TYPICAL RECEIVER DIAGRAMS AND HOW TO ANALYZE THEM

REFERENCE TEXT 35X

NATIONAL RADIO INSTITUTE
ESTABLISHED 1914
WASHINGTON, D. C.

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TYPICAL RECEIVER DIAGRAMS AND HOW TO ANALYZE THEM

General Electric LB-530 A.C.-BATTERY Portable

IDENTIFYING Tube Stages. When starting to identify tube stages on the circuit diagram of a receiver, we often work by a process of elimination. That is, we locate first the tubes which are easiest to identify. Knowing the stages generally used in a superheterodyne, we then concentrate on assigning the remaining tubes to the heretofore unidentified stages.

We will use this process to identify the tubes in the circuit diagram of this General Electric superheterodyne receiver (shown in Fig. 5). (Note: By folding page 2 under page 1 you can refer to this diagram while you study, without having to turn pages back and forth.)

We can start from either end of the receiver, so let us start with the 1Q5GT tube. Since this tube feeds the loudspeaker, we know that it is the output tube.

We know that this output tube should be fed by an a.f. voltage amplifier stage, and we find its input coupled to the triode section of the 1H5GT tube by R-C network *R8-C13-R9*. The control grid is fed by the diode section of the 1H5GT through *R1*, *R7* and *C12*, hence the diode section must be the second detector and the triode section must be the first a.f. stage.

The presence of volume control *R1* in the diode circuit confirms identification of the diode section as the second detector, because the volume control in a superhet is always an a.f. voltage control. A.V.C. voltage is taken from the diode detector load through filter *R4-C10*, for application to the a.v.c.-controlled tubes.

Surprisingly, the second detector is resistance-coupled to the output of a 1N5GT tube. This form of coupling might lead us to believe that the 1N5GT was the second detector if we hadn't already identified the 1H5GT as being in this stage. A glance to the left on the schematic shows two i.f. transformers, so sufficient selectivity is provided to allow the less-expensive and broad i.f. resistance coupling to be used here.

Our knowledge of superheterodyne stage sequence tells us that the 1N5GT is an i.f. amplifier, feeding the 1H5GT. It is transformer-coupled to another 1N5GT tube whose input is likewise fed from an i.f. transformer (identified by the tuned primary and tuned secondary). Thus we know that the left-hand 1N5GT in Fig. 5 is the first i.f. amplifier.

I.F. transformer *T4* is fed by a 1A7GT whose input connects to the antenna loop and whose first grid connects to a tank circuit through condenser *C7*. There are no more tubes in the set, so the 1A7GT must be the oscillator-mixer found in every superheterodyne receiver. In this simple manner we have identified the purpose of each tube in the receiver.

Signal Circuits. The parts list under Fig. 5 indicates that *L1* is the Beam-A-Scope Loop assembly, and it must therefore act as the antenna for the receiver. The expression "Beam-A-Scope" is a trade name used by General Electric to describe their shielded loop antenna. Additional pick-up may be obtained by means of an external loop *L7* which is furnished with the receiver and can be plugged into the terminals shown on the diagram. The two loops are inductively coupled together by the single turn of wire shown around *L1* in the diagram.

Loop *L1* is tuned to resonance by condenser *C1*, so signals picked up by *L1* undergo the usual resonant step-up. The use of *L7* will cause some detuning, but the resulting loss in signal is more than made up by the greater pick-up afforded by *L7*. The incoming carrier signal to which *L1-C1* is tuned acts directly on the control grid and filament of the 1A7GT, because *C10* provides a zero-reactance path to the grounded filament at r.f. and i.f. values.

The first and second grids of the 1A7GT (counting from the filament) serve as oscillator electrodes, the first being the oscillator control grid and the second being the oscillator anode.

The incoming signal and oscillator signal are mixed within the tube, and we have a strong i.f. beat signal developed across the primary of *T4*. The signal induced into the secondary of *T4* is applied to the input of the 1N5GT first i.f. tube, the filament connection being through *C10*. The amplified signal now appears across the tuned primary of *T5*, setting up a high circulatory current at the i.f. value, and this induces the i.f. signal voltage in the secondary of *T5*. Again we have resonant step-up, and the signal voltage across the secondary is applied directly to the input of the second 1N5GT i.f. tube.

The resulting variations in the plate current of the second 1N5GT tube produce a large i.f. voltage across plate load resistor *R5*. This i.f. voltage is applied across resistor *R6* through condensers *C8*, *C21B* and *C9*. The i.f. voltage across *R6* feeds the diode of the 1H5GT, the filament connection being through *C9*. The diode rectifies the signal and detection takes place. The a.f. signal divides between *R6* and *R1*, but since *R1* is many times greater in value than *R6*, the a.f. signal loss across *R6* is so small that it can be forgotten.

I.F. signals are shunted around *R1* by *C9*. The d.c. component of the rectified audio signal is fed through *R4* for use as the a.v.c. voltage for the control grids of the converter tube and the first i.f. tube. *C10* acts as the a.v.c. filter condenser. That portion of the audio signal which is between the movable contact of *R1* and ground is applied across *R7* in the grid input circuit of the 1H5GT triode section through *C12*.

The amplified audio signal across triode plate load resistor *R8* is applied across the grid input of the 1Q5GT through coupling condenser *C13* and through *C21B*. Plate by-pass condenser *C18* removes stray i.f. components from this signal. The plate current of the 1Q5GT, varying at an audio rate and flowing through the primary of output transformer *T1*, induces a voltage in the secondary. The resultant current through the loudspeaker voice coil sets the cone in motion, producing sound waves.

C14, connected between the plate and screen grid of the 1Q5GT, prevents audio oscillation by making the plate load capacitive at the higher frequencies where oscillation would otherwise take place. This condenser also by-passes the harmonics produced within the tube, and hence reduces distortion. The harmonics, being of a higher frequency than the fundamentals, are more easily by-passed by *C14*.

How the Tubes Are Biased. As in all filament-type battery tubes, the effective control grid voltage is the voltage between the control grid and the center of the filament. Naturally we cannot connect our voltmeter probe to the center of the tube filament, so the control grid voltage is measured between the control grid and the negative side of the filament. The tubes all have their negative filament leads grounded to the chassis, and the various grid voltage sources exist between the grids and chassis. The voltage between the center of the filament and ground (half of the filament voltage) serves as an additional bias.

The triode section of the 1H5GT is self-biased by convection currents through *R7*, which has a value of 4.7 megohms.

Bias cells (*B1*) are used to provide control grid voltage for the 1Q5GT power tube. Since *R9* has a value of 2.2 megohms, convection currents wouldn't produce much voltage across such a relatively low value of resistance in the grid circuit of a tube.

Bias cells are more expensive than a single resistor of high ohmic value, but there is a good reason for using them here. The 1Q5GT tube is subject to gas, as are so many power output tubes. If a high-value grid resistor is used with a gassy tube, the resulting gas current through the grid resistor will be opposite in direction to the convection current and much stronger. As a result, the gas current will drive the grid positive, increasing the plate current and releasing more gas, all of which causes serious distortion and shortens tube life.

Because of the low plate and screen voltages which are employed for the converter and the i.f. tubes, no external grid bias sources are necessary for these tubes. The voltages between the centers of the filaments and ground provide sufficient initial bias voltage in each case. When a signal is received, however, the a.v.c. voltage is applied to the converter and first i.f. tube control grids.

The Power Supply. The power supply of this receiver, shown inside the dotted lines in Fig. 5, is as complicated as any you will meet in ordinary receivers. This is due to the switching system and the manner in which the circuit is drawn.

The tube filaments are heated directly by the 2-volt battery, while the necessary high d.c. voltages for the tubes are furnished by a synchronous vibrator used in conjunction with a step-up power transformer and its associated filter circuit. The synchronous vibrator also operates from the 2-volt battery.

Provision has been made to charge the battery directly from the house current without removing the battery from the receiver circuit. Two charging positions are provided on the four-position power selector switch. The "*CHARGE*" position of this switch allows the battery to be charged at the rate of approximately 1.35 amperes from the house current during the period that the receiver is not being operated. The "*AC*" position of the switch allows the receiver to be operated at the same time that the battery is being trickle-charged at a low rate.

Charge Indicator. The degree of charge of the battery can be determined by removing the back cover of the radio and looking at the charge ball indicators which are visible through the hole in the metal battery case.

If the battery is fully charged, three indicator balls will be visible at the surface of the liquid in the battery. When the battery discharges, these ball indicators will sink and disappear in the following order:

1. The green ball sinks when approximately 10% of battery capacity has been discharged.
2. The white ball sinks when 50% of battery capacity has been discharged.
3. The red ball sinks when the battery is 90% discharged.

FM10M350
1950 Edition
Printed in U.S.A.

On charge, the balls rise or float in the reverse order. Charging is complete and may be stopped when all three balls appear in the opening.

To Charge Battery. The battery is charged merely by plugging the receiver power cord into an a.c. wall outlet and turning the selector switch to "*CHARGE*." The charge indicator balls should be checked frequently. Continued charging after all indicator balls are visible will not harm the battery, but will evaporate the water in it faster. A completely discharged battery will usually be restored in 20 to 30 hours.

Power Pack Circuit for "CHARGE." Setting the power selector switch to "*CHARGE*" (for charging the battery from the a.c. power line without operating the receiver) connects switch terminals *2* and *3* together, and also connects *8* and *9* together, as indicated in the box at the left of the diagram in Fig. *5*. When the power pack circuit is redrawn to show only these switch terminals and the associated parts which are effective, we secure the arrangement shown in Fig. *1*. Of course, switches *8-9* and *3-2* would be closed during charging. Charging currents can now be easily traced on this simplified circuit.

During charge, electrons must flow into the negative terminal of the battery and out of the positive terminal. The charging voltage need be only a small amount higher than the normal battery voltage of 2 volts. Transformer *T3* in Fig. *1* provides about 5½ volts a.c. between secondary terminals *x* and *y*. The four copper-oxide rectifiers, each pair in parallel, convert this to the required d.c. voltage.

When point *x* is negative, point *z* is positive. Then electrons flow from *x* through rectifier *Y2* and the chassis to the negative battery terminal, through the battery and back to *z*. Electrons only flow through the copper-oxide rectifiers in the direction from the flat plates to the triangles on the symbols, so there is no electron flow now through rectifier *Y2*.

On the next half-cycle, *y* is negative and *x* is positive, so *z* is now positive with respect to *y*. Electrons flow from *y* through *Y1* and the chassis, then through the battery in the same direction as on the previous half-cycle, adding to the charge of the battery. The electrons coming out of the positive battery terminal return to *z* through switch contacts *3-2*. We thus have a full-wave rectifier, with first one half of the transformer secondary and then the other half furnishing current to the battery.

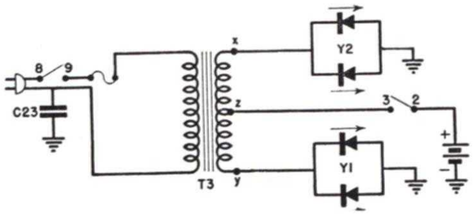


Fig. 1. Effective power pack circuit when power selector switch is set at "CHARGE." Arrows indicate direction of electron flow through rectifier units.

Power Pack Circuit for "BATTERY." When the switch is thrown to the "*BATTERY*" position for portable operation, contacts *4-5* and *2-1* are closed, giving the effective circuit arrangement shown in Fig. *2*. The filaments secure their voltage from the battery through contacts *4-5* and series resistors *R13*, *R11* and *R12*, with the circuits being completed through the chassis by means of grounds.

When the power selector switch is in its "*OFF*" position, all switch contacts are open, and the vibrator reed is in a neutral position half-way between contacts *P1-P2* and *S1-S2*. Only contact *A* on the vibrator is closed.

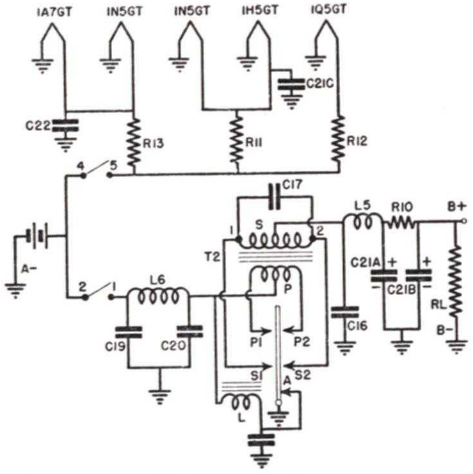


Fig. 2. Effective power pack circuit when power selector switch is set at "BATTERY."

Setting the switch to "*BATTERY*" closes switch contacts *2-1* and *4-5*, and the battery sends current through vibrator contact *A* and through the vibrator coil *L*. This energizes the coil, causing it to attract the vibrator reed. The reed is pulled toward the coil, thereby grounding contacts *P1* and *S1*. This results in electron flow from the grounded terminal of the storage battery through the reed and *P1*, through the left-hand side of the primary of power transformer *T2*, then through *L6* and switch contacts *2-1* to the positive battery terminal.

The sudden rush of current through primary winding *P* causes a high voltage to be induced into secondary *S*. Let us assume that it makes point *1* on the secondary negative with respect to the center tap. Electrons now flow from point *1* through contact *S1* to the chassis, then through all the tube loads in the receiver, represented in Fig *2* as resistive load *RL*. From the *B+* end of *RL* the electrons flow through *R10* and *L5* to get back to the center tap on winding *S*.

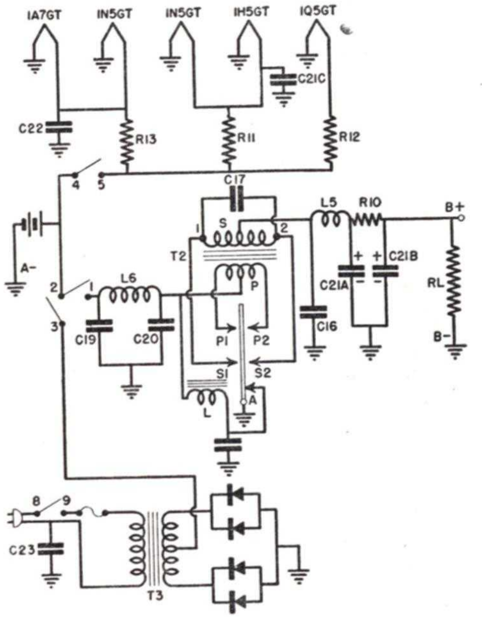


Fig. 3. Effective power pack circuit when power selector switch is set at "AC."

That portion of the induced voltage existing between the center tap and point *2* is not used now, and may be forgotten.

When the vibrator reed is pulled over to contacts *P1* and *S1* by the coil, it breaks the coil circuit at contact *A*. The natural springiness of the reed returns it to the neutral position, but the reed always overshoots the neutral position enough to make contact with *P2* and *S2*.

With contacts *P2* and *S2* grounded by the reed, we have electrons flowing from the minus battery terminal through the chassis to the reed and *P2*, then through the right-hand section of power transformer primary *P* and back through *L6* and contacts *2-1* to the battery. Since this electron flow is in the opposite direction from that which previously flowed through *P*, the induced voltage in the secondary has reversed polarity. Point *1* is now positive with respect to the center tap, which makes point *2* negative with respect to the center tap and gives electron flow through *RL* in the same direction as before.

From this, we see that the center tap on the secondary is positive with respect to whichever outer terminal (*1* or *2*) is being grounded by the vibrating reed. The vibrator thus provides full-wave rectifying action which gives a pulsating high d.c. voltage of the correct polarity between the center tap of *S* and the chassis. This pulsating voltage is filtered by *C21A*, *C21B* and *R10*, then applied to the plates and screen grids of the tubes in the receiver (connected between *B+* and *B—* like *RL*).

When the reed moves over to contacts *P2* and *S2*, it also touches contact *A*. This energizes the vibrator coil and pulls the reed over to *P1* and *S1* just as when the set was first turned on. The entire process then repeats itself.

Power Pack Circuit for "AC." When the power selector switch is set at "*AC*," contacts *1-2-3* are connected together, as also are contacts *4-5* and contacts *8-9*. The power pack circuit arrangement for this condition is represented by **Fig. *3*** if we close the four switches in the diagram.

The output voltage of the charging circuit is now applied directly across the battery just as in Fig. *1*. At the same time, the battery furnishes current for the tube filaments and the vibrator *B* supply. Since the charger furnishes the battery a little more current than is drawn from it by the receiver, the battery will be charged slowly while the set is playing.

