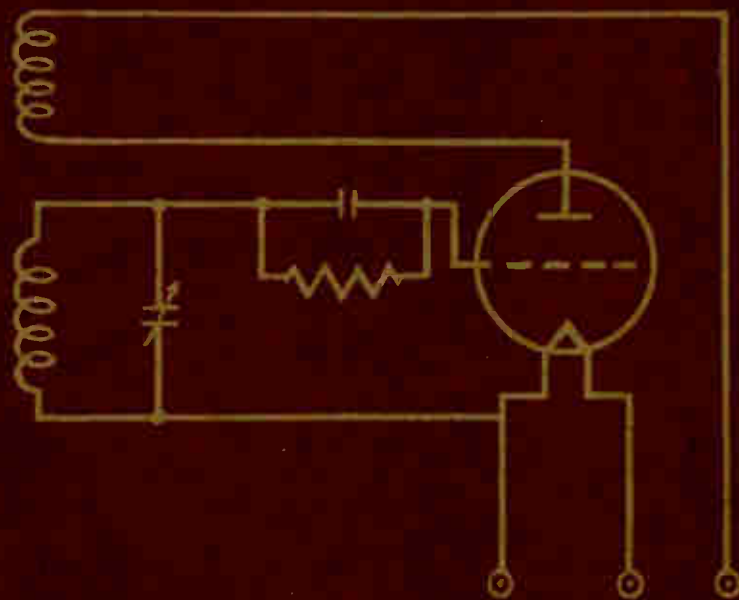
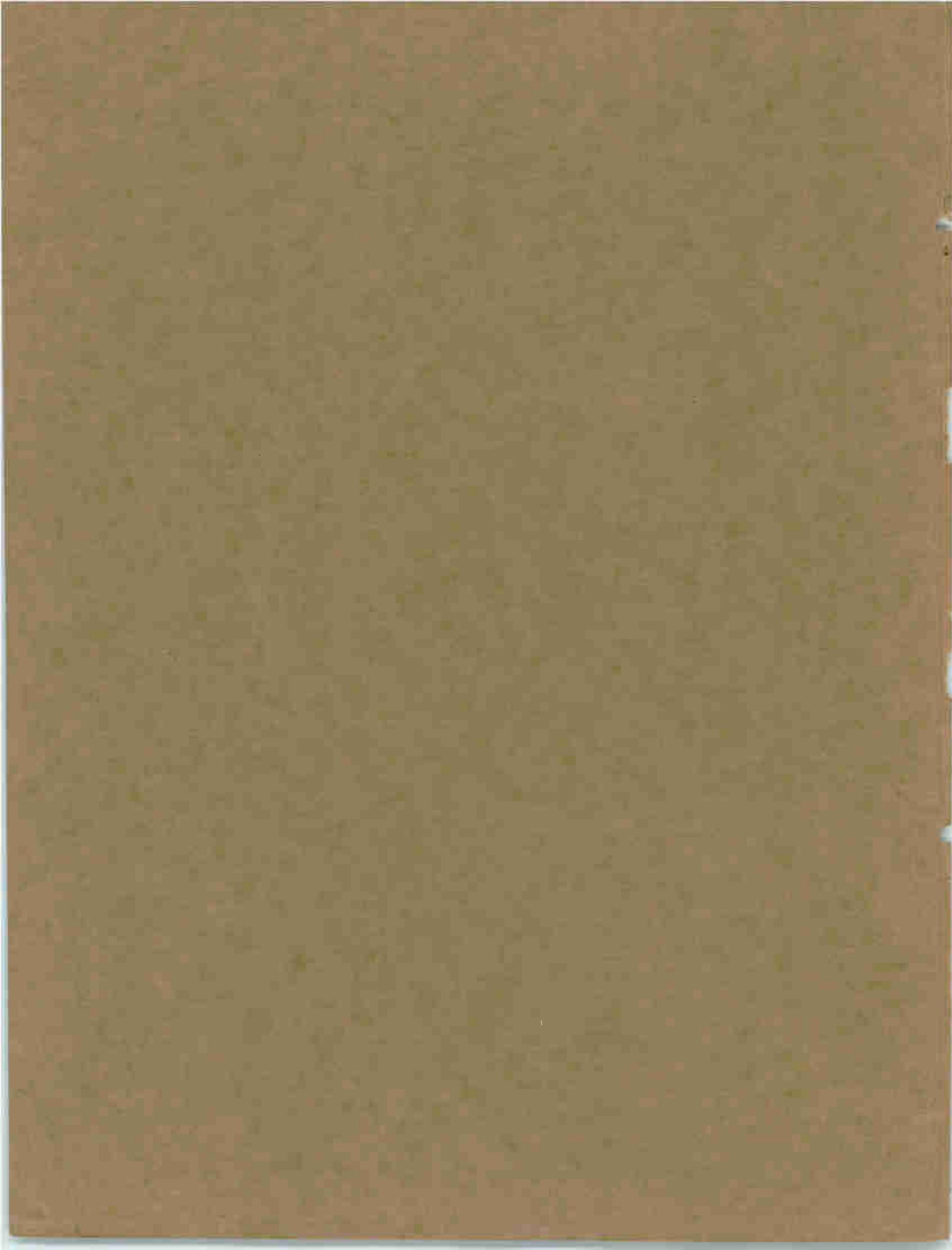


ALLIED'S RADIO-CIRCUIT HANDBOOK



ALLIED RADIO CORPORATION
CHICAGO



A R C

ALLIED'S RADIO CIRCUIT HANDBOOK

A COMPREHENSIVE GROUP OF RADIO AND
ELECTRONIC CIRCUITS WITH ANALYSIS, COM-
PARISONS AND DISCUSSIONS FOR STUDENTS
AND EXPERIMENTERS

Compiled by the Technical Staff of
ALLIED RADIO CORPORATION

PUBLISHED BY
ALLIED RADIO CORPORATION
CHICAGO

A R C

FOREWORD

THE purpose of this book is to illustrate basic radio principles by presenting, comparing, and analyzing some of the most popular conventional radio and electronic circuits. All diagrams cover dependable systems which are in actual use. Each circuit was carefully selected as the result of many years experience of ALLIED'S Technical Staff and Educational Division with radio students, instructors, experimenters and builders.

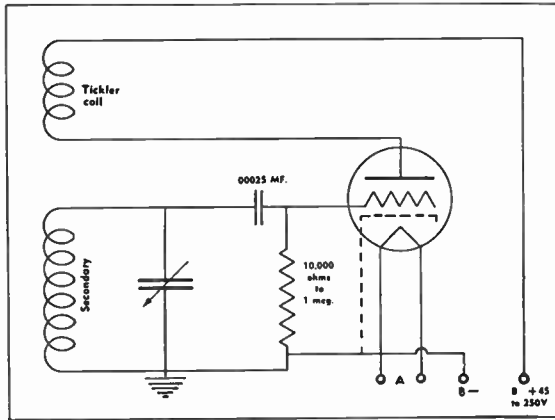
Fundamental principles are illustrated and explained by the "Basic Circuits" and the text in the first part of the book; then the application of these principles to various components of receivers, transmitters and other electronic units is shown. Thus the student gains a knowledge of how and why different circuits operate.

The method of presentation was especially planned to make this book a useful text for the classroom and for home study, as well as a reliable guide for experimenters and builders. For purposes of study and class discussion, actual construction of any unit is not essential.

TABLE OF CONTENTS

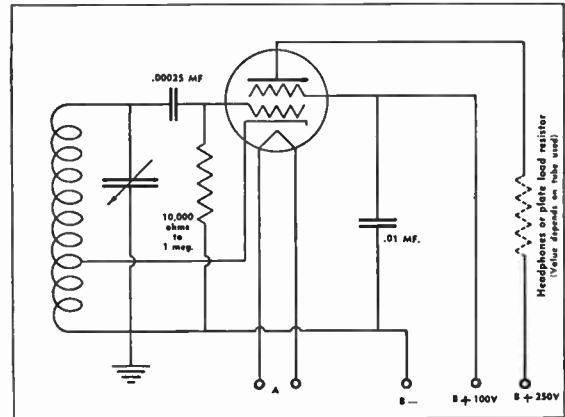
SUBJECT	PAGE	SUBJECT	PAGE
Basic Circuits	4-7	5 Tube AC Broadcast TRF	13
Tickler Coil Oscillator	4	5 Tube AC-DC Superhet	14-15
Electron Coupled Oscillator	4	Frequency Modulated Tuner	16-17
Hartley Oscillator	4	Radio Laboratory Receiver	18
Diode Detector	4	Radio Laboratory Audio Amplifier	19
Grid Leak Detector	5	Radio Laboratory Broadcast Station	20
Biased Detector	5	Radio Laboratory Code Practice Oscillator	21
AC-DC Power Supply	5	Radio Laboratory Capacity Operated Relay	22
Full-Wave Power Supply	5	Beat Frequency Oscillator	23
Power Supply Filter	6	<i>Knight</i> Junior Amateur Radio Station	24-25
Frequency Converter	6	<i>Knight</i> 2½ Meter Transceiver	26-27
RF Amplifier	6	"Communications 5" Superhet	28-29
Automatic Volume Control	6	Code Practice Oscillator	30
Audio Voltage Amplifier	7	3 Tube Phono Amplifier	31
Power Amplifier	7	Four Watt AC-DC Amplifier	32-33
Audio Phase Inverter	7	Fourteen Watt Amplifier	34-35
Push-Pull Power Amplifier	7	Volume Expander-Compressor	36
<i>Knight</i> 1 Tube DX-ER	8-9	Wireless Phono Oscillator	37
<i>Knight</i> 2 Tube DX-ER	8-9	Photo-Electric Cell Circuits	38
<i>Knight</i> 3 Tube DX-ER	8-9	Schematic Symbols Used in Radio	39
1 Tube AC-DC Circuit	10		
AC-DC "Ocean Hopper"	11		
Bandswitch 3 AC-DC TRF	12		

1 Tickler Coil Oscillator



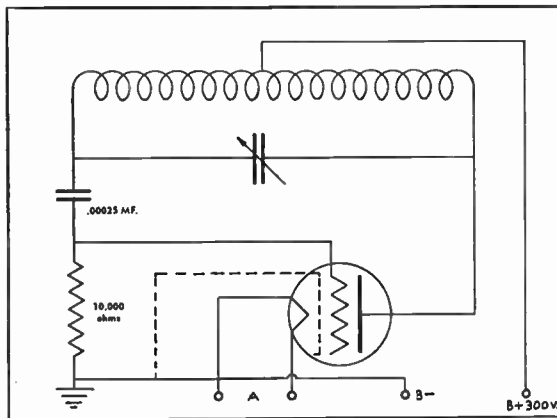
THIS type of oscillator is used in regenerative receivers and in the converter stage of superheterodynes. Oscillation is attained by feeding more energy from plate to grid circuit than the amount required to compensate for the power loss in the grid circuit. Feedback is accomplished by electromagnetic coupling between grid and plate coils. When fed-back energy is greater than the loss in the grid circuit, the tube oscillates at a frequency governed by coil and condenser values.

2 Electron-Coupled Oscillator



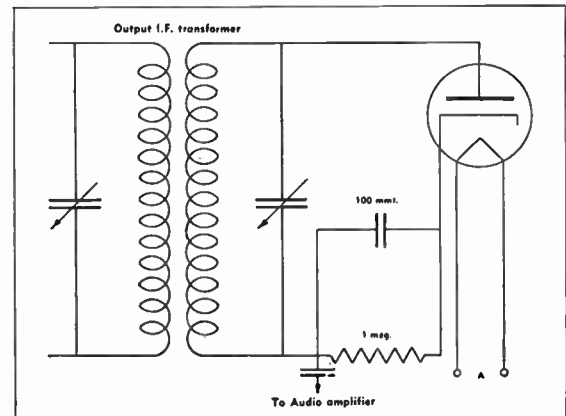
THE single tapped coil operates as two separate coils, divided by the point at which the tap exists. The two parts of the coil, above and below the tap, are mutually inductive. Action is similar, otherwise, to that in the tickler coil oscillator (described at left). The tube elements, making up the oscillator, are the cathode, grid and screen grid. Oscillations are transferred to the plate circuit through the electron stream. Plate current variations do not affect stability.

3 Hartley Oscillator



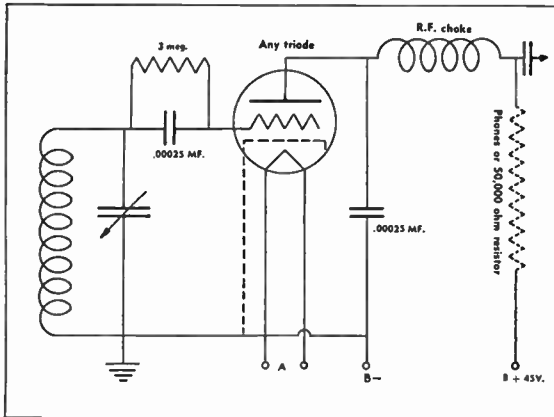
THE Hartley oscillator is commonly used in transmitter circuits. Oscillation is produced by feeding back, from the plate to the grid, a voltage approximately 180° out of phase with the voltage in the plate circuit. This is accomplished by sending part of the plate voltage through the tank circuit, then through the condenser, and back to the grid. Frequency of oscillations is approximately the frequency of the tank circuit. The B tap on the coil should be made at a point of low R. F. potential.

4 Diode Detector



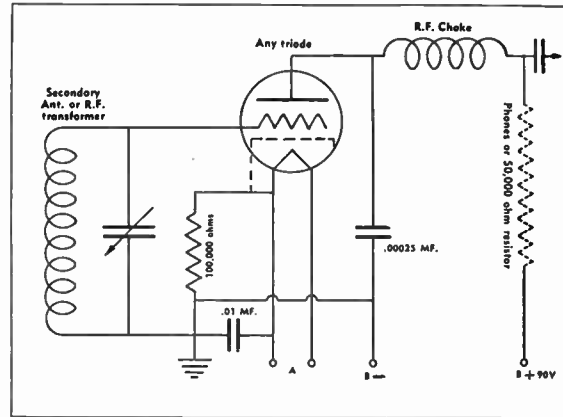
ACTION of a diode detector is like that of a half-wave rectifier. AC current (the modulated input signal) coming from the secondary of the transformer, flows through the plate only on the half cycle when the plate swings positive. The resulting pulsating DC current varies in accordance with the amplitude of the positive half of the modulated wave and produces an audio frequency signal. The condenser across the load resistor must be large enough to smooth out the RF pulsations but not too large, or it will short-circuit the audio signal.

5 Grid-Leak Detector



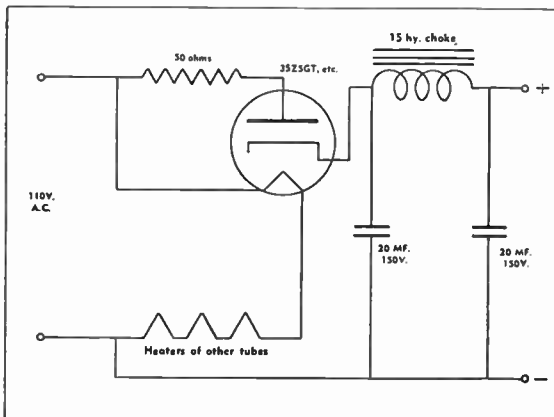
GRID-LEAK detector action resembles that of a diode detector with one added stage of amplification. The grid and cathode of the tube serve as a diode with the grid acting as a plate. The grid-leak resistor and the grid condenser act as an impedance that matches the load impedance of the diode detector. The .00025 mf. condenser in the plate circuit shorts out RF voltage that may have been amplified by the tube. Amplification of the signal voltage is provided by the plate.

