A-C/D-C AND PORTABLE RECEIVERS

Lesson RRT-11

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RRT-11

Radio Reception and Transmission

LESSON RRT-11

A-C/D-C AND PORTABLE RECEIVERS

CHRONOLOGICAL HISTORY OF RADIO AND TELEVISION DEVELOPMENTS

1913—Continuous electric waves were generated with the aid of the 3-electrode vacuum tube by E. H. Armstrong. This development brought into being the art of radio broadcasting.

1915—Western Electric engineers for the first time transmitted voice and speech by radio telephone across the continent, as well as across the oceans to Hawaii and Paris.

1916—Two-way radiotelephone communication established between Schenectady and Pittsfield by Alexanderson with the aid of a newly-developed multiple-tuned antenna.

1916—The superheterodyne receiving circuit was invented by E. C. Armstrong. It has since become the most widely used circuit in radio receivers.

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HUMOR

Humor is too much regarded as one of life's creations. Its value in meeting difficulties is too little realized. As a fact, there is nothing so helpful as humor in dealing with awkward and angry people. It not only calms people but wins them over when argument proves a failure. Make them laugh and you can do anything with them.

—Selected

A-C/D-C PORTABLE RECEIVERS

UNIVERSAL A-C/D-C RECEIVERS

The almost continuous development of smaller and smaller midget and "Personal" radio receivers has induced designers to simplify their circuits and to eliminate as many parts as possible. Because of their small size and weight, receivers of this type are readily portable, and therefore it is desirable that they operate on any lighting circuit, d-c or a-c, and in some cases that they be arranged for battery operation as well.

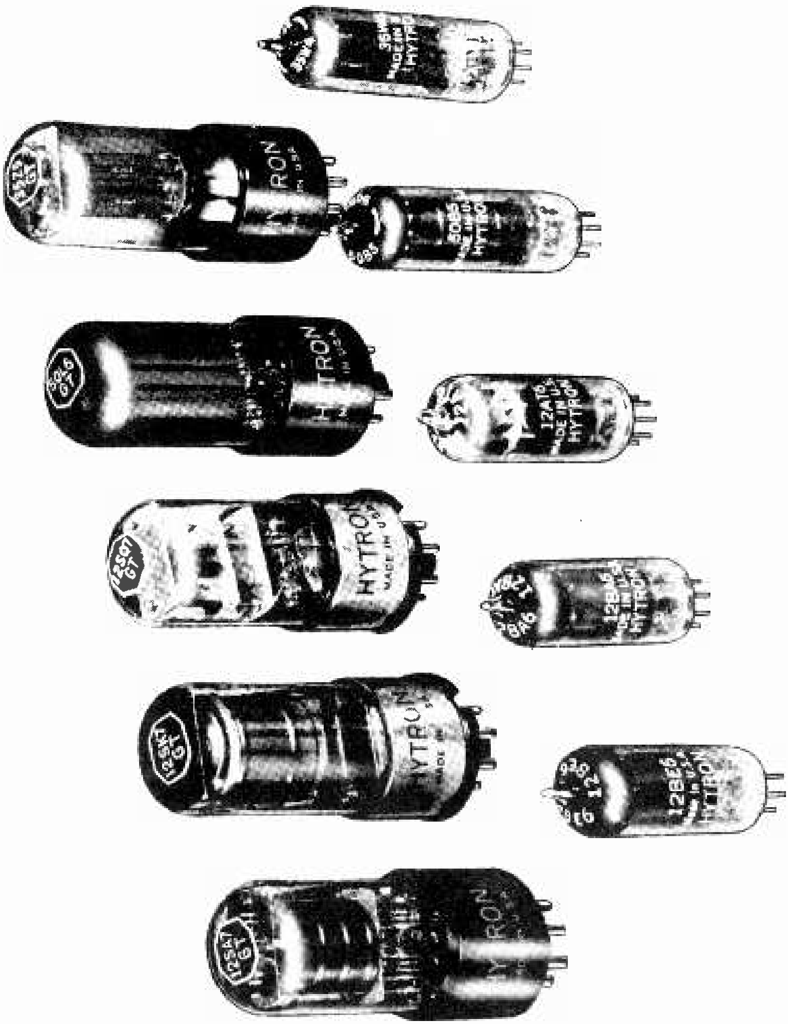
As we will explain in a later lesson, the demand for automobile radio receivers to operate with only the 6 volt storage battery of the auto-electric system as a power supply, was responsible for the development of a battery-operated high-voltage supply.

In this lesson, therefore, we want to explain the common a-c/d-c type of receiver which operates on any 110-120 volt lighting circuit. While our illustrations are chiefly radio receiver circuits, the same general plan is used for public address amplifiers and other similar equipment. Although they are referred to commonly as 110-120 volt receivers, for design calculations a 117 volt line is always assumed, since this value has now become standard practice in the electric power industry.

SERIES FILAMENT CIRCUITS

On looking through the tube tables of an earlier lesson, you will find that most of the filaments or heaters operate at comparatively low voltages therefore, with a high voltage supply, it is most economical to operate a number of such heaters by connecting them in series. As you know, the total voltage across a series circuit is equal to the sum of the voltage drops across its separate parts, but at any instant the current is the same in all parts. Because of these conditions, it is practical to connect heaters of various voltage ratings in series, provided they all require equal current.

Going back to the tube tables again, you will find a wide variety of tube types, the heaters of which require .3 ampere of current for proper operation. Many of these were developed particularly for auto receivers and while the heaters are rated at 6.3 volts, their construction is rugged and they will operate satisfactorily from 6 to 8 volts. Other types have heaters rated at 12.6 volts, 25, 35 and 50 volts.



Tube complement commonly used in universal a-c/d-c receivers. In the upper row are the GT types, and in the lower row the corresponding miniature types.

Courtesy Hytron Radio & Electronic Corporation

Back in the earlier lessons we told you that alternating current usually is compared with direct current through its heating effect, and therefore .3 ampere either a-c or d-c will provide equal heat in the same element. Also you will notice that all of these tubes are of the indirectly-heated cathode type, which makes the heater circuits independent of the signal circuits. Consequently, there will be minimum hum when a-c is used to operate the heaters.

With these facts in mind, we want you to look at the circuit of Figure 1 which is a four-tube trf universal type radio receiver, containing an r-f amplifier tube, a detector tube, an a-f amplifier and a rectifier tube.

To trace the heater circuit, we will start at the lower 117 volt supply wire and follow the path of the current through the switch, resistor R_2, and the heaters of the rectifier, the a-f tube, the r-f tube and the detector. One side of the detector heater connects to the common return which extends to the right and then down to the upper 117 volt supply wire.

For a definite example, we will assume the following types of tubes: 6K7G - r-f, 6J7G - det, 25A6G - a-f, and 12Z3 rectifier. Checking in the tube table you will you find the following heater ratings:

Tube	Volts	Amps
6K7G	6.3	.3
6J7G	6.3	.3
25A6G	25.0	.3
12Z3	12.6	.3

Notice here that the current is the same in all cases, and when connected in series, the total drop across the four tubes will be equal to 6.3 + 6.3 + 25.0 + 12.6 or 50.2 volts. Resistor R_2 is also in series, and with a 117 volt supply the drop across it must be 117 −50.2 or 66.8 volts.

Knowing the values of the current and voltage, we can substitude in Ohm's Law and find that R_2 requires a value of 66.8 volts divided by .3 amps or 222.6 ohms. The tube heaters with a total drop of 50.2 volts at .3 amp, have a total resistance of 50.2 divided by .3 or 167.3 ohms.

The complete filament or heater circuit, therefore, has a total resistance of 222.6 + 167.3 or 389.9 ohms, which at 117 volts, allows a current of approximately .3 ampere.

