 2nd detector tube, since it would place in shunt with the 1. megohm resistor, the 30,000 ohm cathode unit. Furthermore, it would produce a resistance of 93.5 ohms when the circuit between the control grid and cathode were checked. Under normal conditions, this resistance should be approximately 1,030,093.5 ohms.

The plate for the 2nd detector secures its potential through the input a-f transformer T2 and the r-f choke L13. We have found that the normal resistance (volume control set for maximum signal) between chassis and rectifier filament is 22,450 ohms. Working to the plate of the 2nd detector, we must add the a-f transformer primary resistance and the r-f choke resistance, a total of 800 ohms, making a grand total of 23,250 ohms. This assumes that the circuit is perfect. You will note that the rectifier filament is the common voltage supply lead contact. Because of this, we can isolate the a-f transformer primary and r-f choke and check the series resistance of these two units, by working from the rectifier filament to the 2nd detector plate. This resistance should be 800 ohms.

If the r-f bypass condenser were shorted, it would create two conditions. The resistance between chassis and 2nd detector plate would be the resultant of 23,250 ohms in shunt with 30,000 ohms, a final value of approximately 13,000 ohms. The second effect would be a total short circuit between the plate and the cathode of the 2nd detector tube, instead of a resistance of approximately 53,250 ohms.

OUTPUT TUBES.

We now arrive at the output tubes. The midtap upon the secondary winding of the input a-f transformer goes to the midtap upon the voltage divider connected across the speaker field coil utilized as a filter choke, and also to supply the output tube control-grid bias. If you will examine the wiring diagram, you will note that the circuit from either one of the output tube grids, through one-half of the secondary winding to ground, is not through R11 only, which unit is shown closest to ground. You will note that the field coil is also connected to ground and that its other terminal is connected to R10. All in all, the field coil is in shunt with the voltage divider and that when working this circuit you must consider the parallel arrangement. The sum of R10 and R11 is 200,000 ohms. This value in shunt with 1,330 ohms, will have very little effect, so that substantially, the total resistance of the parallel arrangement is 1,330 ohms. However, due to position in which the output tube control-grid bias voltage lead joins the filter system, the circuit to be considered is that of a 100,000-ohm resistor in series with 1,330 ohms and the complete series combination in shunt with 100,000 ohms. All of the computation involved can be simplified by disconnecting the speaker field coil. This is common practice in such work. Immediately, the entire circuit is simplified and the resistance between chassis and either control grid is 103,850 ohms, consisting of the resistor R11 and one-half of the input a-f transformer (T2) secondary.

It is not necessary to disconnect both leads of the speaker field winding. If it is connected to a plug, the plug may be withdrawn. If it is soldered to the circuit, then either lead can be unsoldered.

The total resistance between the two control grids is 5,700 ohms and can be checked by using the two control grids as the points of contact. If the tone control is in good condition it will have no effect upon the grid-grid resistance, irrespective of the setting. The same is true if either the resistance R7 or the circuit connected thereto, or the condenser C14 or the circuit connected thereto, are open. However, if the tone control condenser is shorted, the resistance between grid-grid will be substantially zero, when the variable resistor R7 is adjusted to the mellowest position (all resistance out).

From plate to plate of the output tubes you check the total resistance of the output transformer (T3) primary. This is 360 ohms. This means that each half of the winding has a resistance of about 180 ohms. To check the voltage-supply lead, we can work from chassis to either output tube plate, or from the rectifier filament to either output tube plate. The latter is by far preferable, because it involves fewer units and lower values of resistance, whereby it becomes simpler to determine a defect in either half of the winding. Of course, the plate-plate check would afford an idea of the presence of a defect because of a discrepancy in the measured value of resistance. From chassis to either output tube plate (volume control set for maximum signal) the total resistance would be 22,630 ohms. From rectifier filament to either output tube plate, the resistance would be about 180 ohms.

THE RECTIFIER TUBE.

Now for the rectifier tube. The resistance of the entire rectifier plate winding is 250 ohms, which means that each half is approximately 125 ohms. With the chassis as the common test point, the resistance between the chassis and either anode should be 200,125 ohms. This measurement takes for granted that the speaker field is disconnected. From anode to anode is 250 ohms. The test between chassis and either anode verifies that the 10-mfd. filter condenser is not shorted. If it were, then the resistance between the chassis and either anode would be the resultant of 200,000 ohms shunted by the series combination of R4, R1, R3 and R2, plus one-half of the anode winding. To check the 10-mfd. condenser, measure the resistance between the rectifier filament and one plate anode. It should be the sum of R4, R1, R3, R2, R11, R10 and one-half the rectifier plate winding resistances. If the resistance is 125 ohms, then C10 is shorted. The condition of C19 is indicated by the chassis to output tube grid test (with speaker field disconnected), because if this condenser is shorted, the resistor R11 is shunted by the series combination of R4, R1, R3 and R2.

The field coil resistance is measured separately. The same is true of the output transformer secondary and the voice coil. Without knowing what these values are, it is possible to check for a short circuit, since all voice coils and output transformer secondaries, unless they are of the single copper-bar type, have some value of d-c resistance in excess of .5 ohm. The last test is to again connect the speaker field and measure the total resistance of the parallel circuit.

Again we have to mention the effect of the electrolytic condensers in the circuit. Correct polarity of the ohmmeter is essential, and this fact must be borne in mind during all such tests.

No doubt you can appreciate that it takes much longer to describe such a process of measurement than the actual test. It really does. You will find that the more often you apply the system, the more readily will you be able to analyse the circuit from the diagram and work in rapid manner.

CHECKING CONDENSER CONNECTIONS.

We feel certain that from the examples cited you have discovered the advantage of checking condenser connections even before you attempt the routine resistance measurement. The reason for this is that in the majority of instances a shorted condenser will so alter the resistance networks in the receiver that variations will be experienced at several points. The item of importance in connection with these condensers is a short circuit. An open circuited bypass condenser will seldom cause total cessation of operation. Neither will it influence the resistance values. If we are certain that the bypass condensers are not shorted, we are enabled to render more rapid judgment upon the resistance determinations. Furthermore, if a condenser is shorted, it is detectable in jig time.

In the majority of instances, it may be possible to approximate the kind of fault in a receiver which is dead, by measuring the resistance between the chassis and the rectifier filament, that is the complete voltage divider circuit, inclusive of whatever bleeder units are involved. Low values will invariably indicate a short circuit across some resistor or through a condenser, maybe in some parallel circuit. High values invariably indicate an open circuit in some parallel resistance system.

RESISTANCE VARIATIONS.

In connection with high and low values of resistance, you will find that variations within the realm of normalcy are to be found in carbon and wire-wound units exclusive of coils. Coils are usually held to very close tolerance values of inductance, and since the inductance is a function of the number of turns, and the resistance is also a function of the number of turns, because of unit resistance per unit length of any one wire, that coil resistances will check very closely.

The probability that all resistors in a network will be high or all will be low is very remote. Isolation of the respective units in that system will give you the clue as to whether or not the units are all within normal tolerance. It is possible that during a routine voltage test, the voltage will be low because all of the resistors in that system are "high" but within tolerance limits. This is detectable by individual unit measurement between tube elements in different sockets and your decision to replace all is entirely within your hands. A similar condition exists in connection with a state which will cause "high" voltage and its effects. It is possible that a certain group of resistors are "low," but each remaining within normal tolerance. In such cases, the voltage test is required to prove that the voltage is excessive and the answer is replacement of all of the units. Now in due justice to the manufacturer, we must concede the point that no reliable manufacturer will deliberately produce a receiver in which any group of resistors are "high" or "low" and cause "low" or "high" voltages, with their consequent effects and allow that receiver to leave the shop.

The possibility that any one group of resistors will develop such defects, wherein each one becomes "high" within tolerance or each one becomes "low" within tolerance, is very remote. If a resistor is "low" but within tolerance when the receiver leaves the plant, and that resistor decreases in value during operation, it will without doubt be beyond the tolerance limit. It is of course possible that a resistor was very close to the rated value when new, but decreased or increased in resistance after use. If this increase or decrease is within tolerance limits, it is no different than if that resistor were originally used during the manufacture of the receiver.

As far as the development of trouble is concerned, it invariably means some radical variation in the resistance of a unit. Of course we are referring to the types of defects which are not associated with alignment of trimmers, shorted condensers, open condensers, bad tubes, etc.

You, as the individual called upon to service a receiver will have to exercise your knowledge. In this respect you are no worse off than if voltage tests were made, because if the measurement shows "low" voltage and the group of resistors appear "low" in value, yet within the tolerance limits, according to the ohmic value of that unit as quoted upon the diagram, you must decide for yourself, whether or not replacement is necessary.

This is not a very difficult thing to do. If a number of units within a circuit are "low" according to the rated values, and the trouble with that receiver is of the type which may be due to "high" voltage, you are in a position to suspect those units. You are then called upon to decide upon the reduction of the voltage in the effort to clear up the trouble and accordingly replace one or more resistors as the case may be, to bring about the desired result. This type of problem is not native only to resistance measurement method of service analysis. It is to be experienced in connection with voltage measurement methods as well.

Let us consider another example of point-to-point measurement involving the application of the condenser test as an immediate follow-up of the voltage divider measurement. Figure 68 shows a circuit with electrical values for the resistors and condensers only.

The chassis can be the common terminal. As is evident in the wiring diagram, all bypass condensers join the chassis. To trace the voltage divider network, we start with the rectifier filament and follow it through to the chassis. A second check is made from the voltage distribution points to locate any parallel circuits. The initial investigation shows a circuit through the field coil, the 40,000-ohm resistor (R1), a 30,000-ohm resistor (R2), a 350-ohm resistor (R3) and the volume control resistor of 15,000 ohms maximum, (R4). The total resistance is 87,850 ohms, that is, with the volume control R4 adjusted for minimum volume. With this unit adjusted for maximum volume, which is its setting for all future tests, the resistance is 72,850 ohms.

If for the moment we allow a general tolerance limit of 10 percent, it would be well for you to realize that the sum of a 10 percent plus tolerance for a series of units is the same as a 10 percent tolerance for the sum of those units. Thus, allowing 10 percent plus for each of the units involved, with the exception of the variable control, it means a total variation of about 7,285 ohms which is the actual sum of a 1-percent tolerance allowed for each unit. However tolerance values are usually plus or minus and equal value, although in some instances, a higher plus than minus is allowed. If we allow 10 percent both ways, the normal range of resistance which may be expected between the chassis and the rectifier filament of figure 68 is from 64,565 ohms to 80,135 ohms. This assumes that all the units will be plus 10 percent or all will be minus 10 percent. As a rule, you will not experience such cases. Some units will be plus, others minus and some very close to the rated value. Experience has shown that the final variation of such a group of units in most cases seldom exceeds 3 or 4 percent. Sometimes it is even closer. The reason for this is that there is a division of the units into plus and minus groups, thus creating a sort of balance as far as the total is concerned.

Let us now imagine that the voltage-divider resistance is appreciably less than the required value. Suppose that it is less by about 32,000 ohms. If we checked the circuit we would notice that one part of the network, (R2, R3 and R4) total about this figure with the volume control at maximum signal. We would then suspect condenser C1. However, that is not the method of operation because it involves too much calculation and loss of time. It is by far preferable to check the bypass condenser circuits. Of course if the point-to-point data is available in tabulated form, similar in nature to the present voltage tables, the discovery of the defect is practically automatic. We shall assume that such is not available and proceed to check the circuits which involve bypass condensers connected to the chassis.

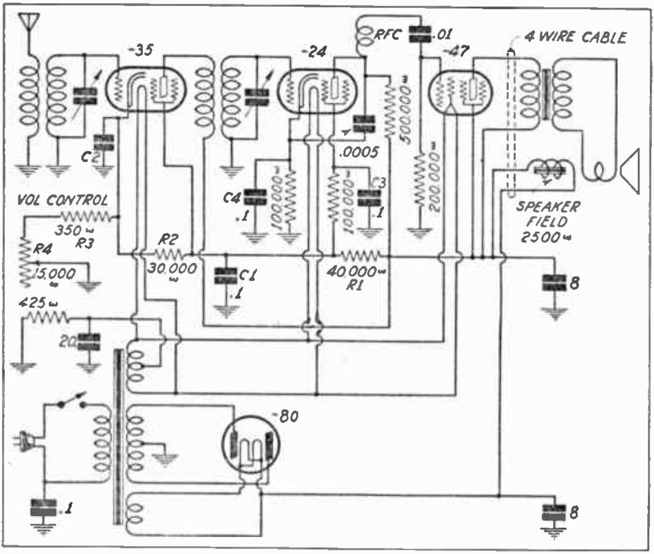


Fig. 68

In this test we are not concerned with the actual resistance of the circuit. What we are after is a direct short, therefore substantially zero resistance. Starting with the r-f tube, the test between chassis and cathode shows resistance. Condenser C2 is intact. Between the r-f screen grid and chassis we find zero resistance. We made the general statement that zero resistance between the screen grid and chassis is seldom experienced in receiver design, perhaps never found. To prove the location of a short circuit at this point, we check between the screen grid and the cathode. With everything normal, this resistance should be 30,000 ohms. However, if C1 is shorted, R3 and R4 are in parallel with R2 and since R4 is adjusted for zero resistance (maximum signal) the ohmic value between the screen grid and the cathode is slightly less than 350 ohms, proving a short circuit in condenser C1.

Let us consider another case. The voltage divider measurement shows a value very close to the lower tolerance limit, namely about 65,600 ohms, which would seem to indicate that all of the values tend to be "low." The next step is one open to discussion. We believe that it should be the condenser test to determine short circuits, because of the possibility of a grounded condenser associated with some high value of resistance. We further believe that the test should become a routine operation, because it takes up very little time, yet will furnish a great deal of helpful information. On the other hand, the condition named is not one which would tend to cause one to become suspicious of some unit. Of course the presence of a defect is indicated by the fact that the receiver does not function at all. We shall proceed against our better judgment and check the resistance of the various circuits rather than test the bypass condensers. We shall enumerate the various steps.

1. Chassis to aerial	normal value of resistance
2. Chassis to r-f control grid	normal value of resistance
3. Chassis to r-f cathode (V.C. Max)	approximately 350 ohms
4. Chassis to r-f screen grid	approximately 23,500 ohms

Obviously there is something wrong. Considering the presence of a 30,000-ohm resistor in the circuit, the variation of about 6,500 ohms is far in excess of the normal tolerance. A supplementary test between the cathode and the screen grid of the r-f tube shows a value of about 23,000 ohms. This would cast suspicion upon the resistor R3. However, since we are working upon the chassis through the tube sockets and the chassis is still within the cabinet, it would be folly to immediately decide that the resistor named is bad and consider that as the defect. If the point-to-point data is tabulated, the reason for such a condition would be stated and a test made. However, since we are operating without such data, further checking is required. In this respect this method of testing is no different than the voltage measurement method. One cannot cease all operation after having discovered that the plate voltage is not being applied to one tube and cease further voltage test at that point. The advantage accruing from resistance measurement is that the time required for the routine voltage test is saved. Accordingly we note the discrepancy and continue.

5. Chassis to r-f plate . . . . approximately 63,000 ohms

Something else to be suspicious about, since two resistors in the circuit (R2 and R1) total 70,000 ohms. However, the variation of 7,000 ohms is within the tolerance limit, and we continue.

6. Chassis to detector control grid . . . . normal value of resistance
7. Chassis to detector cathode . . . . approximately 100,000 ohms
8. Chassis to detector screen grid . . . . zero resistance

Such a value is not normal. Perhaps this is the trouble. According to the diagram, the resistance between chassis and the r-f screen grid should be about 130,350 ohms. The short must be in the condenser, or the screen grid lead is grounded. If the 100,000-ohm resistor were shorted across its terminals, the resistance between chassis and screen grid would be about

30,350 ohms. An examination of the circuit now shows that with C3 shorted, the 100,000-ohm resistor is in parallel with the series combination of R2 and R3, also R4, but since the latter is adjusted for zero resistance it is not added into the circuit.