6 Biased Detector



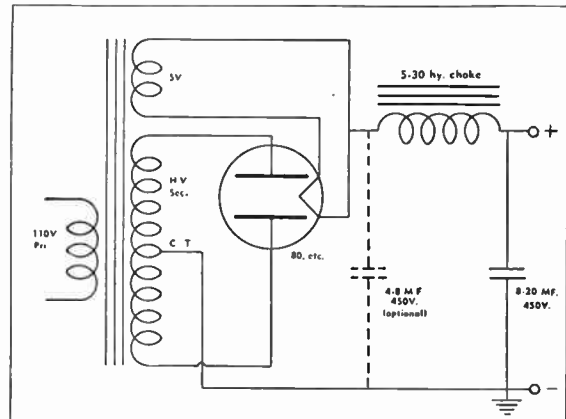
THE grid is biased almost to cut-off because of the high value of bias resistor, and plate current is practically zero with no signal in the grid circuit. When a signal is received, amplification takes place, but more plate current flows on the positive half cycles than on the negative half cycles. This results in demodulation of RF signal in the plate circuit. Filtering of RF currents in the plate is accomplished by the RF choke and the .00025 condenser.

7 AC-DC Power Supply



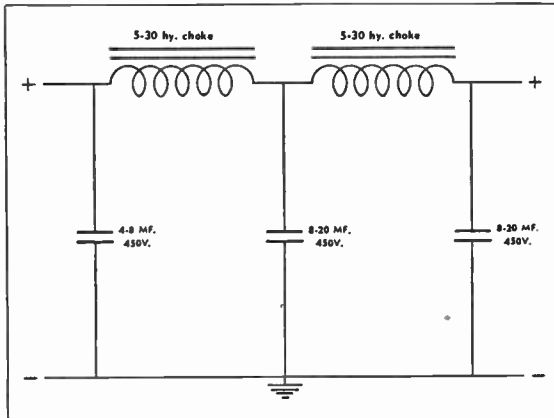
THE function of a power supply is to provide DC power from an AC line. Operation closely resembles that of the diode detector circuit 4. Current flows only on the half-cycle when the plate is positive with respect to the cathode. High values of filter condenser are required to smooth ripple in the tube output since only one-half the AC wave is rectified, and the resulting pulsating DC has a 60-cycle AC component. The 50-ohm resistor protects the tube against the high current surges as the first filter condenser is charged and discharged.

8 Full Wave Power Supply



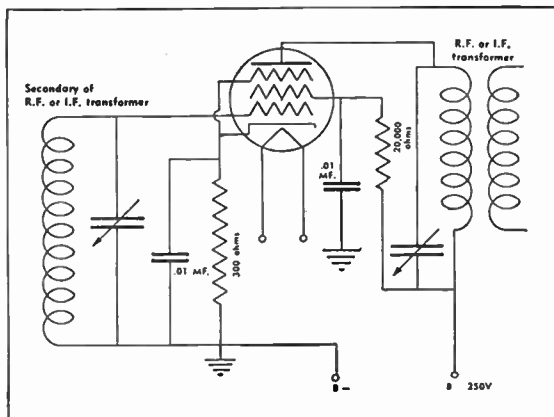
THE diode used here has one filament and two plates. Current flows from each plate alternately on its positive half-cycle and results in pulsating DC, which is at twice the frequency (120 cycles per second) provided by a half-wave system. The full-wave system, since current flow is more uniform, is easier to filter than the half-wave system. The condenser, shown by dotted lines, increases output voltage but decreases regulation. Use of a power transformer provides higher voltages than those available from an AC-DC supply.

9 Power Supply Filter



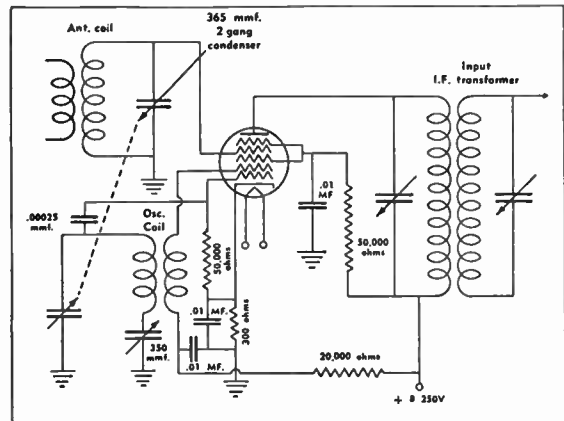
THE function of the filter is to smooth pulsating voltage, supplied by the rectifier output, into steady DC voltage. Filter networks may be single- or double-section types; the latter provides better smoothing. Filter chokes should have high inductance and low DC resistance. Current-carrying capacity must exceed total plate current of all tubes plus any voltage dividers or bleeder resistors. Condenser voltage ratings should be higher than voltage between plus and minus.

11 RF Amplifier



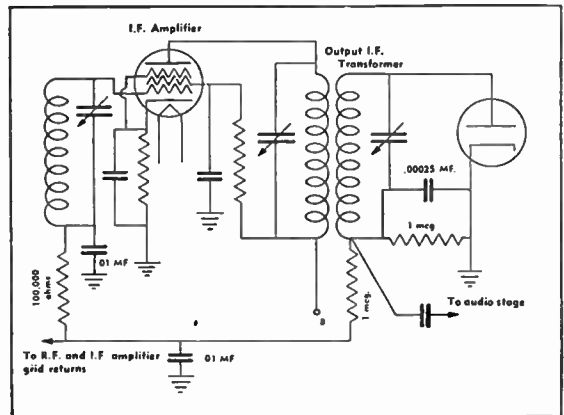
THE principles of RF and AF amplification are the same. A small signal voltage impressed on a grid controls a large output in the plate circuit. The grid must be correctly biased, and the tube must work into the proper load impedance. Bias is obtained from the 300-ohm cathode resistor. Input and output circuits must be thoroughly isolated from each other to prevent oscillation. The necessary high load impedance is secured by use of the parallel resonant circuit. The system amplifies the desired signal and eliminates others.

10 Frequency Converter



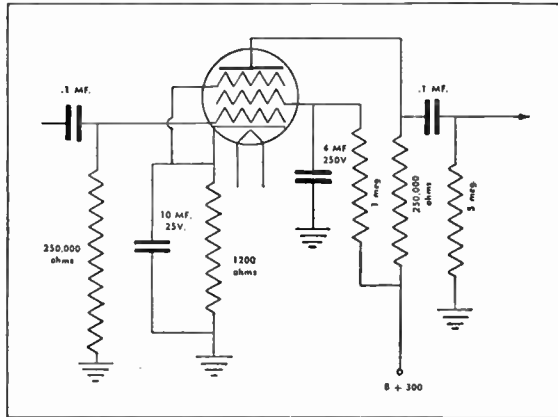
THE frequency converter is used in superhets to change the frequency of the RF signal to an intermediate frequency. The tube used is called a "mixer." The cathode and grids 1 and 2 (from the cathode) comprise a tickler-type triode oscillator. Signals from the secondary of the antenna coil mix with the frequency of the oscillator and result in a new frequency, called the "intermediate frequency," which is equal to the difference between the two.

12 Automatic Volume Control



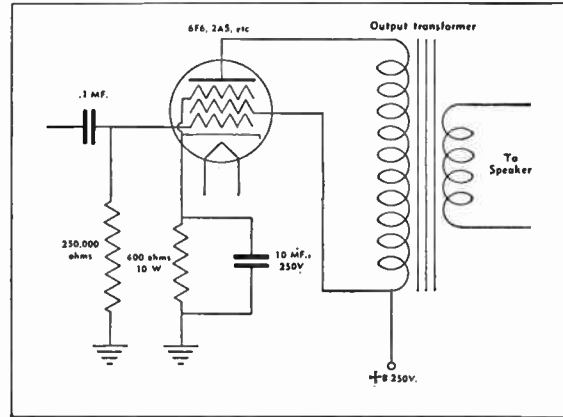
AUTOMATIC volume control is used to provide constant output despite variations (fading or more-than-normal increase) in signal strength. This circuit combines circuits 4 and 11. The rectified DC voltage developed across the 1-meg. diode load resistor is added to the bias voltage of the IF or RF amplifiers. When the signal decreases, the IF output tends to decrease, thereby decreasing the negative bias and increasing the gain of the amplifier. When the signal increases, the process is reversed and gain is reduced.

13 Audio Voltage Amplifier



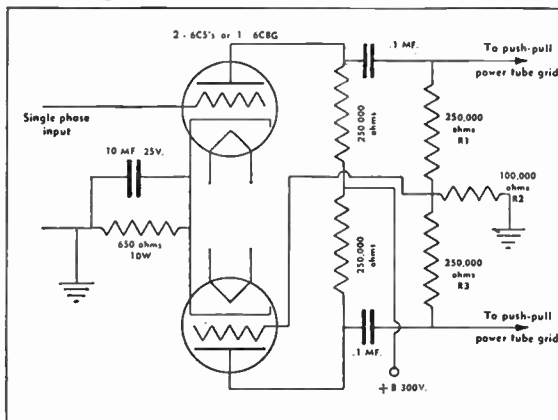
THE tube is operated at proper grid bias to keep input grid voltage on the straight line of the grid voltage vs. plate current characteristics curve. A small signal voltage impressed on the grid is reproduced in essentially the same form, but in increased amplitude, in the plate circuit. The ratio between the signal voltage at the grid and plate voltage in the load resistance is the gain of the tube. In this circuit, gain is 140 if the tube used is a 6J7, 57, 6C6 or 6W7G.

14 Power Amplifier



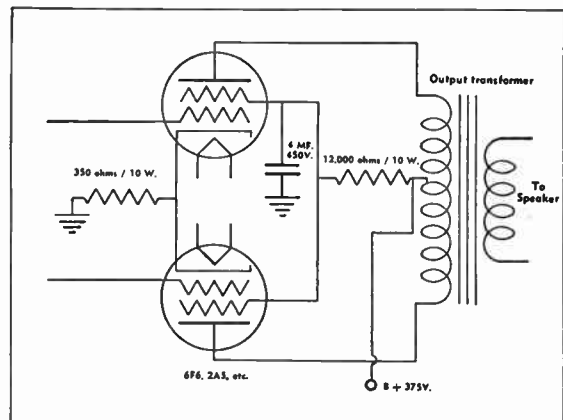
A POWER amplifier must supply large amounts of distortionless power to the loudspeaker. Power amplification is, therefore, more important than voltage amplification. A 6F6, 2A5 or similar type pentode tube may be used with the values of the components shown in the above circuit. The output transformer must have the proper ratio to match the output of the tube to the speaker voice-coil. This circuit is capable of 3 watts output.

15 Audio Phase Inverter



THE function of the phase inverter is to feed signal voltages, 180° out of phase with each other, to the grids of a push-pull stage. When the grid in one tube is swung positive, the grid of the second is swung negative by an equal amount. The output AC voltage from the first triode appears across R1 and R2. The portion across R2 is fed to the grid of the second triode, and its output appears across R3 and R2 but out of phase with the voltage from the first triode. These out of phase voltages are fed to the grids of the P.P. amplifier.

16 Push-Pull Power Amplifier



TWO 6F6 tubes are used in this amplifier. The same value of voltage is applied to the grid of each tube, but voltages are 180° out of phase. The outputs of the tubes are combined by the center-tapped output transformer. The direct currents in the two halves of the primary are in opposite directions, and so DC saturation is impossible. AC hum is eliminated because the two halves of the primary balance each other. P.P. provides more power per tube at less distortion. This circuit develops nearly 20 watts of power.

Knight 1 Tube DX-ER

THE 1-tube DX-ER is a regenerative type receiver. Regeneration (see basic circuit Fig. 1) has the effect of increasing the overall efficiency of a circuit. Add to this the fact that the tube in this circuit acts as an amplifier, and it can be seen that a high degree of efficiency is attained. DX (long distance) reception on the regular broadcast band as well as on the short-wave bands is feasible with the 1-tube DX-ER.

When the regeneration control (δ), which controls the amount of energy fed back to the tuned circuit, is advanced beyond a critical point, the circuit begins to

oscillate. Circuit efficiency increases up to this critical point but not beyond it. When the circuit breaks into oscillation, its value lies only in its ability to permit code signals (C.W.) to be heard. In code reception the R.F. produced by oscillation "beats" with the RF of the incoming signal and produces an audible note.

The tube acts as oscillator, grid leak detector and amplifier. Low amplification triodes make the best detectors in circuits of this type. Amplification is insufficient for loudspeaker performance but is adequate for headphone reception.

Knight 2 Tube DX-ER

IN this circuit one stage of audio amplification is added to the regenerative detector in order to increase output (volume) beyond the amount available from the 1-tube DX-ER. The amplification and audio power, while providing better headphone performance, are still insufficient for loudspeaker performance.

Because the grid resistance of an audio amplifier is high, the detector stage plate circuit is only a light load as compared with headphones used in the one-tube set above. It is possible, therefore, to use a tube having a higher amplification constant as a detector. The 1H5G is a tube of this type.

The 1N5G screen-grid tube, used as an audio amplifier in this circuit, requires high-resistance headphones—the higher, the better. Good operation is possible,

however, with headphones having a resistance as low as 1,000 ohms. Regeneration control procedure is the same as for the 1-tube DX-ER.

The antenna trimmer condenser affects the "loading" of the detector circuit. Antennas "resonate" at frequencies depending upon their length. At resonant frequency, energy will be drawn from the detector circuit. If the capacity of the antenna trimmer condenser is too high, regeneration will be adversely affected. Therefore, at antenna resonance, it is necessary to reduce the capacity of the antenna trimmer condenser. At other frequencies the capacity may be increased for greater pickup. The antenna trimmer condenser should be operated at the lowest possible capacity consistent with good reception.