The battery acts as a low-resistance bleeder across the charging circuit, and thereby keeps the charging voltage from getting too much higher than the rated filament voltages. The battery also acts like a condenser, removing the ripple from the charging voltage. When the charging voltage starts to decrease, the net voltage cannot become lower than the battery

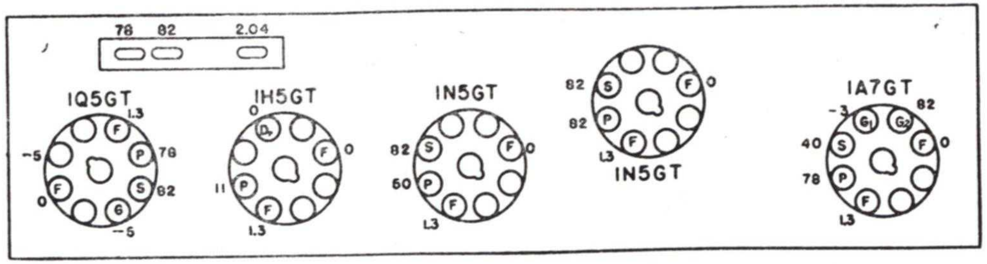


Fig. 4. Socket voltage diagram. The bias battery voltage should be measured only with a zero-current voltmeter, such as a vacuum tube voltmeter. The power switch should be set on "AC," with the charger operating. Tuning dial should be at 1000 kc., with zero volume and zero signal. Battery should measure 2.1 volts. Vibrator B+ voltage should be 95 volts d.c.

voltage because the two voltages are in parallel. The copper-oxide rectifiers prevent the battery from discharging through the charging circuit, because they do not allow current to pass in the reverse direction. For these reasons, the battery must be in the receiver even during a.c. operation. If the set were used on "*AC*" with the battery removed, the tubes would get excessive filament voltages and would burn out, and the vibrator and filter condensers might also be damaged.

Voltage Measurements. Figure *4* shows the socket voltage diagram for this set. The voltages given on it are measured between the points indicated and the chassis. The battery voltage is measured across the battery terminals, and the vibrator voltage is measured from *B+* to the chassis. Condenser *C21A* can easily be located in the chassis; since it is the input filter condenser, the *B+* voltage delivered by the power transformer may be measured across it. The resistance of *L5* is so low that the slight amount of voltage dropped across it will not affect the accuracy of this measurement.

You will find that the value of *R14* is not given. Evidently the factory draftsman forgot this; such errors sometimes creep into diagrams.

If you had to replace *R14*, what would you do? First, you would consider the purpose of *R14* in the circuit. Obviously, it is not purposely used to reduce plate voltage, and neither is it a plate load. It must therefore act with *C24* as a filter to keep r.f. plate current of the 1A7GT out of the B supply. From past experience and from observing many similar circuits, we know that the resistor value is not critical and that manufacturers use values between 1000 and 10,000 ohms for this purpose. We feel sure that the choice of an average value of about 5000 ohms will work nicely.

We can get a confirmation by means of Ohm's Law if we wish. Since the plate of the 1A7GT receives 78 volts and the i.f. screen from which *R14* is fed receives 82 volts, 4 volts are dropped across *R14*. A tube chart tells us that the 1A7GT plate draws about .7 ma., and Ohm's Law says that resistance equals voltage divided by current, so by simple division we arrive at a value of about 5900 ohms for *R14*. Experience tells us that 5000 ohms is satisfactory, but if actual trial shows it to be too low, a larger resistor may easily be inserted.

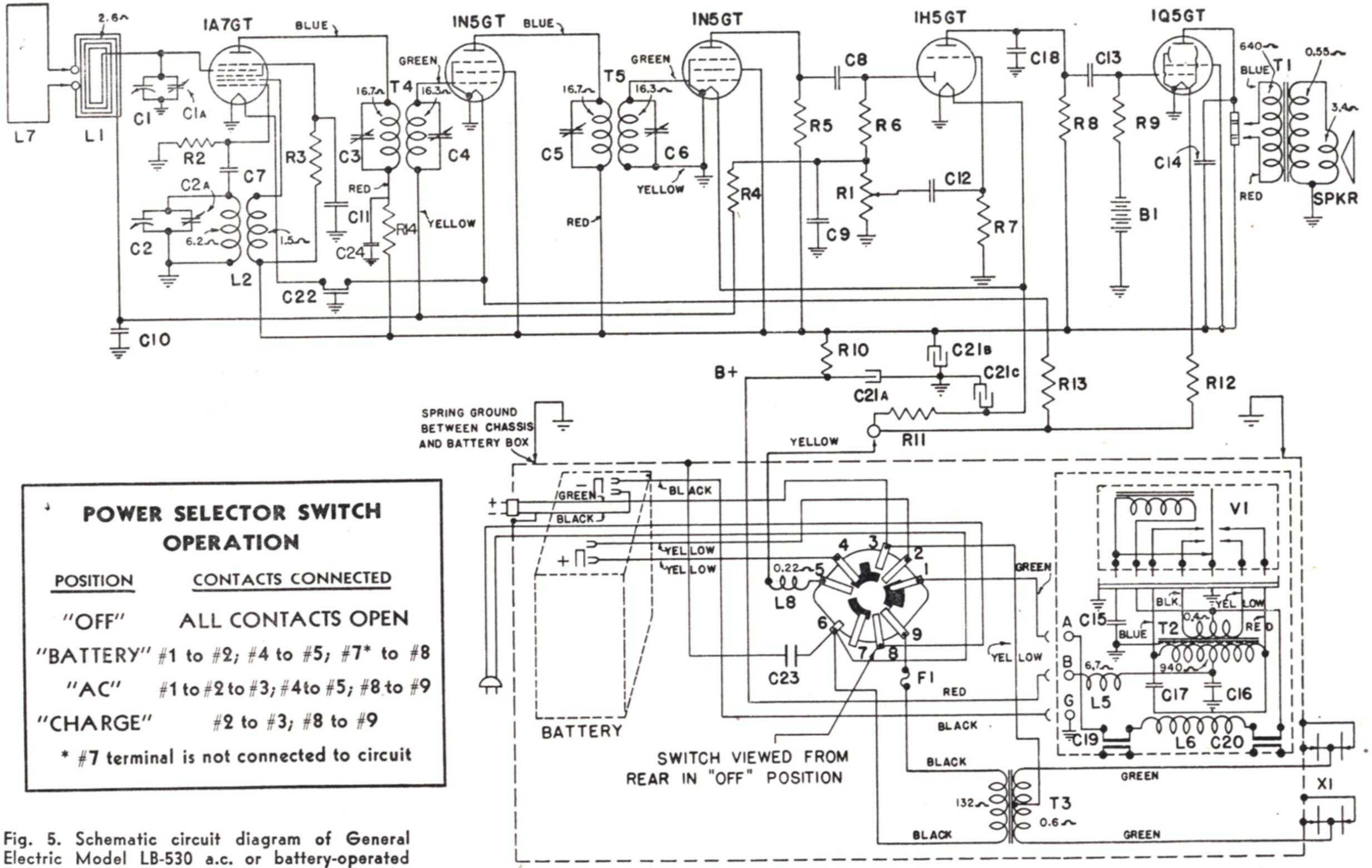
Continuity Tests. Continuity tests are made in the usual way between points at a positive potential and the *B+* terminal, and between points at a negative potential and the *B—* terminal (the chassis here). *B+* is the red lead going from the junction of *R10* and *C21A* to the *B* supply.

The storage battery in this receiver must be disconnected for ohmmeter tests, just as in any other battery set. The bias cells need not be disconnected if you don't check from the grid of the 1Q5GT to chassis. However, a check directly across *R9* is perfectly all right.

To avoid possible short-circuit readings through the vibrator contacts, the plug-in type vibrator is pulled out of its socket during ohmmeter tests.

Expected Performance. With the two stages of i.f., excellent sensitivity and adjacent-channel selectivity may be expected. Some image interference may occur due to lack of preselection, but turning the loop to a different position by rotating the entire receiver will sharply reduce the pick-up of undesired signals.

The 1Q5GT can't deliver much output power, so you won't expect high volume. Both volume and tone quality will be less than that secured with a good table model receiver, but will be entirely satisfactory for a portable.



POWER SELECTOR SWITCH OPERATION

POSITION	CONTACTS CONNECTED
"OFF"	ALL CONTACTS OPEN
"BATTERY"	#1 to #2; #4 to #5; #7* to #8
"AC"	#1 to #2 to #3; #4 to #5; #8 to #9
"CHARGE"	#2 to #3; #8 to #9

* #7 terminal is not connected to circuit

Fig. 5. Schematic circuit diagram of General Electric Model LB-530 a.c. or battery-operated portable receiver.

C1, 2	CONDENSER—Tuning condenser and trimmers
C7	CAPACITOR—47-mmf. mica
C8, 9	CAPACITOR—100-mmf. mica
C10	CAPACITOR—.05-mfd., 200-V. paper
C11	CAPACITOR—0.1-mfd., 200-V. paper
C12, 13	CAPACITOR—.005-mfd., 600-V. paper
C14	CAPACITOR—.01-mfd., 600-V. paper
C15	CAPACITOR—0.1-mfd., 200-V. paper
C16	CAPACITOR—.05-mfd., 200-V. paper
C17	CAPACITOR—.006-mfd., 100-V. paper
C18	CAPACITOR—100-mmf., mica
C19, 20	CAPACITOR—0.5-mfd., 120-V.
C21A, 21B	CAPACITOR—15-mfd., 150-V. dry electrolytic
C21C	CAPACITOR—1200-mfd., 2-V. dry electrolytic
C22	CAPACITOR—0.5-mfd., 120-V. paper
C23	CAPACITOR—.05-mfd., 600-V. paper
R1	VOLUME CONTROL—0.5-megohm volume control
R2	RESISTOR—220,000-ohm, ½-W. carbon
R3	RESISTOR—47,000-ohm, ½-W. carbon
R4	RESISTOR—2.2-megohm, ½-W. carbon
R5	RESISTOR—27,000-ohm, ½-W. carbon
R6	RESISTOR—47,000-ohm, ½-W. carbon
R7	RESISTOR—4.7-megohm, ½-W. carbon
R8	RESISTOR—1.0-megohm, ½-W. carbon
R9	RESISTOR—2.2-megohm, ½-W. carbon
R10	RESISTOR—1,000-ohm, ½-W. carbon
R11, 12, 13	RESISTOR—8.2-ohm, ½-W. carbon
B1	CELL—5.0-V. bias cell assembly
L1	BEAM-A-SCOPE—Loop antenna assembly (inside cover)
L2	COIL—Oscillator coil
L5	CHOKE—B choke
L6	CHOKE—Vibrator choke
L7	BEAM-A-SCOPE—External loop antenna
L8	CHOKE—Filament supply choke
SW1	SWITCH—Power selector switch
T1	TRANSFORMER—Output transformer
T2	VIBRATOR—Vibrator power transformer
T3	TRANSFORMER — 50-60-cycle rectifier step-down transformer
T4	TRANSFORMER—1st i.f. transformer
T5	TRANSFORMER—2nd i.f. transformer
V1	VIBRATOR—Power supply synchronous vibrator
X1	RECTIFIER—Copper-oxide rectifier
Spkr.	SPEAKER—P.M dynamic loudspeaker

THORDARSON 15-WATT AUDIO AMPLIFIER

THIS amplifier, whose circuit diagram is shown in Fig. 6, has sufficient power output to satisfy the requirements of many different public address installations. The versatility of the amplifier is evident when it is realized that it can be used for ordinary p.a. (public address) work, as a phonograph amplifier, for commercial or home recording, or to amplify the output of a photocell.

Starting with the output stage, we see that type 6V6-G beam power output tubes are used in a class *A* circuit. Distortion is kept below 5% even at full output by the use of inverse feed-back. This low level of distortion is quite good.

The high-impedance microphone and high-impedance phonograph channel, with independent gain controls, will allow use of any type of microphone and either a crystal or magnetic pick-up. The gain is sufficient to obtain full output either from the microphone or pick-up under normal operating conditions.

The circuit diagram shows two loudspeaker sockets, in which either electro-dynamic or p.m. dynamic loudspeakers can be plugged. The power pack is designed to serve as field supply for one or two electro-dynamic loudspeakers. More than two p.m. dynamic loudspeakers can be used, but normally there would be no reason to use more than two with a relatively small p.a. system like this.

When a phono pick-up is used, the leads are plugged into the jacks provided on the *PHONO* terminal strip, and microphone volume control *R-8* is set for zero volume (so its movable contact is grounded). The signal voltage from the pick-up is applied across phono volume control *R-6*, and the portion of this voltage between the movable contact and ground is applied to a voltage-dividing network consisting of resistors *R-7* and *R-9*. Only that portion of the signal across *R-9* is applied to the input of the second 6J7 tube, the a.f. signal across *R-7* being lost as far as the amplifier is concerned. This cuts the signal in half, but the gain built into the amplifier takes this into consideration.

The purpose of resistor *R-7* is to isolate phono volume control *R-6* from microphone volume control *R-8* when the microphone input is used. Under this condition, *R-6* is set to zero, and volume is controlled by *R-8*. If it were not for resistor *R-7*, control *R-6* in its off position would connect the control grid of the second 6J7 tube directly to ground, thus cutting off the microphone signals. Resistor *R-7* is 500,000 ohms, which is enough to isolate *R-6* from the microphone volume control.

Note the symbol for the microphone jack. The jack is of the telephone type, the outside shell going to ground and the hot (ungrounded) contact going to coupling condenser *C-2*. When a "mike" is plugged into this jack, one lead makes contact to the chassis through the jack shell, while the other connects to condenser *C-2*.

The mike signal is impressed through *C-2* across the single bias cell and resistor *R-3*. In this way it is fed into the input of the first 6J7 tube. This tube is connected as a high-gain voltage amplifier. The weak a.f. signal applied to its input is amplified many times, so a strong a.f. signal is developed across plate load resistor *R-5*. Capacity coupling through condensers *C-4* and *C-10* allows the signal to be applied across volume control *R-8*, whose setting governs the amount of signal fed into the second 6J7 tube.

At the microphone input, you will notice the terminal strip marked *POL-V*. This means polarizing voltage. When a condenser-type microphone is employed, a wire jumper is used to connect terminals *1* and *2* together, thus applying the necessary high d.c. voltage to the microphone plates. Here resistor *R-2* and condenser *C-1* serve as a decoupler filter, preventing any hum voltage from being applied to the condenser microphone and preventing the microphone signal from traveling through the power supply.

If a photoelectric cell of the gas-filled type is plugged into the mike jack, about 90 volts will be required to operate the cell. At terminal *1* we have about 270 volts, and when a photocell is used this is reduced to 90 volts across the mike jack by connecting a 5-megohm, 1-watt resistor between terminals *1* and *2*.

If a condenser microphone or photoelectric cell is never to be used, *R-1*, *R-2* and *C-1* are eliminated during construction of the amplifier.

The shielding of wires and parts in the circuits of the two 6J7 tubes and the 6C5 tube is very important, if hum and noise are to be eliminated. Any hum or noise signals picked up at these points would receive great amplification. If they were as strong as the a.f. signals normally existing here, they would be just as loud at the loudspeakers, thus preventing use of the amplifier.

The microphone, photocell or phono signals applied to the input of the second 6J7 tube cause a large variation in the tube's plate current. The variation in current flowing through plate load resistor *R-11* produces a strong a.f. output voltage across *R-11*.

Before we follow the signal to the next stage, note the electrode connections employed in the second 6J7 tube. With the screen grid, suppressor grid and plate tied together in this manner, the tube acts as a triode instead of a pentode. The gain as a triode is considerable, but far less than that obtained with the pentode connection used for the first 6J7 tube.

The triode connection was employed because a pentode tube fed with a strong signal will produce very strong harmonics, and these will cause severe distortion. Push-pull action and inverse feed-back permit the use of the 6V6 pentode-type output tubes, while the signal input of the first 6J7 is too low to produce much harmonic voltage. The signal fed to the second 6J7 is, for either microphone or phonograph operation, too large to permit pentode operation of the tube.

The second 6J7 is not replaced with a regular triode tube such as a 6C5, because even when connected as a triode the 6J7 can produce more gain than a 6C5. It is necessary to use a 6C5 in the next stage, for by now the signal is so strong that it would overload the 6J7 even when triode connections were used.

The a.f. signal voltage across *R-11* is applied to grid resistor *R-12* of the 6C5 tube through coupling condenser *C-6* and filter condenser *C-10*. The signal current flowing through grid resistor *R-12* produces a voltage drop which drives the grid of the tube. *R-12* is a potentiometer, and the movable arm connects to ground through *C-7*, a .03-mfd. condenser. As the arm is moved up, more and more of the high frequencies are shorted or by-passed around *R-12*, and hence are not applied to the grid of the 6C5. In this way we achieve tone control, which permits attenuation of high audio frequencies as desired.