Now, if we had made the routine condenser test for short circuit to ground, four moves would have shown the shorted C3. These four moves would have been from

1. R-f cathode to chassis, across C2.
2. R-f screen to chassis, across C1.
3. Detector cathode to chassis, across C4.
4. Detector screen grid to chassis, across C3.

The balance of the tests are routine resistance measurements as previously outlined. Not having specific values of resistance for the various windings, we cannot quote resistance values. However, one learns to judge between good and bad windings according to the function of the unit and its resistance. A discussion of troubles, possibilities and probabilities, limitations of resistance measurement, etc., follows in a subsequent chapter. In the meantime, let us consider a somewhat more complicated d-c receiver and trace point-to-point resistance measurements.

We cannot refrain from repeating that what appears to be a momentous problem, namely the lack of tabulated point-to-point data, is not a great obstacle. A great deal can be accomplished without such data because the faults to be found in radio receivers seldom are those which will cause a minute variation in the resistance of an r-f, i-f or a-f winding. As a general statement, we can truthfully say that in the majority of instances which have come to the writer's notice, very few troubles were due to partially shorted turns in an r-f, i-f or a-f transformer. The same is true of power transformers. We take this opportunity to mention that the tables of troubles in radio receivers as outlined in a subsequent chapter, are quite different from the routine

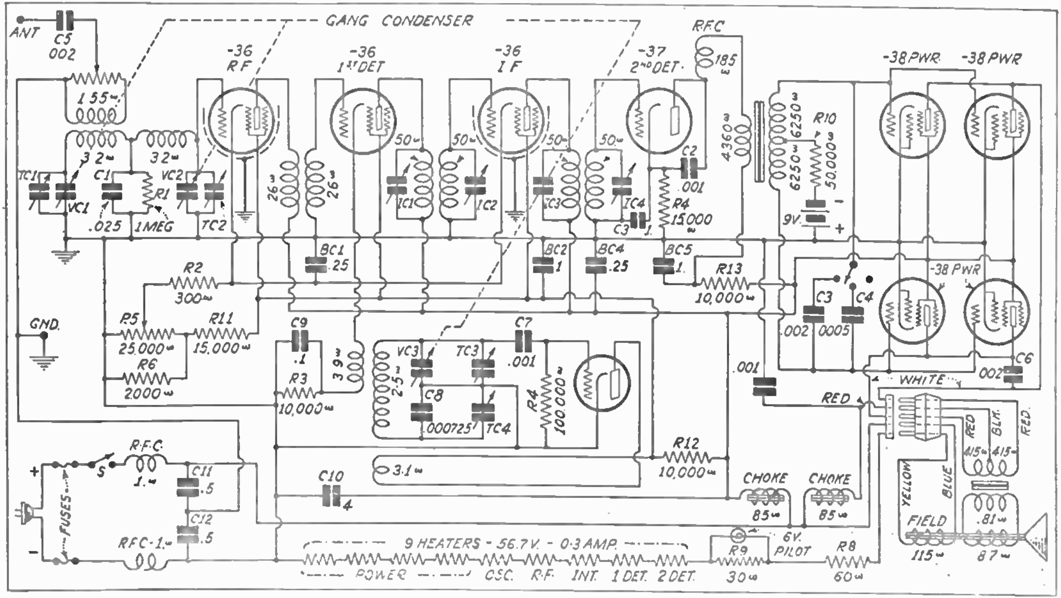


Fig. 69. Schematic diagram of Kolster K-83 and K-93 direct current receiver

references to such items. Strange as it may seem there are many problems which never seem to get into print.

BREAKING DOWN A DIRECT-CURRENT RECEIVER.

The circuit shown in figure 69 is that of the Kolster K-83 and K-93 d-c receivers. The power plug is removed from the supply line, and the speaker is also removed. The tubes are removed from their sockets. An examination of the circuit shows that two plate-voltage supply leads are common to the plus side of the line. One of these is for the output tubes only. The remainder supplies the balance of the tubes and with the various voltage and bleeder resistances constitutes a voltage divider. This voltage-divider circuit takes the shape shown in figure 70.

From plus to minus terminals upon the power plug, (with speaker plug removed) the resistance is 26,938 ohms. This includes the parallel arrangement of resistors R5 and R6. It is significant to note that the resultant resistance of R5 and R6 in parallel is about 1,850 ohms, and if one side (not the movable arm) of R5 opens, the variation in total voltage-divider resistance will be negligible, but the effect will be determinable by measurement involving the r-f cathode to chassis circuit. On the other hand if R6 is open circuited, the resistance of the voltage divider system will rise to about 52,000 ohms. Let us now analyse the following tabulations of the conditions which will cause the resistance variations noted, with our first test for resistance between the plus and minus terminals upon the power plug. If desired, the negative terminal can be replaced by the chassis connection. If the chassis connection replaces the minus plug terminal, the 1-ohm r-f choke in the minus lead is out of the circuit.

During this example of point-to-point measurement, at least during the first stages, we shall neglect reference to the plate and grid windings in the r-f, i-f and oscillator stages. Also, possibilities of open or shorted tuning or trimmer condensers.

We are interested in illustrating the relation between different parts of the voltage distribution system and to show how by accurate measurement of the resistance between two common points in the receiver, it is possible to immediately detect any one of a number of faults related to that system. By correct interpretation, the exact defect can be checked. Once again, we shall devote our attention to those parts which will influence resistance values between any two points, consequently shorted filter and bypass condensers and open resistors. What is to follow is not necessarily a routine resistance measurement test with the idea of service analysis. It will, however, give you an idea of how you can tabulate data pertaining to receivers for which you have electrical values.

1. Between Chassis and Plus Terminal of Power Plug (Vol. Control Max.)

26,938 ohms	Normal.
86 ohms	Filter condenser C10 shorted. To prove, test between chassis and output tube space grid. Bypass condenser BC4 shorted. To prove, test between chassis and output tube space grid. Here is an instance where two condensers will cause the same defect and the only sure method of determining which of these is at fault is to pull the chassis. Since the defect, no matter which one of these condensers is defective, is of the nature which requires removal of the chassis, no unnecessary time is wasted. .001 mfd. r-f bypass shorted. To check, test between red wire to speaker socket and chassis. In all of the above cases, zero resistance between the points mentioned indicates a shorted condenser.
7,366 ohms	Bypass condenser BC5 shorted. When shorted, this condenser places resistor R13 in shunt with

	the series combination of R12, R5 and R6. The resistor R13 is of 10,000 ohms. To prove shorted condenser check between chassis and 2nd detector plate. If shorted resistance will be about 4,500 ohms.
10,086 ohms	Bypass condenser BC2 is shorted. To prove, check between chassis and i-f screen. If condenser is shorted, resistance will be zero.
16,938 ohms	10,000 ohms resistor R12 shorted. To prove, check between oscillator plate and output tube space grid. If resistor is shorted, resistance between points will be 3.1 ohms instead of 10,003.1 ohms.
11,938 ohms	15,000 ohms resistor R11 shorted. To prove, check between r-f screen grid and r-f cathode with volume control set for maximum signal. If resistor is shorted resistance between points will be 300 ohms, instead of 15,300 ohms.
52,000 ohms	2,000 ohm resistor R6 open. To prove, check between r-f cathode and chassis with volume control set to maximum signal. If resistor is open, resistance between points named will be 25,300 ohms instead of approximately 2,150 ohms.
25,087 ohms	Shorted bypass condenser BC1. To prove, test between chassis and r-f cathode. If condenser is shorted, resistance between points will be zero.

The above just about concludes the voltage divider arrangement. Now, it is necessary to mention that there are other types of short circuits which will create similar conditions. These shorts represent a direct electrical contact between the two points connected by the condensers named. Thus if the r-f cathode or i-f cathode becomes grounded it is the same as if bypass condenser BC1 were shorted. The same is true if the cathode end of the 300-ohm bias resistor R2 became grounded. Electrically, this ground is the same as if the two cathodes were grounded or if the condenser were shorted. It is purely a matter of physical location. Here is an example of a trouble reference, which does not appear in general radio service literature. We are too prone to pay attention to condensers of various kinds, without giving any thought to accidental grounding of tube elements or wires because of insulation. However, once the grounded circuit has been located by proper interpretation of the values, the rest is a simple matter.

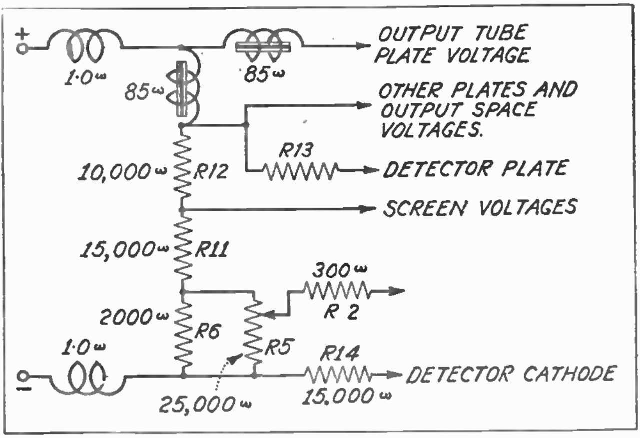


Fig. 70. Equivalent resistor network of receiver shown in figure 69

We cannot help but mention something about service costs at this time. Point-to-point measurement is intended to accomplish two ends. First to enable more direct location of the trouble and second to establish a means of stabilizing service charges. In the example cited, clearing a shorted cathode circuit not due to a shorted condenser, but rather to frayed insulation involves a definite chassis removal cost, but does not entail replacement of a condenser. On the other hand if the trouble is due to a defective condenser, say BC1, the chassis removal cost remains the same, but it is necessary to also consider the cost of replacing the condenser. This example is just one of many which can be named, and represents quite a problem to be solved by the radio service fraternity.

If there were such a thing as absolute accuracy in the manufacture of resistors employed in receivers and very close tolerance limits, it would be possible to carry the analysis of the voltage divider measurements to even greater heights. If we assume absolute accuracy in the diagram shown in figure 69, a resistance of 14,156 ohms or thereabouts would indicate a shorted 2nd detector plate bypass condenser, unit C2 in figure 69. A short circuit in this unit, which can be checked by testing between the 2nd detector plate and the 2nd detector cathode and noting zero resistance if the unit is shorted, creates the circuit shown in figure 71. Even without absolute accuracy of values, this type of test and interpretation can be applied.

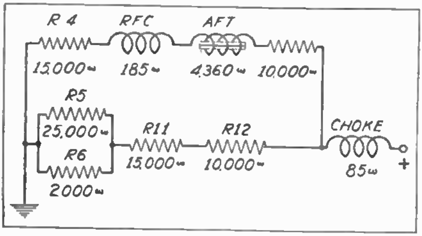


Fig. 71. Type of circuit created by a short in condenser C2 in figure 69

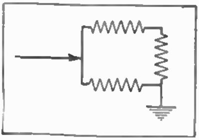


Fig. 72

It is possible to carry on to greater limits by considering the effect of the various condensers in the circuits and by tieing in the different resistors. No doubt you can do this by following the examples set forth so far.

Measuring the resistance between the chassis and the various tube control grids, cathodes, screen grids and plates progresses in the manner outlined for the earlier receivers. However, special reference is required in the case of the aerial-ground test upon the receiver illustrated in figure 69.

This circuit cannot be checked via the binding posts because of the antenna condenser. Access to the coil and control are required. Because of the circuit arrangement, the coil and control must be separated in order to be able to check the system. There is a way of checking these units without disconnecting one from the other, providing access is had to the control arm lead. When the control arm is set at full volume, the resistance between the arm and the ground post is approximately 1.55 ohm. When the control arm is set to approximately the midpoint, and the test is made between the ground post and the control arm, the circuit is as shown in figure 72. The low resistance of the winding is the equivalent of a direct link across the two ends of the resistor. By setting the arm to the midpoint, we create a condition as if the resistor were in two parts connected in parallel. If the resistor varies in normal fashion and is not tapered a point will be found where the resistance between the control and the ground is about 6,250 ohms. This represents the resultant resistance of the two sections (divided by the control arm) in parallel. The important item is not an exact measurement of the resistance but rather a determination of its approximate value or whether or not it has a high value, without disconnecting the resistor from the winding. A means of determining the resistance of the resistor is to adjust the control arm with the ohmmeter connected as stated until the highest value of resistance is indicated. Note this and multiply by 4. The figure obtained will represent an approximation of the value of the resistor when disconnected from the coil.

A peculiar arrangement is found in the r-f grid circuits. A test between chassis and r-f control grid will show continuity through the 1. megohm resistor and the winding nearest the control grid. This resistance will be 1,000,003.2 ohms. Obviously an error of 3.2 ohms in 1,000,000 is beyond the scope of standard service apparatus. To check the resistance of the two coils, contact is required with the stator of VC1 and the control grid. The correct resistance between these two points will be 6.4 ohms.

During the test between chassis and control grid, noting the 1,000,003.2 ohms, it is a check upon the condition, with respect to a short circuit through VC1 and its trimmer and VC2 and its trimmer. If VC1 or its trimmer are shorted, the resistance between chassis and control grid is 6.4 ohms. If VC2 or its trimmer are shorted, the resistance between chassis and control grid will be zero. On the other hand if fixed condenser C1 (connected in shunt with the 1,000,000-ohm unit) is shorted, the resistance between chassis and control grid will be 3.2 ohms.

Several other special points are to be noted in this diagram. Between chassis and the oscillator cathode, the resistance is zero, but between chassis and the 1st detector or mixer cathode the resistance is 10,003.9 ohms. As is evident, there is no isolation of the cathode coupling winding from the balance of the circuit when working through the sockets. However, if this test shows a resistance of only 3.9 ohms, it is a sign of a shorted bypass condenser across the 10,000 ohm resistor R3.

Because of the structure of the oscillator winding, its resistance cannot be checked working through the sockets. Consequently, some other means must be used to determine if the tube is oscillating or the circuit is functioning. However, it is possible to check the remaining essential parts of that system, namely the resistor between the control grid and the cathode, or chassis and the plate winding of 3.1 ohms. To check the latter it is not necessary to work through any resistors, since the i-f screen and the oscillator plate voltage supply leads are one and the same. Hence a resistance test between the i-f screen and the oscillator plate will isolate the 3.1-ohm winding.

With the tubes removed from the receiver it is safe to insert the speaker plug and avoid complication of circuits. Between the plus terminal of the power cable plug and any one of the plates in each leg of the push-pull output, we can check the associated half of the output transformer primary winding. The total resistance of the winding is 830 ohms and the resistance to any one of the plates should be about 501 ohms. This figure includes the filter choke and the r-f choke in the positive power leg. The speaker field unit must be checked separately, although it can be tested when plugged into the speaker socket. In order to test this unit, when in this position, the tubes must be inserted into their respective sockets and the dial light must be removed. Then the resistance across the plus-minus terminals of the power plug would be about 396 ohms. The fact that the voltage divider is connected into the circuit makes very little difference, because about 26,000 ohms are connected in shunt with 396 ohms. However, it might be valuable to test the two control resistors R8 and R9, because a variation in these units will cause a change in the current through the heaters. Accordingly, the field coil terminals upon the speaker socket are shorted and with the tubes in the receiver, the resistance is measured across the power plug prongs. The resistance should be about 281 ohms. The parallel effect of the voltage divider would tend to reduce the resistance to about 275 ohms.

The output tube plate bypass condenser was not taken into consideration during the voltage divider tests, because even if shorted, it would not influence the resistance in as much as it was not connected into the circuit. Such a short will show up when the plate-to-plate test is made to determine the resistance of the complete plate winding.

To check the secondary of the output transformer and the voice coil winding it is necessary to disconnect the two windings. It is possible to test the two connected and the total resistance would be 0.741 ohm, but this value is so close to the resistance of the secondary alone, that it is best to check the windings separately.

BATTERY RECEIVERS.