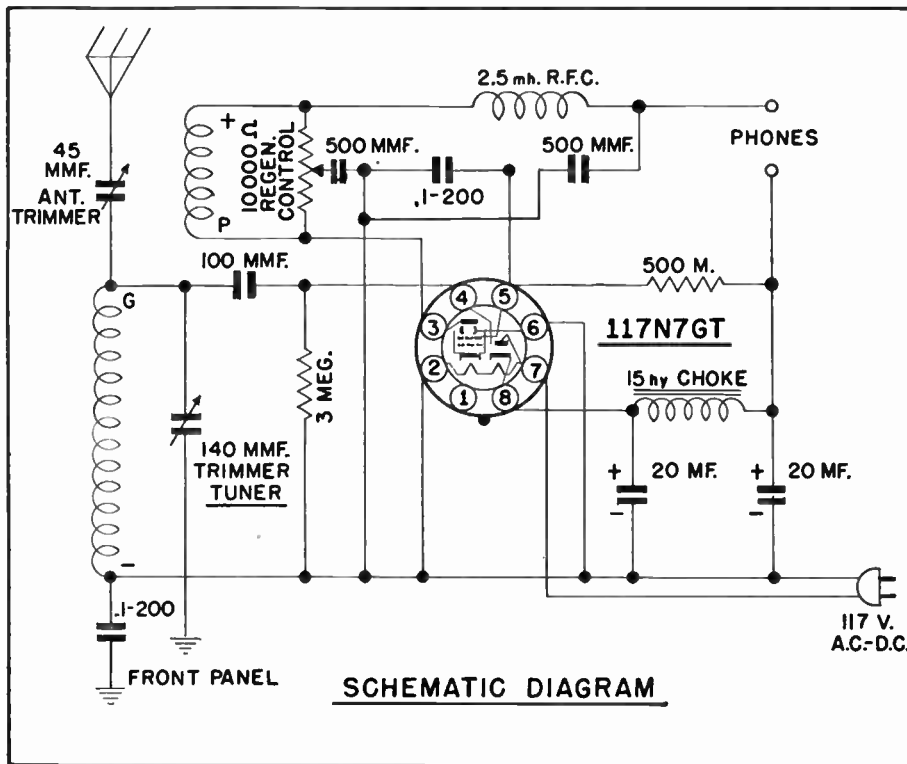
Knight 3 Tube DX-ER

THIS 3-tube circuit of a battery-operated receiver has a radio frequency amplifier stage ahead of the detector and a power amplifier following the detector. The 1N5GT tube used in the 2-tube DX-ER as an audio amplifier serves here as an RF amplifier and includes an additional tuned circuit which increases selectivity. As an RF amplifier it also provides a considerable increase in sensitivity (distance getting ability).

Any inter-action between the tuned circuits on each side of the amplifier tube may cause the tube to oscillate. The coils should be well separated, or a grounded metallic shield should be used between, or over, them. Connections to the grid and plate terminals of the tube socket must be well separated. To make sure that

interaction does not occur in the "B" voltage circuit, "decoupling" must be used. This is taken care of by the .001 mfd. condenser and 100,000-ohm resistor connected in the grid return of the RF amplifier.

Volume is controlled by varying the bias on the RF amplifier tube. Bias for the output tube is obtained by connecting the grid return of the 1C5GT tube to the lower end of the 600-ohm resistor which is at a negative potential. A 50,000-ohm potentiometer is connected across the 600-ohm resistor. Varying the rotating arm varies the bias to the 1N5GT tube. The higher the bias, the lower the amplification. The 3-tube DX-ER will operate a magnetic or a PM dynamic speaker. With the latter a matching transformer is required.



1 Tube AC-DC Circuit

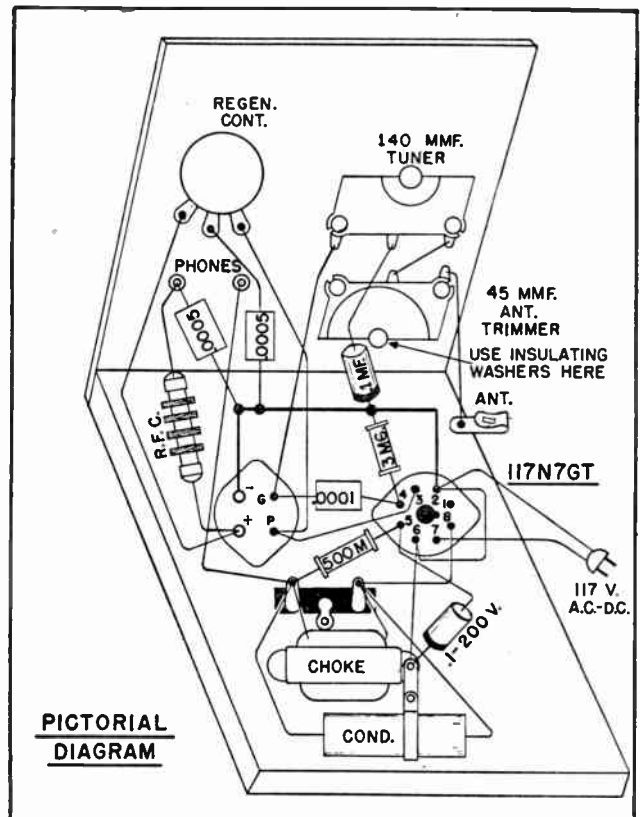
THIS is one of the simplest of all self-powered circuits.

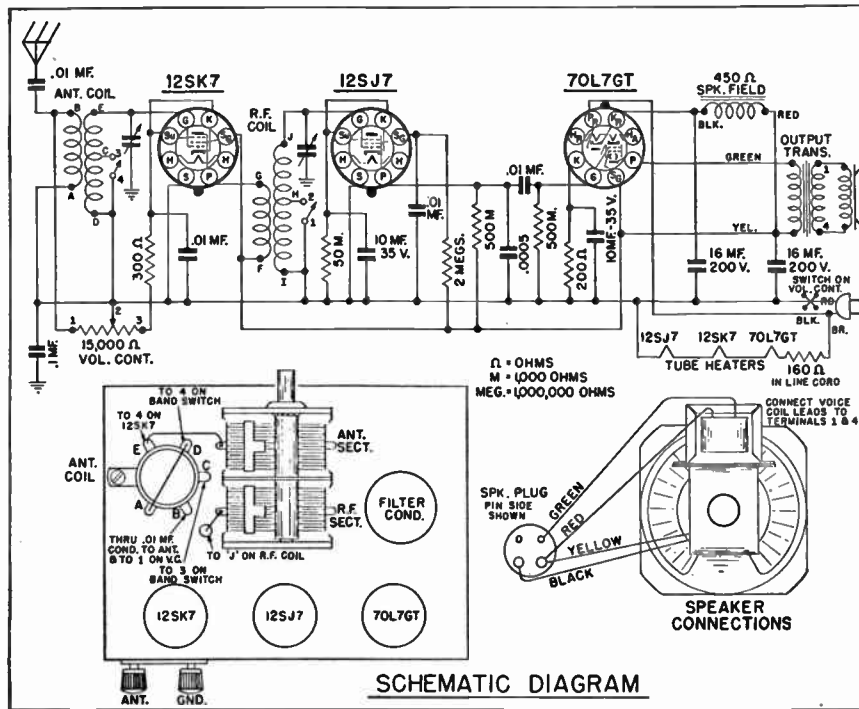
It uses only one 117N7GT tube and operates from any 117-volt AC-DC line. The tube serves the double function of rectifying AC line voltage and as a grid-leak regenerative detector. Neither a transformer or a dropping resistor is required. On AC operation the diode section of tube operates as a half-wave rectifier.

Since this circuit is intended primarily to provide good performance from weak and distant stations, a 500,000-ohm screen-voltage dropping resistor is used. This reduces the power necessary for speaker operation but improves reception from distant stations.

The control of regeneration is accomplished by by-passing the RF voltage across the tickler coil. A potentiometer controls the degree of by-passing.

Because no power transformer is used, an AC-DC receiver is not isolated from the house-lighting circuit. The receiver circuit becomes a part of the power line. No external ground is used. An electrical ground is obtained through the house-lighting circuit. For this reason care must be exercised in handling an AC-DC receiver in order to avoid a severe shock. Metal chassis and panels are isolated from the circuit to protect the operator in case he accidentally touches the panel and an external ground, such as a radiator, at the same time.





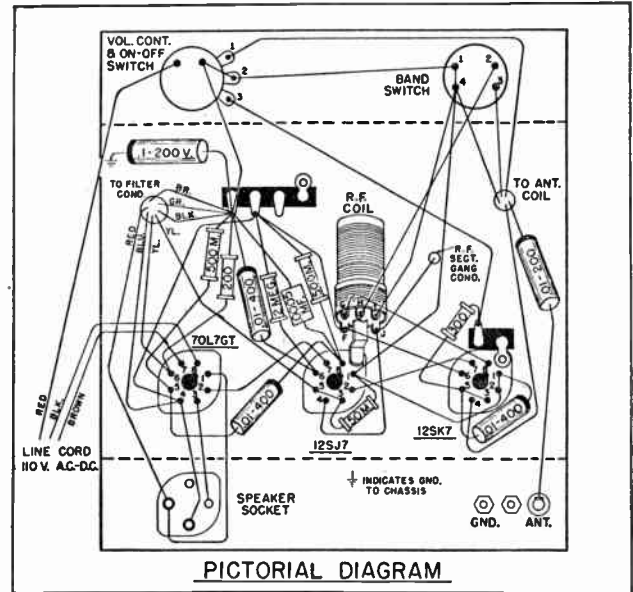
Bandswitch
3
AC-DC
TRF

This receiver is designed essentially for reception on the broadcast band, but the coils are tapped so one short-wave band may be tuned. The variable tuning condenser has two sections, each with a capacity of 365 mmfd. (.000365 mf.). This condenser, together with the proper coil, tunes the entire broadcast band.

The RF amplifier circuit is a standard type designed around a 12SK7 tube. Volume is controlled in this stage by varying the grid bias. A 15,000 ohm potentiometer is used in series with a 300-ohm fixed resistor in the cathode circuit. The 300 ohm resistor establishes the fixed minimum bias recommended for this particular tube for optimum operation. As the arm, terminal No. 2 on the volume control, is moved away from terminal No. 3, additional resistance is added to the cathode resistor. This increases negative bias and decreases amplification (volume).

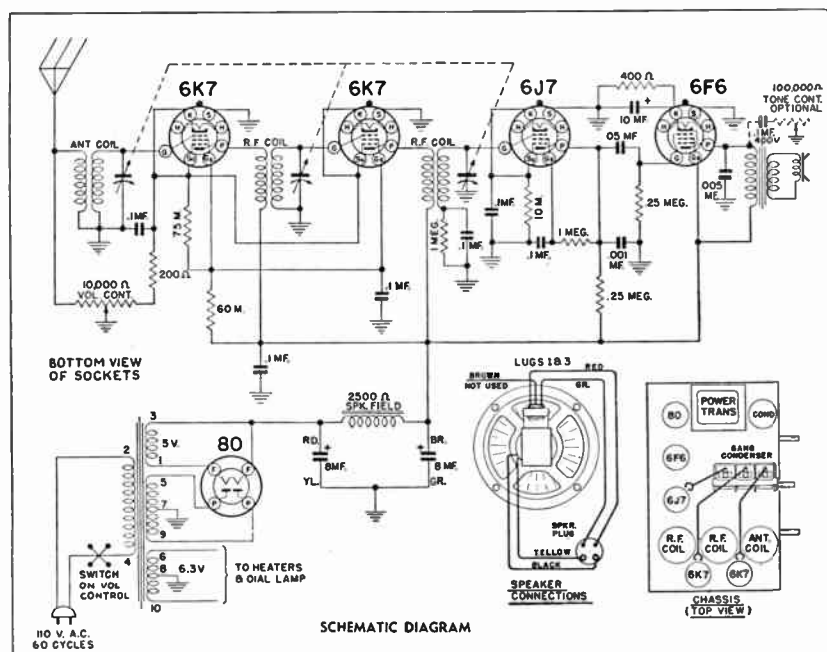
The 12SJ7 tube is a "cathode-biased" power-type detector, so called because it is biased by a high value resistor (50,000 ohms in this case). This type of detector is superior to the grid-leak type in that it will handle stronger signals without distortion.

The output of the detector stage carries only audio signals. Therefore, the values of the constants used in the screen-grid and plate circuits are those specifically required for audio amplifier service. A 2-megohm



resistor drops the voltage on the screen-grid, and a 500,000-ohm resistor is used as a plate load resistor.

Wiring of the 70L7GT power and rectifier stage is similar to that of the "Ocean Hopper." The field coil on the speaker receives excitation current from the receiver power supply and also serves as a filter choke.

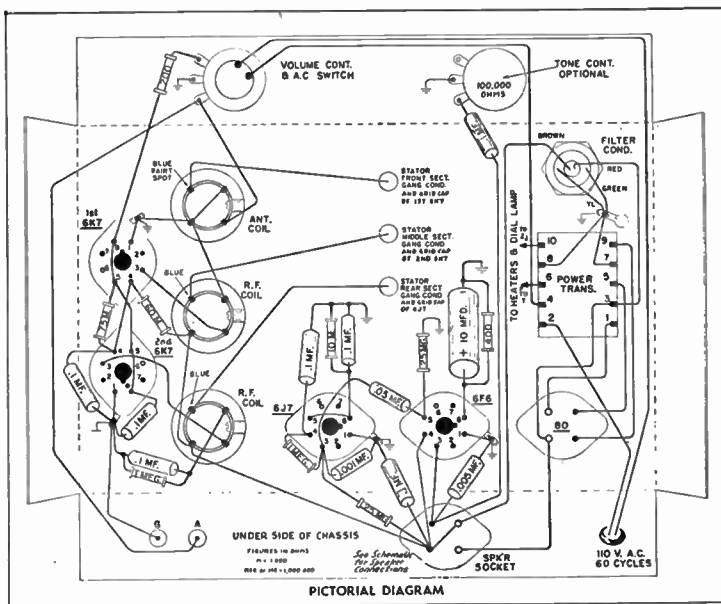


5 Tube AC Broadcast TRF

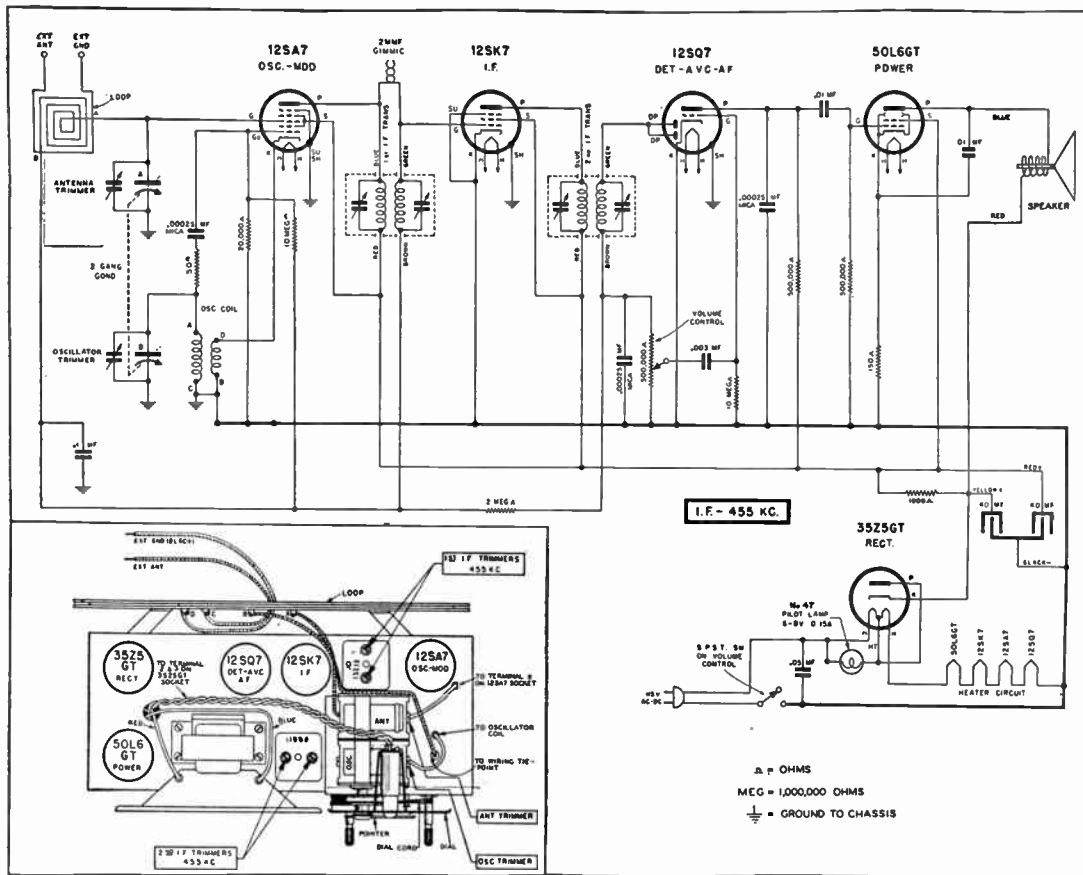
THIS circuit comes close to representing the perfect tuned-radio frequency receiver. Two RF stages and a biased detector, each having tuned input, are used. These provide a high order of selectivity. Three variable condensers are ganged on a single shaft so that tuning may be controlled by a single dial.