Reviewing the earlier lessons again, you will remember that electric power in watts is equal to volts times amperes, or amperes squared times ohms. Here, will 117 volts and .3 amp, the power in the entire circuit will be 117 x .3 or 35.1 watts. For the tube heaters only, 50.2 volts x .3 amp = 15.06 watts, and for R_2 only, 66.8 volts x .3 amp = 20.04 watts.

We mention these values here to bring out the fact that the power lost in R_2 is greater than that in all the tube heaters. As this power is dissipated in the form of heat, R_2 will become quite warm when the receiver is in operation.

To keep this heat out of the receiver chassis, in some models resistor R_2, in the form of a long, small diameter spiral, is placed inside the supply cord alongside the usual pair of line wires. This arrangement is known as a "Line Cord", and can be purchased complete with resistance values ranging from 135 to 360 ohms.

From a practical standpoint, cords of this type become noticeably warm during normal operation, and therefore a hot cord is not an indication of trouble. Should it become necessary to replace the attachment plug or make other repairs, the cord must not be shortened, as this will reduce the value of resistance and allow the tube heaters to operate at voltages high enough to reduce their life.

As we will explain a little later, resistors used for the purpose of R_2 in Figure 1 are often enclosed in a glass or metal bulb mounted on a base the same as the regular tubes, and are known as "Ballasts" or Ballast Tubes".

To reduce the power and increase the efficiency of a series connected heater circuit, there are a wide variety of tube types with heaters designed to operate at various voltages but all of which require a current of .15 ampere or 150 ma. As stated previously, the common operating voltages are 12.6, 25, 35 and 50 volts. The values of 6.3 volts and 12.6 volts are to match the lead-acid type of storage cells, each of which develops 2.1 volts under ordinary operating conditions. Thus the common three cell auto storage battery develops 3 x 2.1 = 6.3 volts while a six cell battery develops 6 x 2.1 = 12.6 volts.

In addition to those mentioned above, a series of miniature tubes, also with 150 ma heaters, is available to assist in reducing the size and weight of portable, 110-120 volt, a-c/d-c receivers. Making use of these types, the tube complement of the circuit of Figure 1 could be as follows:

Tube Function	Glass or Metal Types	Miniature Types	Heater Volts	Heater Amps
R-F	12SK7	12BA6	12.6	.15
Det	12SJ7	12AU6	12.6	.15
Output	50L6	50B5	50.0	.15
Rect	35Z5	35W4	35.0	.15

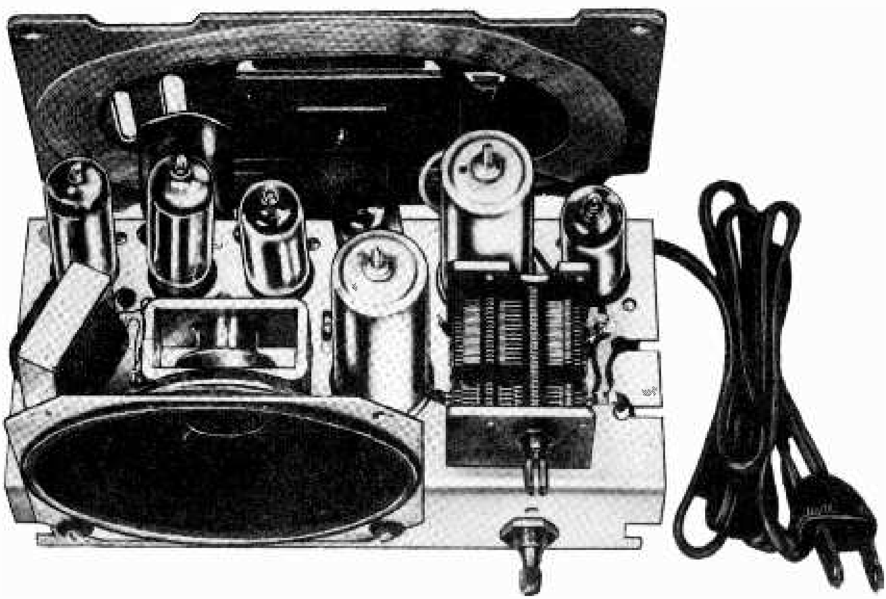
Connected in series, the total drop across these four heaters is 12.6 + 12.6 + 50 + 35 or 110.2 volts and, in some cases, a 6-8 volt, 150 ma pilot lamp is added to raise the total drop to approximately the 117 volts of the supply.

Thus the series resistor or ballast is eliminated and none of the heater circuit power is wasted. For circuits with different numbers of tubes, usually it is possible to select desired tube types with heater voltages that add up to the supply voltage.

PLATE SUPPLY

Starting at the lower wire of the 117 volt supply in Figure 1, there is a direct path to the plate of the rectifier tube. When the plate is positive with respect to the cathode, current will pass through the tube, and its cathode is therefore considered as the plate supply positive.

From the rectifier cathode the circuit continues through the choke, which with condensers C_9 and C_{10}, comprises the filter that smooths out any variations in cathode current. From the choke there is a connection to the screen-grid of the a-f tube, and through the primary of the output transformer T_3 to the plate. Starting at the choke again, there is another path down and over to the left, up through R_6 to the detector plate, and up through R_5 to the detector screen-grid. Going



Typical universal a-c/d-c receiver with attached loop antenna.
Courtesy Motorola, Inc.

further to the left, the circuit continues to the screen-grid, and also through the primary of T_2 to the plate of the r-f tube.

All of these circuits are completed to the other side of the supply circuit through the common return. For the r-f tube, the cathode connects to the return through the fixed resistor R_3 and the variable resistor R_1, which controls the negative grid bias. As a change in bias voltage varies the mutual conductance of the tube and therefore its effective amplification, R_1 acts as a volume control.

The detector tube circuits are completed from the cathode to the return through the bias resistor R_4. The same plan is followed for the a-f or output tube, the cathode being connected to the return through resistor R_8. For all three tubes, the control grid circuits connect through a load directly to the return, while the plate and screen currents of each tube pass through its bias resistor. The voltage drops across these bias resistors make each cathode positive with respect to the return, and as the grids connect to the return, each one will be negative with respect to its cathode. Each bias resistor has a condenser connected across it to maintain a more uniform voltage. The signal circuits of this receiver are the same as those explained for similar units with other types of power supplies.

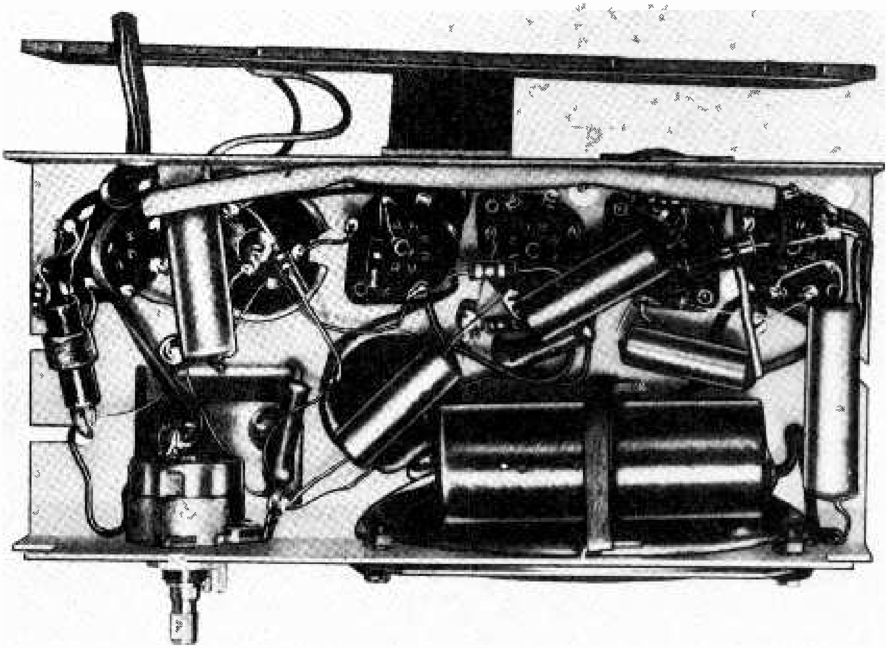
Here, when connection is made to a 117 volt a-c circuit of any frequency, the heaters will operate properly, and the rectifier will allow current during alternate half cycles when the supply wire, to which the plate connects, is positive.