Checking battery receivers is the easiest of the group. The batteries are disconnected and the tubes removed from the sockets. The grounded side of the supply circuit is selected as the common point. In receivers of this type, the grounded side will serve as the common terminal for the filament and control grid circuits, but plate systems and in some instances even grid circuits will have to be checked from the associated battery terminals. The grounded side can be used to check for shorted bypass condensers, by working from the grounded side, which invariably is one connection to the bypass condenser and the battery terminals.

POINT-TO-POINT MEASUREMENT WITH THE CHASSIS REMOVED.

With the chassis removed from the cabinet and the location of the sockets known, it is best to operate in a certain fashion. With the wiring diagram at hand or a tabulation of the resistance between points, it is best to operate from the rectifier tube filament as the starting point. The reason for this becomes evident when you examine the chassis shown in figure 73. In the first place the appearance of the underside of the modern chassis is not as systematic as that of the upper side. In the second place, because of the variable positions of the sockets, the correct tube element terminals may be any place. Third, what with a number of similarly color coded resistors, it is best to select a starting point which cannot be confused and is easily located, due to the minimum number of wires associated with it. Fourth, grounded units are numerous in a receiver, since the chassis is utilized as a conductive element. Hence it is more difficult to select a certain grounded unit and work up to the tube than to start at the tube and work down to the chassis.

There is also a superior method of locating resistor and condenser units than the tracing of circuits. Instead of following through from a certain starting point, when it is necessary to check one particular unit, it is best to locate the nearest tube socket connection and trace from that point to the resistor. The reason for this is, that every effort is made in manufacture to reduce the cost of production and attain greatest stability of operation by the single move of using the shorted leads. If a resistor is associated with a tube element, it will usually be found that the resistor is located close to the tube element. While it is true that the other lead may be long, as convenient, the connection to the tube will be short. There are certain exceptions to this rule, as for example in receivers where all of the resistors are mounted upon a single strip. But even in such cases, it is easier to

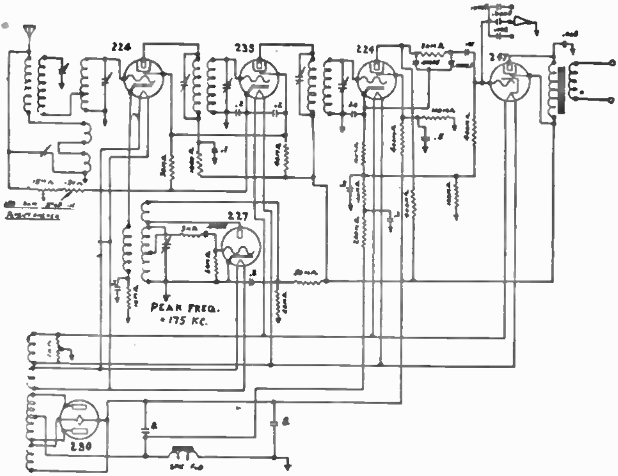


Fig. 73. Schematic diagram of Colonial model 44 receiver
(Courtesy Colonial Radio Corp.)

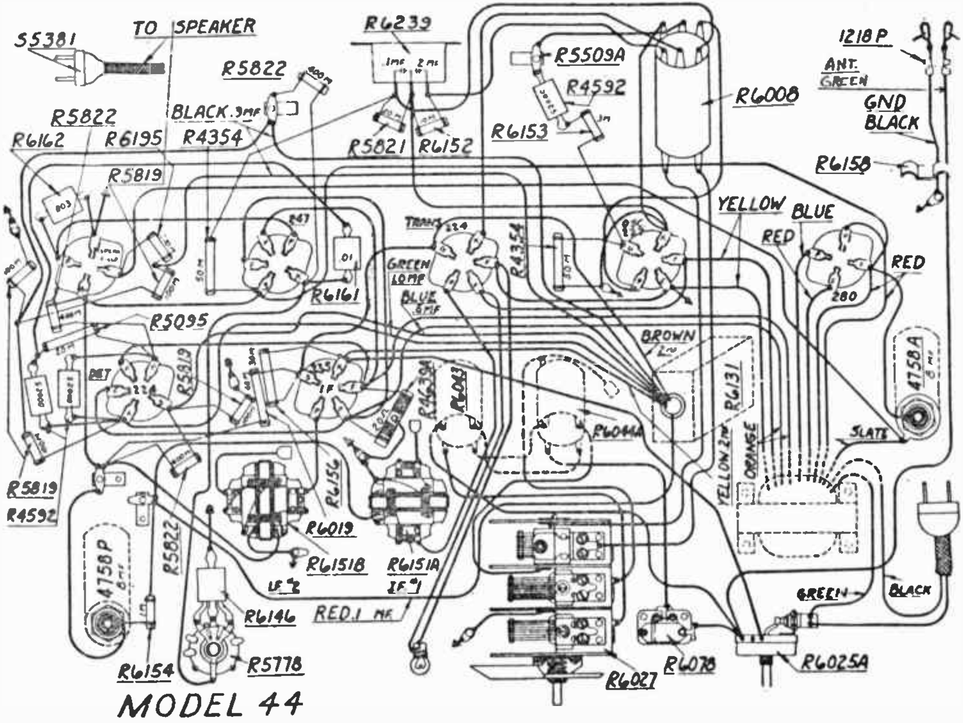


Fig. 74. Chassis wiring and layout of Colonial 44 receiver

locate the required resistor by working back from the tube than by attempting to locate its ground (chassis) junction or its common junction with some other unit. Let us consider a few of these.

Figure 73 is the chassis wiring of the Colonial 44 Superheterodyne. It is a drawn picture of the location of the respective parts upon the chassis. It is quite a complicated mass of wires and parts. Now examine figure 74 which is the schematic wiring of this receiver. You will note the abundant use of resistors of various kinds. Let us try to locate various resistors according to their electrical connections as shown upon figure 74. See how fast you can locate the 50,000-ohm resistor which is connected to the plate-winding of the i-f tube ('35) and also to the oscillator plate coil. You will also observe that one end of this resistance is connected to the space grid of the output tube. This connection is direct, without any intervening winding. Now look at figure 73. Locate the output tube, the '47. The space grid terminal is marked with an S. Connected thereto you will find the 50,000-ohm resistor.

If you attempted to work from the junction between the 50,000-ohm and the 20,000-ohm resistor or the ground connection to the latter unit, you can readily realize the complications. It is even simpler to work from the nearest tube socket and thus locate the resistance than to seek the resistor upon the chassis layout shown. Suppose that we are trying to locate the 100,000-ohm resistor. The nearest tube terminal is the cathode of the 2nd detector. We note that this resistor joins a 100,000-ohm unit, and also a 200,000-ohm unit. This information serves to help identify the exact unit in this maze of similarity. Another significant item is that a third 100,000-ohm unit connected to ground joins the unit we are seeking. Now locate the detector tube in figure 73. Working from the cathode terminal we trace the system and locate the 100,000-ohm unit adjacent to the 200,000-ohm unit, which is connected to one of the terminals upon the speaker field socket.

There is of course the problem of confusion when the resistors in the receiver are not color coded, when the wires are not color coded and when a chassis layout is not available. In such cases it is virtually impossible to operate in rapid fashion unless one starts from some starting point. As far as simple resistance measurement is concerned, either the rectifier filament or the chassis is satisfactory, but when seeking special resistors or condensers, it is best to start from the nearest tube element as represented upon the socket.

In this connection it is necessary to bear in mind that the control grid circuits of the screen grid tubes are not accessible through the bottom of the socket. However, if the test probe has a sharp point, such as that available with a phonograph needle, it will be possible to make contact with the control grid clip circuit by puncturing through the insulation of the control grid lead which passes through the chassis.

There is no doubt about the fact that the greater your knowledge of radio circuits and the greater your experience in service work, the more readily will you be able to check circuits. A certain amount of ingenuity is required on your part. It is more than likely that in times past you have employed point-to-point resistance measurement with the chassis removed from the cabinet. However, if you follow the suggestions made herein for the location of the respective parts, you will find that it is possible to work more rapidly than by other methods.

There is another item which justifies discussion. There are numerous receivers, wherein the various bypass and filter condensers are sealed within a can and only the leads protrude through the chassis. Also, a number of resistors mounted upon a strip and nothing but the contact lugs protruding through the mounting strip.

In cases such as this consider the following: As far as condensers are concerned, modern practice makes use of the can as the common terminal, usually connected to the chassis. The common lead is soldered to the can on the inside. In some cases, however, a separate lead is common and joins the chassis. If the chassis is the common junction, locate the live leads by working from the tube sockets. You will invariably find that the common junction between a resistor and a condenser, when both are connected to a tube element via the socket, is at the socket. There are exceptions, but as a general statement, the former is true. The circuit shown in Appendix 2, has been found applicable for the testing of condensers, without requiring that the condenser be disconnected from the receiver.

What is true about a-c receivers is equally true about d-c and battery receivers. Of course you have no rectifier filament, but there is the chassis as the common point and also the plus or minus terminal of the power cable plug.

In battery receivers, you always have one filament circuit which is common to the balance of the system.

SPEAKERS AND OUTPUT TRANSFORMERS.

The secondary of the output transformer and the voice coil of the speaker are beyond testing by means of tube socket contacts. These circuits must be checked separately and independently of the chassis. Usually the connecting terminals to the voice coil and even the field coil are mounted upon a frame, which is part of the speaker. These leads will have to be disconnected and the windings measured separately. One major reason for this requirement, is the low resistance of that circuit. As a rule, the d-c resistance of the output transformer secondary is less than that of the field coil, which in itself is low, so that the resultant resistance of the combination is very low, and accurate checking is required to show the presence of a short circuit. There are certain special notes pertaining to the use of an ohmmeter to measure low resistances which is given special mention in a subsequent paragraph. Read that data well and digest it thoroughly. It will mean the difference between a successful and an unsuccessful measurement.

FILAMENT WINDINGS AND POWER TRANSFORMER PRIMARIES.

Filament windings and power transformer primaries can be checked without removing the chassis. In view of the fact that the former may be employed without the necessity of using the rectifier tube, and since the resistance of the average filament winding is very low, it is advisable to check this part of the receiver by means of voltage. This refers particularly to a-c operated receivers. In the case of d-c receivers, it is best if the individual resistors are checked and then the filament circuit resistance determined as a unit.

Power transformer primaries are reached via the power plug, hence no special notations are required. The same is true in the case of defective filter condensers connected across the transformer primary. Checking of the primary circuit resistance is a problem, when exact specifications are not at hand. A means of determining if the power transformer primary winding is intact, all other associated units except ballasts excluded, is to measure the filament voltage. As a matter of fact, measurement of the filament voltage is at times unnecessary because it is possible to note whether or not the various tubes in the receiver glow with normal brilliancy. This does not mean that the receiver is to be checked in an operative state. The rectifier is removed and the set turned "on." This will cause the filaments of the various tubes in the receiver, other than the rectifier to light. The voltage can be checked if desired, but the average experienced service man can judge the condition of the system by noting the brilliancy of the filaments or heaters. As a matter of fact it is unnecessary to even have the tubes in the receiver. With all tubes removed a voltage test is made of the line voltage and of the voltage available at the filament or heater terminals of the respective sockets. This test does not involve any circuits associated with the rectifier, plate or grid systems, hence the existing defect will not damage the tubes. Tolerance must be accorded the increased voltage when the power transformer is checked without load.

CONDENSERS AS TEST POINTS.

The variable condenser comes into play when the chassis is removed from the cabinet. In many instances, it is difficult to locate or reach the required r-f, antenna or oscillator winding lead. However, easy access is to be had to the condensers which tune these windings. With the chassis as one terminal and the stator as the other, connection across the winding is to be had. However, there are certain instances when such a connection will not provide the correct continuity. An example of this is shown in figure 75. The blocking condenser C isolates the winding from the variable condenser, as far as direct connection is concerned, but serves as a coupling link as far as radio-frequency currents are concerned. In such cases, it will be necessary to seek the winding connections.

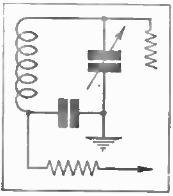


Fig. 75. The blocking condenser isolates the winding from the tuning condenser

When condensers are sealed into cans, there is no need for measurement of the capacity, which means that there is no need to disconnect the condenser. The important item is whether the condenser is good or bad. A capacity test will indicate if the circuit within the condenser can is satisfactory, but it is no indication of whether or not the connection between the condenser lead and the remainder of the circuit are electrically connected. When checking condensers, select the test points close to the chassis contact and the connection to the balance of the circuit. A short circuit test is sufficient, unless the trouble indicates the possibility of an open condenser, in which case a test for continuity is required.

When checking for blocking-coupling condensers such as shown in figure 75, work from the coil as a starting point rather than from the condenser rotor. The reason for this is that both the condenser rotor and one side of the blocking condenser go to ground or chassis. However there is no particular reason why the chassis connection of C should be made to the rotor of the associated condenser. As a matter of fact, this condenser connects to the chassis at the most convenient point, hence it is easiest to locate, by tracing from the coil winding.

CHAPTER VI

CHECKING CONDENSERS

WE feel that this subject deserves a chapter of its own. Although the subject is not lengthy, it nevertheless is one of major importance.

Of the many items in a radio receiver, condenser testing is one of the most difficult. Not so much because of the nature of the unit or the elaborateness of the apparatus requirement, but because of the manner in which a condenser is used and the manner in which it has been tested heretofore.

The solution we will offer in this chapter, may not be the ultimate. All we can say is that our idea has been in use for quite some time and has been found to be satisfactory in the majority of instances, at least sufficiently often to make the apparatus worthwhile.

However, before discussing our idea of condenser testing, let us devote a few minutes to modern practice. Examine figures 76 to 83 inclusive. Here you will find eight different applications of fixed and variable condensers. In nearly every case, the only test which can be made upon these condensers without disconnecting them from their associated units, is that for a direct short circuit. We acknowledge that this is very important information. Fortunately, with very few exceptions the short circuit test can be applied while checking resistance between points.

But—and it is quite an important point, there is another major fault to be found in condensers. This is an open circuit, particularly intermittent opens. At the present time, the radio service industry has available a number of capacity test instruments. As far as utility goes and as far as their intended function is concerned, they work well. However, are they what the industry needs? Is the service industry in need of a unit which will measure the resistance of a condenser or is the industry in need of a unit, which will tell if its continuity is correct or open?

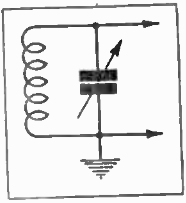


Fig. 76

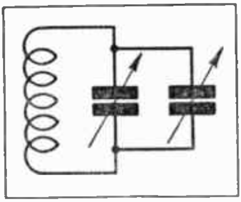


Fig. 77

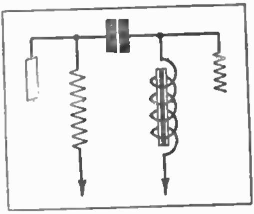


Fig. 78

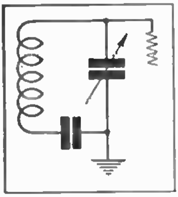


Fig. 79

Just what do we gain by knowing the value of capacity? The information is of value as contained upon a wiring diagram, because it enables replacement with the correct sized unit, in the event of damage to the original. But is it necessary to have equipment which will measure the capacity of a perfect condenser and be useless when a condenser is shorted? Admittedly, the modern capacity tester will not indicate the capacity of a condenser when the unit is shorted or when it is open. Hence, as far as replacement is concerned, we are called upon to know the value of capacity involved, with or without the capacity tester.

The possibility of a defect in the receiver or amplifier because the incorrect value of capacity was used by the manufacturer during the production is so remote as to nullify the value of the unit upon those grounds.

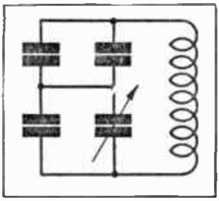


Fig. 80

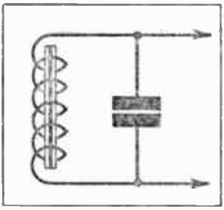
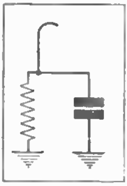
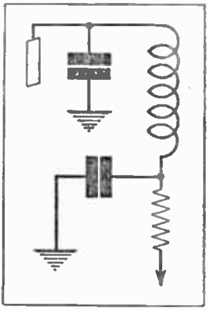


Fig. 81

There is no doubt about the fact that a condenser tester is required. However, it must be of the type which will accomplish certain things.