The principal difference between this circuit and those previously described is in the power source. Note that a power transformer is used in the power supply circuit. Because of this, the receiver will operate only from 110 volts, 60 cycles, AC. The 110 volts supplied by the power line to the primary of the transformer is stepped up to about 600 volts, AC, in the high-voltage secondary (between Nos. 5 and 9 on the transformer). Use of the center tap (No. 7) cuts this voltage in half, but permits full-wave rectification with a single rectifier tube. With full-wave rectification, filtering is comparatively simple. The net DC voltage available for the plate circuits of the tubes is about 275, whereas in AC-DC circuits the maximum is about 130 volts. The tubes, operated at the higher voltages, work at greater efficiency. All heaters are operated at close to ground potential, thereby reducing the tendency towards leakage between heater and cathode.

With the exception of a few special cases, cathodes



and screen-grids are always by-passed for AC voltages whether RF or audio. The screen-grid merely carries a DC potential. The tone control, indicated as optional, operates as a variable by-pass of audio frequencies. Its effect is much greater at the higher audio frequencies, and the ratio of high to low audio frequency attenuation increases as the resistance of the potentiometer is reduced.



5 Tube AC-DC Superhet

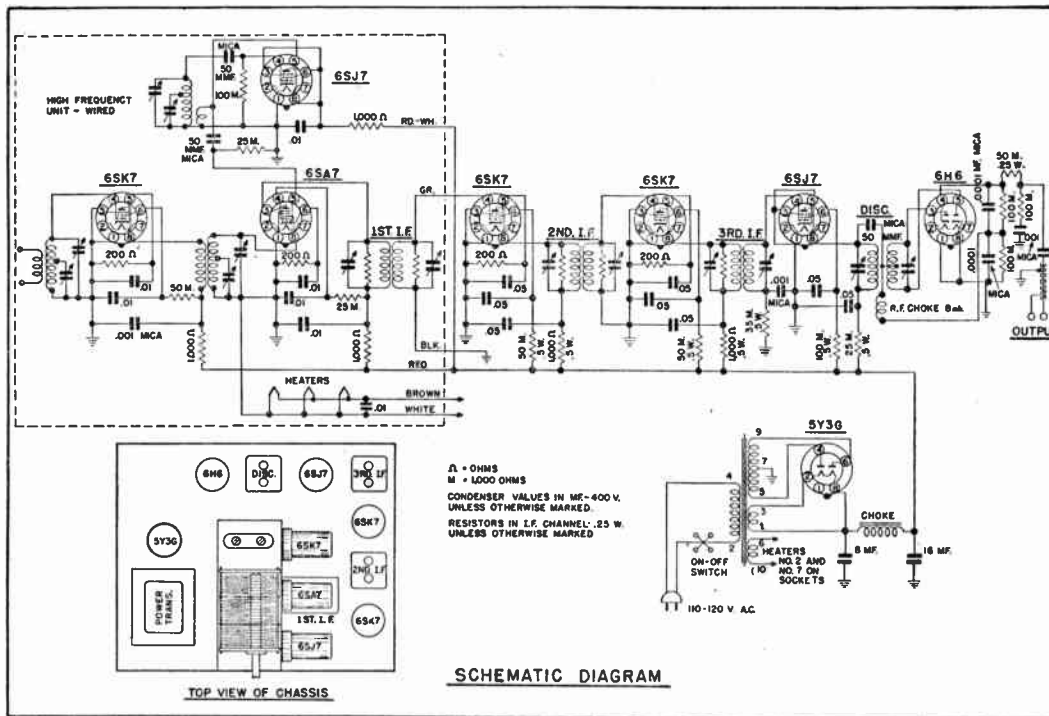
THIS circuit has many unusual features that make it worthy of study. It is so designed that the heaters of the tubes, connected in series, may be operated directly from the 115-volt line without a dropping resistor. The heaters add up to 122.8 volts, but will operate from line voltages as low as 105.

The 12SA7 tube is the converter. It produces local oscillations at a frequency which can be varied. These oscillations beat with the incoming signal, and the combination of the two signals produces a beat signal known as the heterodyne signal. The name "Superheterodyne" is derived from the action. Heterodyning is used to change the incoming signal frequency to a predetermined intermediate frequency (known as I.F.) of 456 KC. The loop antenna is nothing more than an antenna coil, wound so that it is large in size and therefore capable of direct pickup of radio signals without the necessity for an external aerial. It has a primary, like a conventional antenna coil, consisting of

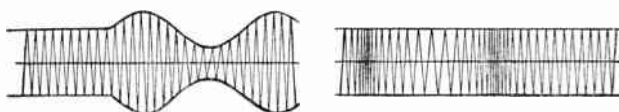
two or three turns of wire wound around the edge of the loop. The ends may be connected to an external ground and antenna for greater pickup.

In order to obtain an I.F. frequency of 456 KC, the oscillator must produce RF voltage at a frequency which is 456 KC higher or lower than the incoming signal frequency. In broadcast band receivers it is customary for the oscillator to be 456 KC higher. While the antenna section of the two-gang tuning condenser tunes the loop to resonate with signals from 1730 KC to 540 KC, the oscillator section of the tuning condenser varies oscillations from 2186 KC to 996 KC. The oscillator section of the tuning condenser has a lower maximum capacity. The oscillator coil has lower inductance than the antenna coil, or loop, and the oscillator section of the condenser and oscillator coil are designed to "track" with the antenna circuit.

The I.F. stage amplifies at high efficiency because its function is to amplify only one fixed frequency. It is



BEFORE the operation of an FM receiver is described, it is well to review briefly the theory of FM transmission. Unlike amplitude-modulated (AM) transmission in which the RF wave varies in amplitude to correspond with the impressed audio signal, frequency-modulated transmission does not affect the amplitude of the wave. It permits the wave amplitude to remain constant but varies wave frequency in accordance with the modulated signal.



Amplitude Modulation
Frequency remains constant.
Amplitude is modulated.

Frequency Modulation
Amplitude remains constant.
Frequency is modulated.

If the carrier frequency of an FM broadcast station is, let us say, 44 megacycles, its frequency under modulation may shift as high as 44,075 KC and as low as 43,925 KC. From this it is seen that a single FM broadcast station may cover a band width in the radio frequency spectrum of as much as 150 KC. This is why FM broadcast stations are located in the ultra-high frequency bands where there is a great deal more room for wide-range high-fidelity transmission than in the regular broadcast band.

Wide Range Reception

The FM receiver is basically a superhet with certain changes which result in two major advantages: wide-range frequency response and elimination of interference. To increase range, the IF transformers are loaded by resistors. This reduces amplification, however, and so an extra stage of IF amplification is often required.

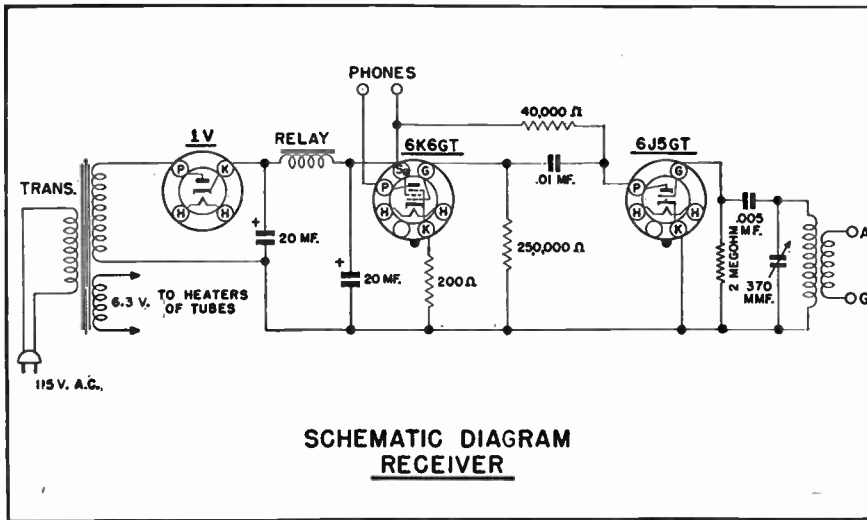
The Limiter

The limiter keeps the FM wave at a predetermined level (see illustrations at left) at which it should consist only of the carrier and the modulated intelligence. Any interference picked up by the wave increases its amplitude, and it is this additional amplitude which is taken off by the limiter. The grid of the limiter tube is operated without fixed bias. A high resistance, shunted by a small capacitance, is used in the grid circuit. The grid draws bias current from the applied signal. This current flows through the grid resistor, and the resultant bias limits the gain of the tube. The tube plate is operated at a low voltage so that it will handle desired signals but will be pushed past saturation point by noise or interference.

The Discriminator

The discriminator is somewhat similar to a second detector stage in a standard superhet. Its function is to

Beginner's Radio Laboratory Receiver

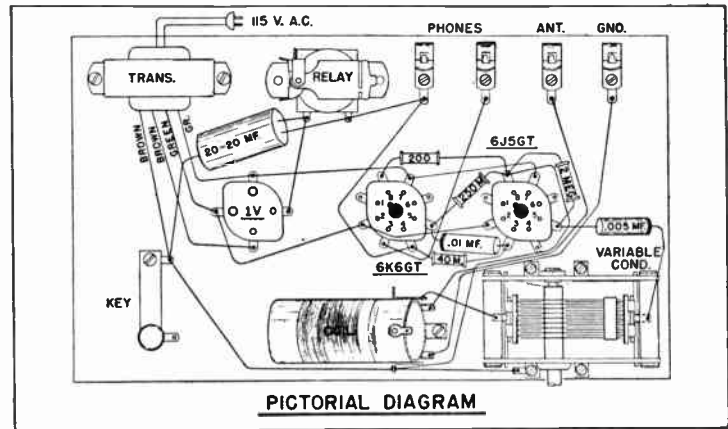


THE Radio Lab Kit was designed to portray the flexibility of radio parts and is especially interesting to beginners. Six different circuits, performing six separate functions, all use the same parts. The circuits were designed around the use of only three tubes which were carefully selected with a view toward efficient operation at low power consumption. Low plate voltages are used to reduce hazard when construction is performed by the younger and less experienced experimenter. Total power consumption from the house lighting circuit is only ten watts. All of the tubes, including the rectifier, operate from a common filament winding on the transformer. A relay, used in the capacity-operated relay circuit, serves as a filter choke in other circuits.

Receiver

The receiver will provide headphone reception from stations within twenty-five miles. A small speaker can be operated when receiving the more powerful local stations.

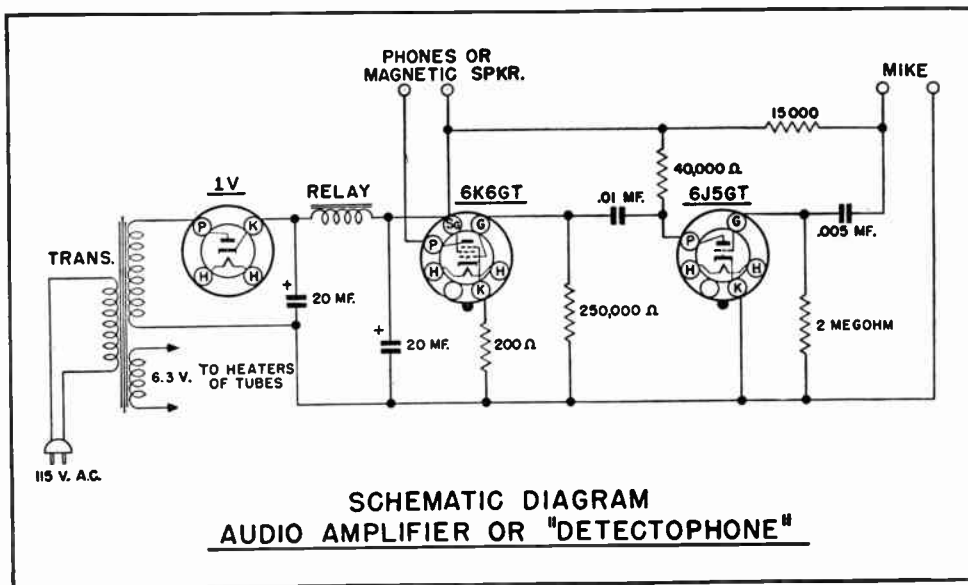
A grid leak detector is used. Both the variable condenser and the antenna coil which is used with it are of values to tune the broadcast band. The grid and cathode of the 6J5GT tube are connected as a diode rectifier which rectifies the AC radio-frequency current developed by the tuned circuit and produces a DC voltage across the two-megohm resistor. This voltage varies in value to correspond with the modulation of the carrier. The varying voltage which appears at the



grid of the tube controls the amount of current passing from cathode to plate and results in a varying uni-potential current in the 40,000-ohm plate circuit of the tube. The AC component of this voltage passes through the .01 mf. condenser to the input of the amplifier tubes.

The 200-ohm resistor in the cathode circuit of the 6K6GT tube develops the bias voltage for the amplifier tubes by means of the DC voltage drop in the resistor. The polarity of the voltage drop is "plus" at the cathode side of the resistor and "minus" on the other side. The "minus" voltage is impressed upon the grid of the amplifier tubes through the 250,000-ohm grid resistor and makes the grid negative with respect to the cathode, which is as it should be. The negative voltage depends upon the value of the cathode resistor and the amount of current passing through it. This method of biasing is used for most power amplifiers.

Beginner's Radio Laboratory Audio Amplifier



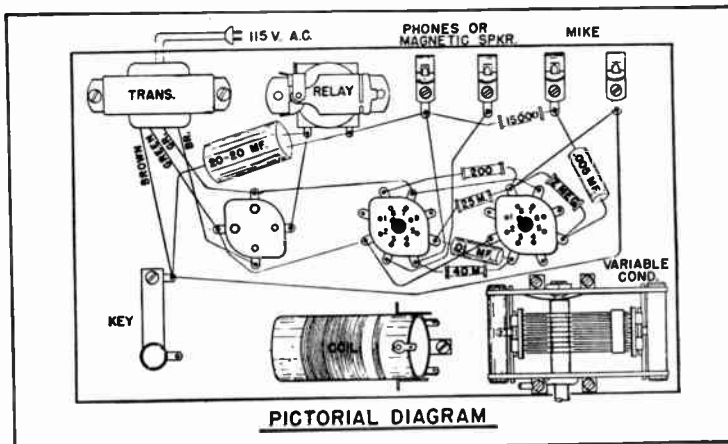
THIS amplifier may be used in a public address system or as a "detectophone" to cover conversations taking place in another room. When used as an amplifier, a magnetic speaker is required. As a "detectophone" the speaker should be replaced by headphones. A microphone, placed in the room in which the conversations are taking place, can be connected to the amplifier with 2-conductor wire such as ordinary lamp cord.