When connection is made to a 117 volt d-c supply line, the attachment plug must be placed into the receptacle so that the positive side of the supply circuit connects directly to the rectifier plate. Under these conditions there will be a continuous current in the rectifier plate circuit.

Keeping the action of the rectifier tube in mind, should the supply cord plug be inserted so that the plate connects to the negative side of the line, there will be no plate current, although the tube heaters light normally. Thus you can understand why, with a d-c supply, it may be necessary to reverse the position of the supply cord plug in the power outlet in order to secure proper operation.

PORTABLE RECEIVERS

To obtain economical and efficient operation with dry batteries as the supply, it is necessary that a few larger cells provide the higher heater current and a larger number of series connected smaller cells provide the higher voltage-lower current for the plate and screen grid circuits. Thus, the A or heater batteries are available from 1.5 to 6 volts while the B or plate batteries are available up to 90 volts. For operation at these voltages, the tube heaters are connected in parallel and to adapt the circuit of Figure 1 for battery operation, a socket and plug have been added.



Bottom-of-chassis view of a-c/d-c receiver shown in previous illustration.
Courtesy Motorola, Inc.

In the former explanation of this circuit, the a-f tube was listed as type 25A6G but, to operate its heater in parallel with those of the r-f and det tubes, it must be replaced with 6.3 volt, .3 amp heater type such as the 6A4. When this change is made, for 117 volt series connected heater operation, the total drop across the tubes will be 6.3 + 6.3 + 6.3 + 12.6 or 31.5 volts. With this arrangement, resistor R_2 must cause a drop of 117−31.5 = 85.5 volts which, at a current of .3 ampere requires 85.5 ÷ .3 = 285 ohms and a power dissipation of 85.5 x .3 = 25.65 watts. With these changes the circuit will operate on a 117 volt, a-c or d-c supply.

For portability, the receiver is to operate also with a 6 volt A and a 90 volt B battery which will be connected to the plug as indicated in Figure 1.

As both the plug and socket are shown from the top, when the plug is inserted in the socket, the corresponding pins will be connected. Thus, the A+ battery wire which connects to the top and left hand plug pins, will make contact with the top and left hand socket connections.

With this in mind, there is a circuit from A+ through the left hand pin, up and over through the a-f heater and back to the lower left socket contact, which connects with A−. From the top contact of the socket, there is a circuit up and to the left, through the r-f heater and back to the lower left contact of the socket.

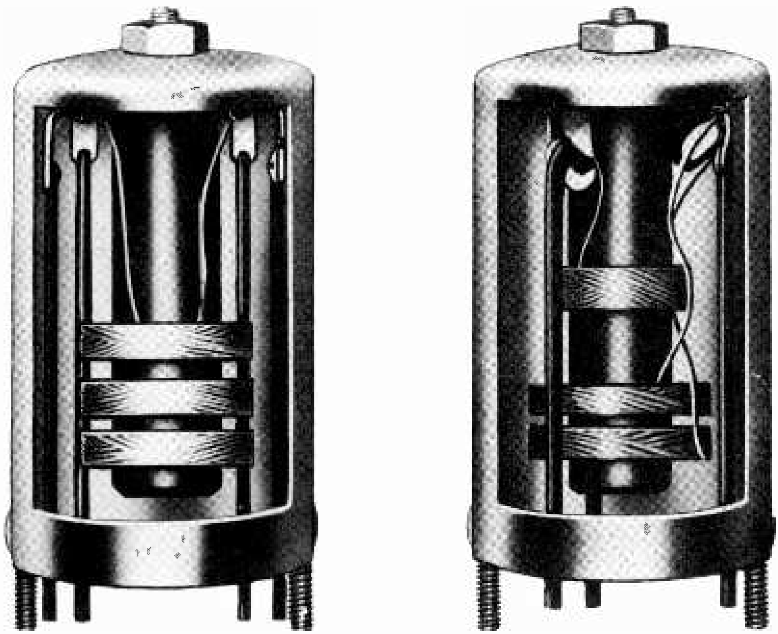
Starting from the top contact of the socket again, there is a circuit up and to the right, through the detector heater, back to the common return, and down to the lower right contact of the socket. As the A+ connects to the top and left contacts of the socket, and the A− connects to both lower contacts, the heaters of the r-f, det, and a-f tubes are in parallel across the A battery. The rectifier tube is not required, and therefore its heater circuit is not completed.

The plate or B battery "+" is connected to the right hand socket contact and its "−" connected to the lower contacts. Extending from the right hand contact of the socket, there is a direct connection to the choke, from which point current is supplied to all plate and screen circuits. These circuits are completed through the common return to the lower socket contacts and back to B−. Although not shown, usually an off-on battery switch is placed in the A−B− wire of the battery connections.

Thus, with a 6 volt A battery and 90 volt B battery, the receiver will operate under practically the same conditions as when it is connected to a 117 volt supply. It may be well to mention here that because the maximum a-c voltage is 1.4 times the effective value, the rectified and filtered 117 volt a-c produces approximately the same d-c voltage as a 117 volt d-c power supply.

There are many variations of this general arrangement by which the tube heaters are connected in series for 110-120 volt lighting circuit operation and in parallel for battery operation. Usually, the batteries are installed inside the cabinet and the 110-120 volt line cord is available for external connection to the lighting circuit. To prevent the simultaneous application of both sources of power and also to simplify the switching, in some models the line cord plug must be inserted into a receptacle on the receiver in order to obtain battery operation.

Other models, designed primarily for battery operation are equipped with tubes, the filaments of which operate at 1.4 volts and .05 ampere. The lower power requirements provide longer battery life and therefore are quite popular. However, these tubes do not have an indirectly heated cathode which makes them subject to hum with an a-c filament supply. Therefore, for 110-120 volt, a-c/d-c operation, the filaments may be connected in series and supplied with the proper d-c voltage from a divider connected across the d-c plate supply.



Shielded iron-core r-f and i-f transformers.
Courtesy J. W. Miller Company

All of these circuit arrangements pertain only to the operating voltages required by the tubes and do not affect directly the type of receiver circuit nor the signal paths through it.

SIGNAL CIRCUITS

Tracing the input circuit of Figure 1, the antenna connects directly to one end of the primary of T_1, while the circuit is completed to ground through condensers C_1 and C_2. Condenser C_1 is connected between the primary and the common return, while C_2 is connected between the common return and the metal chassis.

As you may know, the National Electrical Code requires that all lighting circuits be grounded on one side so that the voltage between the line and ground can never exceed the circuit voltage. In Figure 1, one side of the 117 volt supply connects directly to the common return, and we will assume the plug has been inserted in the outlet so that this is the ungrounded or "hot" side of the supply circuit.

With an external ground made to the chassis, condenser C_2 prevents a short across the supply circuit. Also, it is quite common practice to use steam radiators and other similar grounded metal objects as an antenna, and unless C_1 were in place, again there would be a short across the power supply.