Above, Fig. 82


Right, Fig. 83

The modern capacity tester in the form of an a-c meter does not live up to modern requirements. In the first place, it has a limited operating range. Second, it is useful only where a-c is available. Third, it is necessary to disconnect the condenser in order to test it.

If we recognize that the ohmmeter test will indicate if the condenser is short circuited, the only real function of the modern capacity meter is to indicate the capacity, for by so doing it indicates if the internal connections are perfect. However, to make this test it is necessary to disconnect the condenser. This statement must be qualified by saying that a condenser test is possible with present equipment without requiring that the condenser be disconnected from the balance of the system. However, there are very definite limitations. Calibration for capacity requires that the shunt circuit be taken into effect. What with the possibility of any value of inductance or resistance in shunt with the condenser, it becomes difficult to distinguish between an open condenser shunted by a resistor and a good condenser shunted by a resistor. Tables showing the relation between certain condensers and resistors, with respect to the indication upon the instrument are possible, but they cannot help but be quite complicated. Furthermore, checking a condenser which may be shunted by a coil of few turns or low reactance and low d-c resistance will complicate readings, because such a circuit will cause as much current to flow as a very high capacity and a high value of resistance, when connected in parallel.

Then again a combination of a highly inductive choke of low d-c resistance when connected in parallel with a condenser, will require knowledge of the inductance of the choke in order to enable a final conclusion, in as much as an open condenser will not preclude a reading upon the testing instrument.

Still another important consideration is the need for testing low values of capacity, such as are used for trimmers or tuning i-f transformers.

The system shown in figure 85 is submitted by the writer as an experimental condenser tester suitable for testing without requiring that the condenser under test be disconnected from the chassis circuits. Bear in mind that it is purely experimental and positive results are not guaranteed. Essentially the unit is an oscillator, making it of even greater appeal, because it may be possible to arrange its use as a combination condenser tester and test oscillator. The unit shown was used on a-c. It is possible however that it can be used on d-c and batteries. Experiments along such lines have been found fruitful.

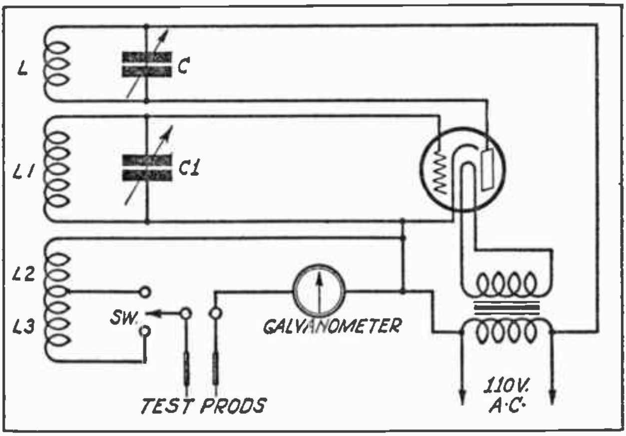


Fig. 85. Schematic wiring diagram of experimental condenser tester

The range of operation of the device, as determined by experiment, does not extend below .00025 mfd. The upper limit was found to be several microfarads. Nothing definite is as yet available concerning electrolytic condensers. but its application to solid dielectric and air condensers is sufficiently extensive to justify further experiments. The device has been used with electrolytic condensers, but the workable range has not been developed. It has been found perfect for the variable condensers utilized for broadcast frequencies. As a matter of fact just about perfection has been attained when checking condensers rated from .00025 mfd. to .008 mfd. These results can lead to but one conclusion, namely that further and extensive experimentation is fully justified.

Operation of the device is confronted with one limitation when checking high values of capacity, but this limitation is related more to critical reading of the meter indication than actual performance of the device. In this connection too, further experiments may remove the problem. The problem referred to is most prevalent when checking condensers rated at 1.0 mfd. Application below and above this value is simple.

CHECKING CONDENSERS

The circuit is shown in figure 85. Figure 85-A shows the coil arrangement. The coil specifications are given in Appendix 2. Coils L and L1 are wound upon the outer form; coils L2 and L3 are wound upon the inner form. L and L1 are separate windings, whereas L2 and L3 is a continuous winding with a tap at the junction between L2 and L3. The winding L2 is used for the high range of capacities, namely between .005 mfd. to several microfarads. The complete winding, consisting of L2 and L3, is used for the low range of capacities, namely from .00025 mfd. to about .008 mfd. As is evident, the two ranges overlap slightly. With about half of C in the circuit, about half of the total capacity of C1 in the circuit, the tube oscillating, and the switch set for the low range, shorting the test prods should show no indication upon the galvanometer. However, when a condenser of from .00025 mfd. to about .008 mfd. is connected across the test prods, current will be shown upon the galvanometer. The lower the capacity of the condenser, the lower the indication, but even the lowest value within the range quoted will cause quarter full-scale deflection. If the condenser under test is shunted by a coil or resistor and the condenser is intact, the meter will indicate about one-tenth full scale.

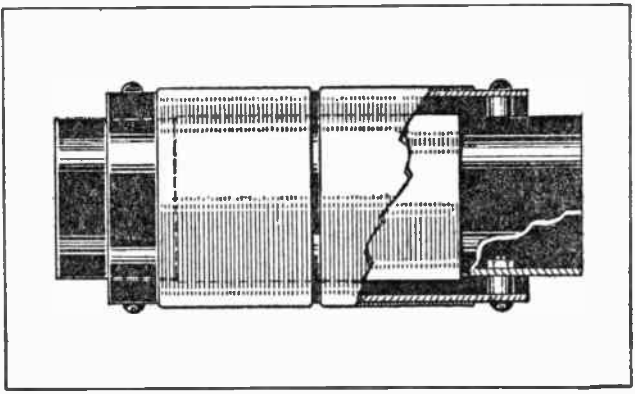


Fig. 85-A. Pictorial illustration of coil arrangement used in condenser tester

The higher the value of the condenser being tested within the low range, the higher is the indication upon the meter, irrespective of the nature of the unit shunted across the condenser, provided that the condenser is intact or the shunted unit is not shorted. Short circuits are checked by means of the ohmmeter. Just as long as the condenser is intact, the meter will indicate current. Short the prods or the condenser and the meter indication will be zero.

When making the initial adjustment, connect a .001-mfd. condenser across the test prods. If the meter goes off scale, vary C slightly until the current indicated is within the range of the meter. Another adjustment to secure the same result is variation of the respective position of the inner and outer oscillator windings. The proper setting under both conditions is zero indication with the test prods shorted and about 80 percent full scale, when the .001-mfd. unit is connected across the test prods.

As to the high range of capacities, the method judging the condition is somewhat different. With only L2 in the circuit, shorting the prongs will cause an indication upon the meter. If the prods are connected across a condenser which is open, there will be no indication upon the meter. If the condenser is shorted, the meter indication will be the same as when the prods are shorted. The fact that current is indicated when the test prods are shorted should not alarm. With but one exception, namely when a 1.0-mfd. condenser is tested, the current indicated upon the meter is different when the condenser is satisfactory, than when the condenser is shorted or the test prods are shorted. We are, of course, referring to the application of the device to the higher range of condensers.

The presence of a shunt resistor or coil will naturally influence the meter indication, providing that the condenser being checked is intact and in good condition. A certain amount of practice and experience will soon divulge the indications to be expected under different conditions and it will be relatively simple to approximate capacity values as well as condition.

Misleading information is possible in the event that a condenser which is open circuited and which is also shunted by a d-c resistance of about 10 ohms, is being checked. However, experience will also guide the operator in recognizing this condition and rendering judgment. Please bear in mind that this unit is strictly experimental in nature.

NOTE—Since this condenser tester was first developed, a number of improved instruments for measuring capacity have appeared on the market. In view of the lower cost and improved performance obtained with these units, we would recommend the purchase of one of these instruments in preference to the tester described on this page.

CHAPTER VII

THE APPLICATION OF THE OHMMETER TO RECEIVER SERVICING

IN view of the fact that there are several types of ohmmeters available on the market, there is no need for special reference as to types. All types of ohmmeters, providing that they are calibrated to show resistance values, are satisfactory. The only requirement which must be fulfilled is that relating to the range of resistance which may be checked with the unit.

In this connection, a great deal is up to you. We fully realize that many commercial ohmmeters have a maximum limit of about 100,000 ohms. As far as receiver and amplifier servicing is concerned, it will be necessary to go beyond this range. Fortunately, the major number of resistors and the greatest number of instances where resistance is involved in a receiver or amplifier, are such as to be within the 100,000-ohm range. However, in order to cover the entire range of resistors, the unit required must have a first division equal to about .2 ohm and the maximum limit must be at least 5,000,000 ohms. A limit of 10,000,000 ohms is much better.

POLARITY.

We have made reference to the fact that an ohmmeter has polarity. This item is important when you are checking a circuit, wherein is used an electrolytic condenser. The method of correctly applying the ohmmeter in order not to cause a confusing indication is to consider the polarity of the circuit or resistor being checked with respect to the normal operating voltages encountered in that circuit. The magnitude of voltage is not important. It is the polarity of the voltage which you must recognize. When this is done, connect the ohmmeter so that the current flowing through the circuit or the resistor is in the same direction as when that unit is used in the receiver.

Thus, if you are checking a grid bias resistor which is shunted by an electrolytic condenser, bear in mind that the grounded (chassis) end of the resistor is negative and the cathode or the filament circuit is positive. The ohmmeter must be connected in similar fashion, the negative end to the chassis or ground and the positive end to the filament or cathode. When checking filter condensers, remember that the rectifier filament is positive with respect to the balance of the circuit and when working from that point to some other, the positive pole of the ohmmeter must be connected to the rectifier filament. A similar condition is to be found in connection with electrolytic bypass condensers connected between plate and cathode or screen and cathode circuits. The plate, screen grid and space grid are positive with respect to the cathodes and the polarity of the ohmmeter must be in accordance with this condition. When testing between plate and cathode or screen grid and cathode, connect the positive pole of the ohmmeter to the plate or to the screen and the negative pole of the ohmmeter to the cathode.

There is one precaution which you must exercise in connection with the application of an ohmmeter to receivers which employ electrolytic condensers and which have been inactive for a period of months. Such condensers will in most cases influence the resistance indication despite the fact that the polarity of the ohmmeter is perfect and despite the fact that there is nothing really wrong with the condenser. A period of inactivity will lower the efficiency of the film within the condenser and thus reduce its action as a condenser. When in such a condition its leakage current is quite high and its resistance is quite low. The best move in such cases is to pull the chassis and disconnect one lead of the electrolytic condensers during the resistance test.

Fortunately such occasions are few and far between, because the majority of service calls are made shortly after the receiver or amplifier has ceased to function perfectly and the condensers are in good shape.

CONTACT RESISTANCE.

One of the problems experienced with low resistance measurements is that of contact resistance. It is possible that the resistance between the ohmmeter prods and the terminals contacted may be greater than the resistance to be measured. If the ohmmeter has a voltage compensator, there is a means of overcoming the effects of contact resistance. Proceed as shown in figure 86. Imagine that you are checking the secondary of an output transformer and the resistance is very low. Select either connection to the transformer winding and short the prods across this connection. Make a good contact between the prods and the transformer terminal. Now adjust the voltage compensator upon the ohmmeter until the instrument shows zero resistance. This will automatically compensate for the resistance of the leads as well as the contact. Then employ the ohmmeter in regular fashion across the transformer and the resistance indication will be that of the transformer winding. The contact re-

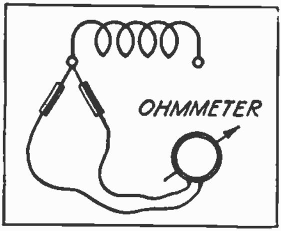


Fig. 86. Compensating for the contact resistance

sistance of the two terminals was taken into consideration when the two test prods were shorted across one of the transformer terminals.

If the instrument is not equipped with a voltage compensator, then it will be necessary to short the leads at one of the contacts and note the resistance indication. Make the regular tests and deduct the resistance shown when the prods were shorted from the value indicated when the ohmmeter is connected across the winding. Such precautions need not be exercised when checking high resistance, since the ohmic value of the connecting leads is infinitesimal in comparison with a high resistance.

Carbon Resistors.

There are certain definite peculiarities attributed to carbon resistors. Due to the nature of the unit, that is the fact that it is heterogeneous, namely that it consists of a number of individual units, infinitesimally small pieces of carbon, making microphonic contact with each other, the flow of current through the material causes an expansion and a variation of the resistance at the contacts between the various carbon particles. This change results in a variation of the resistance of the unit. The extent of this variation depends upon the structure of the unit and the amount of current flowing through it.

This item is given a great deal of thought when the resistors are manufactured and rated. However, you in the field are not equipped to apply various voltages to different values of resistance, so as to keep the variation due to the reason previously mentioned at a minimum. Consequently, all you can do is to bear in mind that such deviations from normal rating are possible, and therefore you must be careful not to overload the unit during the resistance test. Keep the current flow through the carbon resistor at an absolute minimum as limited by the apparatus you have at hand.

Fortunately, the amount of variation due to the causes set forth, is not very great being from 1 to about 3 percent in bad cases. But, this variation when added to the normal tolerance, may produce a result which will exceed the tolerance value and you must recognize this fact.

This condition is not native only to resistance measurement method of analysis. If you operated with a voltage test and were later called upon, as a routine procedure to make a resistance test, the same condition would prevail.

Accuracy Of Readings.

It is quite natural that you make every effort to read the meter indications accurately, but there are times when you can be a bit lenient. When working with transformer windings, such as r-f and i-f, which usually run less than 150 ohms, it is best to make an accurate measurement, that is make an accurate reading. This is so because the tolerance is very close. While it is true that these units are checked for inductance during the time of production, the inductance tolerance is held to such close limits that the resistance variation is minute.

As far as resistors are concerned, with the exception of those used in filament circuits as filament control units, there is no reason to determine the exact value to the last significant figure. In resistors of from 100-1,000 ohms, the last significant figure is of little importance. Between 1,000 and 10,000 ohms, the last two significant figures are of little importance. Between 10,000 and 100,000 ohms, the last three significant figures mean very little because of the tolerance. These statements are not made with the idea of encouraging laxity in measurements, but the truth is the truth. As far as the function of the unit is concerned, the operation is not influenced by because of a variation of 10 ohms in 1,000.

METALLIZED RESISTORS.

According to advice received from the manufacturers of such units, this type is not afflicted with what is known as "voltage co-efficient," so that it is possible to check the resistance of such units at any value of voltage, providing that it is not in excess of the rating of the resistor. This is the same as saying that it can be checked at any value of current, providing that it is not in excess of the value determined by the wattage rating of the unit.

WIRE-WOUND RESISTORS.

Wire-wound resistors can be checked at any voltage, providing that the current through the resistor does not exceed that allowed by the wattage rating.

CHAPTER VIII

WORKING THROUGH THE SOCKETS

THERE are two ways of contacting the various units joined to the tube socket terminals and thus enable measurement of the resistance between these points. One of these is to employ two long probes attached to the ohmmeter. One of these probes may also be connected to a clip for convenient connection to the chassis. The probes then are placed into the various tube socket holes. By switching the location of the probes it is possible to cover the various circuits connected to the tube sockets.

This method of operation has certain definite disadvantages. The first of these is that it is necessary that the socket holes be visible during operation. In certain instances, this is impossible for several reasons. First the socket may be within a shield. Second, the socket may be located in some recess of the receiver, where sufficient light does not penetrate unless the chassis is removed. In order to allow switching of the ohmmeter probes to cover the various circuits, one must be absolutely certain of selecting the correct socket holes. A try and miss system is useless. The time required to check and recheck is very valuable.