The coil and condensers, shown in the pictorial diagram, are not wired into the circuit. They are left in position for convenience in wiring other circuits. The 6J5GT serves as a mike amplifier. No grid biasing is used. The voltage to the plate of the 6J5GT tube is low enough so that saturation does not result even without bias. Note that the cathode resistor for the 6K6GT is not by-passed. This results in inverse feedback.

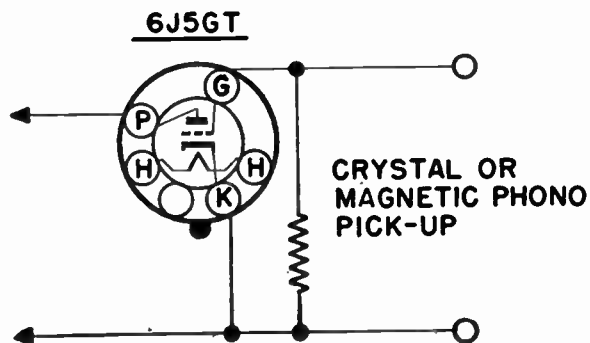
The microphone to be used with this circuit is a high resistance carbon "home broadcasting" type. It obtains operating current through the 15,000-ohm resistor. As the microphone is used, current going through it varies. The AC component of the varying current passes through the .005 mf. condenser into the amplifier and is amplified as described in preceding circuits.

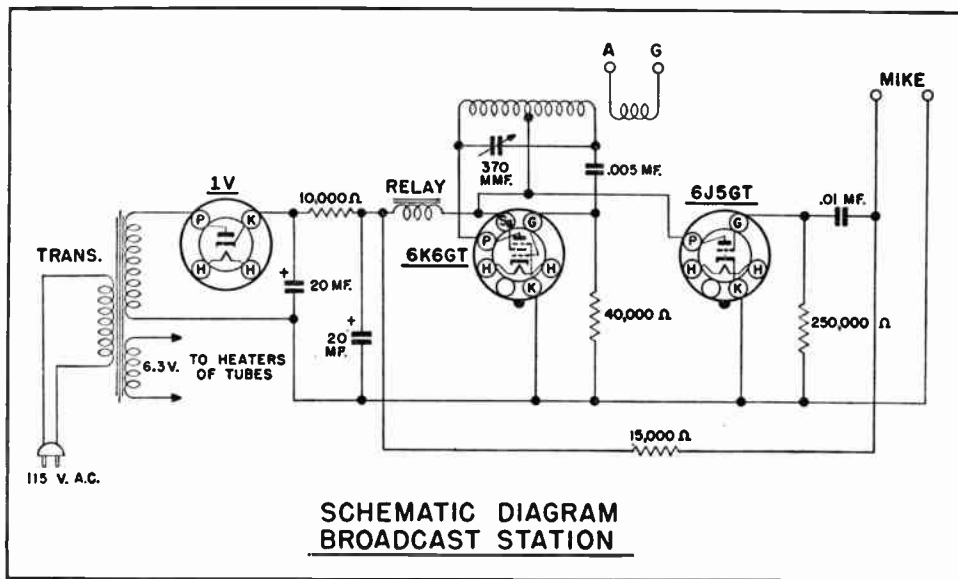
Record Player

The diagram at the right shows the changes necessary to convert the broadcast station into a wireless record player, and the amplifier into a standard record



player. The resistor shown is the one already connected to the grid of the 6J5GT. Any high-impedance type magnetic or crystal phono-pickup may be used. The 15,000-ohm resistor used for the microphone, in the amplifier circuit, should be omitted.





Beginner's Radio Laboratory Broadcast Station

Broadcast Station

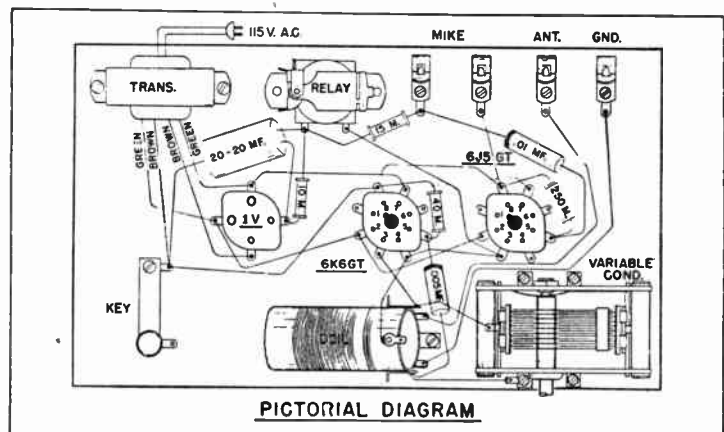
THIS circuit is a standard type and follows the principles of phone transmission described for the 2½ meter transceiver. In this case, however, transmission takes place on the broadcast band.

The 6K6GT tube is used in a Hartley oscillator. The relay acts as a modulation choke with the 6J5GT amplifier stage as the modulator. This method of modulation is known as "Heising" modulation.

A 10,000-ohm resistor replaces the relay for the filter circuit. This helps produce adequate filtering action and a sufficient plate voltage drop to keep the power of the radiated signal at a minimum and within the limits specified by law.

How The Microphone Operates

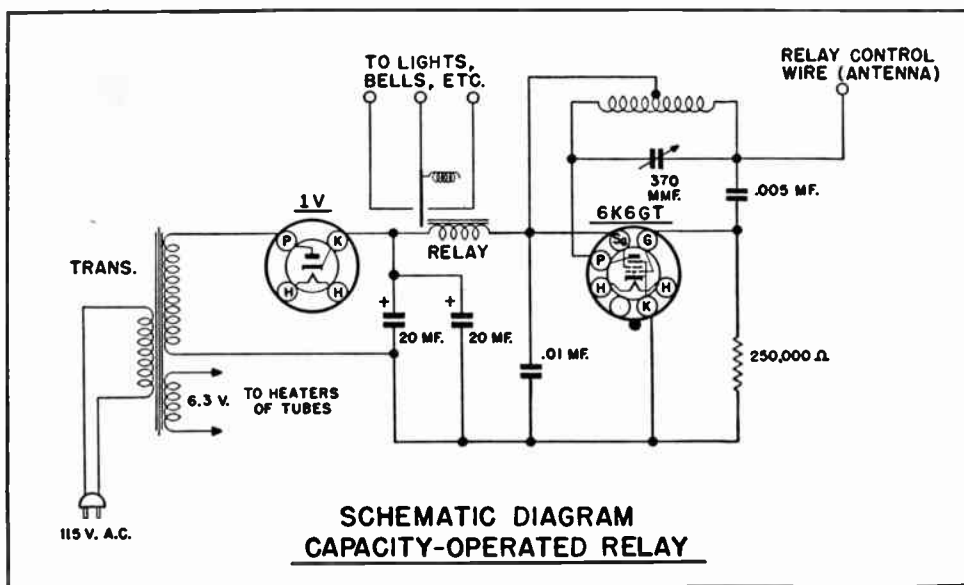
A microphone transformer is not required. The microphone intended for use with this circuit and the preceding one is the inexpensive high-resistance "home broadcasting" carbon type. Operation of the carbon mike is based on the fact that a mass of carbon granules offers resistance to current, depending on pressure applied to the carbon. Speaking into the mike causes the diaphragm to vibrate against the carbon, thereby varying pressure against it and producing corresponding changes in resistance. Microphone current is obtained from the power supply section through a 15,000-ohm current-limiting resistor. The resulting AC component



is passed through the .01 mf. condenser to the input circuit of the modulator tube.

It is important that only a very short antenna is used in order to prevent interference with reception in neighboring receivers. This transmitter is not a professional type. It is intended only for home entertainment and party stunts where some members of the group, located in one room, put on a "radio program" to be picked up on a receiver located in another room in the same house.

The input of the modulator stage may be converted for record-playing purposes. Instructions, and a diagram showing the simple connections necessary for conversion, appear on the preceding page. The resultant instrument is an excellent wireless record player.



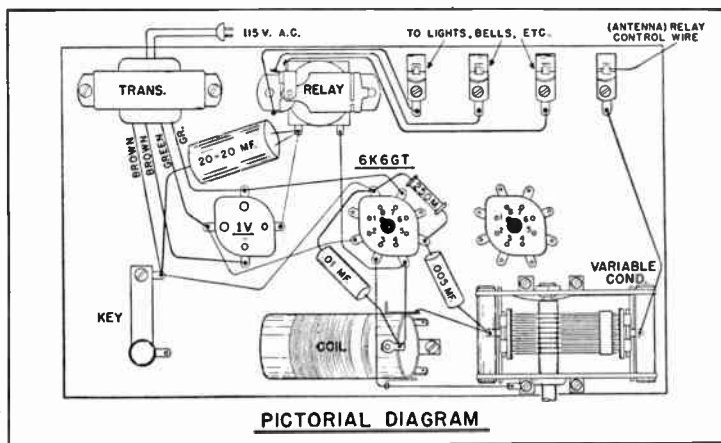
Beginner's Radio Laboratory Capacity- Operated Relay

Capacity-Operated Relay

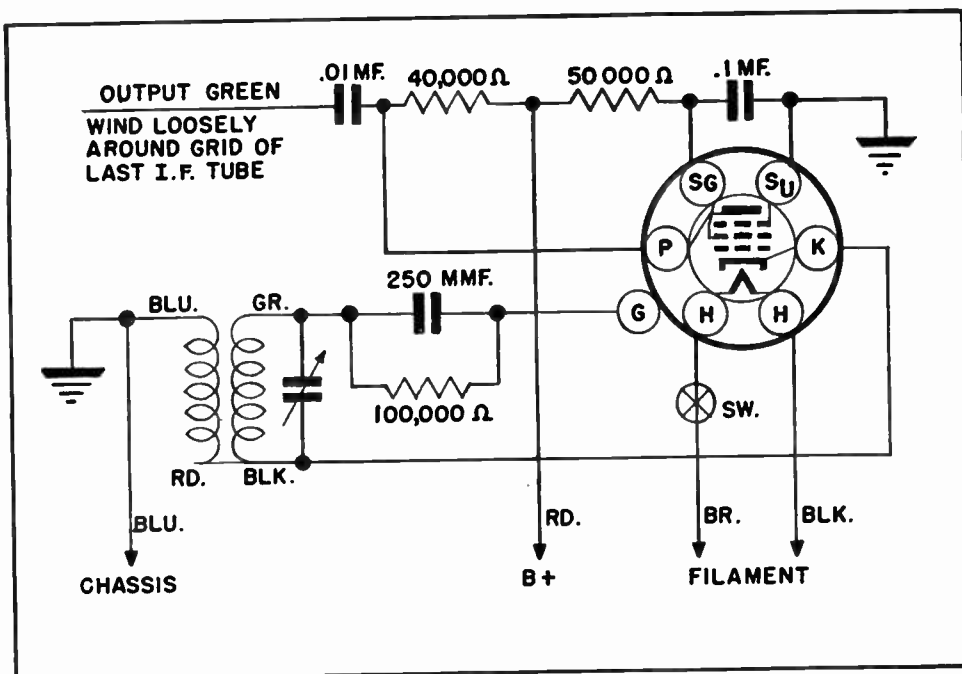
THE Capacity-Operated Relay is an oscillator and relay system which operates by means of an increase in capacity introduced into the circuit by approximation or contact with a human body. Operation is simple. A 6K6GT tube is wired as an oscillator. In oscillating condition, the grid voltage developed across the 250,000-ohm resistor is quite high, and consequently plate current will be too low to actuate the relay and close its contacts. As explained earlier in this book (see description of regenerative receivers), an antenna connected to an oscillating circuit will absorb energy. The wire connected to one side of the coil in the capacity-operated relay circuit serves as an antenna. If this wire is sufficiently short, and in this case it is, it will not absorb enough energy to materially affect the circuit constants, and so the relay will remain open. When a person touches the wire, his body serves as an additional antenna and absorbs enough energy to reduce the bias voltage on the tube. This results in a large enough increase in plate current to operate the relay. The relay may be used to ring bells, turn on lights, or operate any number of devices.

Applications

The system has a number of interesting applications. It serves as a dependable burglar-alarm when wired to a doorknob, or to a wire which has been fastened around the edges of a window casing. When someone touches



the doorknob or window casing, sufficient change in capacity results to provide operation. An application which is becoming increasingly popular is in connection with displays in store windows. A person attracted by a window display walks toward it. When he gets close enough, the capacity of his body helps to actuate the relay which automatically turns on a flood-light, or a record player presenting a sales message. In this application a large metal plate, connected to the relay by wires, is usually placed in an inconspicuous position close to the front of the window. Body capacity affects the metal plate, and performance follows the pattern already outlined. If the device to be controlled requires more than 5 amperes, an auxiliary power relay must be connected to the terminals of the relay in this circuit.



Beat Frequency Oscillator

A BEAT frequency oscillator, coupled to the I.F. channel of a receiver, makes possible the audible reception of code (CW) from any receiver which is capable of picking up short-wave signals. In this circuit a standard B.F.O. coil is used as a cathode-tapped oscillator. The two sections of the coil are connected and may be considered a single continuous winding. The cathode tap is taken from the point where the two sections meet.

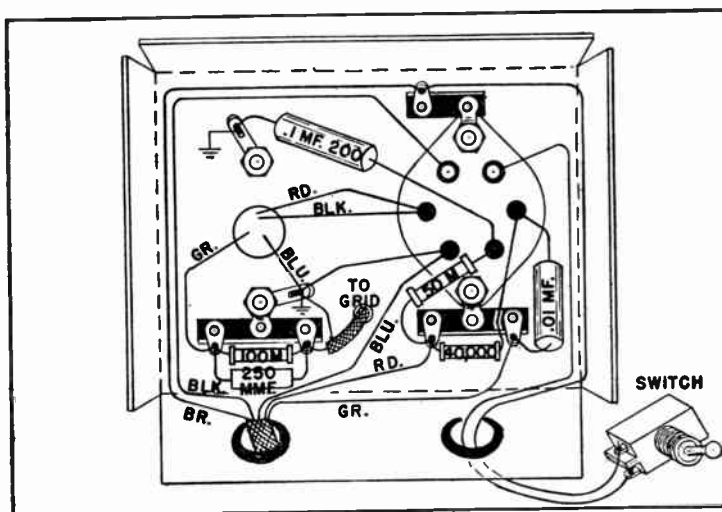
The intermediate frequency of most superheterodyne receivers is either 455 or 465 KC. A 455-KC B.F.O. transformer may be adjusted, by means of a trimmer, to vary from 450 to 525 KC. For receivers of other intermediate frequencies an appropriate coil must be selected.

The tube used may be any one of the screen grid RF amplifier types which will operate from the filament voltage supplied by the receiver.

The plate voltages are obtained from the screen grid of the power tube in the receiver.