The a.f. signal voltage across *R-12* alternately adds and subtracts from the d.c. bias developed across *C-8* and *R-13*, making the grid first more negative and then less negative. This variation in control grid voltage causes a corresponding variation in plate current. As a result, we have a pulsating d.c. plate current flowing through plate load resistor *R-14*. Condenser *C-9* and the primary of *T-1* comprise a short path for the a.f. component, hence the effective plate load for signals is *R-14* in parallel with *C-9* and the primary of *T-1*. Since the resistance of *R-14* is much greater than the impedance of the *C-9 T-1* path at audio frequencies, practically all of the signal current passes through *C-9* and the transformer.

This method of capacity coupling is a little out of the ordinary. If *R-14* and *C-9* were not used, the primary of *T-1* would be placed right in the plate supply circuit of the 6C5. The circuit would function but the d.c. portion of the plate current would tend to saturate the transformer primary, and the mutual inductance of the transformer would decrease. This would decrease the voltage induced into the secondary, and would cause distortion since the change in flux linkage would be greater for a decrease in plate current than for an increase. For distortionless transfer of signal, the flux must follow current changes exactly. The loss in gain would be more serious at the low audio frequencies, because the primary inductance, and hence the plate load impedance, naturally decreases with frequency.

By keeping the d.c. portion of the plate current out of the primary, we avoid transformer saturation and thereby secure good low-frequency response from this stage. Resistor *R-14* and condenser *C-9* do this; the resistor supplies d.c. plate voltage to the tube, and *C-9* blocks d.c. while allowing a.c. to pass. By choosing a value of *C-9* which will resonate with the primary of *T-1* at a low audio frequency, a definite boost in gain at low audio frequencies can be obtained.

A.F. signal current flowing through the primary of *T-1* sets up a flux linkage with the secondary, inducing an a.f. voltage in each half of the secondary. These secondary windings feed the two 6V6-G tubes in the push-pull output stage, with inverse feed-back being provided in the following manner by an extra center-tapped winding on output transformer *T-2*. Let us consider secondary *8-7* of *T-1* first. Terminal *8* goes to the control grid of the upper 6V6-G output tube, while *7* goes to terminal T_2 on the special winding having a center tap marked *CT*. Resistor *R-18* (a C bias resistor in the power pack) completes the path from *CT* to ground. The voltage between *8* and *7* thus acts in series with the a.f. voltage across the lower half of the "*CT*" winding and the d.c. voltage across resistor *R-18*. In a similar manner, the signal voltage between point *5* and point *6* acts in series with the a.f. voltage across the upper half of the "*CT*" winding and the d.c. voltage across *R-18*, all feeding the control grid of the other 6V6-G tube.

The 6V6-G tubes amplify the signals applied to their grids, and the resulting plate currents flow through primaries P_1-*B* and P_2-*B* of output transformer *T-2*. Due to the push-pull action, all even harmonics produced within the tubes are canceled out.

The odd harmonics, of which the third is the strongest and hence most troublesome, are not canceled out by the push-pull arrangement, but are taken care of by inverse feed-back (degeneration). The fundamentals and odd harmonics flowing through the primaries of output transformer *T-2* induce voltages in the "*CT*" winding as well as in the regular secondary. These voltages, as you just learned, act in series with the a.f. voltages applied to the grids of the output tubes but are 180° out of phase, due to the phase reversal provided by the output tubes.

The fundamental component which is fed back out of phase cancels out some of the fundamental at the grid input, thus reducing the gain. The designer took this into account, however, and there is gain to spare. The odd harmonics are also fed into the grid input of each 6V6-G, but since they were produced inside the 6V6-G tubes, they are not originally present in the input circuit. The fed-back odd harmonics thus enter the tubes, and cancel out some of the odd harmonics being produced by the tubes. Complete cancelation is impossible, for we must have some signal induced into the center-tapped secondary of *T-2* for feed-back purposes.

The output signal induced into the secondary of *T-2* thus has only a very small amount of third harmonic distortion. The secondary has a number of taps, so that it can be connected to match most any load. The grounded secondary terminal goes to one load (loudspeaker) terminal by way of terminals *4* or *5* and *A* or *D* on the *SPK.* sockets, and the tap selected by probe lead *C* of the output transformer goes to the other load terminal through *SPK.* socket terminals *3* and *C*.

When the amplifier is to feed a device over a considerable distance, either the 125-, 250- or 500-ohm taps are used, and a special matching transformer is placed at the other end of the line. The lower-impedance taps are used for voice coils, recorder cutting heads or other low-impedance devices.

Most voice coils have an impedance of 8 ohms, so for a single voice coil we would plug probe lead *C* into the jack marked *8*. If two speakers with 8-ohm voice coils were used, the coils could be connected in parallel; the combined resistance would then be 4 ohms, and the 4-ohm tap would be used. While voice coils are not ordinarily connected in series, we could do this and get a combined impedance of 16 ohms, which would be matched by using the 16-ohm tap.

If electrodynamic loudspeakers are employed, 10 watts of field excitation is available for one 5000-ohm or one or two 2500-ohm speaker fields. The following table indicates how speaker field connections are made to the *SPK* sockets. Note that in some cases a jumper wire is used between jacks on the terminal strip marked *FIELD*.

	Connect Jumper Between	Connect Field to Prongs
One 5000-ohm field..	Not used	1 and 5
One 2500-ohm field..	C and 2	2 and 5
Two 2500-ohm fields	Not used	B & E; 2 & 5
P.M. Loudspeaker (no field)	C and 1	....

For practice, see if you can figure out the field supply circuits and the reasons for the connections given in the table. When doing this, take into consideration the ohmic values of the fields and of resistors *R-16* and *R-19*.

The power supply circuit in this amplifier does not represent anything new, being very similar to those you have already studied in receiver diagrams. The rules for tracing circuit continuity apply to this amplifier just as to receiver circuits.

Most troubles which may be expected will take the form of distortion, hum and oscillation. The usual causes are to be suspected, but shielding is particularly important in the case of hum or oscillation. The reason for hum, if shielding is not employed, has already been pointed out. The thing to watch out for is poor ground contacts on the shielding.

The shields on the control grid and plate leads of the 6V6-G tubes prevent electromagnetic and electrostatic coupling between these points and others at a lower audio potential. Suppose, for example, the plate leads of the 6V6-G tubes were inductively coupled to the input of the 6J7 tube by being close to resistor *R-3*. Signal voltage would be induced into *R-3*, and being in phase with the input signal voltage, it would cause oscillation and a loud squeal.

The capacity existing between the 6V6-G plate leads and the grounded shields also tends to prevent oscillation. Beam-power output tubes have a tendency to oscillate and these tubes, when oscillating, have been known to draw sufficient current to damage power transformers. Oscillation will be indicated by serious distortion or a dead amplifier. The d.c. voltages will be very low due to the excess current drain.

In the schematic, you will see the operating voltages marked at the points at which the voltage measurements are generally made. The d.c. voltages are measured between the points shown and the chassis.

The output filter voltage is measured between the positive lead of C-13 and the chassis, and according to the schematic you should read about 310 volts. Now notice that the screens of the output tubes are marked 340 volts. The screens connect directly to the positive lead of *C-13* and hence are at the same potential as *C-13* with respect to ground. The difference between the marked voltages shows that the draftsman who made up this schematic was careless. In a case like this, you must rely on your own knowledge and be able to make up your mind that an error exists. In all probability, 340 volts and not 310 volts is correct.

Note that the 6V6-G plates are marked 306 volts. If 310 volts is right and the plates are marked correctly, there is only a drop of 4 volts across the plate windings of output transformer *T-2*. This is not reasonable. Now if 340 volts is correct, the drop across the plate windings is 34 volts, which is about the amount you would expect.

The plate voltages of the 6J7 and 6C5 tubes were probably measured with a 1000-ohm-per-volt meter. If a more sensitive meter is used, a higher voltage will be measured, since the meter will draw less current through the plate load resistors and hence won't cause as much extra voltage drop to exist across them.

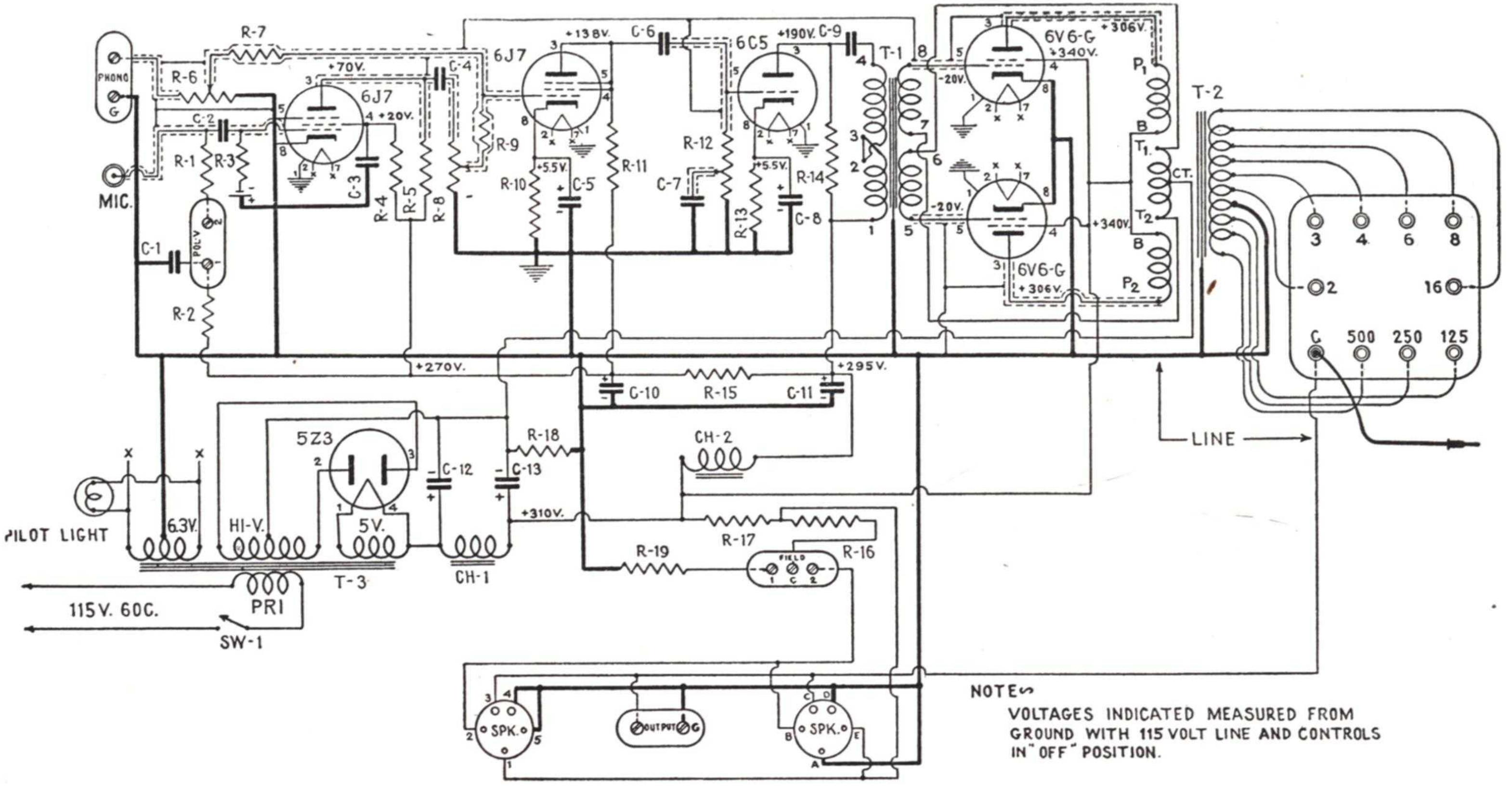


Fig. 6. Circuit diagram of Thordarson-designed 15-watt a.f. amplifier. The parts values are:

T-1	Input Transformer
T-2	Output Transformer
T-3	Power Transformer
CH-1	First Choke
CH-2	Second Choke
R-1	10-meg., ½-W.
R-2	10-meg., ½-W.
R-3	5-meg., ½-W.
R-4	3-meg., 1-W.
R-5	500,000-ohm, 1-W.
R-6	1-meg. Volume Control
R-7	500,000-ohm, 1-W.
R-8	1-meg. Volume Control
R-9	500,000-ohm, ½-W.
R-10	5000-ohm, 1-W.
R-11	100,000-ohm, 1-W.
R-12	500,000-ohm Tone Control
R-13	1000-ohm, 1-W.
R-14	20,000-ohm, 1-W.
R-15	20,000-ohm, 1-W.
R-16	2500-ohm, 25-W. wirewound
R-17	1500-ohm, 25-W. wirewound
R-18	125-ohm, 25-W. wirewound, Tolerance +10%, —0%
R-19	2500-ohm, 25-W. wirewound
C-1	.1-mfd., 400-V. paper
C-2	.1-mfd., 400-V. paper
C-3	.04-mfd., 400-V. paper
C-4	.1-mfd., 400-V. paper
C-5	10-mfd., 25-V. electrolytic
C-6	.1-mfd., 400-V. paper
C-7	.03-mfd., 400-V. paper
C-8	10-mfd., 25-V. electrolytic
C-9	.1-mfd., 400-V. paper
C-10, C-11	8-8 mfd., 450 W.V. electrolytic
C-12	8-mfd., 600-V. electrolytic
C-13	8-mfd., 600-V. electrolytic

EMERSON Model DU-379 and DU-380 Battery Portable

GENERAL Description. Although the diagram of this battery portable (Fig. 7) bears two model numbers, both models are essentially the same. The only difference lies in the degree of portability. The model DU-379 is an outdoor portable and may be carried by the special strap which fits over the user's shoulder. Since the loop is placed in this strap, there is a slight difference in the design of this loop and the one used in the model DU-380. Other than this, the two sets are identical and are both known as the DU chassis.

To achieve real portability, special small-size, low-current-drain tubes are used. Two flashlight cells connected in parallel serve as the *A* supply, and a special light-weight 67½-volt *B* battery is used.

The tubes and their functions, which you should be able by this time to identify without trouble, are: A 1R5 pentagrid converter tube as the oscillator-mixer-first detector; a 1T4 super control tube as the i.f. amplifier; a 1S5 diode-pentode as the second detector, a.v.c. and first a.f. amplifier; a 1S4 power output pentode to feed the loudspeaker.

Signal Circuits. There are a number of small but important variations from normal in the circuits of this receiver which make it of interest. Each item will be explained as we come to it.

Signals picked up by the loop may be tuned in by adjusting the tuning condenser dial, which controls ganged condensers *C1* and *C2*. Condenser *C1* tunes the loop, and the chosen signal receives a boost in strength due to resonant step-up.

In the shoulder-strap model DU-379, the inductance which is tuned by *C1* consists of loop *L2* and an extra inductance *L1*. In home-model DU-380, all of the inductance is concentrated in the loop, which is rigidly fastened in place, and *L1* is absent. In model DU-379, the loop shape will change as the wearer breathes and moves around. This results in some inductance change; to avoid serious detuning, most of the circuit inductance is concentrated in *L1*. Then even large changes in the loop inductance have only a small effect on the total circuit inductance and hence on tuning. The shoulder-strap loop is primarily a pick-up device rather than a tuning coil.

In both models, the resonant circuit is completed through *C5* which, as far as r.f. is concerned, acts like a short circuit.

The modulated carrier of the selected station appears across *C1*, and is applied to the input of the first detector. The filament connection is made through the chassis and the lower half of oscillator tank coil *T1*. At the same time, the oscillator signal is injected into the first detector. The two signals are mixed inside the tube. The resulting i.f. beat voltage, bearing the original carrier modulation, is applied to the primary of i.f. transformer *T2*.

An examination shows the oscillator circuit to be different from that found with the usual pentagrid converter tube. First, you will note that we have been speaking of the 1R5 as a pentagrid converter, when only four grids are shown. The facts of the case are that the manufacturer's draftsman took a little poetic license and left out the suppressor grid, figuring perhaps that the tube drawing was going to be spread out enough as it was, and it didn't matter as far as service work was concerned. In this he was right, for the extra grid, placed between the screen and plate, connects inside the tube envelope to the negative side of the filament, and serves to prevent secondary emission from the plate to the screen. A serviceman can't get at this grid or do anything about it, so it doesn't enter as a service problem. If the grid shorts to the plate, a tube tester will show this up in the usual manner, and in the set the short, if it occurred, would appear to be between the plate and filament.

The oscillator is an ordinary Hartley with the plate grounded. Here the screen grid acts as the plate, and the screen is kept at r.f. ground potential by means of by-pass condenser *C9*. The screen also acts as the virtual cathode as far as the detector section is concerned. The third grid, which is the detector control grid, controls the stream of electrons coming through the screen grid. This electron stream is varying at the oscillator frequency, so the i.f. beat is produced in the detector (mixer) section of the tube.