If the chassis is removed from the cabinet, then the probing system is very satisfactory, but even then both hands are busy making contacts and there are times when the resistance must be checked during the manipulation of volume control. Also, changing the range of the ohmmeter requires a free hand.

A far more satisfactory method is the use of a plug-cable system, identical to that used for voltage tests. The difference is found in the special arrangement used for the load socket. An idea of what we have in mind is illustrated in figure 87. The load sockets may be of the five- or six-prong type. In view of the fact that this unit was designed prior to the advent of the six-prong tube, five-prong load sockets are shown. You will note that the sockets are identical to the conventional kind. The major difference between this and the ordinary load arrangement, is that each of the load socket terminals makes contact with an external pin jack.

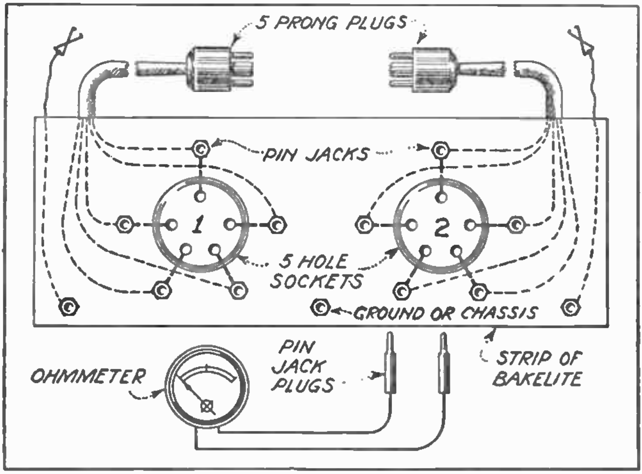


Fig. 87. An example of load socket arrangement whereby it is possible to contact the tube circuits for resistance measurement. Suitable adaptors are used

If a tube is to be plugged into the load socket, it can be done in the ordinary manner. With the tube in the socket, it is possible to check the voltage across whatever elements are desired by simply plugging the voltmeter into the proper pin jacks connected to those circuits.

When resistance is to be measured, there is no occasion for plugging the tube into the socket. The ohmmeter then is plugged into whatever pin jacks connect across the circuits desired.

Now, according to previous statements, one would expect at least one four-prong load socket, the one associated with the rectifier tube. Connection and use of this tube can be arranged with either one of the five-prong load sockets by the use of a 5-4 adapter for the plug and another 5-4 adapter for the socket.

The reason for the use of two five-prong plugs and sockets is to enable the checking of units connected with two tubes other than the rectifier in the receiver or amplifier. You no doubt realize that it is a simple matter to adapt a five-prong plug and socket to a four-prong system, whereas it is somewhat difficult to adapt a four-prong plug and cable to a five-prong system without shorting one circuit. We are not allowed to short any circuits in this manner, because we may want to test the resistance between those circuits. By working from 5-4, we are not called upon to short any part of the receiver system.

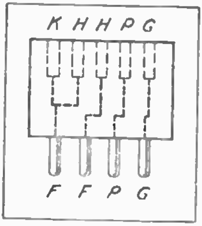
Obviously, access to the sockets in the receiver is no more difficult in this manner as in the conventional voltage-measurement circuits. The plugs are of the standard style and standard length. The use of two plugs offers certain advantages, but it is possible to operate with one plug only. With one plug, it is inserted into the required socket, depending upon the circuit to be checked and one lead of the ohmmeter is connected to the chassis. The other lead or probe from the ohmmeter is inserted into the correct pin jack.

Because of the plug-cable arrangement, there is no fear of connecting the ohmmeter to the wrong circuit. Operating from the load socket, we are not concerned with how much or little light is available upon the chassis. It is a simple matter to locate the tester in the most convenient position required to allow most rapid operation. Because of the plug-cable-socket system, you have the means of checking resistance or voltage as you desire.

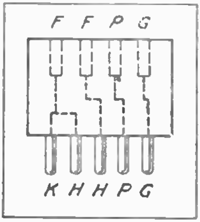
The system shown is quite elementary in contrast to what can be done with a series of switches. Each of the load socket terminals can be connected to a contact upon a rotary switch. The ohmmeter can be joined to the two blades of these switches, and thus connected between whatever terminals are desired. Both of these switch blades can be connected to ground via a push-button, so that only one switch must be manipulated when working between the chassis or ground and the various tube socket terminals. In this way, the arrangement of the system is identical in convenience to that offered by some voltage measuring testers.

A separate lead and clip is provided for contact with the control grid circuit clip when testing screen grid systems. This lead terminates in a separate pin jack. When a standard type of tube is tested, the external control grid lead is ignored and the test made via the control-grid terminal upon the load socket. These load sockets when utilized with the plug connectors represent the tube sockets in the receiver. Whatever tests would be made through the direct contact with the sockets in the receiver can be made through the load sockets. The leads used in the cable have very low resistance, so as not to introduce appreciable resistance into the measuring system.

The transposition of the circuits when four-prong adapters are used with the five-prong plugs is shown in figure 88. The cathode lead of the five-prong plug is joined to one of the heaters. Since there is no cathode in a four-prong tube circuit, this link is of no importance. The major fact is that the plate and grid of the five-prong plug are correctly connected to the plate and grid prongs of the four-prong plug. In turn the heater leads from the five-prong plug are joined to what normally are the filament prongs of the four-prong plug. The 5-4 adapter for the load socket is shown in figure 89. What was said in connection with the plug adapter is true in the case of the socket adapter. As a matter of fact, the socket adapter is required only when a tube is to be inserted into the load socket. If such is not to be done, then the contacts are made with the regular pin jacks, bearing in mind that the heater terminals become the filament terminals and the plate goes to plate and the normal control grid goes to control grid. These facts can be comprehended by studying the two adapter arrangements. In view of the fact that the modern tubes are of the six-prong variety, it is best if the load sockets are of the six-prong variety and the adapters used are 6-4 and 6-5 as required.



Left, Fig. 88. 5-4 adaptor



Right, Fig. 89. 4-5 adaptor

By arranging two separate leads from the ohmmeter, rather than permanently fastening one of them to the ground or chassis jack, the necessity for polarity reversal requires nothing more than switching of the positions of the ohmmeter probes between the two same contacts. Let us apply this unit to a part of a receiver.

The wiring diagram in figure 90 illustrates the tube sockets according to the normal position of the elements when viewed from the top of the socket. This is the same as used for the load sockets. Suppose that we check the circuits connected to ground. Plug 1 is inserted into tube socket 1. One ohmmeter lead is inserted into the chassis or ground pin jack. The other ohmmeter probe is inserted into the control grid pin jack to check L for resistance and also C for a short circuit. The free test probe, if we may call it that, is inserted into the cathode pin jack to check R and R1, at the same time C1 for a short circuit.

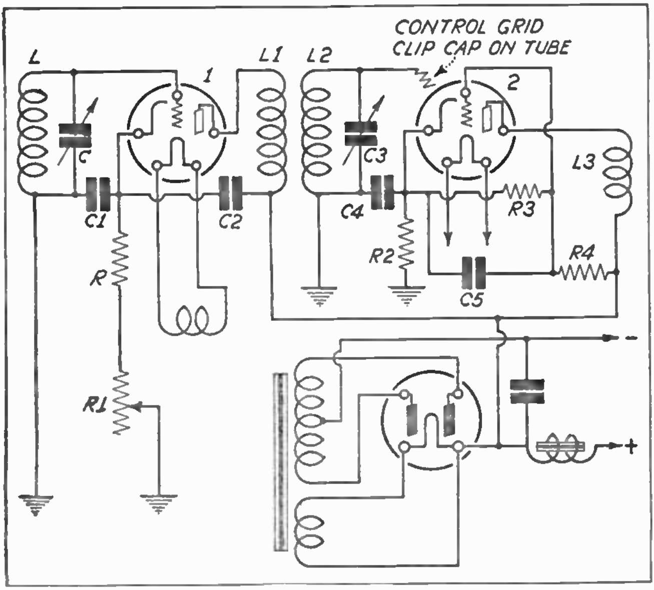


Fig. 90. Illustrating the method of contacting the tube element circuits through the load sockets and plugs

If we wish to simultaneously check the plate and screen circuits, a 5-4 adapter is attached to plug 2 and it is inserted into the rectifier socket. The grounded test probe is removed from the ground pin jack and inserted into either heater pin jack upon load socket 2. The other test probe then is inserted into the plate pin jack for load socket 1 to check the resistance of inductance L1.

The condenser C2 can be checked by means of the oscillator tester by connecting the condenser tester probes to the plate and cathode terminals upon load socket 1. C1 can be checked by connecting the condenser tester probes between the ground pin jack and the cathode pin jack. Condenser C can be checked by connecting the condenser tester probes between the chassis pin jack and the control grid pin jack.

Suppose that plug 2 in its original form (5 prong) is inserted into the socket of receiver tube number 2. At the same time plug 1 remains in tube socket number 1. We now can reach every part of tube 1 and tube 2. The control grid pin jack is connected to the control grid clip of tube 2. With one test probe in the chassis pin jack, we can check L2 by placing the free test probe into the control grid (2) pin jack. To check R2, the free probe is placed into the cathode pin jack. To check R3, we can do either of two things. Place the free test probe into the screen grid pin jack, and thus consider R2 and R3 in series, or move the test probe from the chassis pin jack and insert it into the cathode pin jack and place the free test probe into the screen grid pin jack. The latter arrangement isolates resistor R3 and it alone is measured. This move also gives us a short circuit test upon C5. To test R4, we must work in series with L3, unless we wish to move plug 1 into the rectifier socket. Let us say that we do not wish to make this move. The test probe now in the cathode pin jack is moved to the plate pin jack and we test R3 in series with L3. To check L3, we can work to the rectifier filament or, if so desired combine it with L1 and measure between the plate of tube 1 and the plate of tube 2. The test probe now in the screen grid pin jack is moved to the plate pin jack of load socket 1, thus advising the total resistance of L1 and L3 in series. Both of these windings can be isolated by working between the respective plates and the rectifier filament.

There is no necessity for further explanation of the application of this type of tester. The various plugs are moved from socket to socket as desired and the actual motions of testing are governed by the application of either plan as outlined in a preceding chapter.

As to the application of the condenser tester, the simple instructions given earlier in this chapter, will no doubt suffice.

The time has arrived to apply resistance measurement to the actual servicing of a receiver. This detail is the subject of the next chapter.

CHAPTER IX

SERVICING RECEIVERS BY MEANS OF RESISTANCE MEASUREMENT

AS stated in the introduction to this book, this system is predicated upon a certain method of operation. One of these is that the tubes be tested separately from the receiver, irrespective of its type and be the first test made upon that installation.

We also made the statement that resistance measurement method of analysis does not wholly supplant voltage measurement. However, we minimize the number of times when such tests should be made. These follow.

LINE VOLTAGE.

A line voltage test is required in every a-c or d-c installation. This is necessary in order to enable correct adjustment of the power transformer primary circuit in the event that some sort of a fixed compensating device is used. Also to assure the correct setting of the power transformer primary tap or the resistance tap in d-c systems. In some cases it will indicate the need for a fixed voltage-reducing resistor or for the incorporation of a ballast.

And last but by far not the least, because it assures that the correct line voltage is being applied to the transformer, which information is of definite value in judging whether or not the filament and rectifier winding voltages are normal. In the case of d-c receivers, the line voltage is of great importance, because it serves as a guide of whether or not the correct voltages are being applied to the tubes, when the resistance of the various circuits has been checked and found correct.

BATTERY VOLTAGES.

Battery voltages must be checked, whenever batteries are used. This applies strictly to battery receivers as well as d-c receivers. Quite a few of the latter employ batteries to supply the control-grid bias voltages. It is understood, however, that these tests are applied to the batteries and not to the complete circuit inclusive of the tubes.

OPERATING VOLTAGES.

There are many who feel that a routine voltage test should be the final test of a receiver. With this we do not agree. Irrespective of the type of receiver, a complete resistance and condenser test will indicate the condition of the circuit components. If these are perfect and the tubes used in the receiver are perfect, the final test is one of receiver performance. Of course, all batteries have been checked and if perfect, one takes for granted that the connections to the batteries have not developed defects since the test. We of course designate that the resistance or continuity test of the receiver components include the battery leads, from the battery terminals through the terminal board, to the respective tube elements.

FILAMENT VOLTAGES IN A-C RECEIVERS.

We do recognize the need for filament voltage tests in a-c receivers. In view of the very low resistance of the various filament windings, it would be somewhat difficult to check the condition of the winding, for the simple reason that modern test apparatus in use by the service industry are not capable of accurate measurements of d-c resistance less than perhaps .1 ohm. In this connection we are concerned solely with the filament winding because all other resistors, such as filament shunt units and bias resistors are checked during the routine resistance test.

The best that one can expect when checking the filament transformer windings through the sockets, is an indication of very low resistance. For that matter, the same indication will be had when working on the chassis. Because of the normal low resistance, it is better to check the voltage. There are two possible times when this voltage can be checked. One of these is when the chassis is first inspected. The other, after the tubes have been removed, inclusive of the rectifier. The latter is preferred, because it removes all possibility of damage to the tubes in the event of some trouble. There is a choice of checking the voltage at one socket and then checking continuity to the rest and checking the voltage at the filament or heater terminals of all sockets. It is entirely optional. Whichever system is used, you must remember that the no-load voltage of the power transformer will be higher than the voltage under load, that is when the filaments or heaters are connected to the transformer winding.

RECTIFIER ANODE VOLTAGES.

Measurement of the rectifier anode winding voltage serves a definite purpose. If we check this voltage and know it to be normal, find that the rectifier tube is good, and the various circuit resistances are found to be correct, we are practically assured of correct operating voltages upon the various tubes. This method of operation when properly carried out relieves all need for supplementary voltage tests after the defect has been remedied.

LINE VOLTAGE BALLASTS.

The line voltage ballasts referred to are those of the variable voltage drop type, which automatically keep the voltage at the power transformer primary at a predetermined value. An example of these is the Amperite. Another is the Duresite. Under normal conditions these units either function or are open circuited, that is the thermal element is open. The best method of determining if the unit is functioning is to check the voltage at the lower supply line plug and across the transformer primary. If an a-c ammeter is available, it can be inserted in series with the primary circuit. Continuity through the unit will be shown by current.

The two types of automatic ballasts named function normally without an incandescent state of the thermal element. In some instances, the element glows dull red. As far as the Amperite is concerned, a degree of brilliancy greater than dull red glow indicates an overload.

To check the voltage control action of the device, it is necessary that the full load be applied to the power transformer secondary windings. Then the voltage at the power supply base plug and the power transformer is determined. With full load applied, the line voltage should be greater than the voltage across the primary. The only real purpose of this test is to indicate whether or not a ballast which is not incandescent, is connected into the circuit and is not shorted. It is said that these units either work normally or burn out. The end of useful operating life is burnout of the thermal element.

GENERAL SERVICE CONSIDERATIONS.

There are certain fundamental types of troubles which have no bearing upon the resistance between points in a receiver, consequently no effect upon the voltage between points. If it were possible to definitely establish that the defect existing is of this type, much time would be saved. Unfortunately—and it really is unfortunate, this cannot be done for the simple reason that numerous flaws in a radio receiver will be productive of a similar symptom. In other words, excessive regeneration in a radio receiver may be due equally often to any one of the following:

a. Excessive operating voltages
b. Imperfect neutralization
c. Excessive signal strength
d. Poor ground or shield connections
e. Placement of aerial, grid or plate leads
f. Open bypass condensers
g. Unsuited tubes

Excessive Regeneration.

A few of these items can be checked without either resistance or voltage tests. The balance require work of major type upon the chassis. After due consideration of all factors involved and very close observation of service procedure in large and small plants, we have come to the conclusion to definitely make the recommendation that all those service operations which require major work upon the chassis should follow resistance measurement. Prior to transfer of attention from voltage measurement to resistance measurement, it would have been quite natural to say, make voltage test the first test. On the same grounds, we say make the resistance test. As a matter of fact, we even go beyond that and say, make the condenser test.