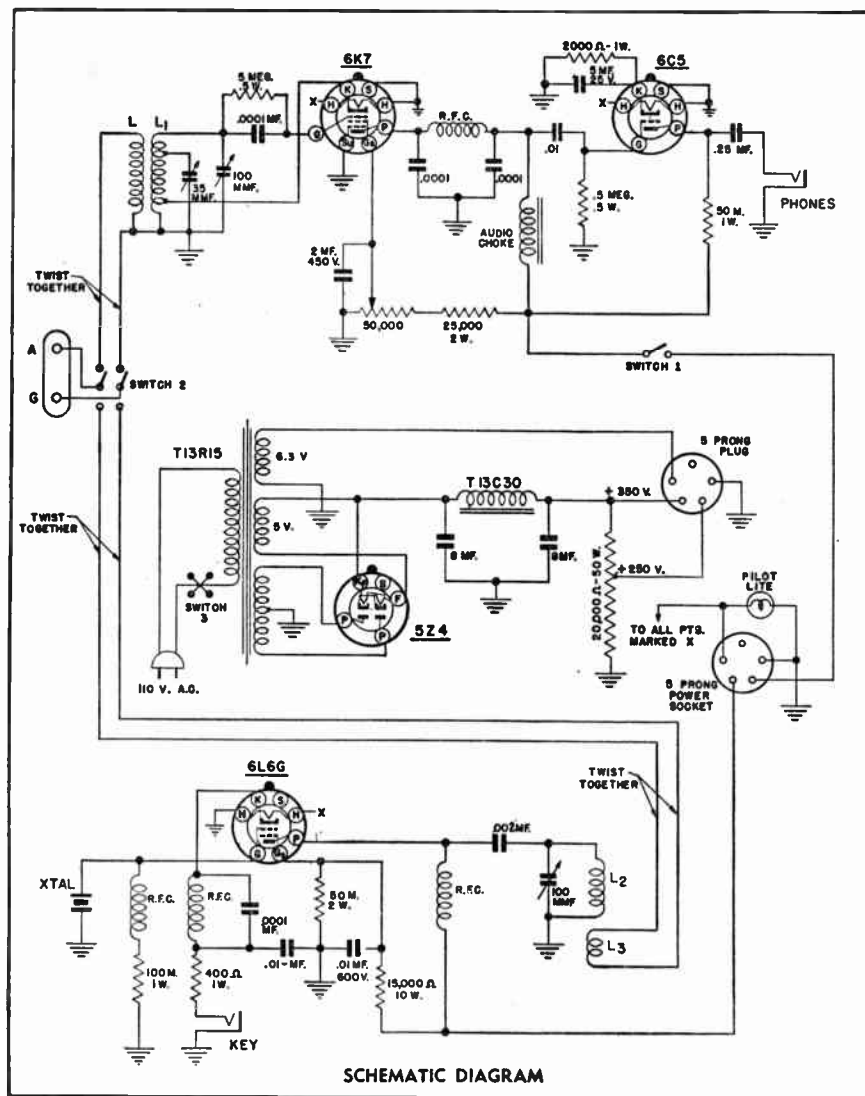
The oscillator is an electron-coupled type (see basic circuit 2). The output of the oscillator is taken from the plate of the tube through a .01 mfd. condenser which passes the radio frequency voltage but does not pass the DC in the plate circuit.

Coupling to the receiver is made by winding an



insulated wire from the plate of the oscillator around the grid lead of an IF tube. Coupling must be loose and should be adjusted when a weak signal is received. If coupling is too tight, oscillation produced by the B.F.O. will block weak signals.

In operation the B.F.O. oscillator condenser is adjusted close to the IF frequency of the receiver. The frequency of the audio tone produced will be equal to the difference between the signal in the IF channel and the frequency of the B.F.O.

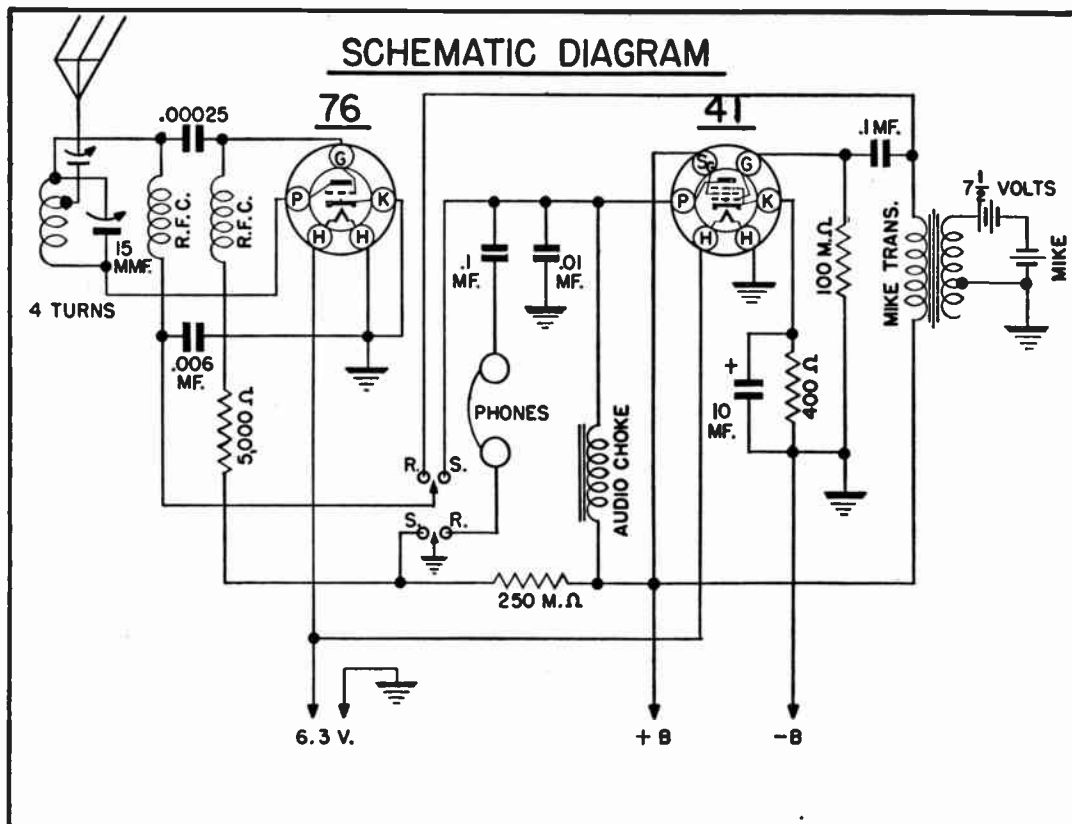


Knight Junior Amateur Radio Station

This Station consists of an autodyne regenerative receiver and a 25-watt crystal-controlled CW transmitter, both operating from a single power supply.

In the receiver, the cathode lead of the detector is tapped part way up the secondary of the antenna coil and a 100-mmf. tuning condenser is used. In addition, a 35-mmf. "vernier" condenser is connected between the bottom of the coil and a point somewhat below the top of the coil. The closer to ground the top connection to the coil is made, the finer will be the vernier action of the condenser. The audio amplifier is built around the type 6C5 triode amplifier tube.

Since amateurs are particularly interested in reception on the amateur band, the receiver circuit was designed for amateur band coverage only. The coils, therefore, should be hand-wound to cover only the amateur frequencies. The primary (L) of the coil for the 80-meter band should have ten turns of No. 24 D.S.C. wire, close wound. The secondary winding (L₁) should be one-eighth inch above the primary and should have a total of twenty-seven turns of wire with the cathode tapped one and one-quarter turns up from the ground side. The tap for the bandspread condenser should be from two to ten turns from the top of the winding.



Knight 2½ Meter Transceiver

“**T**RANSCEIVER” indicates that the instrument is built as a single unit to alternately perform the functions of reception and transmission. This circuit diagram covers a 2½ meter amateur transceiver for use in the range between 112 and 116 megacycles.

Selection of Tubes

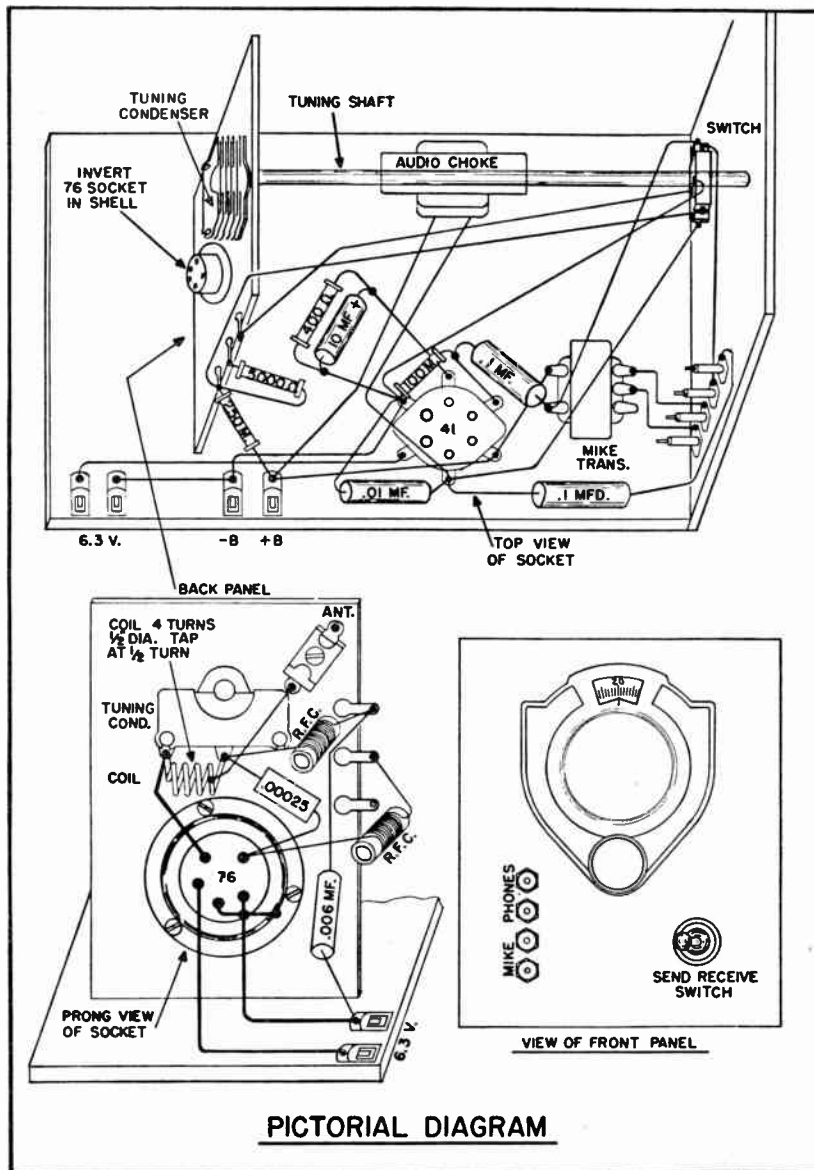
Any triode with low interelectrode capacities, such as the 76, may be used in this circuit as an oscillator or super-regenerative detector. The type 41 tube serves as the modulator or audio amplifier. When used as a modulator, its grid circuit is excited by a simple single-button microphone, connected to an appropriate mike transformer in series with a 7½ volt battery.

The position of the switch determines whether the tubes are to be used for receiving or transmitting. When the switch is in the “R” (receive) position, the output of the 76 tube as a detector is connected to the grid of the 41 tube. The audio frequencies are amplified and impressed upon the headphones which are in the plate circuit of the 41 tube. One lead from the phones

is switched to the ground to complete the circuit.

When the switch is in the “S” (send) position, the plate circuit of the 76 tube is connected in parallel with the plate circuit of the 41 tube. The junction of the 5,000 and 250,000-ohm grid leak resistors is grounded. Only the 5,000-ohm resistor, then, is effective as a grid leak. This results in lower grid bias, higher plate current and stronger oscillations for transmission.

The values of the component parts used in connection with the detector, especially the value of the grid leak, causes the detector tube to oscillate at a super-regenerative frequency in the receive position. Actually the tube oscillates at two frequencies, one at the RF frequency in the 2½ meter band to which the coil is tuned, the other at a frequency above the audio spectrum, depending upon the value the grid-leak used. Super regeneration is also the result of the fact that the grid leak return is to +B rather than ground, which would be the conventional practice. A super-regenerative detector is extremely sensitive—much more so than an ordinary type regenerative detector. It is not



Knight 2½ Meter Transceiver

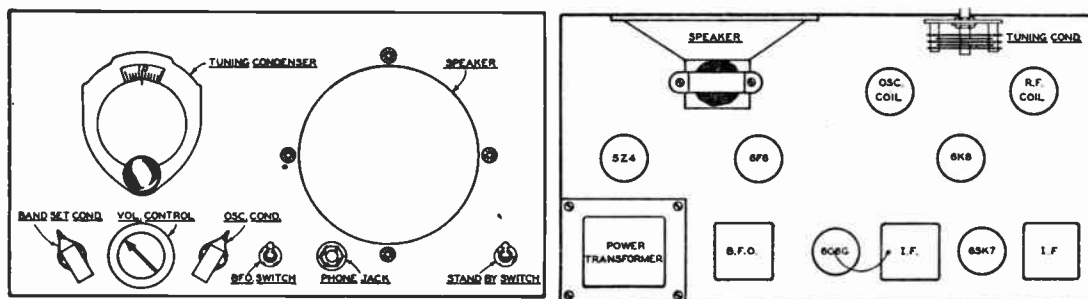
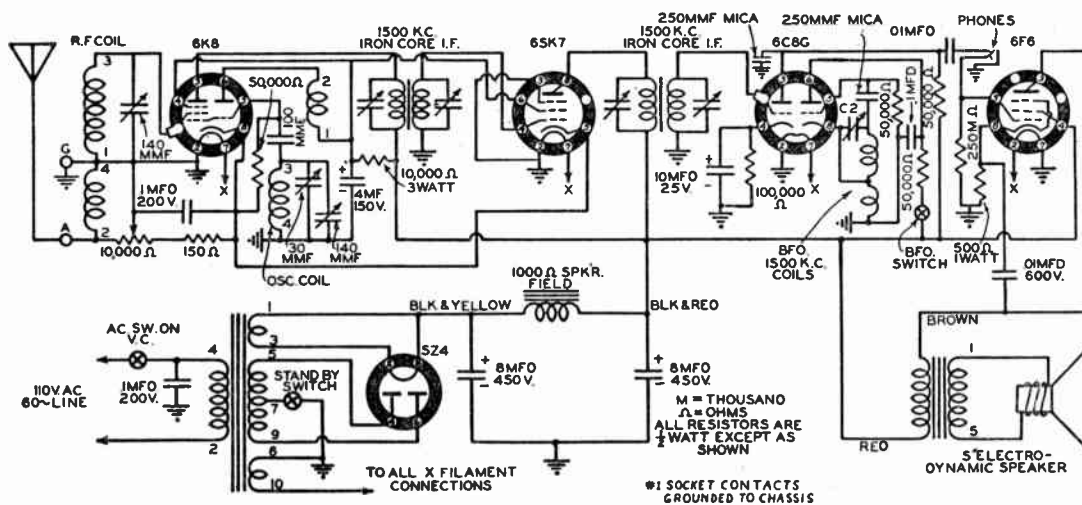
used on other bands because it tunes too broadly and would pick up transmissions from several stations at once. It is ideal, however, for reception of signals from other transceivers because the transmitted signal, in the high-frequency area used, is normally broad. Super-regenerative receivers are so sensitive that electron noise in the tube can be heard as a hiss in the headphones. The hissing is apparent, however, only between stations. It disappears when a signal is picked up.