Feed-back in the oscillator is obtained by causing the plate current to flow through the tapped portion of *T1*. The voltage induced into the rest of *T1* causes the circuit consisting of *T1-C2* to oscillate at its resonant frequency. The oscillator voltage is applied to the oscillator control grid through *C6*. *R1* is the oscillator grid resistor, and *L3* is used to prevent the 1R5 filament and the *A* battery from shorting the tapped section of *T1*. Such a short would prevent the oscillator from working.

Now that the oscillator has been investigated, let us return to the i.f. signal delivered by the 1R5 to resonant circuit *T2-C7* of the first i.f. transformer. This circuit is adjusted to resonance at the i.f. value (455 kc.), not by varying the capacity of *C7* but by adjusting the inductance of the primary. This winding has a pulverized iron core which can be screwed in or out of the coil to change the inductance. As more of the core is moved into the coil, the inductance is increased and the resonant frequency thereby lowered.

By mutual induction a voltage is induced into the secondary shunted by *C8*, and again the circuit is tuned to 455 kc. by adjusting the coil inductance.

The i.f. signal across the secondary of *T2* is fed to the input of the 1T4 i.f. tube, the filament connection being through *C5* and the chassis.

The 1T4 causes a large i.f. signal current to flow through the primary of *T3*. A voltage is induced into the secondary, where it undergoes resonant step-up. The primary of *T3* is untuned, and hence the coupling in this transformer may be close enough to give high gain. This is typical of any i.f. transformer where only one winding is tuned.

The large i.f. voltage across *C11* is applied to the diode and filament of the 1S5, the filament connection being through *C12*. As a result, rectification occurs, and we have the audio modulation plus a d.c. component across volume control *R5*, which is also the diode load resistor. As previously stated, *C12* prevents any i.f. voltage from being dropped across the diode load, thereby insuring that all of the signal is applied between the diode plate and filament.

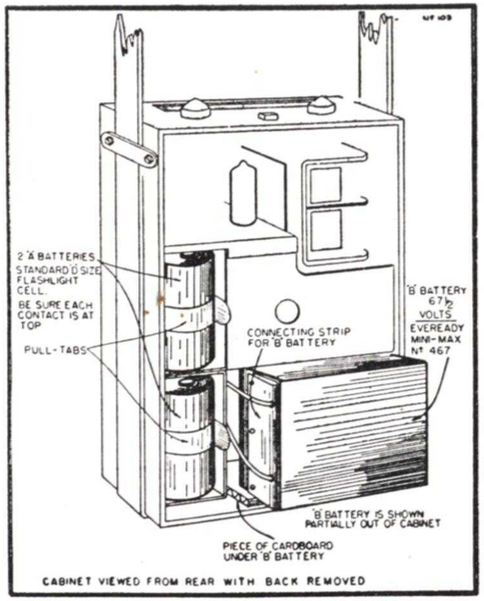
The d.c. voltage across *R5* is used for a.v.c. purposes, since it will vary directly with the strength of the carrier applied to the second detector. The ungrounded end of the resistor is negative with respect to the filament of the 1R5, which is at d.c. ground potential. Tracing the circuit from the negative side of *R5*, we see that part of this voltage is applied to the first detector control grid (third grid of the 1R5) through resistor *R4*. This resistor and condenser *C5* serve to remove the audio signal voltage, and only pure d.c. is available across *C5* for a.v.c. bias purposes.

The full d.c. voltage across *R5* is not used, for *R12* and *R4* are across *R5* and hence act as a voltage divider. The voltage across *R12*, which is in parallel with *C5*, is the a.v.c. voltage fed the 1R5 tube. Since *R4* and *R12* are both 5 megohms (the same size), both have equal voltage drops, and only half of the voltage across diode load *R5* is used for a.v.c. purposes. Thus, while a.v.c. action is reduced, the danger of cutting off the plate current of the 1R5 tube and causing blocking or motorboating on strong signals is eliminated.

The a.f. voltage across volume control *R5* is applied across resistor *R6* through coupling condenser *C13*. Since *C13* connects to the movable arm of the control, the setting of this arm will determine the amount of signal voltage fed to *R6*. As *R6* is directly in the grid input circuit of the pentode portion of the 1S5, the tube amplifies the audio signal fed it, and we have the amplified signal voltage across plate load resistor *R8*.

Condenser *C14* serves to by-pass any stray i.f. signal which may have been amplified by the tube.

The audio signal across *R8* is transferred across *R9* and *R11* through *C16*, *C10* and the chassis. The signal voltage across *R9* and *R11* is amplified by the 1S4 and delivered by impedance-matching output transformer *T4* to the loudspeaker voice coil, and is then converted into sound waves.



Rear view of Emerson Model DU-379 portable receiver, with back cover removed to show batteries. Note how the shoulder-strap antenna encircles the entire set. Control knobs and tuning dial are at top of set, between the loop straps.

Condenser *C17* prevents oscillation at high audio frequencies, and also tends to reduce harmonic distortion by acting as a by-pass for the higher audio frequencies which comprise the harmonics. In addition, inverse feed-back further reduces distortion.

As already pointed out, the input signal voltage is developed across *R9* and *R11*. No by-pass condenser is used across *R11*, and since the plate current of the 1S4 flows through this resistor, we have an audio signal produced here. This signal is 180° out of phase with the applied signal and cancels out the original signal produced across *R11*. In addition, distortion currents produced inside the 1S4 tube flow through *R11* and create voltages of the same distorted form across this resistor. These voltages were not there to start with, and they control the plate current of the tube in such a way as to reduce greatly the distortion inside the tube. The over-all loss in gain due to cancellation of desired signals across *R11* can easily be tolerated.

Biasing Methods. As you already know, the grid bias of a battery-operated filament-type tube is measured between the control grid and the negative side of the tube filament. The effective bias, however, is the difference in voltage between the center of the filament and the grid. Therefore, any voltage between the center of the filament and the negative filament terminal is added to the voltage between the negative filament terminal and the control grid.

In these special low-voltage tubes which handle only small amounts of signal voltage, the bias is quite small. The a.v.c. voltage across *R12* is added to the voltage drop in one-half the tube filament to form the bias for the 1T4 i.f. tube and the 1R5 first detector tube. Since these tube filaments are supplied with approximately 1.4 volts, half of this or .7 volt is used as the initial bias. When signals are received, the a.v.c. bias voltage is added to this. The oscillator grid of the 1R5 receives half the filament voltage plus the voltage created across *R1* by grid current through this grid resistor.

The voltage drop across *R6* due to convection current through it, plus one-half of the filament voltage, biases the pentode section of the 1S5 first audio tube.

The 1S4 power output tube requires considerable bias, more than can be readily furnished by convection current through the grid resistor or by the filament voltage drop. Bleeder bias is employed by causing the plate currents of all tubes to flow through *R11*. The voltage drop across this resistor makes the 1S4 control grid (which connects to the negative end of the resistor) negative with respect to its filament, which connects to the grounded positive end of *R11*.

Battery Economizer. We have now considered the bias arrangement of all the tubes, but the discussion of the 1S4 bias brings up another related object. As you will note, the receiver is equipped with a two-position switch called an *economizer*. By throwing this switch to the "*OUT*" position, maximum power output is obtained from the 1S4 tube, so the total *B* current drain is 7.5 milliamperes. With the switch thrown "*IN*," the *B* drain is reduced to only 5 milliamperes, a considerable saving.

The economizer increases the bias on the 1S4 tube. When the switch is "*IN*" (when the switch bars are across the upper pairs of contacts), resistor *R10* is no longer in parallel with *R11*, and the total resistance between *B*— and the chassis is increased. Therefore the voltage drop across *R11* increases, and this increase in grid bias cuts down on the 1S4 plate current.

As in any battery set, the d.c. plate and screen voltages are applied between these electrodes and the tube filaments. The filaments are grounded to the chassis as shown. Therefore, since the voltage between *B*— and the chassis is increased when the economizer switch is "*IN*," the voltage between filaments and screens and between filaments and plates has decreased. This is unimportant save in the case of the 1R5 and 1T4 screen voltages. A decrease at this point results in a loss in sensitivity. To keep the sensitivity constant, the economizer switch in the "*IN*" position shorts out *R2* in the screen supply circuit of these tubes, thus keeping the screen voltage constant and preventing a loss in sensitivity.

Voltage Measurements. The operating voltages for each tube are measured with a d.c. voltmeter. The negative probe of the voltmeter goes to the negative filament terminal (grounded terminal) in each measurement except for control grid voltage, where the positive meter probe goes to ground and the negative probe to the control grid.

A definite control grid voltage will be measured only on the 1S4 tube and, due to the high resistance of *R9*, the exact voltage will not be measured. However, this control grid voltage can be checked by placing the meter probes directly across *R11* (positive probe to chassis).

Miscellaneous. The alignment of the receiver follows standard superheterodyne procedure. There are only three i.f. adjustments, since the primary of *T3* cannot be tuned. There is no low-frequency oscillator padder condenser.

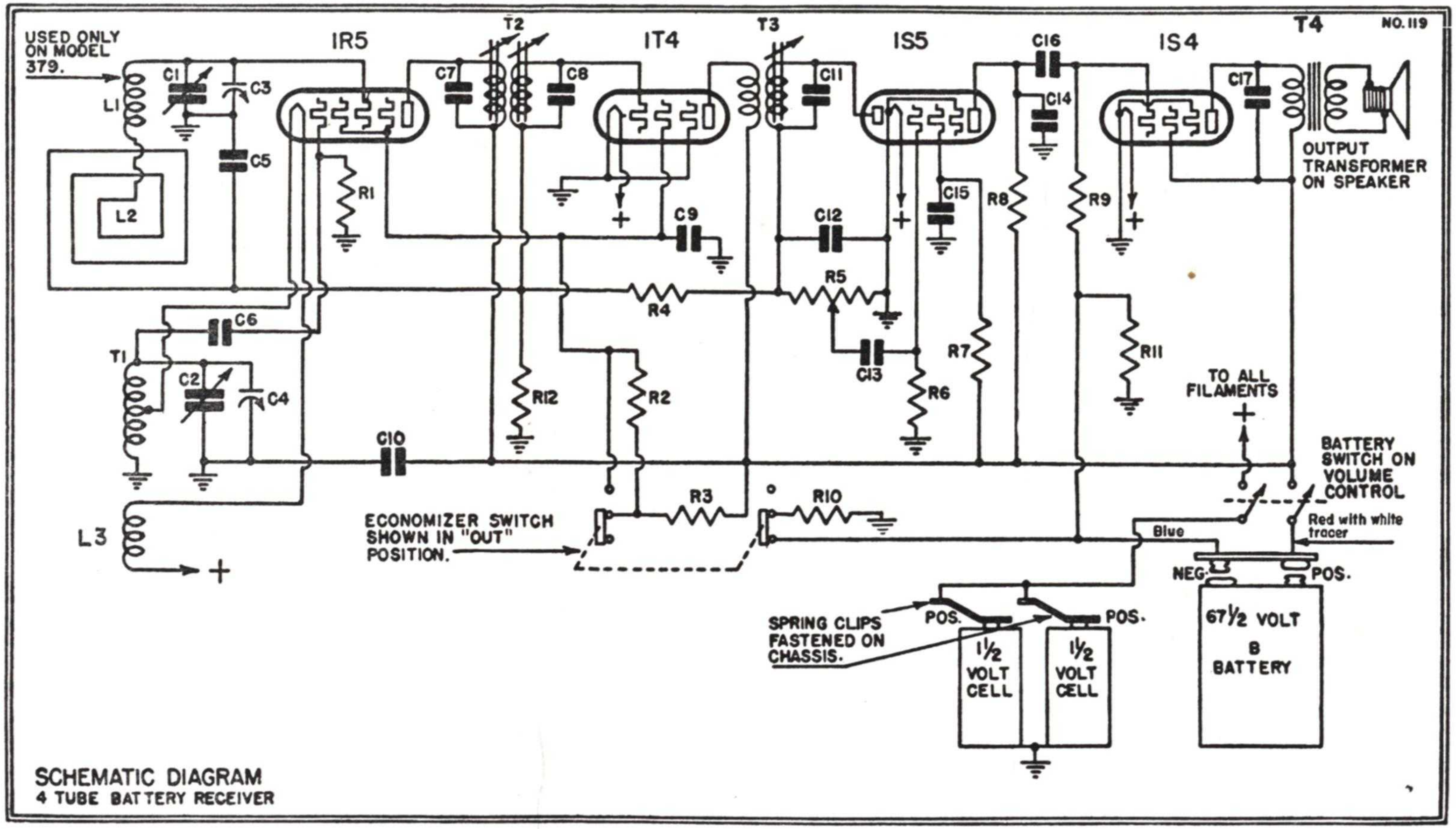


Fig. 7. Circuit diagram of Emerson Model DU-379 and DU-380 battery portable receivers.

L1	Iron-core loading coil (Model DU-379 only)
L2	Shoulder-strap loop assembly (Model DU 379 only)
L2	Loop antenna (Model DU-380 only)
T1	Oscillator coil
T2	Iron-core double-tuned 455-kc. first I.f. transformer
T3	Iron-core single-tuned 455-kc. second I.f. transformer
R1	100,000-ohm ¼-W. carbon resistor
R2	5000-ohm, ¼-W. carbon resistor
R3	10,000-ohm, ¼-W. carbon resistor
R4, R12	5-megohm, ¼-W. carbon resistor (R12 is omitted on later models)
R5	Volume control, 1.5-megohm, with double pole battery switch
R6	10-megohm, ¼-W. carbon resistor
R7, R9	3-megohm, ¼-W. carbon resistor
R8	1-megohm, ¼-W. carbon resistor
R10	2200-ohm, ¼-W. carbon resistor
R11	1800-ohm, ¼-W. carbon resistor
C1, C2	Two-gang variable condenser
C3, C4	Trimmers, part of variable cond.
C5, C9, C15	0.02-mfd., 200-volt tubular cond.
C6, C12, C14	0.00011-mfd. mica condenser
C7, C8, C11	Fixed trimming condensers, contained inside i.f cans
C10	10-mfd., 100-volt dry electrolytic condenser
C13	0.002-mfd., 600-volt tubular cond.
C16, C17	0.001-mfd., 600-volt tubular cond.

4" permanent magnet dynamic loudspeaker
Double-pole, double-throw "Economizer" switch

Automatic Model P57 Three-Way Portable Receiver

GENERAL Description. The Automatic Model P57 can be powered from three different sources—self-contained batteries, a 110-volt a.c. power line, or a 110-volt d.c. power line. In other words, this is an a.c.-d.c.-battery receiver.

A study of the diagram in Fig. *8* shows that the receiver consists of a 1A7G pentragrid converter tube, a 1N5G i.f. amplifier tube, a 1H5G combination second detector—a.v.c.—first audio tube, a 1A5G power output tube and a 25Z6 rectifier.

Excellent reception can be had by using the self-contained loop aerial alone. Terminals *A* and *G* are provided, however, for connecting to an outside aerial and ground when more distant reception is required. When an aerial and ground are used, the antenna current flows through the wire placed around the outside of the loop, and induces a signal voltage into the loop.

Signal Circuits. The signal picked up by the loop is resonated by the tuning condenser, and the stepped-up signal voltage is applied to the input of the 1A7G type tube.

An r.f. oscillator signal is being produced at the same time in the 1A7G tube, due to feed-back from the oscillator coil plate winding to the tank circuit. You will note that the first two grids of the tube are used as the oscillator grid and anode electrodes. The tank circuit is coupled to the oscillator grid through the .0001-mfd. condenser. The 50,000-ohm resistor produces the oscillator grid bias due to the rectified grid current flowing through it.

The varying electron stream leaving the second grid passes through the screen grid to the plate. This electron stream is acted on by the signal voltage applied to the input of the tube, and the oscillator and incoming signals are thus mixed within the tube.

The screen surrounding the 1A7G control grid (the fourth grid from the filament) prevents any interaction between this grid and the oscillator electrodes, and also acts as a capacitive screen between the plate and the detector control grid.

The i.f. signal voltage developed across the primary of the first i.f. transformer causes a large i.f. current to flow through the transformer winding.

By mutual induction a signal appears in the secondary of the transformer and there undergoes resonant step-up. This signal is applied directly to the input of the 1N5G i.f. tube. Since this is a high-impedance pentode tube, a large i.f. voltage will be built up across the primary of the second i.f. transformer, much larger than the one which was applied to the input of the 1N5G tube.

The i.f. signal voltage induced into the secondary of the second i.f. transformer is now large enough for detection.