Very likely, some of you who read these lines may think that this is an unnecessary waste of time. Think twice before you render a definite decision. There have been innumerable examples of receivers which were classed as having been repaired which were definitely inferior to the same receiver prior to the development of the defect. In other words, the proper repair was not made.

A neutralizing condenser adjustment may compensate for the effects of a shorted or open resistor, which does not materially influence the voltage, assuming that a voltage test is made. A similar neutralizing condenser adjustment may compensate for an open bypass condenser which will not influence operating voltage, assuming that such a test, or even a resistance test without a condenser test is made. However, the amount of neutralization required to compensate for such deficiencies may be enough to greatly reduce the sensitivity of the receiver. Conditions of this type have been reported on very many occasions. There are other instances of where all attempt to neutralize a receiver failed and resulted in a badly messed job, because no effort was made to check for an open bypass condenser and even neutralizing condenser.

Make every effort to definitely establish that the trouble is due to incorrect adjustment of the neutralizing condensers (when used) before you start reneutralizing a receiver. Bear in mind that if the trouble is elsewhere and you accomplish partial remedy, that the other defect must also be remedied and, after that remedy has been effected, it is necessary to again reneutralize the receiver. Thus in the long run, you will lose more time and gain time, by immediately starting to reneutralize a receiver.

We realize that it is a difficult matter to unsell you upon the idea of making resistance, rather than voltage measurement tests. However, whichever you use, pay attention to condensers as well and check them wherever possible. The greatest complaint voiced in the radio industry today—and for a long time past—has been constant and intermittent opens in condensers of various kinds. Don't tamper with adjustments of trimmers, neutralizing condensers or tuning condensers, until you have made certain that the fault is definitely established as being in that part of the receiver. The process of neutralization is explained in Appendix 3.

There are times when replacement of tubes requires reneutralization. Even in such cases, try to avoid such operation. Try interchanging tubes before you vary the neutralizing adjustment screws. When you do, work slowly. Radical changes in the adjustment of neutralizing condensers will not be required. The possible differences between two sets of tubes of like, or even unlike, but reputable manufacture will not be very great. You may find that a slight adjustment upon one neutralizing condenser will solve the trouble.

Bear in mind the possible things which will cause excessive regeneration in a receiver which heretofore has been operating in perfect shape and in which the tubes have not been changed. Do not take for granted that the neutralizing condensers are out of adjustment. It is better if you do the reverse. Consider these condensers as innocent until they are proved guilty.

LOW VOLUME.

You are no doubt aware of the greater number of conditions which will cause a symptom of this type. One failing of the service industry and we shall speak truthfully, is that too much attention is paid to alignment and trimmers. There are a myriad of other reasons. Leave the trimmers alone until you know definitely that everything else in that receiver is in perfect shape. The tubes being checked separately are considered separately. Before starting alignment procedure, unless you know definitely that the trouble is of that nature, due perhaps to new tubes, check the resistance of the various circuits and check the condensers. You will be able to discover fully 90 percent of all troubles due to open or shorted resistors, open or shorted windings, and open or shorted condensers by working through the chassis.

If you consider the symptom of "low volume" as a single condition, the number of defects of other than tracking or alignment, so greatly outnumber the number of tracking or alignment troubles, that there is every reason for the resistance and condenser test to precede the alignment test.

This may be sacrilege to give such brief mention to what is considered such a momentous problem. With one possible exception, which shall be named later, we are firm in the belief that not over 25 percent of all the alignment adjustments made are really required. However, once made, there is frequent occasion for further adjustments.

We do not mean to say that alignment troubles do not present themselves. They are numerous, considering 16,000,000 radio receivers in the field. But—and again we reiterate, do not make alignment adjustments until you have checked the tubes, resistors, condensers and windings in the receiver. If you are positive that the trouble at hand is some sort of alignment disorder, then proceed to correct the difficulty. If not, prove that it is before you tamper with the adjustments.

Our reasons for making such statements are not difficult to comprehend. They are made upon basic grounds. It has been impossible to interview all service men who are running service establishments. In the same manner it has been impossible to interview every radio service manager employed by large dealers, distributors and receiver manufacturers. However, the men consulted have definitely established the fact that imperfect tracking or alignment is not the frequent complaint one normally imagines.

Certain references have been made to types of alignment troubles which are more frequent then others. Fortunately, these are easily distinguished and it is unnecessary to make resistance and condenser tests before remedying the alignment trouble. We are referring to type '27 tubes as oscillators in superheterodynes. The use of one brand of tube for alignment in the manufacturing plant and the use of another brand of tube in the receiver frequently results in a frequency shift upon the low wavelength end of the dial. In this respect we have noted from 25 to 40 kc. variation upon the high frequency end of the dial. Generally speaking this is due to a variation in tube characteristics and interelectrode capacity.

In tuned radio-frequency receivers or in the radio-frequency end of superheterodyne receivers, such troubles are as a rule limited to the high-frequency end of the tuning spectrum.

Because of satisfactory operation upon the high-wave portion of the dial and poor operation upon the lower wave portion of the dial, one is given evidence of the type of trouble at hand. In such instances, recognitions of the symptoms and consideration of the effects of other forms of troubles, such as would be caused by open condensers, shorted resistors or windings, one has proof that the trouble is incorrect alignment.

As far as the superheterodyne problem is concerned, the most feasible step is to attempt to prove in a simple manner that the oscillator system does not track. This is accomplished by the use of an r-f unmodulated oscillator utilized in conjunction with a search coil. The search coil consists of a winding of from 15 to 20 turns of such diameter as to fit over the first detector tube. The search coil is connected to the oscillator output by means of a shielded lead. The local oscillator tube in the receiver is removed. If you desire to maintain a uniform load upon the receiver with this tube removed, connect a 20,000-ohm resistor between the cathode and plate of type '27 oscillator tube sockets. No load is required when screen grid type oscillator tubes are removed. If the receiver employs a combination oscillator and first detector tube, you naturally cannot remove this tube.

The search coil is placed atop the 1st detector tube and the external oscillator is tuned to the proper beating frequency. The signal from the search coil is passed into the 1st detector circuit through induction through the glass housing and possibly through other forms of inductive coupling. By properly manipulating the tuning of the external oscillator it is possible to simulate the local oscillator and thus determine whether or not the receiver oscillator is at fault.

The system is checked in the following manner. Select a known broadcasting station and adjust the receiver tuning dial to the known carrier frequency of this station. Now adjust the tuning of the external oscillator to a frequency equal to that of the broadcast station plus the intermediate frequency of the receiver. In other words if the receiver is peaked at 175 kc. and the broadcast station is operating upon 1,050 kc., adjust the external oscillator to 1,225 kc. If the receiver tuning dial is properly calibrated and the r-f circuits in the receiver are right, and the external oscillator is properly calibrated, the 1,050-kc. broadcast station will be heard in the receiver.

A similar test can be made upon that portion of the tuning scale, where the receiver oscillator appears to be out of alignment. If normal operation is secured with the external oscillator, it is clear evidence that the receiver oscillator is at fault.

All of this has very little to do with resistance measurement, but there are certain other considerations outside of resistance or condenser measurement. When the evidence points to a form of trouble as outlined, alignment can be tried. If not successful, then it is time to investigate the condensers in the circuit. It is also necessary to check the resistors for the simple reason that a defective unit in the plate or screen or cathode circuit may not interfere with the operation of the oscillator as an oscillator upon the higher wavelengths, but may cause lack of operation upon the lower wavelength part of the oscillator frequency spectrum.

No doubt you realize the many possible reasons for low volume other than alignment. For all of these resistance and condenser tests are required and these should be the first made. The application of these tests is as outlined in connection with point-to-point measurement in a preceding paragraph. There have been numerous attempts, and the writer is also numbered in that group, to diagnose troubles by aural observation. Some of the attempts were successful and others were dismal failures. In days gone by, when receivers were simple, such tests were accompanied by a chance of success. Not so with modern receivers. For that matter not so with receivers produced during the last three or four years. There are entirely too many defects which will cause the same reaction.

Isolation of circuits to check a point, is satisfactory in certain instances, but modern receiver design has made it quite inconvenient to generally apply such isolation tactics. Investigation has definitely disclosed that more time is lost than gained, although there are times when mental diagnosis and isolation are applicable.

Once again, we must mention that mental diagnosis is possible only when the character of the symptom is such as to definitely isolate the trouble as being in one part of the receiver. Such troubles are tuning troubles, which appear across a certain portion of the dial and are absent over the remainder. In such instances it is possible to eliminate the audio frequency amplifier and the power pack as probable points of fault.

It is also possible to isolate the a-f from the balance of the receiver, by feeding an i-f signal into the second detector of a superheterodyne or a modulated r-f signal into the detector of a conventional t-r-f receiver. The desire to carry out such isolation tests depends entirely upon the conditions met in service. We assume that such tests are made prior to a detailed voltage investigation, for if the latter is made first, we cannot refrain from repeating that a resistance and condenser test should come first.

There have been attempts to segregate troubles in r-f amplifiers, sometimes related to distortion and excessive regeneration, into open condenser systems in plate, cathode and screen grid circuits. The system does not work. This statement is the result of actual experience on the part of the writer and experience of many others. True that it is possible to distinguish between excessive regeneration in the r-f, detector or i-f systems and the a-f system, but isolation of the trouble by listening to the character of the audible sounds is virtually impossible. To say that one type of audio sound is due to an open r-f plate bypass condenser and that another is due to an open cathode or screen grid bypass condenser is groping in the dark, possibly based upon one or two coincidental experiences, which may not be repeated for many moons to come.

It is far better to recommend a routine test of all condensers, starting from a certain point and working towards the other end of the receiver. One thing is certain in radio receiver service. It may appear difficult upon the surface because of past methods of operation. Routine testing should be carried out in every case. It must be systematic to achieve its end. Chaotic and haphazard operation may be productive in a few isolated instances, but it is far from productive over a long period of time.

BREAK-IN SYSTEMS.

Low volume, distorted or otherwise, may be due to a defect in the first r-f stage just as readily as in the speaker. Which of these is to be checked first? Isolation of the r-f and detector by means of a plate break-in adaptor and head phones, may indicate that the trouble is in the system ahead of the detector or it may indicate that the trouble is in the system following the detector. Some time can be saved in this manner, but it is not often practical to break into the detector plate circuit. When it can be done, it is helpful. When it cannot be done, there is nothing else left but a routine resistance test starting with the aerial system and working right back to the speaker.

The break-in unit is nothing more than a plate circuit break-in adaptor which is inserted into the detector circuit, and a pair of headphones are connected into the system. In connection with this type of apparatus, several precautions must be exercised. The first is that the rectified r-f current must be bypassed around the plate-coupling unit. A high value of capacity is required for this work and should be connected between the low end of the headphones and the chassis. The second is the danger of a shock, when a high plate voltage is being applied to the detector tube. This consideration taboos the idea in power detectors, unless a phone transformer is used. The third is that the a-c voltage developed across the phones may be small, particularly in resistance-coupled systems; consequently, it may be difficult to judge by what is heard in the phones. The fourth is that combination detectors and automatic volume control units cannot be used in this fashion. What with this and that complication, the complete resistance and condenser test remains the favorite.

DEAD RECEIVERS.

When the receiver is dead, there is no better test than complete resistance measurement and condenser test in all circuits. Of course you are called upon to employ your radio knowledge, with respect to the condition of the tubes in that receiver. There is no doubt about the fact that if you notice that none of the tube heaters or filaments are incandescent, inclusive of the rectifier, that you will check the basic source of this voltage, the power line and the primary of the power transformer before starting a routine resistance measurement.

At the same time, you cannot help but employ that simple finger tapping test upon the detector tube, when all of the tubes light in normal fashion, yet there is no sound from the speaker. Tapping the detector tube should produce a sound in the speaker. Mind you, we say should. There is nothing to guarantee, that with a perfect amplifier and a rigidly constructed detector tube, such sounds will be heard. At the same time, you cannot consider the lack of speaker sound output to definitely indicate that the a-f system is dead. All of which amounts to the statement, that such elementary tests are not practical with modern receivers and modern tube construction.

We are making no effort to play the role of one who tries to contradict every existing tradition. Neither are we trying to paint a picture of service work as a highly technical operation. Nothing can be simpler than a simple resistance test, for that is as elementary as the series and parallel and series-parallel circuits you learned during your early radio training days and contact with Ohm's law. There has been a total disregard for the service problems which are actually existent. We have been accustomed to a listing of various types of defects represented by certain symptoms. Such listings are obsolete today for the simple reason that to check every one of the items mentioned is the equivalent of a routine test upon the receiver.

It is possible that the first named item was the cause and the value of such a list increases in proportion. But it is also possible that the item at fault was the last upon the list and would have been discovered shortly after the routine test was started. Six of one and a half dozen of the other—at least in appearance—yet the routine resistance and condenser tests are to be preferred because they mean systematic operation.

It is also true that there are two isolated parts of a radio receiver which may contribute to the dead condition and which can be checked before a routine test is made, without interfering with systematic operation. We refer to the aerial system and the speaker voice coil and output transformer secondary circuits.

GENERAL TROUBLES.

We are interested in the general acceptance of point-to-point resistance measurement as the basis for service analysis on the grounds that it is of value to the service industry at large. Service men there are many thousands. Operating systems there are many thousands, yet we cannot help but note that while the mode of operation enables a profit upon a certain service job, that same mode of operation becomes very costly upon other jobs. Many believe that every radio receiver service call is a distinctly different and separate study. Basically that is not so. Actually, it appears so. The discrepancy between the two is found in the fact that the general types of troubles which have been exploited do not represent a fair portion of the actual troubles which may be encountered in a receiver. When the service analysis is predicated upon certain popular forms of defects and these defects do not materialize the problem immediately becomes complex.

There is no doubt about the fact that modern radio receiver design is far more complex than in years gone by. There is absolutely no doubt about the fact that the present-day service man cannot profitably operate upon a receiver unless he knows what is inside of that job. This information is in the form of wiring diagrams. Such diagrams are essential upon the job. He must have electrical values for checking the circuits. This type of data is imperative. With this information at hand and general knowledge concerning types of troubles, plus a certain amount of analytical power, any type of defect in a radio receiver can be found within a profitable amount of time.

Here are a few examples of actual troubles in receivers which seldom receive attention and are finally discovered because there is nothing else left.

1. Open coupling condensers in r-f and a-f amplifiers. In some instances these condensers are known as blocking condensers. The capacities are very small.

2. Loose single turn coupling windings in r-f transformers. They cause wavering and fluttering, often referred to as fading.

3. Intermittent opens in a-f blocking condensers. The condenser open circuits and the volume drops. The switch is turned on and off and the volume increases to normal.

4. Poor connection between the rotor of the tuning condenser and its grounded contact maybe the shaft.

5. Short circuit between the control-grid clip of screen grid tubes and the tube shield.

6. Plate lead of r-f and i-f transformer shorted to shield can because of frayed insulation.

7. Leakage path between cathode and control grid of detector tubes, on the socket.

8. Waveband switches in short-wave convertors.

9. Trimmer condenser base impregnated by moisture.

10. Worn adjusting screw thread.

11. Oscillator drift. Particularly when '27 type tube is used and line voltage variation is excessive.

12. Incorrectly poled field coils. This will cause hum.

13. Open hum filter neutralizing circuits. Used in some receivers.

14. Parasitic oscillations in superheterodyne oscillator. Will cause a continuous whistle.

Now, all of these troubles are not necessarily discoverable by means of resistance measurement, but we have found that those items related to poor contacts are detectable by measurement of the resistance between the two nearest points across the elements which are supposed to be in contact with each other. The items related to condensers are checked by means of the condenser test.

The remainder of the special items listed are to be checked separately after a routine resistance and condenser test has shown everything to be perfect. In very many cases, the various tests cannot be made by working through the sockets. However, if the nature of the trouble is such that it cannot be discovered by working through the sockets and special tests are required, it is quite in order to operate with the chassis removed, because removal of the chassis is required to effect the repair.