Therefore, circuits of this general type must be arranged to eliminate all direct connections between either of the power supply line wires and any external connections which may be grounded. In addition to preventing power line shorts, the use of condensers in the antenna signal circuits permits operation of the Universal receiver without an external or separate ground because the signal circuit is completed to ground through the power line wires. For example, if the upper line wire of Figure 1 is the grounded side of the circuit, the common return is grounded also, and the antenna signal circuit is completed to ground through C_1 only.

On checking briefly through the signal circuits, at the left the tuned secondary of antenna coil T_1 is in the control grid circuit of the r-f tube. The signal is carried over to the bias type detector grid through the r-f transformer T_2, the primary of which is in the plate circuit of the r-f tube, and the tuned secondary in the detector grid circuit.

The detector is resistance-capacitance coupled to the a-f or output tube, which has the output transformer T_3 in its plate circuit. The output transformer secondary connects to the speaker, which is of the magnetic or permanent magnet type. In some receivers of this type, you may find the windings of a high-impedance type speaker are connected directly into the plate circuit of the output tube, thus eliminating the output transformer.

DUAL BAND RECEIVER

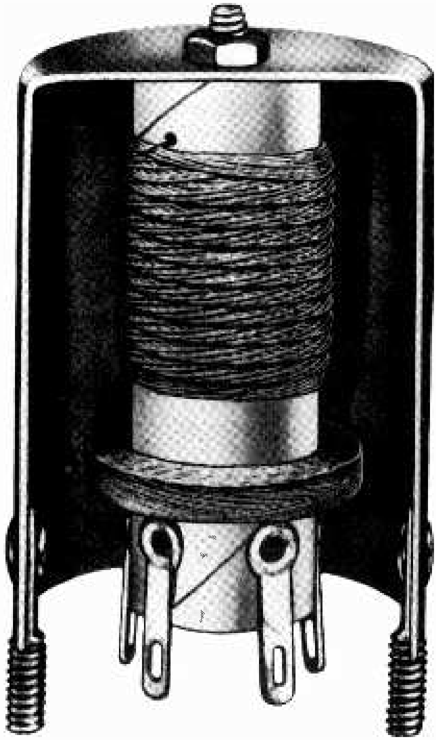
Although the superheterodyne type of receiver has made the older trf circuit almost obsolete, there are many of them still in use therefore, as Figure 2, we have drawn a circuit of this type and included a band switch, dynamic speaker, dial lamps and a ballast or resistance tube.

As far as the signal circuits are concerned, the arrangement of Figure 2 is practically the same as that of Figure 1. Again you will find a stage of tuned r-f, a tuned detector, and pentode a-f or output stage, resistance-capacitance coupled to the detector. The rectifier is of the full-wave type with two plates and two cathodes. However, as there is no power transformer arranged to provide full-wave rectification, both plates are connected to the same supply wire and the tube operates as a half-wave rectifier.

Tracing the filament or heater circuit and starting at the lower wire of the power supply, the path is through the ballast tube, rectifier heater, a-f heater, det heater, r-f heater and back to the other power supply wire. Here again the heaters are connected in series and the line cord resistor R_2 of Figure 1, is replaced by the ballast or resistance tube of Figure 2.

BALLAST TUBES

Ballasts of this type are made in the same general shape and mounted in a socket the same as



Perko shielded r-f transformer.
Courtesy Linell Engineering Corporation

the common receiving types of tubes, and are designed with specific values of resistance for various heater circuits. As shown in Figure 2, it is common practice to tap the ballast tube resistor and bring out a third connection so as to include the dial lamps in the heater circuit.

Because of the many variations, the ballast or resistance tubes are given definite type numbers, and like other tubes, should be replaced only with one of the same type and number.

Looking at Figure 2 again, there are two dial lamps connected in series across part of the ballast resistor. Therefore, for proper operation, the dial lamps also must have the correct voltage and current specifications.

DIAL LAMPS

The dial lamps in most common use operate at 6.3 volts, but have current ratings of .15 amp, .2 amp, or .25 amp. With this in mind, you can remember that the "K" series of ballasts or resistance tubes are designed for .15 amp dial lamps, the "M" series for .2 amp lamps, and the "L" series for .25 amp lamps.

To show you how these various values are worked out, we will assume that the heaters of the r-f and det tubes are rated at 6.3 volts, .3 amp., the heaters of the a-f and rect tubes are rated at 25 volts, .3 amp., the dial lamps are rated at 6.3 volts, .15 amp. and the power supply is considered as 117 volts.

Following the explanation of Figure 1, in Figure 2 the total drop across the tubes will be 6.3 + 6.3 + 25 + 25 or a total of 62.6 volts. With a 117 volt supply, the drop across the ballast must be 117−62.6 or 54.4 volts. As the dial lamps are in series, the drop across them is 6.3 + 6.3 or 12.6 volts, and thus there must be 12.6 volts across that part of the ballast in parallel with them. The other part of the ballast resistance requires a drop of 54.4−12.6 or 41.8 volts.

As the first part of the ballast carries the total current of .3 amp., to produce a drop of 41.8 volts its resistance must be 41.8 ÷ .3 or 139.3 ohms. The second part of the ballast carries the total current minus the dial lamp current, which in this case is .30 − .15 = .15 amp. To produce a drop of 12.6 volts with a current of .15 amp., the second part of the ballast requires a resistance of 12.6 ÷ .15 or 84 ohms.

Should either of the dial lamps burn out, the total resistance of the circuit will be increased 42 ohms and the current will be reduced to approximately .27 ampere. The 42 ohm increase of effective resistance is due to the 84 ohm dial lamp circuit which was in parallel with the 84 ohm section of the ballast. Under these conditions, the drop across the 84 ohm section of the ballast tube will be 22.68 volts while the drop across the other part will be 37.61 volts. Therefore, the total drop across the ballast will be 22.68 + 37.61 or 60.29 volts.

With a 117 volt supply, there will be 117−60.29 or 56.71 volts across the tube heaters, which is about 90% of their rated voltage. In actual values, this means the 6.3 volt heaters would operate at approximately 5.67 volts. We mention these facts merely to emphasize that in circuits of this type, the dial lamps are often quite important with respect to the proper operation of the rest of the equipment.

BAND SWITCH

To increase the tuning range of this receiver, the two-section "Band Switch", when closed, shorts out a part of the tuned secondaries of T_1 and T_2. In effect, the closing of this switch reduces the number of turns in the coils and thus reduces their inductances.

As the tuning condensers are not changed, a reduction in the inductance of the coils allows the circuit to resonate at a higher frequency, or shorter wavelength, thus providing what is known as a "2-Band" receiver. In the usual models, the tuning range is from 550 to about 180 meters with the band switch open, and from 180 to 75 meters with the band switch closed.

The longer wave band covers all the standard American and Canadian standard Broadcast Stations, while the short wave band covers Police and other short wave stations.

PLATE SUPPLY

The high voltage plate supply can be traced from the lower power supply wire up to the rectifier plates and through the tube to the cathodes which are externally connected. From the cathodes there is one path through the speaker field and back to the other supply wire, thus completing the field circuit. Notice that condenser C_8 is connected across the field to insure a steady uniform field current.

Starting from the rectifier cathodes again, there is a path over to the left to the a-f tube screen and plate as well as to the screens and plates of both the r-f and det tubes.