When the i.f. signal makes the diode plate of the 1H5G tube positive, electrons flow from the filament to this plate, through the secondary of the second i.f. transformer and through the volume control to the filament. The i.f. component is prevented from flowing through the volume control by means of the .0002-mfd. by-pass condenser connected from the hot side of the volume control to the chassis. The filament side of the volume control is grounded to the chassis by means of the .1-mfd. condenser.

The a.f. signal voltage appearing across the volume control is applied to the 15-megohm grid resistor and the grid of the 1H5G tube through the .01-mfd. coupling condenser.

The amplified a.f. signal appears across the 1-megohm plate load resistor of the 1H5G tube. This signal is also applied across the 2-megohm grid resistor for the 1A5G type tube through the .002-mfd. coupling condenser and the 20-mfd. output filter condenser, with the filament connection being through the 100-mfd. electrolytic condenser.

The application of the signal to the input of the 1A5G tube causes large changes in plate current flowing through the primary of the output transformer, and this a.f. plate current induces the signal voltage in the secondary. This causes a.f. current to flow through the voice coil, thus setting the cone in motion and producing sound waves. The output transformer serves to match the impedance of the voice coil to the a.c. plate resistance of the output tube.

The .002-mfd. condenser connected from the plate of the output tube to the chassis makes the plate load of the tube essentially capacitive and thereby prevents any oscillation at ultra-high audio frequencies.

The A.V.C. System. The a.v.c. system for the receiver is entirely conventional. The d.c. component of the rectified i.f. carrier current developed across the 750,000-ohm volume control is applied to the control grid of the 1A7G, after the audio signal is removed by the 1-megohm resistor and .1-mfd. condenser. A.V.C. is not applied to the control grid of the i.f. tube.

You will note that the filament end of the volume control connects to the positive side of the 1A7G filament. Therefore, the detector portion of the 1A7G tube is supplied with a slight initial positive bias. As soon as a signal is received, however, this positive bias is overcome by the negative voltage produced across the volume control.

The Power Supply. At first glance, the filament and power pack connections in Fig. *8* appear somewhat unusual, but when the circuit is redrawn as in Fig. *9*, we can see that there are really four independent circuits, each quite conventional in design. Let us consider each in turn.

When the two switches marked *SW* (operated simultaneously by the volume control shaft) are open, both the 6-volt battery and the power line are disconnected from the filament circuits so the set cannot operate. The 90-volt B battery cannot supply current under this condition because the tubes are not conductive when the filaments are cold.

When switches *SW* are turned on but the power cord is not plugged in, the rectifier tube filament is not heated and hence the two sections of the 25Z6 rectifier are not conductive. The 6-volt battery now furnishes current to the filament circuits of the tubes, however, and the 90-volt B battery furnishes plate current to the four signal circuit tubes.

Examining the filament circuits of the tubes more closely, we see that the filaments of the four 1.4-volt tubes are connected in series across the 6-volt battery, with the circuit being completed through the chassis. The 1000- and 2000-ohm resistors merely provide extra paths to ground for the plate currents of the 1N5G and 1A5G tubes, so as to reduce the amount of plate current which flows through the other two tube filaments to ground.

The 1H5G filament is next to the 1A7G filament in the line-up for a definite reason, to prevent the filament voltage drop of the 1N5G from serving as bias for the 1A7G. The 1A5G is at the + end of the line-up for the opposite reason, so the 4.5-volt drops

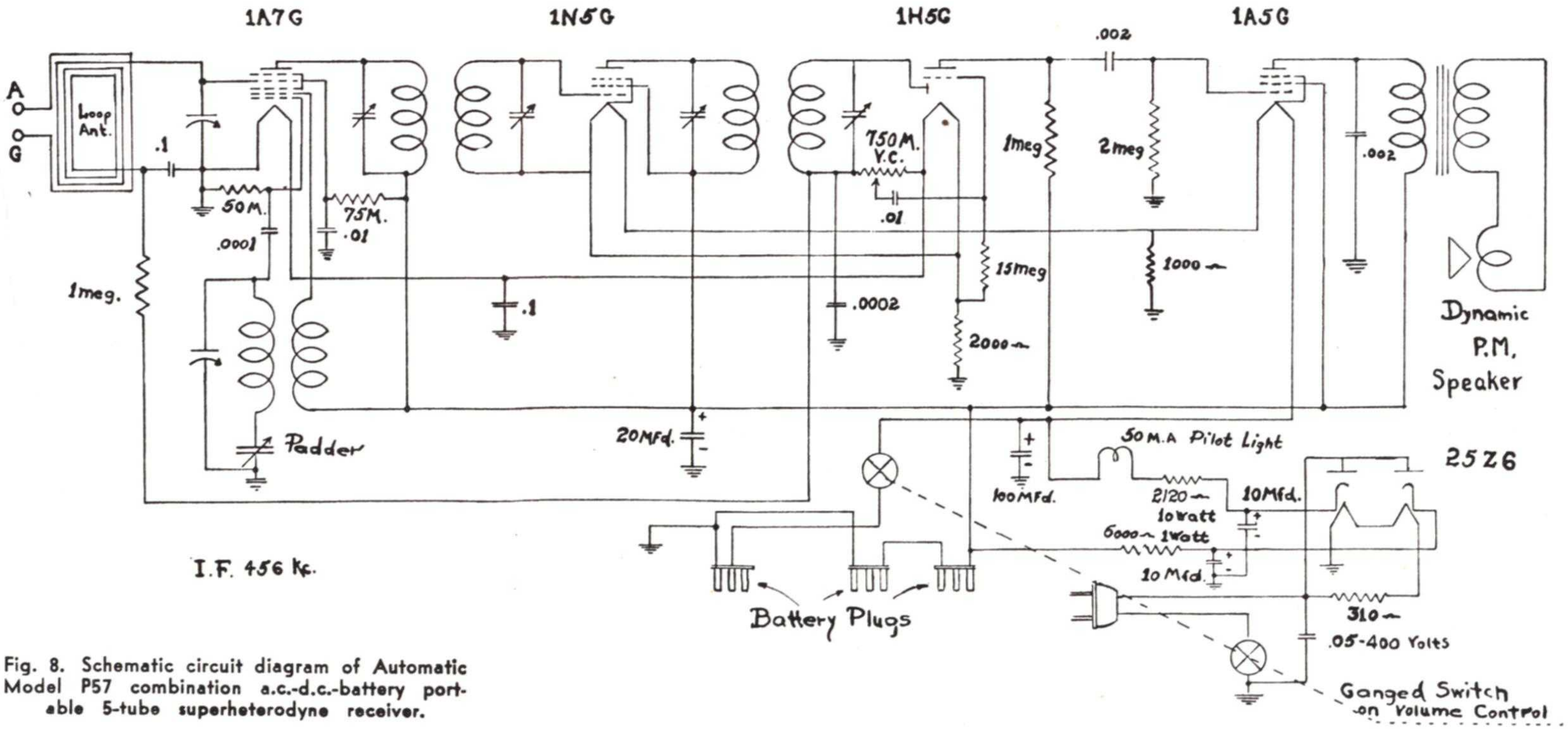


Fig. 8. Schematic circuit diagram of Automatic Model P57 combination a.c.-d.c.-battery portable 5-tube superheterodyne receiver.

across the other three filaments will serve as its bias (the grid circuit of the 1A5G traces from the control grid through the 2-megohm grid resistor to the chassis, through the chassis to the grounded filament lead of the 1A7G, through the 1A7G, 1H5G and 1N5G filaments in turn to the filament of the 1A5G).

When the power cord is plugged into a 110-volt a.c. line and switches *SW* are closed, the set starts operating almost immediately from batteries. After about ¾ minute of battery operation, the filament of the rectifier has warmed up sufficiently so that the 25Z6 rectifier is conductive. Now both the 6-volt filament supply circuit and the 90-volt plate supply circuit are operating as conventional half-wave rectifiers with resistor-condenser filters.

The 6-volt section of the 25Z6 provides a d.c. voltage just enough higher than the A battery voltage so this half-wave rectifier circuit supplies filament current for the four tubes and at the same time sends a small charging current through the 6-volt A battery.

In an identical manner, the 90-volt section of the 25Z6 provides a voltage enough higher than the B battery voltage so this section furnishes all plate current requirements and also sends a small charging current through the 90-volt B battery. Under these conditions, the batteries act like condensers and improve the filtering.

For 110-volt d.c. operation, the plug must be inserted in such a way that the two plates of the 25Z6 go to the positive side of the line. The rectifier sections then conduct current continuously, and the filament and plate filter supply circuits merely act as voltage dividers which cut down the 110-volt d.c. line voltage to 90 and 6 volts respectively for the receiver circuits.

With this arrangement, no switching is necessary in changing from battery to electric current operation. If the power cord is not plugged in, the set operates from its batteries. When the power cord is plugged in, the set starts operating from batteries after being turned on, but automatically changes over to a.c. operation after the rectifier tube warms up.

Whenever the set operates from a power line, the pilot lamp glows. If the electric plug is removed while the set is playing, the set keeps right on playing from its batteries but the pilot lamp goes out, showing that the line is not supplying power. If desired, the receiver can be operated from a.c. or d.c. lines even with all batteries removed.

As with all other receivers that operate from 110-volt d.c. lines, there is a right and a wrong way to put the plug into the socket. If it is in the wrong way, connecting the rectifier plates to the negative side of the line, the set will operate entirely from batteries, and the pilot lamp will not glow. Rotating the plug half a turn in the wall outlet will then make the rectifier plates positive, and the set will operate entirely from the 110-volt d.c. line as soon as the rectifier tube warms up. The pilot lamp will glow.

When the set has been used a long time on battery power and the batteries have become weak, they can be recharged rapidly by operating the set from a 110-volt a.c. or d.c. line with the 1A5G tube removed. Twenty-four hours of this charging will give about 20 hours of service on the batteries. This quick rejuvenation should not be used until the batteries get low, and then for not more than 40 hours at a time. It can be repeated a great many times.

Removal of the 1A5G type tube interrupts the filament circuit, so that only the rectifier tube draws filament current. The supply voltage then rises much higher than 6 volts, and we secure rapid charging of the run-down A battery. Also, no plate current is being drawn through the 6000-ohm B supply filter, hence a higher voltage is applied to the B batteries for charging.

This is not strictly a recharging process, since dry batteries cannot be recharged. However, the negative battery electrodes become polarized during use, raising the internal resistance of the batteries and thereby lowering their output voltages under load. This rejuvenating process depolarizes the electrodes, lowering the internal resistance and permitting normal use of the battery until such time as all of the active ingredients in the cells have been used.

Biasing Methods. As we have previously pointed out, the control grid of the 1A7G type tube is biased by the voltage drop across the volume control and half of the 1A7G tube filament. In a filament-type tube, the effective control grid voltage is that existing between the control grid and the center of the filament. Voltage measurements, however, are made between the control grid and the negative side of the filament.

The grid return of the 1N5G i.f. tube is made directly to the negative side of its filament. Therefore, the effective d.c. grid voltage is half of the filament voltage.

The diode plate of the 1H5G tube likewise returns to the negative side of its filament (through the volume control), so the plate has an initial small negative bias. This has no effect on local reception, and does not seriously interfere with reception from weak distant stations.

The control grid of the 1H5G tube connects to the positive side of its filament through a 15-megohm resistor. Some of the electrons which start out for the plate hit this grid and flow through this resistor to the filament, producing a voltage drop which serves as the negative bias for the grid of the tube. Remember that when electrons flow through a resistor, the end at which they enter is always negative with respect to the end at which they leave.

The control grid of the 1A5G tube connects to ground through a 2-megohm resistor. Reference to the simplified wiring diagram in Fig. *9* will show that between the negative side of the 1A5G tube and the chassis we have the filaments of three tubes, each getting about 1.5 volts. This means that the grid of the 1A5G tube is about 4.5 volts negative with respect to the negative side of the 1A5G tube filament.

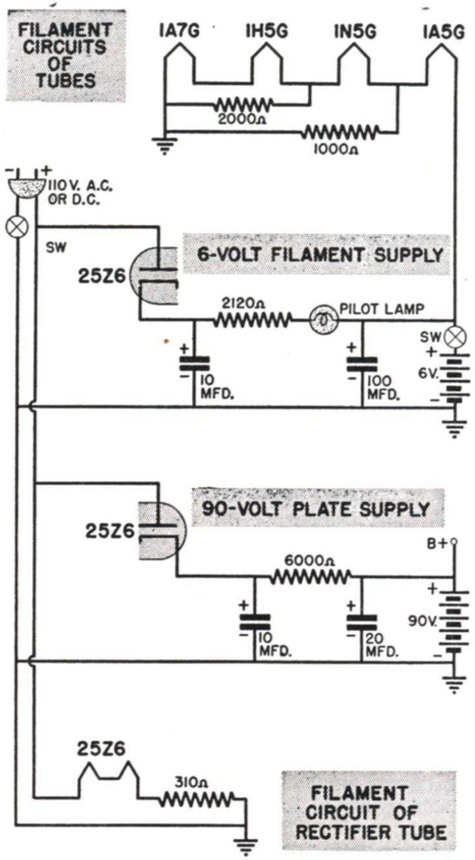


Fig. 9. The power pack and filament circuits of the Automatic Model P57 receiver have been redrawn here to show that the individual circuits are simple and quite conventional.

The 2000-ohm and 1000-ohm resistors in the filament supply circuits are used as shunts to take care of the plate currents of the tubes. Flowing through the 1A7G and 1H5G filaments are the .05-ampere filament currents and the plate currents of these tubes. The plate current of the 1N5G divides between the 2000-ohm shunt resistor and the filaments of the 1A7G and 1H5G tubes. The plate current of the 1A5G tube divides between the 1000-ohm resistor and the circuit consisting of the 1A7G, 1N5G and 1H5G filaments and the 2000-ohm shunt resistor. While the receiver would work without the shunts, the current through the filaments would be excessive and would tend to shorten tube life.

Servicing Hints. Receivers of this type are subject to the same defects as are encountered in a.c.-d.c. or battery receivers. Bear in mind, however, that when the receiver is operated from the power line, a defect in one power supply may be masked by proper operation of the other supply. For example, the rectifier tube may be worn out, but the receiver will play normally on the power line, for the batteries will furnish power. Bad batteries, on the other hand, will be masked by the power pack on power line operation.

We are most concerned here with straight battery operation, since you are familiar with a.c.-d.c. power supply troubles. About all that could occur to the power pack would be tube and filter condenser troubles, or burning out of the pilot lamp. If the pilot lamp must be replaced, use an exact duplicate as no other will work properly A burned-out pilot lamp should be replaced as soon as possible, because its failure forces the 6-volt battery to supply filament current during a.c or d.c. operation.

On battery operation, most trouble is due to worn-out batteries. If the battery voltages will not come up to normal and give satisfactory results even after prolonged operation of the receiver from the power line with the 1A5G tube removed, new batteries are necessary.

The battery voltage should be measured with the receiver operating only from batteries and all of the tubes in place. This places a normal load on the batteries, so high internal resistance which causes appreciable internal voltage drop in a bad cell will be revealed. Without normal load, a high-resistance serviceman's voltmeter won't draw enough current to produce an appreciable voltage drop in the batteries, and normal voltage will be measured even though the batteries are run-down.

Low battery voltages will usually affect the operation of the oscillator first, since this circuit is the most critical as to voltage. Since it is harder for oscillation to be maintained at the lower frequencies, the receiver will first go dead at the low-frequency end of the dial. As the batteries continue to deteriorate, the set will go dead over the entire dial, since the oscillator will refuse to operate at any point on its range.

When an oscillator goes dead in this manner, a very characteristic effect is sometimes observed; a powerful local station, usually one at the low-frequency end of the dial, will be heard regardless of how the receiver is tuned. Such an occurrence is definite proof of oscillator failure, and indicates that the set is acting as a broadly-tuned t.r.f. receiver.

About the only other trouble peculiar to battery receivers is intermittent reception and noise caused by poor or corroded connections inside of the batteries. A substitution of new batteries or a careful voltmeter check will show up such trouble.

Philco Model 610 Three-Band A.C. Superheterodyne

GENERAL Description. The Philco Model 610 is a three-band a.c.-operated superheterodyne using a type 6A7 mixer, a type 78 in the i.f. amplifier, a type 75 as a combination detector, a.v.c. and first a.f. tube, a type 42 in the power output stage and a type 80 rectifier in the power supply. All of these stages are clearly identified on the schematic circuit diagram in Fig. *10*. The wave-band coverage is: Band 1, 530-1720 kc.; band 2, 2300-2500 kc. (2.3-2.5 megacycles); band 3, 5700-18,000 kc. (5.7-18 megacycles). The design of this receiver is straightforward, the circuits being similar to those which you have already studied.