There are numerous types of troubles which are in a way associated with a current test. In other words, current tests have been employed in the past to indicate the presence of the fault. Shorted output transformer secondaries are common faults. The usual method of detecting such shorts, when across the winding or in the voice coil and a resistance test is not made, is to insert a current meter into the output tube plate circuit and look for radical fluctuations during the passage of the signal. The arrangement works well, but since it is necessary to check the voice coil and output transformer windings for a short circuit, there is no need for the original current test.

TESTING APPARATUS.

Although we have not dealt at great length with test equipment other than the ohmmeter, the condenser meter and the tube checker, we have made mention of a combination r-f and i-f oscillator and the output meter. We have also shown the need for an a-c voltmeter and for a d-c voltmeter. If we add to this the use of a d-c current meter for leakage tests upon electrolytic condensers, the sum total of the apparatus about equals what is common practice today. The only difference between the equipment we have outlined and that to be found in modern service apparatus, is the condenser tester. This means that a great deal of the apparatus in use today can be utilized in connection with our conception of radio receiver service work. For that matter, we can even visualize the present set analyzer or set tester equipped with the proper type of ohmmeter, with respect to range, applied to resistance measurement method of service analysis by probing through the sockets with the ohmmeter test prods. Naturally, this method is far more difficult than if the load socket arrangement is like that described in figure 87.

We in no way dispense with oscillators or output meters. They have their usual functions. It is simply a matter of the time when they are applied. Thus, whatever data you have covering the application of such devices it is applicable in every respect providing that you recognize the correct time to apply those units.

It is virtually impossible to list every trouble likely to occur in a radio receiver. Every single unit may develop a defect and every single joint may develop a defect. The same is true of every single length of wire. Add to this the possibilities of incorrect alignment and you have a fair picture of what is to be expected. There is no doubt about the fact that a knowledge of radio is required in order to service a radio receiver. There are certain peculiarities associated with each type of circuit and each type of receiver. These cannot be described because they differ in a myriad ways. It is impossible for any one individual to list the vagaries of radio installations. All we can hope to do is to suggest a systematic method of testing and then leave the remainder of the problems for individual solution. Fortunately, these individual problems are not very numerous after the systematic test has been applied.

One of the greatest examples of the value of systematic testing is found in the instance where the final conclusion points to the use of incorrect apparatus on the part of the radio receiver manufacturer. Examples of such instances are few and far between, but it is these examples which prove the point. We have record of three instances. In the first, the complaint was rapid breakdown of the output tubes. Time and again, it was necessary to replace the output tubes after about two or three months of use.

The receiver possessed excellent operating characteristics. The power output and the sensitivity and selectivity were all that one could want. . . . But output tubes went bad after a period of use. Finally an operating voltage test was made. It showed that all of the operating voltages in the receiver were high. Not only those applied to the output tubes, but to all of the grids, plates and screen grids. Only the filament and heater voltages were normal. Such a condition points to an open resistor somewhere in the main voltage supply circuit. A point-to-point test was made according to the electrical values specified upon the diagram. Everything was found to be perfect. The filter chokes were checked and found perfect. The hum level in the receiver was entirely normal. The only conclusion to be reached in this case was that the power transformer originally employed in the receiver was not the correct one for the receiver. No other conclusion was possible because every part of that receiver checked perfectly. The a-c plate voltage was measured and found to be much higher than normal. The transformer was removed from the receiver and it was discovered that it was not the correct one for that system.

Another valuable example is that related to defective operation of the volume control in a screen-grid r-f system. The normal design of the receiver was such that a bleeder current of 3 milliamperes was fed into the cathode bias resistor (also volume control) from the plate voltage supply source, so as to afford satisfactory control of volume at low signal levels, that is, after the volume control has been advanced somewhat for signal reduction. The normal plate current always flowed through the unit. After a period of time, it was noted that the control did not function well at low level adjustments. Voltage check showed no discrepancy. The volume control was replaced with an original model and known to be perfect, yet the same condition prevailed. The old and new units were compared and found perfect in every respect. Plate current was normal.

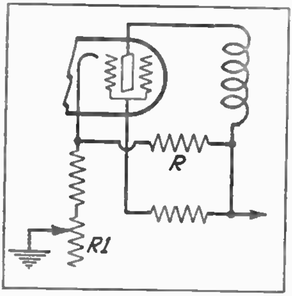


Fig. 91

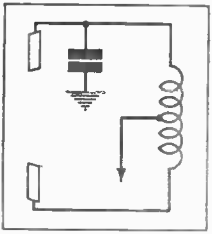


Fig. 92

Examples of conditions which cause peculiar indications

A point-to-point resistance test was made and the bleeder resistance between the plate and tube cathode was found open. The reason for the defective operation of the volume control was the open bleeder. See figure 91. Resistor R is the bleeder unit. Now, this resistor has no connection with the operation of the volume control R1 other than to supply current for that unit. A check from chassis to cathode would show the correct resistance with R open. A check of the voltage between control grid and chassis with the control set at maximum would show a difference when compared with the standard, but because of the normally low value, it would not cause suspicion. Furthermore, suspicion is minimized because the circuit shows normal continuity, the tube is found to be good and the plate current is also found to be normal. The routine resistance test made through the sockets actually indicated the exact unit at fault.

In another instance, a receiver was oscillating. The voltages applied to the tubes were normal. The resistance between points was normal. Every conceivable test was made in the r-f system. The positions of leads were changed without any help. Finally a condenser test was made and the last unit to be checked was a bypass condenser connected between one plate of a push-pull pentode output and the chassis, as shown in figure 92. This was found open circuited. Now, no one would imagine that this condenser when open would cause excessive regeneration, yet the fact remains that it did and it required a systematic condenser test, starting with the r-f tubes and working to the speaker to locate this defect.

SPECIAL CIRCUITS AND WIRING DIAGRAMS.

The majority of radio receivers contain some special unorthodox circuit, or the use of a unit in some unorthodox position. The greater the advance in receiver design, the greater is this probability. To attempt to repair a modern radio receiver without some type of service information, at least a wiring diagram which shows electrical values, or a table of electrical values of resistance between points and the presence of condensers between points, is tackling a difficult job. We do not mean to say that service work requires such information. A receiver can be serviced without such data, but—how long will it take?

A man who is specializing in receivers of a certain brand can familiarize himself with the various peculiarities to be found in the circuits produced by that manufacturer. But the man who is called upon to service any and every type and make of receiver placed before him, must have service information if he is going to do a good job in rapid time and meet competition upon a competitive basis. We speak from actual experience along such lines. We are willing to admit that after 22 years of radio experience at the time of this writing, and engineering education and lengthy experience along service lines, we cannot forsee any and every type of circuit combination possible in the radio receiver design field. How is any one individual, expected to know the type of circuit employed in any one modern receiver? They all look alike from the front of the cabinet and when you gaze down upon the tops of the tubes, but when you must service that receiver, information is essential. A single schematic wiring diagram will tell the story. It may be difficult to locate the respective parts when the chassis is removed from the cabinet but you at least have an idea of what you are seeking.

There has been an aversion to the use of wiring diagrams upon the job. There has been an aversion to the use of data tables upon the job. To maintain any such idea upon the grounds that it would cause apprehension upon the part of the customer is wrong. You may not want to carry a complete file of all diagrams with you because it may be cumbersome. By properly planning your itinerary for the day, and by making an effort to learn the receiver models which you will be expected to service, you can take with you the required amount of service information. If you find use for the diagram in the shop, why not in the customer's home? If you are familiar with the receiver to be serviced, you do not have to refer to the diagram. If, however, you are not familiar with the receiver, you should have service data with you.

The radio receiver manufacturers spend hundreds of thousands of dollars each year for the printing of service manuals which they distribute to their jobbers and dealers. Mind you, this material is mailed to the organizations to specialize in their receivers. These jobbers and dealers come in daily contact with the sets, yet the manufacturers feel that the service literature is valuable. Receiver manufacturers do not spend this money because they have no other outlet for their finances. They realize that the data is essential and you should not be ashamed, in this day of complex receiver circuits, to have service data with you on the job.

At the advent of the a-c receivers, when all receivers were very much alike, there was no need for such data on the job.

If you operate by removing the chassis and taking it back to the shop, shooting the trouble, and then advising the customer as to what it will cost, you do not require service data when visiting the customer's home. However, that is not modern practice. The present-day receiver is far more complicated than in years gone by. You require service information if you are going to operate in the modern manner. The present-day receiver owner desires to know what the receiver will cost to repair before it leaves his home. To be able to give this information, you must analyse the trouble right in the home. To do this in the shortest possible time, you require service information and modern servicing methods.

We could give you innumerable examples of special automatic volume control circuits. Without a diagram you are lost in the effort to distinguish the various components of the circuits. As a matter of fact, it is even difficult to locate which of the tubes is the automatic volume control tube, unless you go to a great deal of trouble, or you have a socket layout. AVC circuits are only one of many intricate combinations, not necessarily intricate with respect to the solution, once you see the circuit on paper, but to know which of the various combinations is being used in that particular system, without any electrical data. It just cannot be done.

We have heard and read various quotations to the effect that a good service man will repair a receiver with no equipment other than a voltmeter, a battery and a pair of head phones. We will grant that the statement is true, but we personally would not have our set repaired upon an hourly basis, with no tools other than those named.

TUBES.

There are certain troubles to be experienced with receivers which are due to the combination of the circuit used and the types of tubes available in quantity production. Gas content in tubes is of major importance. A point-to-point resistance test may show a perfect electrical circuit, yet the receiver does not operate in a correct manner, due to excessive gas content in the tubes. The only solution to this problem is the development of a tube checker which will also show gas content.

An example of such a condition is the pentode output stage, wherein the grid circuit resistance is very high and the tube gas content is high. The circuit is shown in figure 93-A. With certain output tubes, this circuit will produce a buzzing sound, due to the flow of direct current in the grid circuit. When checked for resistance the circuit may show a normal state, yet the trouble will continue. If the tube checker does not contain means for indicating gas content, the trouble will be difficult to locate. In a case such as this a plate current test in the output tube plate circuit will indicate a discrepancy, which may or may not be interpreted to signify that either the tube or the circuit must be changed. Now, there is nothing wrong with the circuit. The reason for the condition produced is that the tube used has an excessive gas content. More than likely a different tube will remove all signs of such trouble.

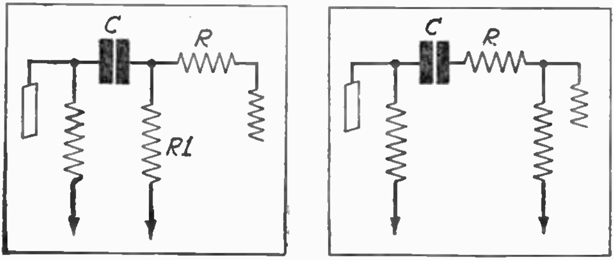


Fig. 93-A

Fig. 93-B

Shifting the position of R from A to B improves operation

Now, it is impossible to state that a voltage test affords an advantage over a resistance test, as far as troubles from bad tubes are concerned. The reason for this is that the circuit usually involved in such difficulties contains a sufficient number of resistors to nullify the use of the voltmeter to indicate a high bias voltage across, say, R and R1 in figure 93-A. The same is true in the case of the automatic volume control tube, which is gassy. The actual condition produced is a high control-grid bias upon the controlled tubes. However, it is difficult to detect this condition by means of a voltage test, for the simple reason that the structure is such that the voltmeter will not indicate the true value. The high resistances present in the circuit act as multipliers.

The small amount of gas needed in an AVC tube to impair its operation is difficult to measure. As far as routine voltage tests are concerned, this is absolutely a fact. Thus we are forced to depend upon inter-changing tubes as a means of ascertaining if the tube is unsuited for use in the AVC position, or upon the design of the separate tube checker.

Referring once more to 93-A, the change recommended by the manufacturers who use this circuit, that is, when trouble of the nature described is encountered, is to alter the position of R, to that shown in figure 93-B or to remove it entirely.

HUM.

To locate the reason for hum in a radio receiver is one of the most difficult problems. At the same time, there exists the possibility of deciding what is wrong by general conditions. However, to be on the safe side, one might do well to remember the following: There are many reasons for hum, but the most prevalent in either d-c or a-c receivers is the open bypass condenser. There are a few special items, as for example incorrectly connected field coils, open hum-neutralizing circuits, close proximity between a-c and grid and plate leads, induction into the speaker circuit and hum due to lack of proper filtering across the a-c power line. In addition, we have defective filter condensers, shorted filter chokes, poor rectifiers and poor tubes.

Of these items, one, possibly two, are detectable by means of resistance measurement. These are the shorted filter choke and the shorted hum bucking coil. For that matter the shorted hum bucking coil, normally used in series with a fixed condenser can be checked by means of the condenser test. The remainder must be sought as individual faults, some by means of the condenser test and others by visual examination of leads, etc. As a matter of fact, a third type of trouble is detectable only by means of resistance measurement. We refer to the unbalanced state produced by an open section of a filament shunt resistor.

As far as the tubes are concerned, there is no better test than replacement with the exception of the plate current test upon rectifiers. Certain a-c tubes will be productive of hum, despite the fact that the tube is normal in every other respect. No amount of conventional tube testing will point to the fault. It is inherent within the tube. Nothing but replacement will prove this type of fault, unless a complicated hum test is made. This type of test is out of the question as a routine procedure. No amount of voltage testing will show up this type of defect; consequently the inability to detect such faults with resistance measurement does not constitute a flaw in the system.

DISTORTION.

There was a time when the problem of distortion represented an endless chain of possibilities. Today we have but a few major considerations. One of these is tube overload. The second is excessive regeneration. The third is incorrect circuit structure which may or may not influence operating potentials. The fourth is incorrect alignment of speaker units. There is a fifth, which because of its relation to incorrect alignment of tuning condensers is considered as a branch of that type of service operation. The tubes are taken care of in the tube tests.

Tube overload, we can determine by simply reducing the signal input. This includes the condition of excessive grid bias in variable control grid bias type of volume control systems. Incorrect alignment of speaker voice coils is a visual examination. The remainder of the items are essentially related to resistance measurement and condenser testing. A change in circuit structure may be discovered by resistance or condenser testing in practically every case. This is particularly true if the state of distortion is not accompanied by any other form of defect which would place it into another category, one of those listed previously. The only possible exception to this may be distortion due to excessive regeneration, which in turn is due to incorrect location of leads, etc.

If you analyse the various items which would tend to cause distortion and at the same time influence operating voltages or alter circuit structure, you will immediately realize that each of these is detectable by means of a resistance test. Thus, if one-half of a push-pull transformer secondary is shorted, it will be detected when the grid-to-grid resistance test is made. If on the other hand a tone control condenser is shorted, thus connecting the tone control resistor across a winding, it will be detected when the resistance of that winding is checked. If on the other hand, a bypass condenser is open across a bias resistor, it will be detected when the condenser test is made.

Open halves of push-pull windings will likewise be detected during the resistance test. If a condenser, normally in parallel with a winding, is shorted it will be detected during the resistance test. If it is open, it will be detected during the condenser test. If a resistor, normally in shunt with a winding, is open it will in the majority of cases be detected with the resistance test.

GENERAL SERVICE ROUTINE.

Before starting upon our discussion of general service routine with respect to the application of resistance measurement and condenser testing, we want to make specific mention of the fact that you should not overlook those items related to a defect in a receiver, which are quite obvious. There are times when the symptoms definitely indicate what is wrong.

There is no doubt about the fact that you may encounter a receiver wherein the rectifier tube is overloaded and the owner advises you that the set does not play and the rectifier plates get white hot. In such cases, the fault is obvious and it would be quite natural for you to try to locate the fault, without further consideration of systems and methods.

Another example of a simple trouble as advised by the receiver owner is that the set (a t-r-f receiver) plays normally over a portion of the dial. When a certain point is reached, the receiver goes dead. At times a scraping sound is heard. It would be quite normal in a case such as this to immediately check for a short circuit in one of the tuning condensers.