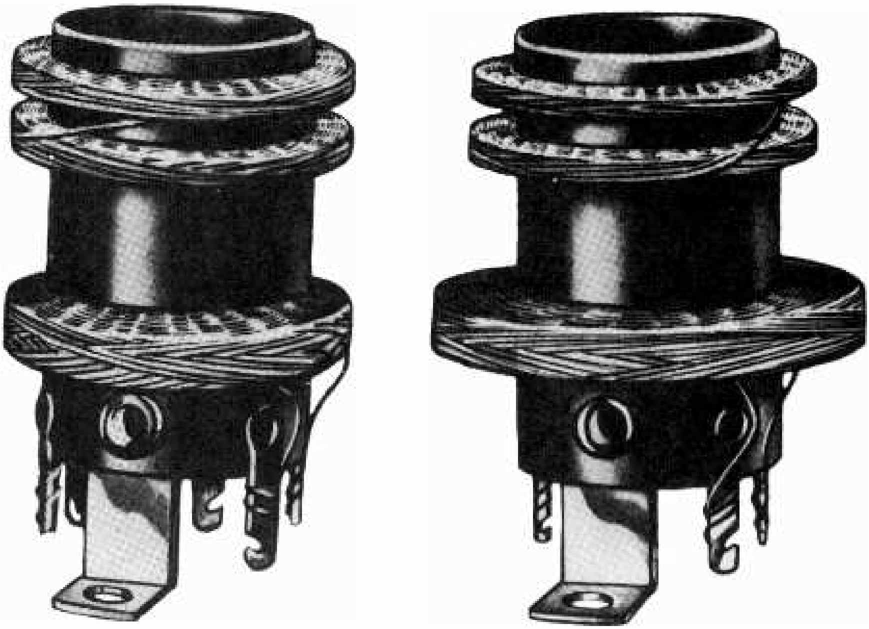
Because there is no provision made for an external ground, the common return is shown as the chassis ground, and the screen and plate circuits of the r-f tube are completed to ground through the cathode and volume control.

VOLUME CONTROL

The arrangement used here is similar to that explained for Figure 1, except that the volume control is in the form of a potentiometer with its third terminal connected to the antenna. Starting at the grounded movable contact, that part of the control to the left in the drawing, is in parallel with or across the primary of T_1, while that part of the control to the right is in series with the cathode of the r-f tube.

As the movable contact is turned to the left in the drawing, the amount of resistance across the antenna circuit is reduced, while the amount of resistance in series with the cathode of the r-f tube is increased. This action causes the input signal voltage to be reduced, and at the same time, by increasing the bias voltage on the r-f tube, reduces the gain and hence the signal output voltage.

When the movable contact is shifted to the right in the sketch, the action is reversed, and both the input and output signal voltages of the r-f tube are increased. Because of this double action, the arrangement of Figure 2 is commonly used as a volume control in the smaller and simpler models of receivers.



Typical high-gain air-core r-f coils.
Courtesy J. W. Miller Company

GRID BIAS

Another interesting feature of this circuit is the method of obtaining the grid bias voltages for the det and a-f tubes. We have already traced the plate and screen-grid circuits to the tubes, and the cathode of each is grounded directly without the series resistors shown in Figure 1.

To complete the high voltage circuits of Figure 2, the cathode circuits extend to the grounded end of R_5 and pass through this resistor and filter choke to the power supply line. As far as the tube circuits are concerned, the choke is connected in the negative side, and with condensers C_8 and C_9 forms a filter like the choke and condensers C_9 and C_{10} in Figure 1.

Because they are carrying current, there will be a voltage drop across R_5 and the choke, the polarity of which makes this side of the power supply line negative with respect to the "ground" of the receiver.

To make use of this negative voltage, the control grid circuit of the detector tube is completed to cathode, or ground, through the secondary of T_2, R_1 and R_5. R_1 is merely a filter or isolating resistor, because with no grid current there will be no voltage drop across it. However, the drop across R_5, caused by the plate and screen currents of the r-f, det, and a-f tubes, acts as the bias voltage for the detector grid.

Since the usual form of tuning condenser is built so that the rotor plates are grounded, the tuned secondary circuit of T_2 is completed through condenser C_3. Thus, one gang of the tuning condenser and C_3 are connected in series across the secondary, but as the capacitance of C_3 is large compared to that of the tuning condenser, it causes but a slight increase of the total capacitance.

However, a good condenser will not conduct current, therefore, while the low reactance of C_3 does not interfere with the tuning action, it prevents the lower end of the secondary from grounding directly and allows the d-c voltage drop across R_5 to be applied as the bias on the detector grid.

A similar arrangement is used for the a-f tube, where the control grid circuit is completed directly to the power supply end of the choke and to ground through both the choke and R_5. Thus, the bias voltage on the control grid of the a-f tube is equal to the sum of the d-c voltage drops across the choke and R_5. The input signal circuit, however, is completed through R_3 and C_6.

In the circuits of Figure 1, the tubes are said to be "Self-Biased", because each bias resistor carries only the current of the tube to which it is connected. The arrangement of the det and a-f tubes in Figure 2 is known as "Semi-Fixed" bias, because the bias voltage for any one tube does not depend entirely upon the plate and screen currents of that tube.

SPEAKER FIELD

The speaker field is connected directly from the rectifier cathodes to the power supply, and thus, with the exception of obtaining its current from the rectifier, is not in any of the tube or signal circuits. We have previously shown circuits in which the speaker field acted as a filter choke, but frequently this is not done in a-c/d-c circuits on account of the comparatively low supply voltage, which makes it difficult to allow the required voltage drop across the field. As shown in Figure 2, the field operates at the full d-c plate voltage, which allows the proper field power at comparatively low current.

Formerly advertised as a five-tube receiver, the circuit of Figure 2 has but three tubes in the signal circuits. Although the ballast and rectifier tubes are necessary, they form a part of the power supply, and strictly speaking are not a part of the receiver proper. Therefore, the receiver should be described as "three tubes plus rectifier and ballast".

THREE WAY BATTERY PORTABLE

The "three way" battery portable type of receiver has become quite popular and for Figure 3 we have drawn the circuits of a typical model. Designed primarily for dry battery operation, its utility has been increased by the addition of an a-c/d-c power supply which permits operation on any ordinary lighting circuit whenever one is available. This arrangement provides a much longer battery life as they are used only when the receiver is taken to the beach, on picnics or other remote locations.

The circuit is a conventional four tube superheterodyne and the signal, picked up by a tuned loop antenna, is impressed on the signal grid of a pentagrid converter tube. The converter is followed by a pentode i-f stage which drives a diode detector that also provides avc voltage. The detector is part of a diode-pentode tube, the pentode section of which operates as the first a-f stage and drives the output tube. The p-m speaker does not require a field winding.

The tubes are miniature types, to provide a compact, light weight assembly, and have filaments rated at 1.4 volts and .05 ampere or 50 ma. The output tube filament is center tapped and with both sections in series requires 2.8

volts at 50 ma. With the sections connected in parallel the complete filament requires 100 ma at 1.4 volts.

The double pole, single throw switch S_1 is mounted on the volume control and acts to turn the power on and off. The four pole, double throw switch S_2 provides for 117 volt a-c/d-c line or battery operation. For the convenience of the user, the line cord is equipped with a bakelite prong that fits in a slot in the metal chassis. This prong operates switch S_2 and when the cord is removed for use, the switch circuits are as shown in Figure 3. When battery operation is desired, the cord prong is inserted in the chassis slot thereby throwing switch S_2 to its opposite or battery position.

The specified B battery develops 67-1/2 volts while the A battery consists of five 1.5 volt dry cells connected in series. Thus, for line operation, the a-c/d-c supply should furnish approximately 67-1/2 volts for the plates and screen grids with 7 volts for the filaments. Designed for battery operation, the tubes have directly heated cathodes, or filaments therefore, to prevent hum, they require d-c operation.

Starting at the upper line wire, there is a circuit up and over to the right through the selenium rectifier to contact B on switch S_2. The selenium rectifier is a dry plate type and replaces the usual half wave rectifier tube, thereby saving space, weight and

"Plug-in" type electrolytic condenser as used in the rectifier filter systems in radio receivers.

Courtesy Tobe Deutschmann Corporation

power required to heat a rectifier tube filament.