Wave-Band Switch and Circuits. A radio technician is only interested in that section or circuit in which trouble exists. He is guided to this point either by the symptoms exhibited by the receiver or by a stage isolation procedure as outlined in the Advanced Course in Radio Servicing. The rest of the receiver he ignores. With this method, he will probably escape the necessity of delving into the wave-band switching circuits.

However, if trouble is encountered in the preselector-mixer-oscillator system, he must be able to unravel the wave-band circuits and make tests on them. Furthermore, to align the set, he must be able to identify the trimmers appearing in the diagram and, from their electrical positions in the circuit, determine their purpose.

In such a case he sees the same thing you see here—a conglomeration of switch contacts, coils, condensers and wires. The expert ignores all this and sets about systematically to trace through the circuits. He knows that the 6A7 has a tuned input circuit, because no manufacturer would build a receiver without a preselector between the mixer and antenna. Furthermore, this tuned input circuit must connect between the 6A7 top cap and the a.v.c. bus. These two points are readily located in the diagram, the a.v.c. bus being the wire lead connecting to the junction of a.v.c. filter condenser *25* and filter resistor *29*.

Let us trace the tuned input circuit. We start with the 6A7 top cap, and follow the lead down to terminal *S* of switch section *2*. Looking at this section, we see that there are two other terminals like *S*, marked *G* and *P*, each feeding a different set of leads through contacts. We rightfully assume that this is a three-pole, three-position switch and that terminals *S*, *G* and *P* are input terminals for the three poles of the switch.

With the switch set to position *1* as shown in the diagram, terminal *S* makes contact only to terminal *M* through the round black "ball" which represents the movable contact element for this pole of the switch. This black ball always makes contact with *S*.

From *M* we go to the junction of trimmer *5* and tuning coil *L2*. We ignore the tap on *L2*, as a glance at terminal *G* of switch section *2* shows it isn't used. The other end of *L2* connects to the a.v.c. bus, which is the other end of the tuned input circuit we were tracing.

This gives us the general technique for tracing through the wave-band switch, and we can now trace the other circuits for switch position *1*. Coil *L3* and its primary *L1* are ignored, because coil *L2* is being used and we wouldn't expect another tuned circuit to be employed at the mixer input at the same time. Since *L2* is in use, its primary is in use, and we may be sure the primary is carrying energy delivered to it by the antenna system. The primary is checked by connecting an ohmmeter between the *ANT* lead and the chassis. We will expect a reading of about 32 ohms if everything is intact.

Switch position *1* is for the broadcast band (the lowest-frequency band on the set), because coil *L2* (connected to *S* for position *1*) has a higher resistance and hence a greater number of turns than coil *L3*. *L3* must be the short-wave coil for band *3*, since it has the lowest resistance and therefore the lowest inductance.

Since *L2* is the broadcast band antenna coil, its associated trimmer *5* is the broadcast band antenna trimmer, and is to be adjusted somewhere near the high-frequency end of its band (1400 kc. is a popular adjustment point).

Now that we have accounted for the preselector, let's take a look at the oscillator. We have two sets of coils, *L4-L6* and *L5-L7*. Coils *L6* and *L7*, being connected to trimmers, are the tank coils. Since *L6* has the greatest resistance, it is the broadcast band oscillator coil, in which we are now interested.

Again we have two reference points—the 6A7 oscillator grid, which is the first grid from the cathode, and the cathode of the 6A7. Since the cathode goes to chassis through resistor *16*, we will use the chassis for reference purposes.

Follow the lead from the oscillator grid, noting that it connects from oscillator tuning condenser *19* to pole *P* on switch section *2*.

The switch contact connects it to switch terminal *Q*, and from here we go to tank coil *L6*. This coil connects to tuning condenser *19* through condenser *10* which, being in series with the tank circuit, is the oscillator low-frequency padder. This padder, as its name implies, is to be adjusted at the low-frequency end of the broadcast band; 600 kc. is the most favored adjusting frequency.

Trimmer condenser *11*, which is in shunt with the oscillator tuning condenser, is the high-frequency oscillator trimmer. Like trimmer *5*, it is to be adjusted at 1400 kc. The position of resistor *17* is a little unconventional, but all oscillators of this type have a bias resistor somewhere between the oscillator grid and cathode. Resistor *17* must therefore be the oscillator self-bias resistor for band *1*.

Coil *L4* is the oscillator feed-back coil, and must receive energy from grid *2* (the oscillator anode grid) of the 6A7. The connection to padder *10* means that we have capacitive coupling as well as inductive coupling from the feed-back coil to the oscillator tank circuit.

Tracing the other lead of *L4*, we go to terminal *E* on switch section *1*, and through the black "ball" contact to pole *D*. Condenser *7* is the means of coupling the feed-back coil to the oscillator plate.

We have now traced all the oscillator and preselector circuits for the broadcast band.

A quick glance at the schematic as a whole reveals much the same maze of wires as in the preselector circuits, but now you know that if you go at the problem logically and follow through each circuit one at a time, you can get any information you need for test purposes. Don't expect circuits of this sort to look easier as you progress in radio. Wave-band circuits always *look* complicated, and you always have to trace them when you need any special information from them.

The work we have done so far has been fairly straightforward. Figuring the new contacts made through the wave-band switch when it is thrown to one of the other positions is a bit more difficult.

Experience and a knowledge of how the circuits should be arranged will help you. The little black balls on the switch sections represent the movable contacts. As there are two other positions on this switch, it's not so hard to visualize the balls moving clockwise one space for each new switch position. To make this easy, the switch settings for all three ranges are drawn in Fig. *11*. We have already covered position *1* for the broadcast band, so now will examine switch position *2*.

Let us assume that instead of using a Philco two-wire antenna system connected to the *RED* and *BLACK* terminals, we are using this time an ordinary aerial and ground connected to the *ANT.* and *GND.* posts. Remember that the switches are in position *2* as shown in Fig. *11*.

Antenna current now flows through the antenna primary coils *L* and *L1*, inducing voltages in *L2* and *L3*. The voltage set up in *L3* is very small and can be neglected, since *L3* is not connected to the tuning condenser.

The upper section of *L2* is short-circuited by switch contacts *G* and *J* of switch section *2*, so this portion doesn't play any part in the circuit either. Since switch contacts *G*, *J*, *M* and *S* are connected together, the tap on *L2* connects to the main tuning condenser and the 6A7 top cap. The lower section of *L2* goes to the a.v.c. circuit, then through a.v.c. condenser *25* to the grounded rotor of the tuning condenser.

The preselector section of the condenser gang therefore tunes the lower section of *L2* to resonance. The signal so chosen is applied to the mixer input of the 6A7 tube. The band coverage of this circuit is from 2300 kc. to 2500 kc.

Notice that this band is only 200 kc. wide, so only a portion of the dial is used—the por-

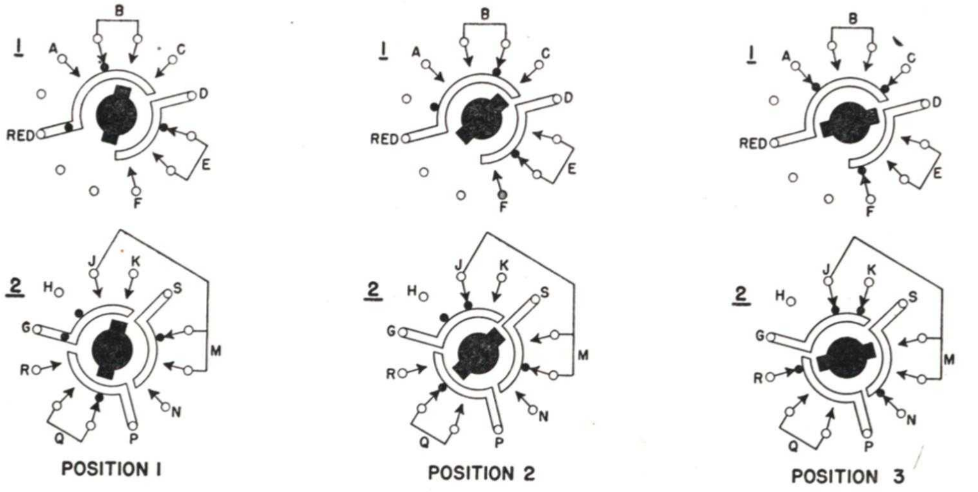


Fig. 11. Connections made for each of the three positions of the band-changing switch are clearly shown here. Note that the black balls all advance one step clockwise as the switch is advanced from Position 1 to Position 2 and from Position 2 to Position 3.

tion corresponding to 1380 kc. to 1580 kc. on the broadcast band. When this set was built, the bands just below 2300 kc. and above 2500 kc. contained nothing of interest. Anything which was picked up at such frequencies was due to lack of preselection. On this band, only local police stations operating around 2400 kc. will ordinarily be heard.

Due to the tying together of the switch contacts at *Q* on switch section *2* and the tying together of the switch contacts at *E* on switch section *1*, the oscillator connections are the same as they were for the broadcast band. This means that the oscillator will produce a frequency 460 kc. higher than the dial setting for the broadcast band, or from 990 kc. to 2180 kc. However, the preselector only works from 2300 kc. to 2500 kc., corresponding to the 1380-kc. to 1580-kc. markings on the broadcast band dial. When the set is tuned to 2300 kc., the oscillator is working as it did for 1380 kc. on the broadcast band. In other words, it is producing 1380 kc. + 460 kc., or 1840 kc. Now, if a 2300-kc. signal is picked up, the difference between it and the oscillator working at 1840 kc. is 460 kc., which is the i.f. value of the receiver. At the 2500-kc. dial setting, the oscillator is at 2040 kc., the same as it was for 1580 kc. on the broadcast band. The difference between 2040 kc. and the top of band *2* (2500 kc.) is again 460 kc., the correct i.f. value.

From these figures we see that the oscillator works below the frequency of the preselector for band *2*, and this band does not cover the entire dial. The receiver can be tuned below 2300 kc. and above 2500 kc., but the oscillator and preselector won't track exactly and satisfactory reception isn't to be expected.

Now let's go to switch position *3* in Fig. *11*. Here the antenna current flows through the primary of *L1*. Note that *L* is shorted through switch contacts *A* and *C*. If the special two-wire Philco antenna is used, the *RED* lead makes contact through switch terminal *C* directly to the antenna lead and *L1*, while the *BLACK* lead connects to the grounded end of *L1*.

By keeping the short-wave antenna currents confined to *L1*, better results are obtained. The signal current flowing through *L1* causes a voltage to be induced in *L3*. One end of *L3* connects to the a.v.c. circuit, and the other end connects to the main preselector tuning condenser through switch contacts *N* and *S* of switch section *2*. Trimmer *6* shunts the gang tuning condenser section, and is the high-frequency preselector trimmer. It is adjusted at the high-frequency end of the short-wave band.

The resonant circuit composed of *L3*, the tuning condenser and trimmer *6* selects the desired station signal, which undergoes resonant step-up. This signal is applied to the mixer input of the 6A7 tube. At the same time, *L2* is completely shorted by switch contacts *J*, *K* and *G*, thus making this coil inactive when switches are at position *3*.

The oscillator tank circuit for band *3* starts from the oscillator grid, and traces through switch contacts *P* and *R* to coil *L7*. The position of trimmer *12* indicates that it is the oscillator high-frequency trimmer; it is to be adjusted at the high-frequency end of this band.

The other end of *L7* connects to ground and to the rotor of the oscillator tuning condenser through fixed condenser *14* and adjustable condenser *13*. These condensers are in series with the oscillator tank circuit, and comprise the low-frequency padder for the short-wave band. Padder *13* is to be adjusted at the low-frequency end of this band. Resistor *18* is the oscillator grid resistor for this band.

The connection of *L5* to the padder condenser means that additional feed-back is obtained in the short-wave oscillator circuit by capacity coupling. The other end of *L5* connects through resistor *9*, switch contacts *F-D* and condenser 7 to the grid serving as the oscillator plate.

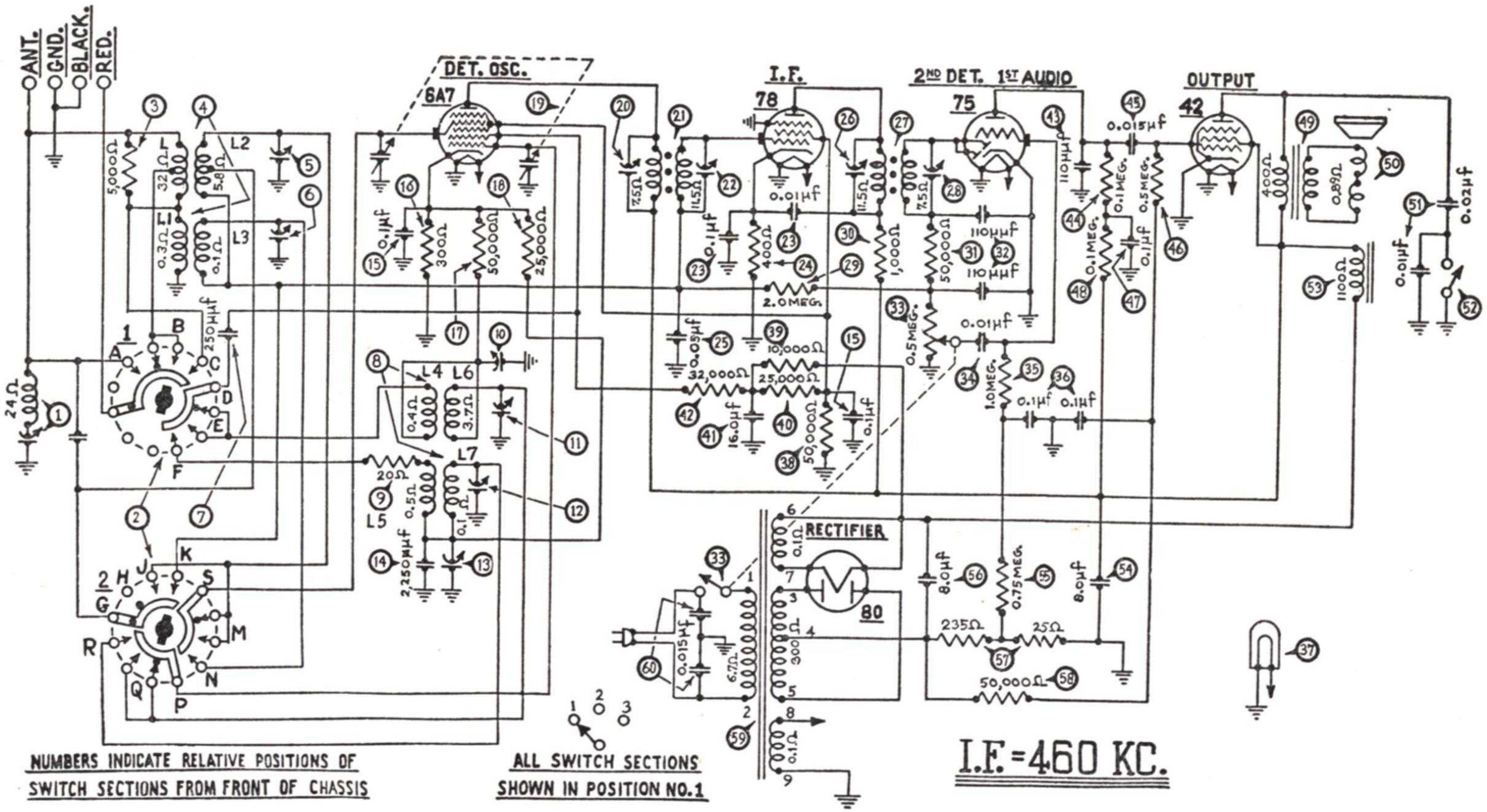


Fig. 10. Schematic circuit diagram of Philco Model 610 three-band superheterodyne receiver.

We have now investigated the important sections of the preselector and oscillator circuits for all bands. In each case, the oscillator signal and the preselector signal are mixed in the 6A7, and produce a 460-kc. beat. This is passed into the i.f. amplifier through the first i.f. transformer (*21*). After amplification by the type 78 i.f. tube, the i.f. signal is transferred to the diode detector circuit of the type 75 tube by the second i.f. transformer (*27*).

After detection, the rectified signal voltage appears across volume control *33*, which is also the diode load resistor. The signal amplified by the triode section of the 75 tube is passed by means of resistance coupling to the type 42 power output tube. The output of this tube feeds the loudspeaker voice coil through output transformer *49*.

Since this receiver was chosen to give you practice with wave-band switch circuits, we have omitted discussion of the rest of the receiver circuits. These circuits have previously been covered, and should hold no secrets from you. However, if you want a little practice you might explore their possibilities and explain them to yourself as we have done for similar diagrams.