Other such simple faults can be named and again we repeat that it is quite in order to immediately check for the location of the suspected defect.

However, supplementary to the location and remedy of these various defects, it is essential that a routine test of all the tubes be made. If desired, and it would be advantageous, a complete resistance test should also be made. If you have reason to believe that the receiver is perfect, such a test is not imperative.

If you have a tabulation of point-to-point data, it will serve as your guide. If you do not have such data, then the following method of progress is suggested. We assume that the wiring diagram of the receiver is available.

A.C. RECEIVERS.

1. Test the tubes independently of the receiver voltages.
2. Measure the line voltage. Also transformer voltage (across primary) if ballast is used. (One side of ballast and one a-c plug prong will give access to transformer primary winding.)
3. Test a-c filament voltages across tube sockets in receiver (if possible) with rectifier and all tubes removed. Also rectifier plate winding.
4. Test aerial-ground system.
5. Test output transformer secondary and voice coil of speaker. Access to output transformer secondary may be had at voice coil terminals.

6. Starting with the tube nearest the aerial, check for the resistance of the various units, working between the chassis and the respective tube terminals and between the rectifier filament and the various tube terminals. An idea of the resistance of various windings, if not shown upon the diagrams, is given on page 12. Simultaneously with the resistance test, you can check the condensers, if you have a condenser checker such as shown in this volume. If you do not have such a unit, then complete the resistance test and if the fault has not been discovered, check for open condensers by means of the conventional methods recommended with the standard condenser testers.
7. Then apply whatever other tests you deem necessary to prove the reasons for excessive regeneration, incorrect alignment, i-f circuit out of adjustment, etc. (See previous general discussion in this chapter.)

D.C. RECEIVERS.

1. Test all tubes independently of receiver.
2. Measure line voltage.
3. Test aerial-ground system.
4. Check output transformer secondary and speaker voice coil systems.
5. Starting with the tube nearest the aerial, check the resistance between the plus power plug and the various plate, screen and space grid circuits. Also between the negative power plug terminal and the various grid and cathode circuits, or between the chassis and the various grid and cathode circuits or filament circuits, depending upon the tubes used. (See instructions regarding a-c receivers for condenser testing.)
6. Remove pilot light and check for resistance of filament circuit. Insert tubes, if necessary to complete filament system. The resistance of tube heater or filament is equal to the voltage across it divided by current consumption.
7. Then apply whatever other tests you deem necessary to prove defect and make remedy accordingly.

BATTERY RECEIVERS.

1. Check tubes independently of receiver voltages.
2. Disconnect batteries.
3. Test aerial-ground system.
4. Test output transformer secondary and speaker voice coil.
5. Measure battery voltages.

6. Starting with the tube nearest the aerial, check from the C-terminal of the battery-connecting board to the various tube elements associated with that terminal. It is possible by inter-connecting all of the terminals upon the battery-connecting board to check the various tube circuits from this common connection. Then check condensers by whatever means you have. If you have the tester shown in this volume, check condensers simultaneously with the resistance measurements.
7. Then apply whatever other tests you deem necessary to prove the trouble existing. (See previous general discussion in this chapter.)

An example of tabulated point to point data is as follows. A more elaborate tabulation would include the reasons for high and low values of resistance, thus indicating the unit at fault and the cause for the incorrect reading.

RCA R5-X

All tests are made with tubes removed from their sockets and with the a-c plug removed from the power circuit.

Aerial post to Ground post	20,000	ohms
From Ground to R-F control grid	5.3	ohms
From Ground to R-F cathode	600	ohms
From Ground to R-F screen	13,000	ohms
From Ground to R-F plate	33,091	ohms
From '80 filament to R-F plate	91	ohms
From Ground to Detector cathode (Vol. Control Max.)	12,000	ohms
From Ground to Detector cathode (Vol. Control Min.)	40,000	ohms
From Ground to Detector control grid	5.5	ohms
From '80 filament to Detector plate	245,080.4	ohms
From Ground to '47 control grid	542,470	ohms
From '80 filament to '47 space grid	0.0	ohms
From '80 filament to '47 plate	350	ohms
From '80 anode to '80 anode	480	ohms
From '80 anode to ground	2,224	ohms
Across a-c plug	9	ohms
Speaker field disconnected.		
Across speaker field only	2,000	ohms

CHAPTER X

ANALYSING SPECIAL CIRCUITS

A CIRCUIT becomes special by virtue of the fact that it differs from the ordinary. However, variation from conventionalism, as far as radio receivers and amplifiers is concerned does not necessarily complicate the measurement of resistance between various points. Because of the circuit, it may be impossible to measure voltage with any degree of reliability, due perhaps the difference in arrangement between the potential drops in the circuit and the arrangement for measurement as contained in the test instrument. But where resistance is concerned, no such limitation exists, in as much, as the grounded point can be anywhere in the system. The ohmmeter is free to be moved (electrically speaking) from one point to another. There is no fixed point which serves as a common point of reference.

Consider the Loftin-White Amplifier shown in figure 94. This is a simplified version of this system, yet even in this simple state, the circuit cannot be correctly checked by means of voltage tests. The primary reason for this limitation is found in the method of voltage distribution. You will note that one resistor R4, is common to the plate of the first tube and the grid of the second. You will also note that its method of connection does not allow, a test of the control grid bias applied to the output tube, by connecting the voltmeter between the control grid of tube 2 and the filament. Furthermore, because of the method of voltage distribution, the control grid bias is the differential between two voltages, namely between the voltage difference between the control grid of tube 2 and ground and the voltage difference between the filament of tube 2 and ground. The latter voltage is more negative than the former is positive. The combined result is that the control grid of tube 2 is negative with respect to the filament of tube 2, by a certain amount.

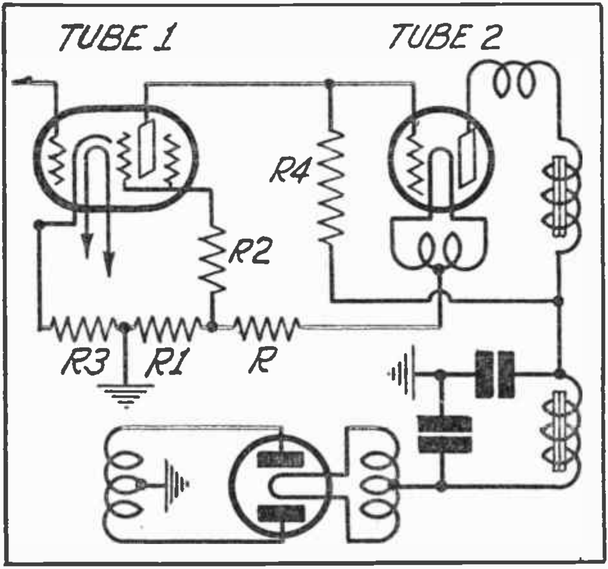


Fig. 94. Simplified version of Loftin-White amplifier

With known values of resistance for R, R1, R2, R3 and R4, it is possible to check the various circuits by working between tubes 1 and 2 and the rectifier tube. As far as resistance measurement is concerned, this circuit is no more complicated than any other, for after all, the most complicated of systems can be resolved into a simple resistance structure.

Class A and class B amplifiers may be attacked with equal facility. The distinction between these two types of system is found in operating characteristics, grid and plate voltages and not in the ohmic value of the components of the system.

Tubes with one, two or three or more grids, introduce just so many more circuits to be tested. Each of these circuits may represent one or more values of resistance, but they remain just resistances. The fact that the multiplicity of grids with the possibility of various kinds of connections may complicate voltage and current measurements, is of no consequence in resistance measurement. If the circuits are tied together with one or more resistors, the most difficult problem to be encountered will be a parallel or a series parallel circuit.

We shall close this volume, as we started. Point-to-point resistance measurement is based upon an elementary electrical subject. If you know your ohm's law, you will have no trouble applying this system. It is as old as electrical circuits. Modern practice forces us to revert to old methods. There is no denying the fact that it offers the solution to many problems and if we have converted the reader to service receivers by measuring resistance and checking condensers, the book has fulfilled its aim.

APPENDIX 1

RESISTANCE RELATIONS.

OHM'S LAW.

RESISTANCE is equal to voltage divided by current, viz:

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

If E is expressed in volts, the current I must be in amperes. This equation shows that the resistance varies inversely with the current when the voltage is fixed. Also that it varies directly with the voltage when the current is fixed.

VOLTAGE is equal to the resistance multiplied by the current, viz:

$$E = R \times I$$

If I is expressed in amperes, voltage will be in volts or fractions thereof, depending upon the magnitude of the current. This equation shows that voltage varies directly with resistance or current when one or the other is fixed.

CURRENT is equal to the voltage divided by the resistance, viz:

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

This equation shows that the current varies inversely with the resistance when the voltage is fixed, and directly with the voltage when the resistance is fixed. If E is expressed in volts and R in ohms, current I, will be expressed in amperes or fractions thereof, depending upon the magnitude of the other figures.

The WATTAGE rating of a resistor or winding is equal to the current squared times the resistance of the winding or resistor, viz:

$$W = I^2 \times R$$

where W is expressed in watts, current I, in amperes and R in ohms. The wattage rating is also the power rating of the unit or the power dissipated in the unit. The current I, is the current flowing through the resistor or winding. Power dissipated is also equal to the voltage across the unit times the current flow through it, viz:

$$W = E \times I$$

where W is expressed in watts, E in volts and I in amperes.

The wattage or power rating of a resistor of known value determines how much current can be passed through the resistor. To determine the permissible current through the ENTIRE resistor, apply

$$I = \sqrt{\frac{W}{R}}$$

where I is in amperes, W in watts and R in ohms.

The permissible current is also determinable by solving in the following manner, assuming that the voltage applied across the resistor is known, viz:

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

where I is in amperes, W is in watts and E is in volts.

If a resistor is rated at a certain number of watts, which permits the application of a certain voltage to that unit, it should be understood that the rated voltage must be applied across the entire unit and NOT across any part of the unit.

If the current through a resistor of fixed value is to be increased two-fold, the wattage rating of that resistor must increase as the square of the current increase. If the current is increased two-fold, the wattage increases four-fold; if the current increases three-fold, the wattage rating increases nine-fold.

SERIES RESISTORS.

In view of the fact that the current flow is the same through all parts of a series circuit, the lowest wattage rating of any unit in that series circuit is dependent upon the current through the system. Resistors of various wattage rating may be used in series, but the lowest wattage cannot be less than that required by the current flow.

PARALLEL RESISTORS.

When two resistors are connected in parallel, the wattage rating of each resistor can be half of that required for a single resistor of the current value. Thus if the total current in a parallel circuit is 10 amperes, and the final resistance of the parallel circuit is 10 ohms, the wattage dissipation across that circuit is 1,000 watts. Two 20 ohm units, each rated at 500 watts, will provide the required 10 ohms with a rating of 1,000 watts. This division of wattage is made possible by the fact that the current divides between the branches of the parallel combination. The wattage rating of each branch is determined by the current flow through that branch and the resistance of that branch.

APPENDIX 2

CONDENSER TESTER SPECIFICATIONS.

With respect to the constants of the coils and condensers shown in figures 85 and 85-A, L and L1 are wound upon the same form. Each winding consists of 90 turns of No. 28 silk-enamel wire wound upon a 1¾ inch form with ⅛ inch separation between the coils. The inside diameter of this form is 1⅝ inches. L2 and L3 are also wound with the same size wire. L2 has 3 turns and L3 has 70 turns, the tap being taken off at the third turn. The galvanometer is a Weston 425. The tube is a '27 or its equivalent, depending upon the heater voltage. The transformer can be of any design which will furnish the required heater voltage, when operated upon the available power-supply system. The condenser C is of the midget variety and rated at 100 micromicrofarads maximum. C1 is a 50-micromicrofarads unit and is also of the midget kind. Coils L2 and L3 are wound upon a 1½ inch form and so arranged that the entire winding may be slipped within the outer coil. The approximate position of L2 and L3 is such that the major portion of L3 is within the grid coil L1 and the 3-turn winding L2 is just within the plate winding L. No separation is required between L2 and L3.

This tester supersedes the one described in Volume II of the Perpetual Trouble Shooter's Manual. The coupling in the form tester was found extremely critical.

APPENDIX 3

NEUTRALIZATION.

Two methods of neutralizing are possible. One employs a current meter in the detector circuit, (2nd detector in superheterodynes) and the other makes use of an output meter.

In both cases, the idea behind the process is to get minimum transfer of signal through the receiver at maximum resonance when the dummy tube is in the socket. The result of neutralization of a stage amplification is that minimum signal is transferred from the grid to the plate circuit when the proper tube is not in the socket and minimum regeneration or feedback from the plate to the grid circuit of the same tube takes place when the correct tube is in the socket.

To neutralize a receiver, a dummy tube, identical to the type of tubes used in the stages to be neutralized is required. This dummy neutralizing tube is like the normal tube, except that one filament or heater prong is so arranged (usually cut off) so that when the tube is inserted into the socket, the tube will not light.

When working with a plate milliammeter as the indicator, the milliammeter is connected into the detector plate circuit. In grid-leak condenser systems, the milliammeter will kick "down" as the signal is applied to the grid. The process of neutralization is carried out until the meter shows minimum movement or minimum signal input into the detector.

In grid bias detector systems, the plate milliammeter will kick "up" as the signal is applied and the process of neutralization is carried out until minimum movement of the pointer is obtained. In both of these systems it is well to employ the audio amplifier and speaker as a supplementary check. Minimum signal should be heard after a stage is neutralized while the dummy tube is in the socket.

The process of neutralization is usually carried out upon the r-f stages of some of the older t-r-f receivers and upon some of the i-f stages in the older superheterodynes.

When an output meter form of indicator is used, it is connected across the secondary of the output transformer or across the primary of the output transformer. The condition desired is minimum signal output when the dummy tube is in the socket and the stage has been neutralized.

The process of neutralization is the same for the r-f or i-f stages, assuming that the design of the receiver requires neutralization.

When neutralizing an r-f amplifier, adjust the local oscillator for a signal of approximately 1,400 kc. The wave should be modulated. Provide a fairly strong signal but be certain that you are not overloading the r-f amplifier tubes. Then place the dummy tube into the 1st r-f socket and the balance of the receiver has its regular tubes and the correct voltages are being applied to these tubes. All tube shields and condenser shields should be in place, inclusive of that used in the stage being neutralized. In some instances it is necessary to use a dummy condenser shield because the regular shield does not have a hole to admit the neutralizing tool.

Adjust the r-f amplifier for maximum volume and tune to resonance with the oscillator signal. Watch the output indicator, whichever system is used. Adjust the neutralizing condenser until minimum signal is indicated upon the meter or is heard in the speaker. Now replace the dummy tube with a good tube and remove the 2nd r-f tube, inserting the dummy tube in its stead. Repeat the process outlined until all of the stages have been neutralized upon 1,400 kc. Now repeat the process at about 700 kc., taking care that you vary the neutralizing condensers just enough required for minimum signal. Recheck at 1,400 kc. You may find some difference between the setting at 1,400 kc. and 700 kc. Select the setting which gives an optimum condition between these two frequencies. Make certain that you tune to exact resonance with the oscillator during the operation.

Then insert the correct tubes in all of the sockets and tune for maximum signal. Vary the neutralizing condensers very slightly so as to secure maximum signal consistent with the proper state of neutralization. When tuning for maximum signal at the completion of the neutralizing procedure, the dectector plate meters should show maximum pointer movement and the output meter should show maximum output.

A low range milliammeter O2 milliamperes d-c will be found suitable for most detector circuits. In the case of the grid bias system it may be necessary to reduce the amplification by means of the volume control or the signal input, so as not to exceed the range of the meter.

I-f stages are neutralized in the same manner, except that the frequency employed for the neutralization process is the peak frequency of the amplifier. The indicator units are located in the places named. The signal for neutralization can be fed into the 1st detector or mixer tube or can be a constant signal of broadcast frequency, modulated, and fed into the receiver and the required i-f signal produced through the regular channels.