The coil used consists of four turns of No. 14 wire, wound on a half-inch form.

The antenna connection is for a "buggy whip" antenna, an ideal type for mobile work. A higher

antenna, connected to the transceiver by means of feeders, as in the case of the Junior Amateur Transmitter and FM Receiver previously described, may be constructed like any other resonant di-pole antenna except that the overall length for 2½ meter work should be about four feet. The feeders should terminate in a loop of about one or two turns of wire, coupled to the coil. The distance between the coil and loop should be varied until best operation is obtained.

Any power supply having an output of 6.3 volts AC and 250 to 300 volts DC at 75 MA may be used. Batteries can also be used with good results, but battery life will be rather short.



“Communications 5” Superhet

SIMPLICITY of circuit and economy in the use of parts were the main considerations in the design of this five-tube “Ham” receiver. Essentials for good operation were, of course, carefully maintained.

The circuit is superior to those used in the Junior Amateur Radio Station and in the 2½ meter Transceiver. It is more selective, a highly desirable feature in the crowded Amateur band, and has the sensitivity necessary for DX reception. Basically a conventional superhet, it varies somewhat from common types.

The ordinary communications-type superhet requires a minimum of seven tubes. By using two dual-purpose tubes, only five are necessary in this circuit.

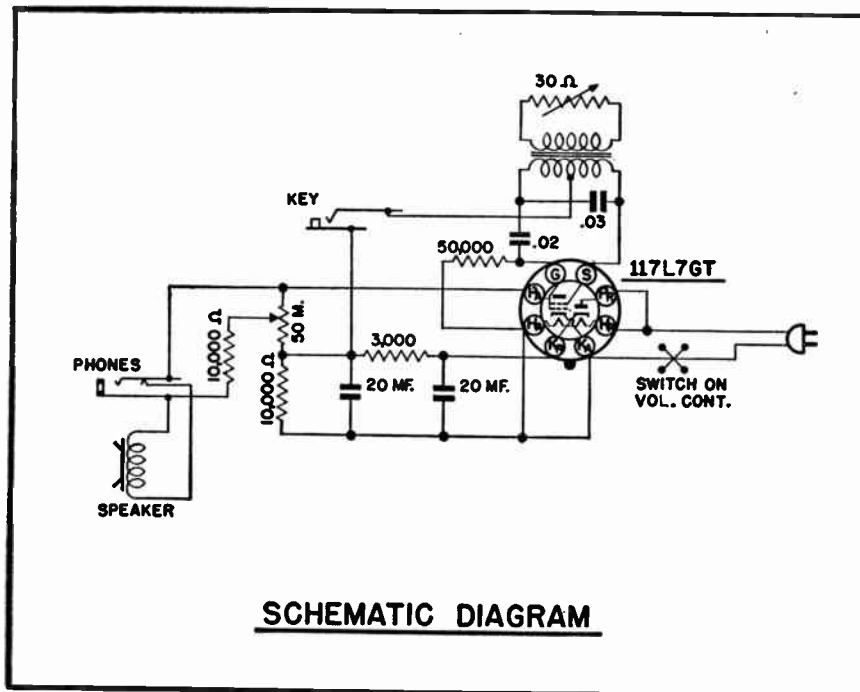
The High Frequency Converter

A 6K8 tube acts as a combination first detector (also known as a converter) and high-frequency oscillator. Actually, the 6K8 is two tubes built into one envelope, a converter and a separate oscillator, and should not be

confused with the usual multi-grid converter. Use of the 6K8 results in excellent stability and less pulling effect by the RF portion against the oscillator on the higher frequencies. The coils in the antenna and oscillator section are of the plug-in type and are easily changed when switching bands. Each coil is connected to a 140-mmf. midget variable condenser for accurate “band-setting.” The condensers are tuned until the amateur band at which operation is desired, is found. Actual tuning of the signal is accomplished by means of a 30 mmf. variable condenser connected in parallel with the oscillator band-setting condenser. On the wider amateur bands a slight readjustment of the band-setting condensers will be necessary for tuning various parts of the bands.

The Intermediate Frequency Stage

The output of the converter stage is to a 1500 KC iron-core IF transformer. The use of 1500 KC for an

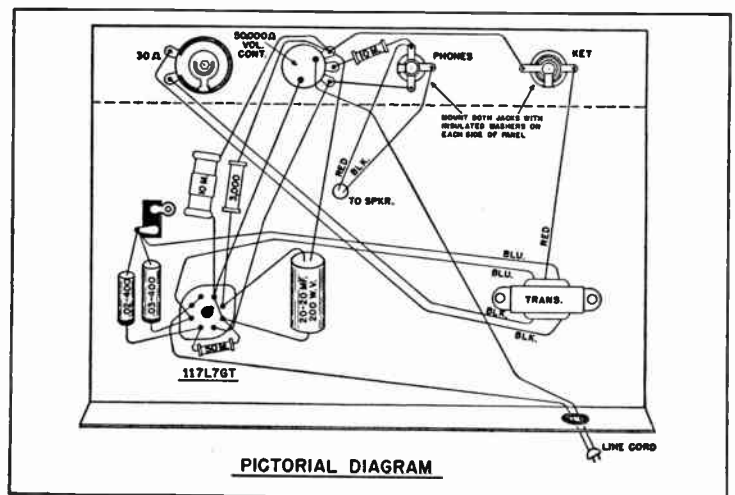


Code
Practice
Oscillator

THIS code practice oscillator is one of the most recent in design and incorporates many excellent features. The use of a 117L7GT tube permits direct operation, without dropping resistors in the filament circuit, from an AC or DC line which has an output ranging anywhere from 105 to 125 volts. The tube is a dual-purpose type with a beam tetrode amplifier and diode rectifier in one envelope.

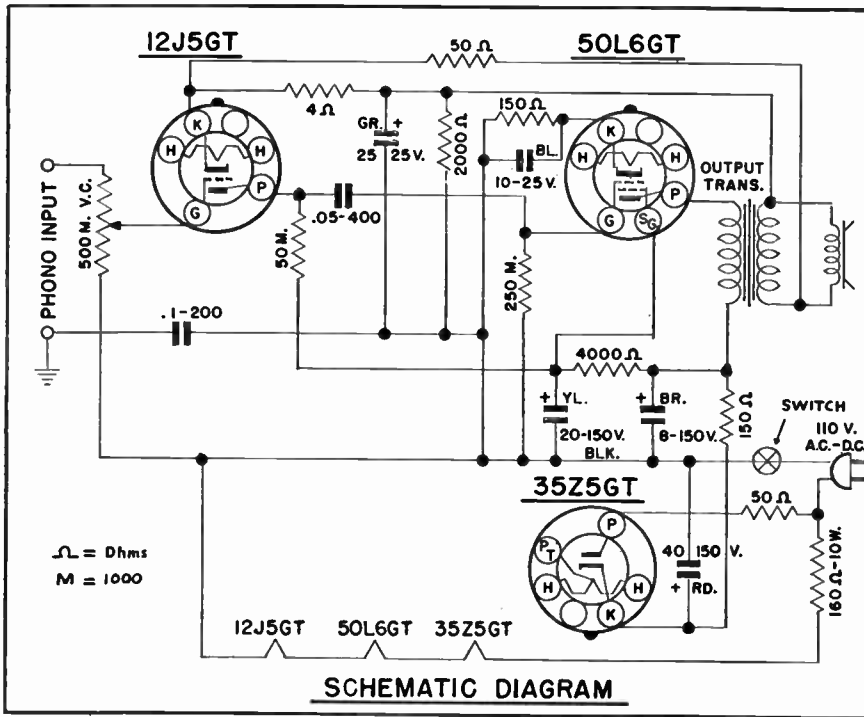
The amplifier portion of the tube is made to oscillate at audio frequencies. A center-tapped output transformer is connected as a Hartley oscillator. The inductance of the transformer and capacity of the parallel .03 mf. condenser are selected so that oscillation results in the audio frequency band. Frequency is varied by the 30-ohm rheostat connected to the secondary of the transformer. This has the effect of varying the inductance of the transformer itself. The .02 mf. condenser is used only to keep the DC on the transformer from reaching the grid of the tube. The 50,000-ohm fixed resistor is the grid leak.

The output of the diode circuit is filtered by means of a dual-section 20-20 mf. electrolytic condenser and a 3,000-ohm resistor. When the headphone plug is inserted, the speaker is automatically disconnected. Keying is accomplished by breaking the DC voltage to



the oscillating circuit. Keying quality is very good.

This unit will handle up to twenty pairs of ordinary phones. A plate impedance match of approximately 10,000 ohms should be maintained for maximum output. To maintain this impedance match, headphones may be connected in either series, parallel, or series-parallel, depending on their resistances. Impedance matching is important only when a great many headphones are used. When only a few are used, sufficient volume is available without impedance matching.

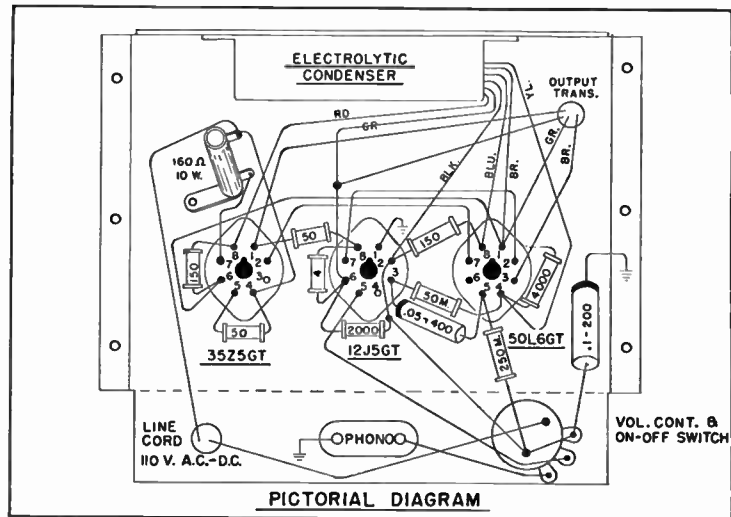


3 Tube Phono Amplifier

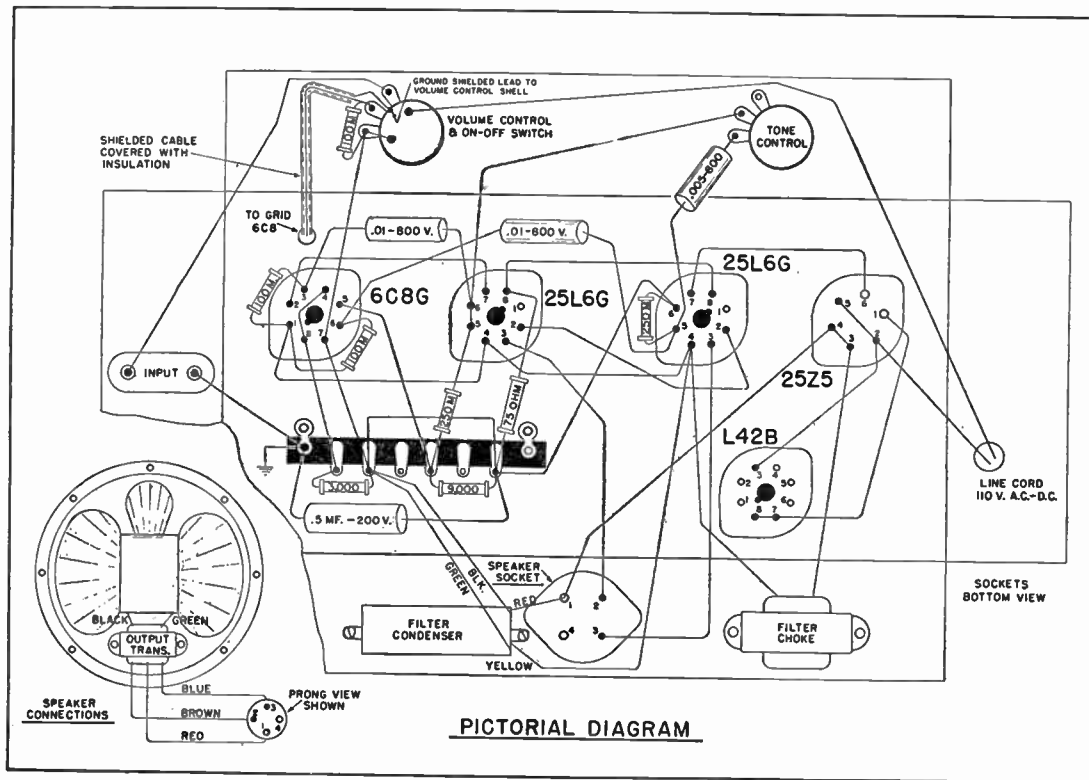
THIS AC-DC phono amplifier has sufficient amplification to operate dependably with even the lightweight crystal pickups which have very low output. Inverse feedback is incorporated to extend frequency response and reduce distortion and hum. The filaments of the three tubes are connected in series and include a 160-ohm resistor in the series circuit so that the net current passing through all of the tubes is .15 amperes. The 12J5GT tube operates as a voltage amplifier feeding the input of the 50L6GT beam-power amplifier. The output of the power tube is connected to the primary of an output transformer which is required to match the speaker and plate circuit of the power tube.

Bias for the 12J5GT is obtained from the 2,000-ohm cathode resistor. The output of the speaker transformer is connected across the 4-ohm resistor, but has a 50-ohm resistor in series with the connecting leads to reduce the amount of energy fed back into the cathode circuit. Care must be taken to determine, by experiment, the correct polarity of the leads connected to the output of the speaker transformer. The wrong polarity would result in regeneration.

Filtering is accomplished by a double filter section.



Most of the hum is eliminated by the 40 mfd. electrolytic condenser between the cathode and common negative of the rectifier. Further filtering for the plate of the power stage is obtained by use of the 150-ohm resistor and the 8-mfd. condenser. The 4,000-ohm resistor and 20-mfd. condenser reduce hum still further for the screen of the power stage and plate of the voltage amplifier stage.



Four Watt AC-DC Amplifier

tion between the two grid resistors of the 25L6G tube. Amplification takes place in the plate circuit of the 6C8G tube, and the signal is impressed upon the grid of the second 25L6G tube but is out of phase, though equal in voltage, with the signal at the grid of the first 25L6G. This is "phase inversion."

Push-Pull Power Output

The two 25L6G tubes are now operating as a beam power push-pull stage. Their output is connected to the primary of a center-tapped speaker-matching transformer. Proper impedance matching in the output transformer (matching the impedance of the speaker to the required impedance of the tubes in push-pull) is necessary if the full power output of the power stage is to be secured. Amplifying tubes, like any other voltage-generating equipment, must operate into an optimum load impedance in order to provide greatest possible power. In the case of 25L6G tubes in push-pull, the optimum load resistance to be matched is about 4,000 ohms from plate to plate of the two tubes.