Here is a little additional work of a practical nature. The following symptoms are often encountered in this receiver and are due to the causes listed. Try to figure out why these particular defects (causes) should result in these symptoms.

Symptom	Cause
Dead only when tone control *52* is on.	Short in .02-mfd. section of *51*.
Hum when cone is replaced.	Voice coil connections reversed.
Hum stops only when *42* is removed.	Open in right-hand section of condenser *36*.
Distorts; clears up when hand is held on 75 top cap and chassis.	Leakage in *45* or *47*.
Distorts and cuts off on strong signals when volume control is advanced.	Leakage in *34*.
Dead; circuit disturbance test shows all stages pass signal.	Open in resistor *42*.
Blasting when tuning from one station to another.	Short or leakage in condenser *25*.
Audio oscillation when tone control *52* is off.	Open in .01-mfd. section of condenser block *51*.

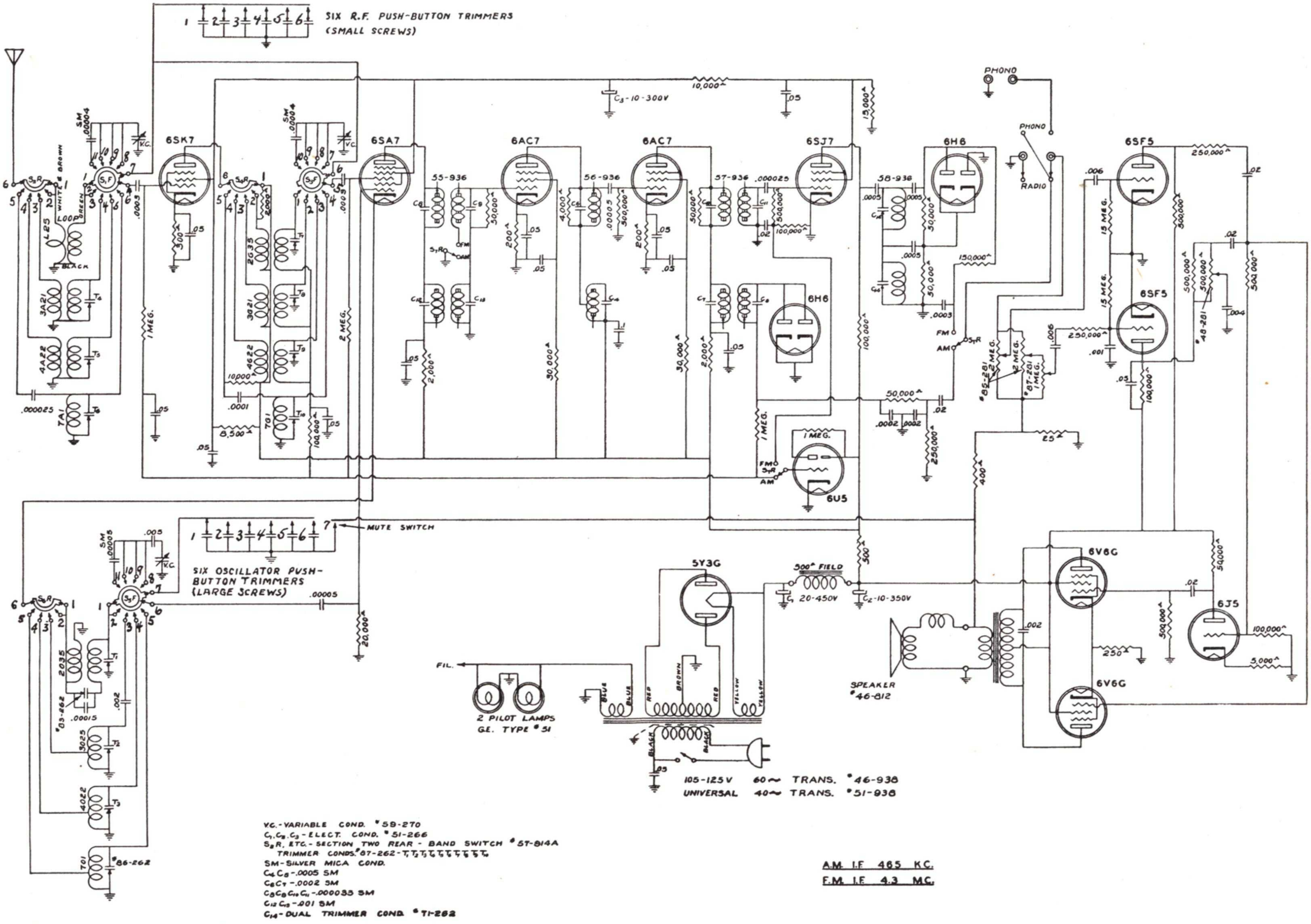


Fig. 12. Schematic circuit diagram of Howard Model 718FM-X four-band, fourteen-tube f.m.-a.m. superheterodyne receiver.

HOWARD Model 718FM-X Frequency Modulation Receiver

GENERAL Specifications. This Howard Model 718FM-X is a combination frequency modulation receiver with three amplitude modulation bands and six push buttons for automatic tuning on the broadcast band. The receiver is equipped with a loop for the broadcast band, has a built-in phono switch, bass and treble controls, and utilizes inverse feed-back to reduce audio distortion.

Signal Circuits. The wave-band switch presents no great difficulty in the circuit diagram of this set as shown in Fig. *12*, because all of the coils are plainly in view and their purposes evident. The switch has six sections, three facing the front of the set and three facing the rear of the set. The sections marked S_1F, S_3F and S_5F face the front of the set, and are shown as they appear when you look at the switch from the *front*. Sections marked S_2R, S_4R and S_6R face the rear of the set, and are shown as they appear when you look at the switch from the *rear*. The movable contact arms of the *F* sections rotate *counter-clockwise on the diagram* as the switch is advanced from position *1* (in which all switches are shown here) to position *5*, and the movable contact arms of the rear (*R*) sections rotate *clockwise on the diagram* as the switch is advanced.

The chart in Fig. *13* tells which switch terminals are connected together for each of the five positions. Position *1* is for push-button operation, covering the broadcast band. Position *2* is for manual tuning of the broadcast band. Position *3* gives coverage of the police and aviation bands, while position *4* covers short-wave programs, and position *5* covers the f.m. band.

Switch Position 1. We will study band switch position *1* first, and trace its circuits to the input of the i.f. amplifier. Since all switches are shown in position *1* in Fig. *12*, we can trace switch connections directly on the diagram.

When an outdoor antenna is used, signal currents flow through contacts *6-1* of switch section S_2R, and then to ground through the few turns of wire which are inductively coupled to the *LOOP* (drawn like a coil in this diagram). The loop is tuned to resonance, since it is connected through terminals *1-7* of switch section S_1F to r.f. trimmer *1*, whose button is shown as being depressed. Any signal at the resonant frequency of the loop undergoes resonant step-up when induced in the loop by antenna current through *L25*. The resulting signal is applied to the control grid of the 6SA7 first detector tube through contacts *6-5* of switch section S_3F and through the .0003-mfd. coupling condenser.

We have not mentioned the 6SK7 r.f. tube, but an examination shows that the signal is also applied to the input of this tube through contacts *7-6* of switch section S_1F and the .0003-mfd. coupling condenser for this stage. The r.f. tube will amplify this signal, but the plate of the tube connects through contacts *6-1* of switch section S_4R directly to B+. Thus, no load exists in the plate circuit and no amplified r.f. voltage is developed, even though the plate current is varying at an r.f. rate. The r.f. stage is therefore inactive when push-button tuning is used.

Now, we will investigate the oscillator. We see that the grid next to the cathode of the 6SA7 tube is the oscillator grid. It connects to the chassis through a 20,000-ohm resistor which is used for self-bias purposes. (Oscillator grid current flowing through this resistor produces the bias voltage.) The grid connects through the .00005-mfd. coupling condenser and switch contacts *6*, *1* and *7* of switch section S_5F to the oscillator tank circuit. The tuning condenser is oscillator trimmer *1*, whose push button is depressed, and the tank circuit coil is connected between switch contacts *1-2* and the padder marked *83-262*. Trimmer T_1 is the oscillator high-frequency trimmer for the broadcast band, but its capacity is negligible compared to that of the push-button trimmers.

The left-hand winding of oscillator coil *2035* is connected between the padder and ground, but has only a small effect on the inductance of the circuit. As you can see, it is in the cathode circuit of the 6SA7 tube and hence is the feed-back coil. The cathode current of the 6SA7 tube flows through this coil and induces a voltage into the tank coil. This variation in grid (tank) voltage causes further variations in cathode current, and in this manner oscillation is maintained. The grid bias voltage produced across the 20,000-ohm self-bias resistor prevents the cathode current from exceeding the safe rating of the tube.

SWITCH POSITION	BAND	BAND-SWITCH SECTIONS						
		S_2R	S_1F	S_4R	S_3F	S_6R	S_5F	S_7R
1	BROADCAST, PUSH-BUTTON	6-1	6-1-7	6-1	5-6	6-1	1-6-7	AM
2	BROADCAST, MANUAL	6-2	6-2-8	6-2	1-5-7	6-2	2-6-8	AM
3	POLICE BAND	6-3	6-3-9	6-3	2-5-8	6-3	3-6-9	AM
4	SHORT-WAVE	6-4	6-4-10	6-4	3-5-9	6-4	4-6-10	AM
5	FREQUENCY MODULATION	6-5	6-5-11	6-5	4-5-10	6-5	5-6-11	FM

Fig. 13. Table showing band switch terminals which are connected together at each of the five switch positions.

Due to the oscillator action, the electron flow from the cathode through the oscillator grid and the screen grid (oscillator plate) to the plate of the 6SA7 is a pulsating stream. As far as the mixer grid is concerned, however, the screen grid is the virtual cathode which is supplying a pulsating electron stream.

At the third grid from the cathode (mixer grid), the incoming signal is applied. It mixes with the local oscillator signal, and the resulting beat (the difference between the two signal frequencies) forms the intermediate frequency.

Switch Position 2. When the band switch is thrown to manual tuning, the switch connections are those shown for position *2* in Fig. *13*. Let us analyze the circuits which are in action now.

Antenna current flows through switch contacts *6-2* of section S_2R and through the primary of coil *L25* to ground. Section S_1F connects contacts *2*, *6* and *8* together so the secondary of *L25* is tuned by variable condenser *V.C.* The signal undergoes resonant step-up, after which it is applied to the 6SK7 r.f. amplifier tube in the usual manner. The amplified signal current flows through the primary of coil *2G35*, which is shunted by a 2000-ohm resistor to broaden the tuning and thus prevent side-band cutting. A voltage is induced in the secondary, where it undergoes resonant step-up, and the resulting signal is applied to the 6SA7 input through the .0003-mfd. coupling condenser.

In the oscillator circuit, the connections and circuit action of coil *2035*, with its trimmers and padder, remain the same as for push-button operation. However, contact is made to *8* instead of *7* on switch section S_5F, to put main tuning condenser *V.C.* in the circuit in place of the push-button trimmers. Mixing occurs in the 6SA7 as before, and the i.f. signal is delivered to the i.f. amplifier.

Switch Positions 3 and 4. The circuits for these two short-wave band positions are identical to those for the broadcast band, and hence need not be traced in detail. The selector switches merely place different sets of coils in their respective circuits.

The A.M. I.F. Amplifier. From the schematic diagram, you see that there are two i.f. transformers between the mixer and the 6AC7 first i.f. tube, one for f.m. and the other for a.m. We identify the top transformer in the schematic as the f.m. transformer because its secondary connects to the *FM* terminal of S_7R. The primary of this transformer offers little opposition to the 465-kc. i.f. signal, so the a.m. signal passes through it to the primary of the a.m. transformer.

A large 465-kc. current flows in the tuned primary of the a.m. transformer, and a corresponding signal, which also undergoes resonant step-up, is induced into the secondary. This is applied to the control grid of the 6AC7 first i.f. tube through condenser C_9 and to its cathode through the chassis and the .05-mfd. cathode by-pass condenser.

The tube amplifies the signal and a large i.f. voltage is built up across the plate load. But what is the plate load? It is not the resonant circuit formed by coil *56-936* and condenser C_6, for these are shunted by a 4000-ohm resistor which is not used in a.m. loads. We can assume that condenser C_6 acts as a short across the coil and resistor at a.m. i.f. frequencies. The next device in the plate circuit is a tapped resonant circuit, and this is what serves as the a.m. plate load.

It is unusual to see a tapped resonant circuit of this sort, for only the lower coil section, between the tap and B+, acts as the load. The voltage across this section is large, due to the resonant step-up provided by tuning the circuit. This voltage is transferred through C_6, the .00005-mfd. coupling condenser and the .1-mfd. plate by-pass, and appears across the 500,000-ohm grid resistor for the next stage.

The 500,000-ohm grid resistor, therefore, shunts the lower section of the coil. The resistor is not across the entire resonant circuit, however, and because of this, a reasonable degree of selectivity is still secured. At the same time, since the entire voltage across the resonant circuit is not transferred to the grid resistor, the gain is reduced. With two stages of i.f. amplification, there is gain to spare, and the slightly broadened response curve of the i.f. amplifier results in good fidelity. The f.m. transformer is not tapped in this manner because both broad tuning and all available gain are desired.

The i.f. current flowing through the grid resistor builds up a large signal voltage across it. This voltage is applied to the grid-cathode circuit of the tube, the cathode connection being through the cathode by-pass condenser.

Amplification of the signal by the second i.f. tube results in a large signal voltage being developed across the resonant plate load formed by C_7 and the primary of the third i.f. transformer. The resonant frequency of the f.m. transformer is 4.3 mc., which is so far from 465 kc. that for all practical purposes, no a.m. signals are set up in the secondary of the f.m. transformer. However, a large i.f. signal is set up in the secondary of the last a.m. transformer, and this a.m. signal is applied to the plates and cathodes of the 6H6 second detector. The cathode connection is through the .0002-mfd. condenser and the chassis.

The A.M. Second Detector. When the i.f. signal makes the 6H6 plates positive, electrons leaving the cathodes are attracted to the plates. From there, the electron flow is through the i.f. secondary, the 50,000-ohm i.f. filter resistor and the 250,000-ohm diode load resistor to ground, then back to the 6H6 cathodes. Current flow is blocked when the signal makes the plates negative with respect to the cathodes. This is the action of a typical diode detector.

We have the rectified a.f. signal existing across the 250,000-ohm load resistor. Due to the smoothing action of the two .0002-mfd. condensers, we also have a rather large d.c. voltage across the diode load. The a.f. signal, being unaffected by the .0002-mfd. condensers, adds to this d.c. voltage and causes it to increase and decrease, forming a pulsating d.c. voltage across the load resistor. No i.f. signal appears across it because the i.f. is shunted around the diode load by the i.f. filter composed of the 50,000-ohm resistor and the two .0002-mfd. condensers.

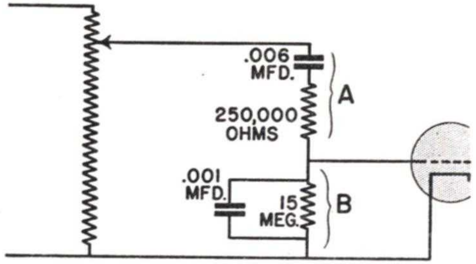


Fig. 14. Bass-boosting circuit.

The d.c. voltage across the 250,000-ohm diode load is used for a.v.c. purposes and to operate the tuning eye. The a.v.c. filter network is made up of the 1-meg. resistor connected to the tuning eye grid through switch S_7R, and the .05-mfd. condenser in the control grid return circuit of the 6SK7 tube. Note that this a.v.c. voltage is used only for a.m. reception.

The Audio Amplifier. The audio signal component across the diode load is applied across the dual volume control through the .02-mfd. d.c. blocking condenser, contact *AM* of switch S_7R, the *RADIO* contact of the *PHONO* switch and the 25-ohm resistor between the volume control and the chassis.

Now we come to a unique method of tone control which is becoming more and more popular in high-fidelity audio amplifiers. Note that the dual volume control simultaneously feeds two 6SF5 tubes, and that the outputs of these tubes feed through .02-mfd. coupling condensers into a common load consisting of 500,000- and 100,000-ohm resistors connected in series between the control grid of the lower 6V6G output tube and the chassis.

The upper 6SF5 tube and its 15-megohm grid resistor are fed by the first section of the volume control through a .006-mfd. coupling condenser, with all audio frequencies being transferred about equally well.

Potentiometer *87-281* is connected to control the amount of signal which the right-hand volume control feeds through the .006-mfd. coupling condenser and a 250,000-ohm resistor to the 15-megohm grid resistor of the lower 6SF5 tube. A .001-mfd. by-pass condenser is in parallel with the 15-meg. resistor, so the impedance of the grid input circuit is a combination of these values. This is the special arrangement which provides tone control, so let us study its action in detail.