The pulsating d-c output of the rectifier can be traced through pole B of switch S_2, through resistors R_9, R_8 and R_{10} to switch pole D. From D, the circuit continues to the right and up through the filament of the output tube, to the left and through the filament of the i-f tube, back to the right through the filament of the Det avc 1st a-f tube and back to the left through the filament of the converter tube to the common return. The circuit continues to the right through the common return then down through switch S_1 and through pole C of switch S_2 to the lower line wire.

Thus the filaments of the tubes, in series with each other, are in series with the selenium rectifier, resistors R_9, R_8 and R_{10} across the 117 volt a-c/d-c line. The voltage drops across the other parts of this circuit must be of such value that there is but 7 volts across the filaments.

However, series connected filaments give rise to other problems. For example, in addition to its normal current, each filament must carry the plate and screen grid currents of its tube. Thus, the last series connected filament would carry its normal filament current plus the sum of the plate and screen currents of all the other tubes.

For definite values, assume the converter tube is a type 1R5, the i-f amplifier a type 1T4, the Det 1st a-f a type 1S5 and the output a type 3S4. Operating with 67½ volts on the plates and screens their characteristics are approximately as follows:

Tube Type	Plate and Screen Grid Currents
1R5	5.0 ma
1T4	5.0 ma
1S5	2.5 ma
3S4	7.5 ma
	Total 20.0 ma

With a standard 300 ma heater, this 20 ma would make little difference but, for a 50 ma filament, it amounts to a 40% overload and must be avoided. Retracing the filament circuit, from the center tap of the output tube filament, resistor R_{19} connects to the common return. From the junction between the output and i-f tube filaments, resistor R_{20} connects to the common return and thus is across or in parallel with the filaments of the converter, i-f and detector tubes. Condenser C_{28}, usually of about 100 mfd, is connected across resistor R_{20} and acts as a filter to maintain a uniform voltage. This parallel arrangement, in series with one half of the filament of the output tube, is shunted by resistor R_{19}.

To operate at 1.4 volts and 50 ma, the filaments have a resistance of 28 ohms and the double filament of the output tube has a total series resistance of 56 ohms. Thus, by themselves, the series connected filaments have a total resistance of 140 ohms which, with the normal current of 50 ma, develops a drop of 7 volts. Assuming R_{19} and R_{20} each have a resistance of 1000 ohms, their shunting action reduces the total effective resistance of the entire filament circuit to approximately 100 ohms and thus it requires a total current of 70 ma to provide the required 7 volt drop.

Going back to the selenium rectifier, its circuit must carry the 50 ma filament current plus the 20 ma total plate and screen grid currents. Thus, resistors R_9 and R_8 will carry the total 70 ma. Resistor R_9 is of comparatively low value, usually less than 100 ohms, and it acts to protect the rectifier against overloads by limiting the peaks of current pulses which charge filter condenser C_{16}. As the plate supply connects to the junction between resistors R_8 and R_{10}, the drop across R_8 must reduce the voltage available at its output to the 67½ volts supplied by the B battery. Neglecting the small drop across R_9, for R_8, the drop must be 117 − 67.5 = 49.5 volts. With a current of 70 ma, the resistance of R_8 must be 49.5/.07 = 700 ohms (approx.)

Connected in series with the filaments, resister R_{10} carries a current of 50 ma and for the required 7 volts across the tubes, the drop across it must be 67.5 − 7 = 60.5 volts. With a current of 50 ma, the resistance should be 60.5/.05 = 1210 ohms. For protection against line voltage surges, in practice this value is increased about 10% and, in commercial values, 1400 ohms would be satisfactory.

The power dissipation of a resistor is equal to I^2R and, for the values of this example.

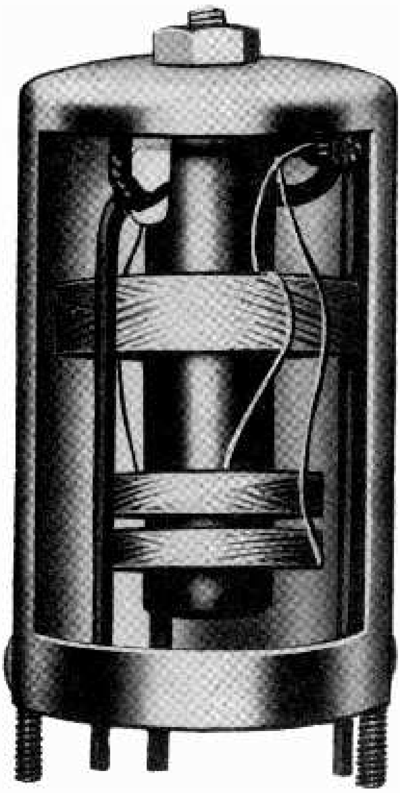
$$\text{For } R_8,\ P = .07 \times .07 \times 700 = 3.43 \text{ watts}$$

$$\text{For } R_{10},\ P = .05 \times .05 \times 1400 = 3.5 \text{ watts}$$

For conservative design, commercial 5 watt resistors would probably be installed in both cases.

Returning to the junction between resistors R_8 and R_{10}, the plate supply circuit continues through pole A of switch S_2, over to the right and up to resistors R_{14} and R_{16} which are in series with the screen grid and plate of the 1st a-f tube. Also, there is a path down through S_1 and back up to a tap which connects to the screen grid and plate of the output tube. From the tap, the path continues to the left with connections to all other screen grids and plates.

With series connected filaments, the common cathode bias resistors can not be used and, for proper bias voltages, the control grid returns can not connect to a common point. For example, the control grid circuit of the output tube can be traced down through load resistor R_{17}, filter resistor R_{18}, left along the common return and back up through the filaments of the converter, 1st a-f and i-f tube to the filament of the output tube. As the output tube is at the positive end, the drop across the filament circuit provides the negative bias for its grid.



Shielded r-f transformer with part of metal shield cut away to show internal coil arrangement.
Courtesy J. W. Miller Company

The triode control grid circuit of the 1st a-f tube is completed through load resistor R_{13} to the negative end of its filament and the control grid circuit of the first i-f tube is completed through the secondary of i-f transformer T_2 and resistor R_6 to the negative end of its filament. For the converter tube, the oscillator grid circuit is completed through resistor R_3 to the negative end of the filament while the signal grid circuit is completed through resistors R_2, R_4, R_{11} and R_{12} to the positive end of the filament. Resistors R_{11} and R_{12} develop the avc voltage with resistor R_4 and condenser C_9 acting as the avc filter.

As indicated by the ground symbol at the left center of the diagram, there is but one connection to the metal chassis and that is through the .25 megohm resistor R_1 shunted by the 1 mfd condenser C_1. Thus the chassis is isolated for d-c and low frequency a-c but is at r-f ground potential.

When the line cord is removed from a power outlet and its prong inserted in the provided chassis slot, switch S_2 is thrown to the battery position. When this is done, pole A connects to B +, pole B is open, pole C connects to A− B− and pole D connects to

A + thereby supplying the tube circuits with essentially the same operating voltages as with the 117 volt a-c/d-c source. For a-c/d-c operation, the plate supply filter is made up of resistor R_8 with condensers C_{16} and C_{22}. For battery operation, condenser C_{22} is connected directly across the B battery and supplies the necessary filtering action.

11 TUBE SUPERHETERODYNE

To show you that circuits of this general type are not restricted entirely to small units, in Figure 4 we have the circuits of an a-c/d-c eleven tube 3-band superheterodyne radio receiver.

Starting at the antenna, there is an r-f amplifier stage, a combined first detector and oscillator stage, one i-f amplifier stage, a combined second detector and avc stage, followed by three a-f stages, the last of which has two tubes in push-pull.

To supply sufficient current for the plate and screen circuits of all of these tubes, as well as the speaker field, two rectifier tubes are needed, and in addition there is another tube used as a "Tuning Eye".