The tone control circuit has been redrawn in Fig. *14* to simplify our discussion of it. The signal dropped across section *B* is fed to the lower 6SF5 tube for amplification, while the signal dropped across *A* is not amplified. As in any voltage divider, the voltage distribution will depend upon the ratio of impedances of the two sections. If both are equal, each will receive the same amount of voltage. If one has ten times the impedance of the other, it will have ten times as much voltage. Let's investigate.

The .006-mfd. condenser in series-section *A* has a value of about 5000 ohms at 5000 cycles, which is negligibly small in comparison to the 250,000 ohms in series, so the combined impedance of section *A* is essentially 250,000 ohms.

At 5000 cycles, the .001-mfd. condenser across shunt-section *B* has a reactance of about 30,000 ohms, as compared to 15 megohms for the resistor. This makes the combined impedance of this section only about 30,000 ohms (the lowest reactance governs the impedance of parts in parallel). Therefore, at 5000 cycles almost all of the signal is dropped across *A*, with practically none across *B*, and the lower 6SF5 tube gets very little signal voltage at 5000 cycles and higher.

At 1000 cycles, the .006-mfd. condenser has a reactance of about 30,000 ohms, and this in series with 250,000 ohms of resistance gives a combined impedance of about 252,000 ohms for section *A*.

At 1000 cycles, the .001-mfd. condenser has a reactance of around 150,000 ohms. The 15-megohm resistor shunting this has negligible effect, so the combined impedance of section *B* is essentially 150,000 ohms. Now section *B* gets almost as much of the signal as section *A*, so the lower 6SF5 tube gets quite a bit of signal voltage at 1000 cycles.

Now let's drop down to the real low notes, say 100 cycles. The .006-mfd. condenser has a reactance of about 280,000 ohms now, and this in series with a resistance of 250,000 ohms gives a combined impedance of about 375,000 ohms for section *A*. The 2-megohm reactance of the .001-mfd. condenser at 100 cycles makes the impedance of section *B* essentially 2 megohms. Our voltage divider now consists of 375,000 ohms in *A*, and 2,000,000 ohms in *B*, so section *B* gets over five times as much signal voltage as section *A* at 100 cycles. As we go still lower in frequency, we will find that practically all of the signal voltage appears across section *B* and is transferred to the lower 6SF5 tube.

The lower 6SF5 tube is thus a bass amplifier or bass-boosting tube. Since the amount of signal made available for the frequency-discriminating network is controlled by potentiometer *87-281*, this is the bass tone control.

The signals receiving bass-boosting action by the tube are developed across the 100,000-ohm plate load resistor. The .05-mfd. condenser across this resistor takes out signals above about 1000 cycles, so we have only the signal voltages of deep boomy bass notes across this resistor. These signal voltages are fed through control *48-281* with its 500,000-ohm shunt resistor, the .02-mfd. coupling condenser, and the 500,000-ohm resistor to the 100,000-ohm grid resistor for the 6J5 phase inverter tube. This control has no effect on bass notes because its .004-mfd. condenser is so small in comparison to the .05-mfd. plate by-pass condenser for the lower 6SF5 tube, but it does serve as a conventional type of tone control for the upper 6SF5 tube.

The upper 6SF5 tends to amplify all signals about the same amount but puts just a little more emphasis on the very high notes. It has a 500,000-ohm plate supply resistor across which the audio signals are developed. From here, the signals are fed through the 250,000-ohm resistor, the .02-mfd. coupling condenser and the 500,000-ohm resistor to the 100,000-ohm grid resistor for the 6J5 phase inverter. Thus, both 6SF5 tubes deliver signals to the phase inverter.

When the movable arm of tone control *48-281* is moved toward the .02-mfd. coupling condenser, the higher audio frequency signals (of which there are normally an over-abundance) passed by the upper 6SF5 tube are attenuated (cut down). When moved in the opposite direction, the effect is to give increased treble response, for the control then lets the over-amplified high audio frequencies come through.

The 250,000-ohm resistor between the upper 6SF5 amplifier plate and the .02-mfd. coupling condenser is used so the high audio notes will divide between them and the .004-mfd. tone control condenser when the tone control is set for minimum treble response. This arrangement also prevents interaction between the normal output circuit and the bass-boosting amplifier circuit.

The audio signals across the 100,000-ohm grid resistor are amplified by the 6J5 tube. The signals developed across its 50,000-ohm plate resistor are 180° out of phase with the grid signals, just as in any resistance-coupled stage. The signals across the 50,000-ohm plate load resistor are transferred to the input of the upper 6V6G output tube through the .02-mfd. coupling condenser and 10-mfd. filter condenser C_2.

The lower 6V6G grid is fed directly from the output of the 6SF5 tubes, and hence receives a signal 180° out of phase with that delivered to the upper 6V6G by the phase inverter tube. In this way, the 6V6G tubes are fed with signals 180° out of phase, as is necessary in any push-pull system.

The lower 6V6G receives far more signal than the 6J5, because of the 500,000-ohm and 100,000-ohm voltage divider system used to feed the latter tube. By choosing the right plate load for the 6J5, its gain is made just high enough so both 6V6G tubes receive the same amount of out-of-phase signal.

By using a push-pull arrangement, second harmonic distortion is avoided and we get the benefits afforded by the powerful 6V6G tubes. The odd harmonics, such as the third, fifth, seventh, etc., remain to be dealt with.

The .002-mfd. condenser between the 6V6G plates tends to by-pass third and higher harmonics produced in the output tubes. Nevertheless, some of these harmonics will reach the voice coil and cause it to move, with consequent distortion of the clear tones which would otherwise be produced. The effect is not very bad because it is almost entirely eliminated by degeneration.

Note the 400-ohm and 25-ohm resistors shunted across the voice coil. These resistors act as a voltage divider, and the small signal voltage developed across the 25-ohm resistor acts on the grid input circuits of the 6SF5 tubes. The signals across the voice coil are 180° out of phase with the signals fed from the second detector to the volume controls and the 25-ohm resistor.

What is the effect of feeding a signal into an amplifier which is 180° out of phase with the regular signal? The effect is just the same as if we were to turn down the volume control a certain amount, for due to cancellation we are in reality feeding less signal into the amplifier input. Since all frequencies at the output transformer secondary receive exactly the same treatment, how do we discriminate against the distortion-producing harmonics? The harmonics are eliminated because they were not in the input to start with! They were produced somewhere in the a.f. amplifier, and by feeding them out of phase into the amplifier input, they are practically wiped out at their point of origin and only a trace appears across the voice coil.

After this discussion, you can now appreciate the care taken in the design of this amplifier, and can see that excellent tone quality should be expected either on a.m., f.m. or phonograph operation.

Tracing the F.M. Signals. Band switch position *5* is for f.m. reception, so we will trace the f.m. signals from the antenna to the volume control at the input of the a.f. amplifier, from which point the audio amplifier works in exactly the same manner as for a.m. reception. The three switch sections marked S_7R are all in the *FM* position now.

The f.m. signals flowing in the antenna are capacitively transferred to the antenna coil through contacts *6-5* of switch section S_2R

and the .000025-mfd. condenser. The antenna coil is tuned to resonance by trimmer T_6 and *V.C.*, the latter being connected to the coil through the .00004-mfd. condenser and contacts *11-5* of switch section S_1F. The .00004-mfd. series condenser is used to reduce the over-all capacity of the circuit so the ultra high-frequency f.m. band may be tuned with the regular gang tuning condenser.

Switch contacts *5-6* of S_1F connect the tuned circuit to the control grid of the 6SK7 r.f. amplifier tube through the .0003-mfd. coupling condenser, the cathode connection being through the chassis and the cathode by-pass condenser. Contacts *6-5* of switch section S_4R connect the plate circuit of the r.f. tube to its 10,000-ohm load resistor. Capacity coupling through the .0001-mfd. condenser transfers the amplified signal from the plate load resistor to r.f. transformer *7G1*. Only a small part of the possible gain of the r.f. tube is utilized due to the use of a 10,000-ohm plate load resistor, but a small value of resistance is necessary to shunt coil *7G1* and broaden the tuning.

The signal fed the r.f. coil is tuned to resonance by r.f. trimmer T_{10} and main tuning condenser *V.C.* which connects to the coil through the .00004-mfd. condenser and contacts *4-10* of switch section S_3F. Contacts *4-5* on this switch connect the resonant circuit to the 6SA7 mixer tube through the regular .0003-mfd. coupling condenser. The cathode connection is through contacts *5-6* of switch section S_6R, the oscillator coil and the chassis, so we have a duplication of the circuit used in previous band positions.

The oscillator uses coil *701* and trimmer *86-262*, with connections being the same as for previous bands. The variable condenser tunes the oscillator circuit through the .005-mfd. and .00005-mfd. condensers and contacts *11-5* of switch section S_5F. Contacts *5-6* on this switch connect the oscillator tank circuit to the oscillator grid of the 6SA7 through the .00005-mfd. coupling condenser.

Oscillations are maintained in the usual way, and the local oscillator and incoming signals are mixed within the tube. Since the oscillator and incoming signals differ by 4300 kc. (4.3 mc.), the i.f. carrier signal produced in the plate circuit of the tube has a frequency of 4.3 mc.

You will remember that in our previous discussion of the i.f. amplifier, the lower transformers were identified as being for the a.m. section. Now, of course, we are dealing with the upper or f.m. transformers. The primary of the first i.f. transformer, shunted by condenser C_8, is tuned to resonance by adjusting the iron core so that more or less of the core is inside the coil. The resonant circuit so formed offers a high impedance to the 4.3-mc. i.f. signal, and a large i.f. voltage is built up across the coil.

Resonant step-up results in a large circulatory current at the i.f. value, and the signal is induced into the secondary. The a.m. primary on the first i.f. transformer acts as a short as far as the f.m. signals are concerned, and this is also true in the case of the other a.m. circuits.

The f.m. secondary is connected to its trimmer C_9 through the low-reactance a.m. secondary when switch section S_7R is thrown to the *FM* position. Note the 50,000-ohm resistor shunted across C_9 and used to broaden the tuning of the first f.m. i.f. transformer. As was the case with the primary and all other i.f. transformers, resonance is obtained by core adjustment. The discriminator is an exception, being tuned by means of the two trimmers marked C_{14}.

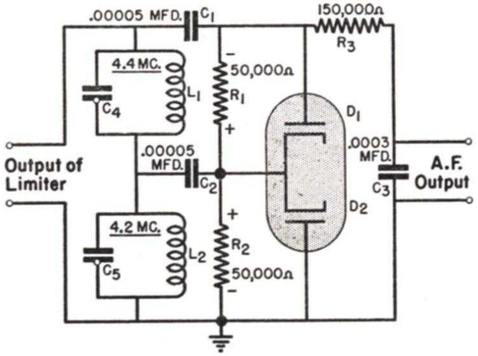


Fig. 15. Discriminator circuit. The i.f. value is 4.3 mc.

The signal applied to the input of the first i.f. tube is amplified, and appears across the broadly resonant plate load formed by coil *56-936*, C_6 and the 4000-ohm resistor. By capacity coupling through the .00005-mfd. coupling condenser and the .1-mfd. plate by-pass condenser, the signal is fed to the 500,000-ohm resistor and to the grid-cathode of the 6AC7 second i.f. tube. The cathode connection, of course, is through the cathode by-pass condenser.

The amplification contributed by the second 6AC7 tube results in a large i.f. signal across the broadly-resonant plate load formed by the transformer primary, condenser C_{10} and the 50,000-ohm shunt resistor. The signal induced into the secondary is applied directly to the grounded cathode of the 6SJ7 tube, and to its grid through the .000025-mfd. coupling condenser.

This 6SJ7, being a sharp cut-off pentode and being operated at low plate and screen grid voltages, acts as the limiter and delivers a signal of constant amplitude to the next stage, regardless of surges in signal strength that may result from static or other noise. Of course, the incoming f.m. signal must be strong enough to drive the 6SJ7 to the point where limiter action starts. The rectified voltage across the 100,000-ohm resistor in the control grid return of the 6SJ7 is applied to the grid of the 6U5, so that the 6U5 may be used as a tuning indicator on f.m. reception.

Due to the rectification taking place in the limiter grid circuit, the negative signal peaks are almost cut off. The missing portion of the wave form is built up, however, by the flywheel action of the 6SJ7 resonant plate load. The i.f. limiter plate load consists of the two coils, tuned by trimmers C_{14}, in parallel with the 100,000-ohm plate supply resistor. The reactance of the .0005-mfd. coupling condenser is so low that it acts as a short at the i.f. value.

The discriminator, as the second detector of an f.m. receiver is called, differs somewhat from those you studied in the text on f.m. However, it's very easy to understand.

To simplify our study of the discriminator, its circuit has been redrawn by itself in Fig. *15*.

In an f.m. system, the strength of the carrier peaks has nothing to do with the audio signal, and carrier peaks may therefore be limited without distortion of the signal. In f.m., the carrier is caused to swing above and below its assigned or resting frequency. The greater the carrier frequency excursions away from the resting frequency, the greater the audio signal strength.

The rate or frequency of these frequency deviations is controlled by the frequency of the audio signal. Suppose we had a 5000-cycle audio signal and a 1000-cycle audio signal, both of the same strength. If they were used to modulate an f.m. system, both being the same strength would cause the f.m. carrier to swing the same distance in kilocycles above and below its resting frequency. However, the 5000-cycle audio note would make the carrier swing above and below the resting frequency 5000 times each second, while the 1000-cycle note would only cause the carrier to swing 1000 times each second. In this way, these two frequencies have indelibly stamped their characteristics on the f.m. carrier.

Because variations in audio signal strength cause the carrier frequency to change so much, an f.m. receiver must tune broadly. Sharp tuning would cut down the amount of carrier frequency variation, thereby reducing the range of audio volume.

If the limiter delivers an i.f. of 4.3 mc. (the resting frequency) to the discriminator, both diode plates will receive the same amount of signal voltage, because the reactance of C_4-L_1 is equal to that of C_5-L_2. When plate D_1 is positive, electrons flow from the cathode to the plate and through R_1, producing a voltage drop having the polarity shown. On the next half cycle, D_2 conducts while D_1 rests, and the resultant diode current produces a voltage drop across R_2 with the indicated polarity.

The a.f. output voltage of the discriminator circuit appears across the outside ends of R_1 and R_2. At the resting frequency, however, the two voltages are equal and opposite, and no voltage exists between the diode plates.

We must get a difference in the amount of voltage across R_1 and R_2 before we can obtain any output. This is done by tuning C_4-L_1 to 4.4 mc., which is 100 kc. above the resting frequency, and C_5-L_2 to 4.2 mc., which is 100 kc. below the resting frequency. Now when we tune in an f.m. program, the carrier will be swinging above and below the resting value of 4.3 mc. When it swings to a higher frequency, the voltage across C_4-L_1 increases, while the voltage across C_5-L_2 decreases. The resultant changes in diode currents D_1 and D_2 cause more voltage to exist across R_1 than across R_2, and the output is the difference between the two voltage drops. When the carrier decreases in frequency, the action reverses, and since C_5-L_2 now gets the greater part of the signal voltage, the drop across R_2 is greater than the drop across R_1.

The number of times per second the carrier swings back and forth across the resting frequency governs the frequency of the a.f. output voltage of the discriminator, and the amount of variation in the carrier frequency governs the strength of the a.f. output.

As you can see, R_3 and C_3 form an i.f. filter, used so that only the pure audio output of the discriminator will be available for application to the volume control through contact *FM* of switch section S_7R and the *PHONO-RADIO* switch in Fig. *12*.

We have now covered the important signal circuit features for the entire receiver. The power supply circuits are quite conventional, and you should be able to trace them yourself without difficulty.

THE ERROR OF HASTE

The fable of the hare and the tortoise is more than an interesting childhood story—it carries an important message we sometimes forget in this age of speed.

The hare, you will recall, started off in great haste. Soon he was so far ahead of the slow-plodding tortoise that he became over-confident and took a nap. The tortoise kept going steadily and won the race.

Haste does not always mean progress. Too often it leads instead to errors, to actual waste of time and energy, and even to complete failure as in the case of the hare.

We must learn to work and wait. Take time for all things, because time often achieves results which are obtainable in no other way. Shakespeare expresses it thusly: "*Wisely and slow; they stumble who run fast.*" More emphatic still was Benjamin Franklin, who said: "*Great haste makes great waste.*"

Don't risk the dangers of haste. Keep going steadily like the tortoise, and you'll approach your goal in radio steadily, inevitably.

J. E. SMITH