While the simple band switch of Figure 2 made it possible to extend the tuning range, the circuit of Figure 4 has a more elaborate switching arrangement which provides for 3 bands. You will find the antenna, r-f and oscillator coils are made in three separate parts which we have marked, "S" for short, "M" for medium, and "L" for long wave.

The band switch S_1 is made with 5 gangs which, while electrically separate, are mechanically connected and work from a single control. Gang "S_1A" controls the input circuit of the r-f tube. Gang S_1B controls the input circuit of the first detector. Gang "S_1C" controls the oscillator grid, and gang "S_1-D" the oscillator plate circuit.

To aid in tuning, gang "S_1-E" controls the band indicator lamps so that as each band is switched in, the dial will be properly illuminated.

Switch S_2, operated from the panel, has three gangs, and in the upper position of our drawing provides "Selective" reception necessary when tuning for distant stations. In the center position "High Fidelity" reception is obtained, and in the lower position the three audio stages act as an amplifier for a phonograph pick-up plugged into the terminals shown just below switch gang "S_2-B".

In the "Selective" position, gang "S_2-A" connects the tuned secondary of IF_1, across the control grid circuit of the i-f amplifier tube. Gang "S_2-B" connects the volume control in the second detector circuit while gang "S_2-C" connects the tuning eye grid to the avc circuit.

In the "High Fidelity" position, gang "S_2-A" connects an extra inductance in the secondary circuit of IF_1, detuning it sufficiently to reduce the selectivity and allow a greater range of signal frequencies to pass. Gang "S_2-B" has its two upper contacts shorted and thus there is no change from the "Selective" position. Gang "S_2-C" connects the tuning eye grid to the chassis and thus causes it to be inoperative.

In the "Phono" position, gang "S_2-A" opens the secondary circuit of IF_1, gang "S_2-B" connects the volume control to the insulated phono jack, and gang "S_2-C" again keeps the tuning eye inoperative.

To simplify the drawing, the heater circuits are shown separately at the lower right, and you can consider those of the rectifier and output tubes as 25 volts while all the others are 6.3 volts.

Instead of a ballast or resistance tube, here you will find a network of resistors numbered R_{29} to R_{35} inclusive, and arranged to provide for two pilot lamps and also to allow the unit to operate on power supply circuits from 100 volts to 250 volts.

Each rectifier has its own filter, and you will notice the upper one in our drawing supplies only the output tubes. The lower rectifier supplies the speaker field and other tubes on the same general plan as explained for Figure 2.

The bias for the 1st A-F amplifier is supplied by a "Bias Cell," a very low current, constant voltage device. It supplies 1.5 volts and will last indefinitely if not overloaded.

IMPORTANT WORDS USED IN THIS LESSON

BALLAST RESISTOR—A resistor connected in the line feeding a series filament circuit to drop the line voltage to the required value.

BAND SWITCH—A selector switch of two or more sections that simultaneously makes all the circuit changes required to shift the operation of a receiver or transmitter from one band of frequencies to another.

DIAL LIGHT—A small electric lamp used to illuminate the tuning dial of a radio receiver. (Also known as a pilot lamp.)

FIXED BIAS—A practically constant bias voltage supplied to a tube from some portion of the power supply system.

LINE CORD—A 3-wire cable used for connecting a series-filament receiver to the wall outlet. In addition to the two electric line wires it contains a resistance wire which serves to drop the line voltage to the value required by the series filament circuit.

PORTABLE RECEIVER—A compact, completely self-contained, battery-powered radio receiver, that can be carried from place to place and will operate in any location.

RESISTOR TUBE—Same as ballast resistor, but with the resistance element mounted in a housing resembling an electron tube.

SELF-BIAS—A tube circuit in which the plate and screen grid currents, carried by a cathode resistor, develop a voltage drop that is employed as the negative control grid bias.

UNIVERSAL RECEIVER—A radio receiver designed to operate on either a-c or d-c power without requiring any circuit changes. It does not require a power transformer.

STUDENT NOTES

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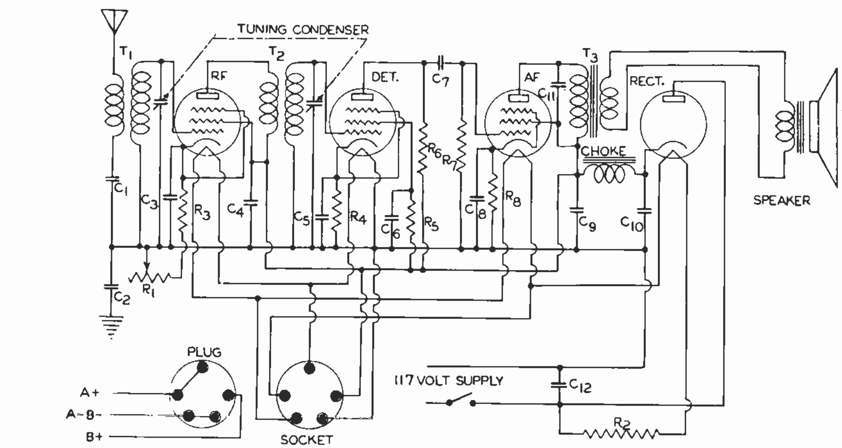
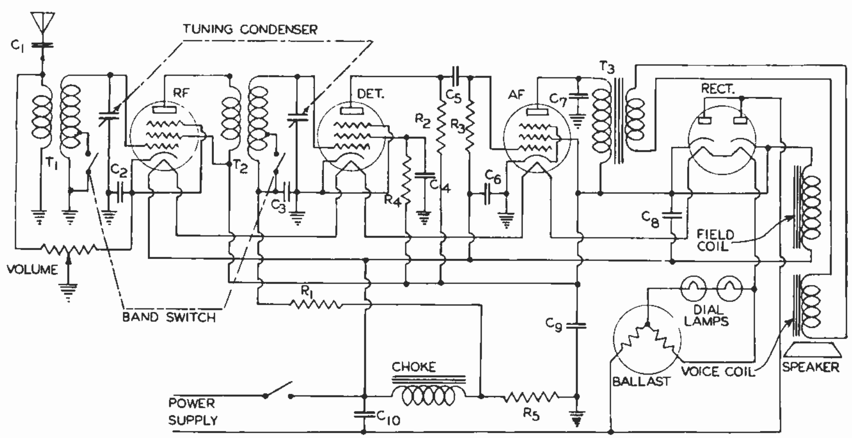


FIGURE 1



RRT-11

FIGURE 2

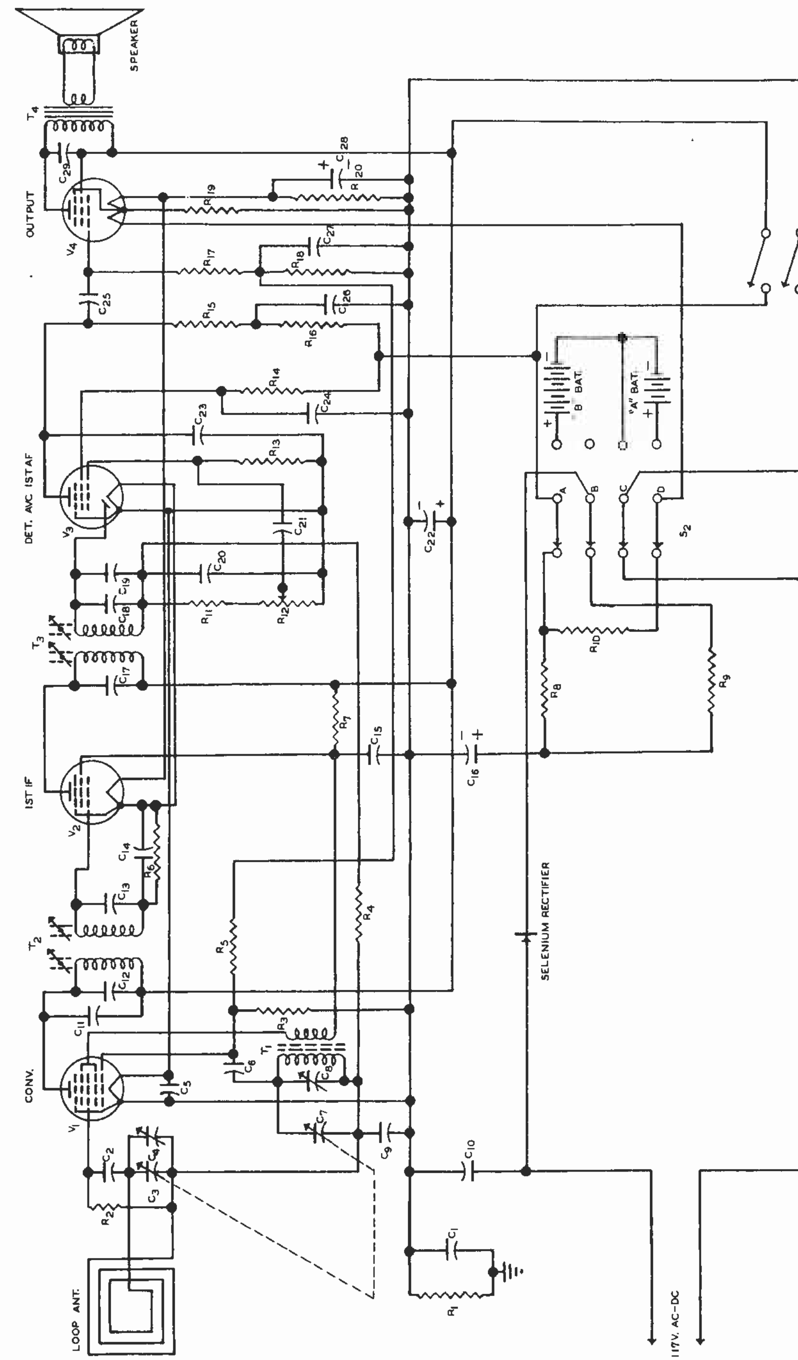


FIGURE 3

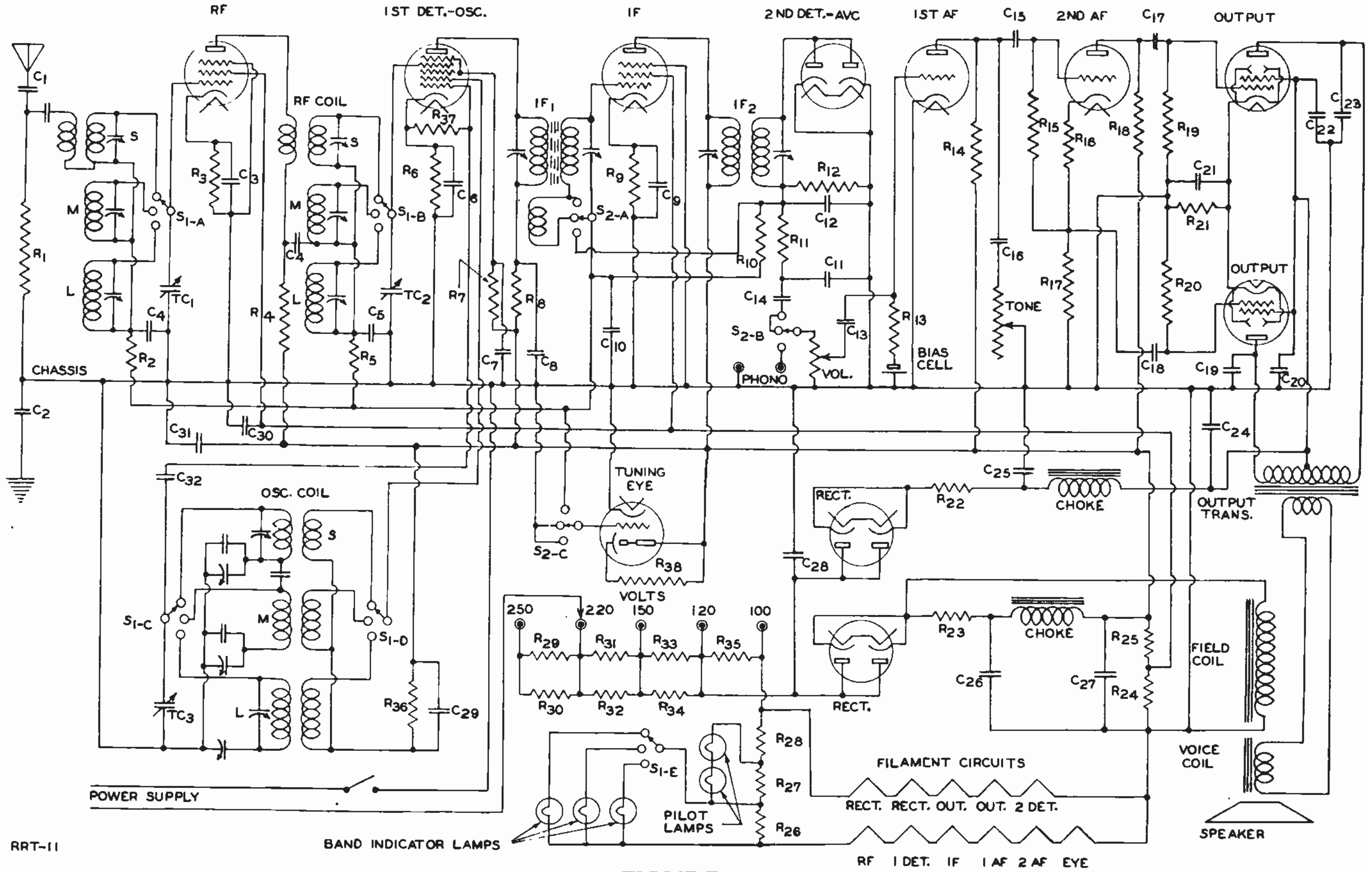

RF
1ST DET.-OSC.
IF
2ND DET.-AVC
1ST AF
C15
2ND AF
C17
OUTPUT
RF COIL
IF1
IF2
S1-A
S1-B
S2-A
TC1
TC2
CHASSIS
PHONO
VOL.
TONE
BIAS CELL
OSC. COIL
TUNING EYE
S2-C
VOLTS
250
220
150
120
100
RECT.
CHOKE
OUTPUT TRANS.
FIELD COIL
VOICE COIL
SPEAKER
S1-C
S1-D
S1-E
TC3
POWER SUPPLY
PILOT LAMPS
BAND INDICATOR LAMPS
FILAMENT CIRCUITS
RECT. RECT. OUT. OUT. 2 DET.
RF 1 DET. IF 1 AF 2 AF EYE
RRT-11

FIGURE 4

FROM OUR *President's* NOTEBOOK

ANTICIPATING OPPORTUNITY

It might be a good thing if those people who wait so patiently for opportunity to knock at their door would vary their program a little and give a good resounding knock at opportunity's door. This Micawber-like attitude of always waiting for something to turn up has its drawbacks. Time has a habit of slipping away unnoticed, and while these waiters are biding their time at home, others are out and abroad carving their destiny by virtue of their own hands and talents. Like many other proverbs that because of their brevity have been taken to be the soul of truth, the saying that "opportunity knocks once at every man's door" has been abused. Opportunity may come to a man who waits for it, but it is more often found by those who go looking for it.

Yours for success,

E. B. deVry

PRESIDENT

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