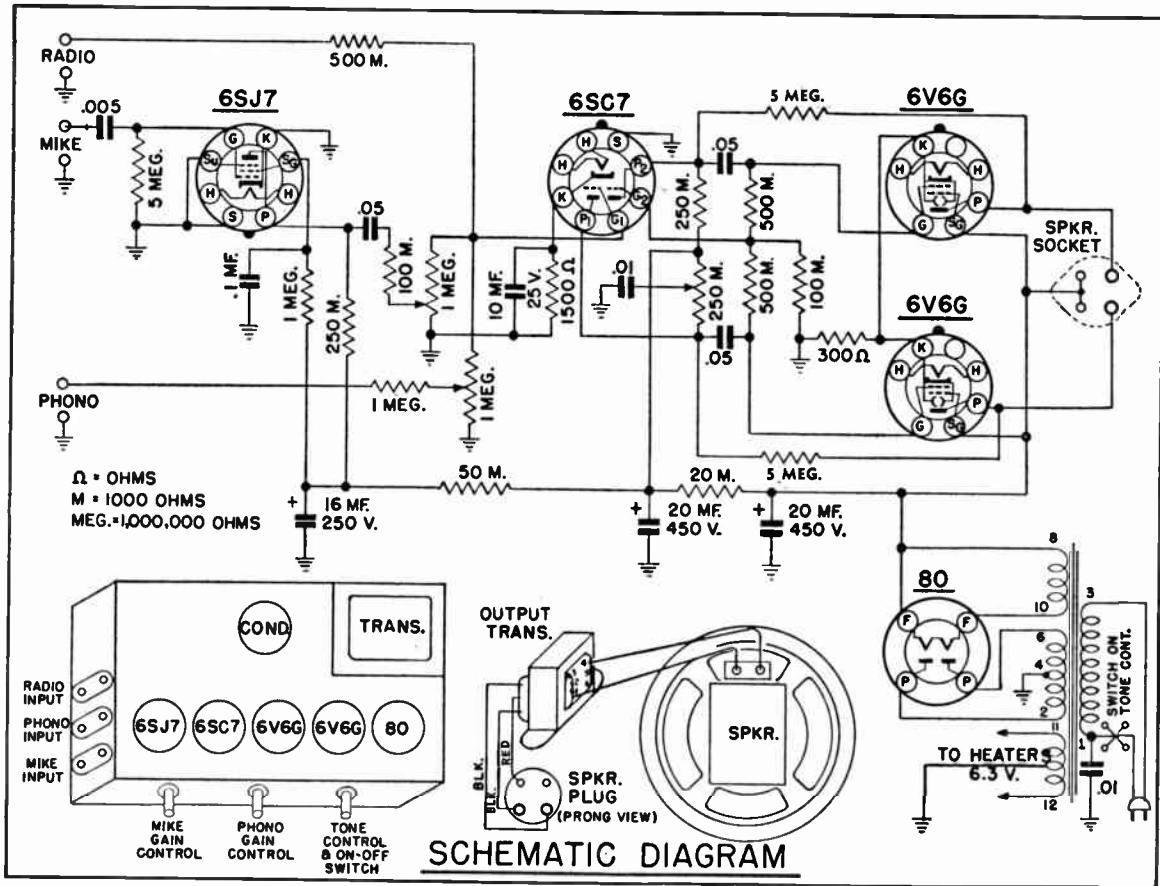
The output transformer must be a step-down type

so that when an eight-ohm speaker is connected to its secondary, the resulting impedance reflected to the tube will amount to about 4,000 ohms as the result of the ratio between the two windings of the transformer. Impedance ratio varies as the square of the turns ratio in output transformers. Universal output transformers are provided with taps on the secondary, and the manufacturers' instructions, included with the transformer, provide full specifications, i.e., output at the taps, etc.

The Power Supply

The 25Z5 rectifier has two diode sections. These are connected in parallel so that the tube may stand up under the high current consumed by the two 25L6G tubes. Two electrolytic condensers, 25 mf. and 10 mf., respectively, together with a filter choke, filter out the hum in the plate supply circuit.

Tone is controlled by the attenuator-type tone control, between the two grids of the 25L6G tube. As the resistance of this 500,000-ohm potentiometer is reduced, more of the higher frequencies are short-circuited by the .005 mf. condenser.



Fourteen Watt Amplifier

THE many features incorporated in this circuit are found in some of the finest of commercial amplifiers. Complicated novelty circuits are avoided so that the action of the average high-gain amplifier may be better understood.

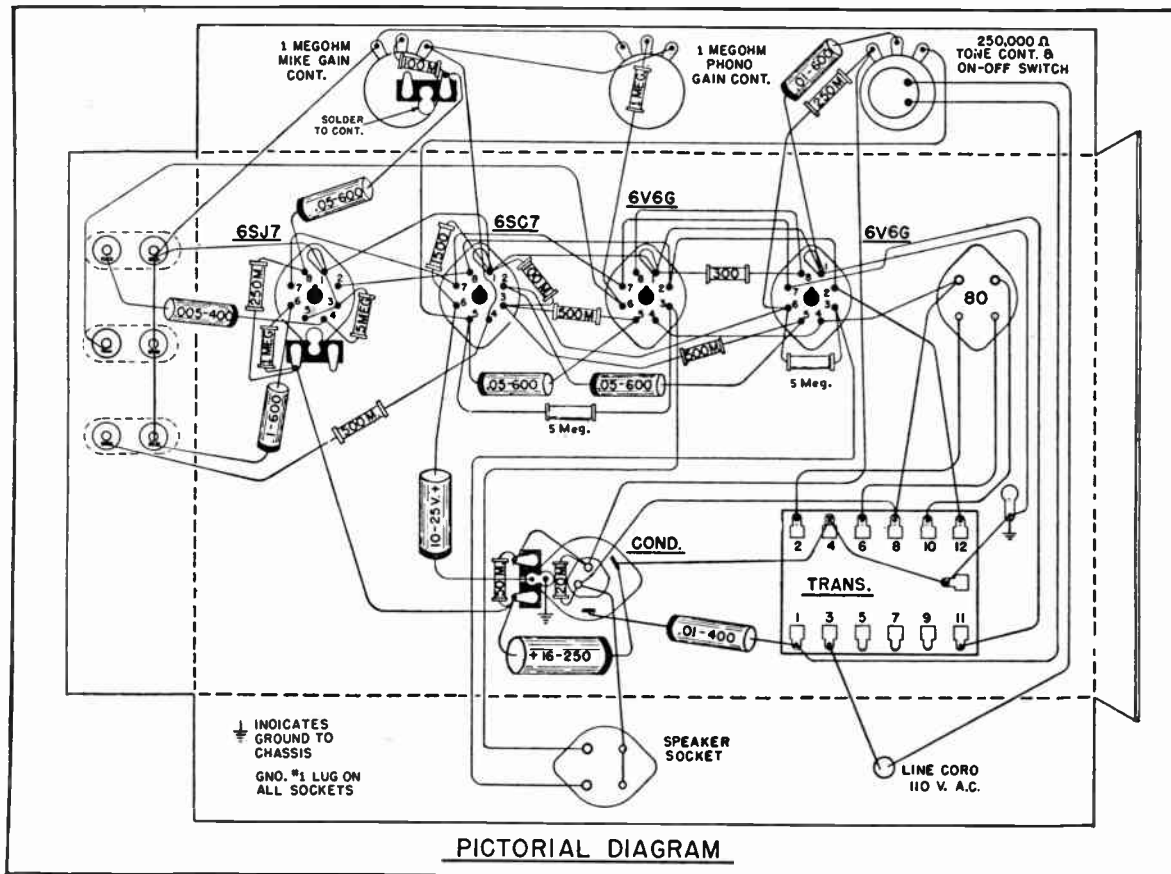
The amplifier will operate from 105 to 125 volts, 50 to 60 cycles AC. It has sufficient amplification for use with a crystal or other high-impedance microphone and will deliver up to fourteen watts of audio power, with low distortion, to a speaker or system of speakers. Features include the use of three inputs which may be operated simultaneously or separately; contact potential biasing of the first audio tube; phase inversion; inverse feedback; and push-pull beam power output.

The Input Stage

The output of the microphone is fed into the input of the 6SJ7 pentode tube, connected as a high-gain audio amplifier. The output of this tube is fed into a volume control, connected backward. The reason for this will

be explained shortly. The cathode of the 6SJ7 is grounded directly. Biasing is attained by inserting a 5-megohm resistor in the grid circuit. The .005-mf. condenser is used to isolate the DC bias voltage from the input circuit. The output of the voltage amplifier is fed to the following stage through the .05-mf. condenser. The values of the screen and plate resistors of the 6SJ7 tube are typical for pentode tubes operated as high-gain voltage amplifiers.

The microphone input, phono input and radio input are all connected to the phase inverter grid (see diagram above) just after the first amplifier tube. No volume control is required for the radio input since volume is usually controlled at the radio. The phono input passes through a 1-megohm resistor and to the center arm of a 1-megohm potentiometer. The 1-megohm resistor prevents short-circuiting of phono input, and any detrimental effect on frequency response when volume control is near zero. It is now apparent why the



Fourteen Watt Amplifier

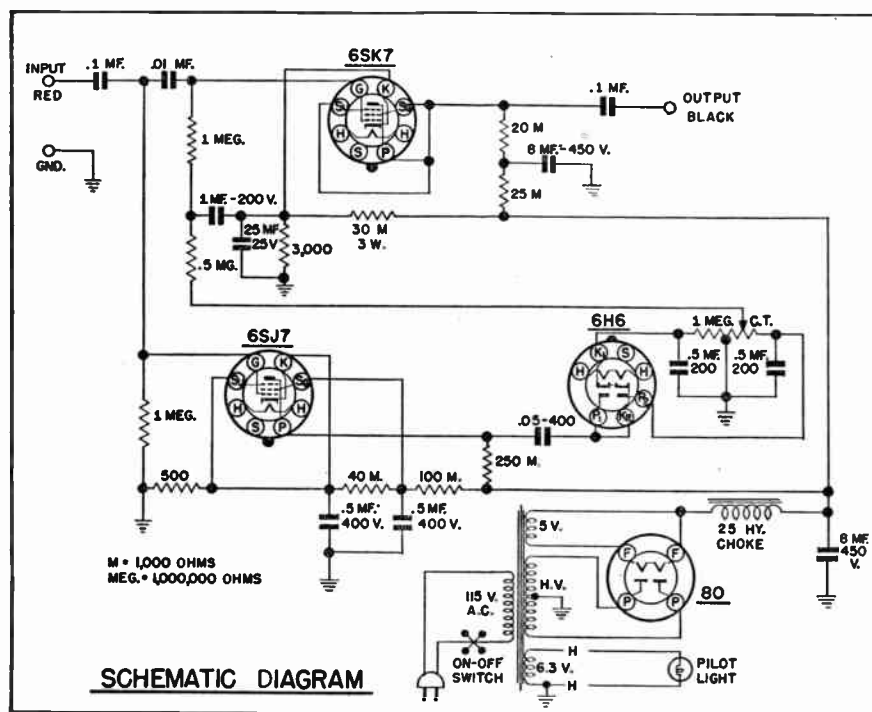
microphone stage volume control is connected backward. If connected in the conventional manner, the grid input of the phase inverter stage would be short-circuited at zero volume setting, and the phono and radio input signals would not reach the inverter.

Balanced Phase Inversion

The 6SC7 tube circuit is a balanced phase inverter. Its action is similar to that in the four-watt AC-DC amplifier except that the connection for the grid of the second triode in the 6SC7 is made at the mid-point of two 500,000-ohm resistors in series which are connected to the grids of the output push-pull stage. This mid-point is also connected to ground through a 100,000-ohm resistor which will carry voltages of both phases of the push-pull stage. The voltage appearing in the resistor as the result of the upper half of the push-pull stage is out of phase to that in the lower half and is, therefore, degenerative in its effect on the second half of the phase inverter section and so reduces gain.

Inverse feedback is accomplished by the use of two 5-megohm resistors. Each resistor is connected from the plate of the output tube to the plate of the triode section in the phase inverter which feeds that tube. Since the plates of the output and inverter tubes are out of phase with each other, there is a small amount of out-of-phase voltage fed back from the output to the input of the power stage.

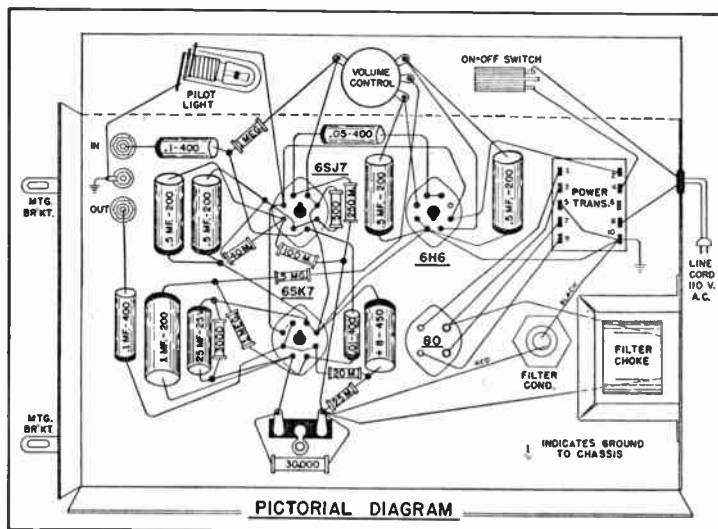
Bias for the phase inverter and output stages is obtained by means of cathode resistors. Cathode resistors in push-pull stages need not be by-passed with a condenser. A choke is not required in the filter section. Properly balanced push-pull stages cancel any hum that may appear in the plate circuits. Any small amount of unbalance is taken care of by the 20-mf. filter condenser. Those parts of the circuit which draw very little current are adequately filtered by the 20,000-ohm resistor with its 20-mf. filter condenser, and 50,000-ohm resistor with its 16-mf. filter condenser.



Volume Expander-Compressor

VOLUME range of a program being fed into a transmitter is compressed in order to maintain balance between strong and weak passages. An expander in a receiver restores the program to its original range. In a public-address amplifier, where strength of signal-input may vary because the speaker moves about before a microphone or shifts his head as he speaks, the use of a compressor-restores balance and produces constant output.

This unit provides expansion or compression by means of a single control. The principle of operation is similar to AVC in a superhet. The tube used is the 6SK7, a type commonly used in the RF and IF stages of receivers. In the latter applications a DC voltage is developed in the diode load circuit of the detector and, added to the fixed bias of the IF and RF tubes, it results in a decrease in amplification. In this circuit, however, an audio voltage is fed to the grids of both the 6SK7 and 6SJ7 tubes. The 6SJ7 tube amplifies this voltage and passes it on to the 6H6 where it is rectified. A rectified DC voltage in the one-megohm center-tapped potentiometer will vary according to the audio voltage reaching the grid of the 6SJ7. The center tap of the potentiometer is grounded. The two ends of the potentiometer are of opposite polarity. The left end of



the control will have a positive potential, and the right end will have a negative potential. With the control arm to the left of the potentiometer, positive voltage, which varies with the audio voltage input, is added to the fixed bias on the 6SK7, thereby increasing its amplification and resulting in volume-expansion. With the control arm to the right of the potentiometer, a negative voltage is added, the amplification is decreased, and volume is compressed.

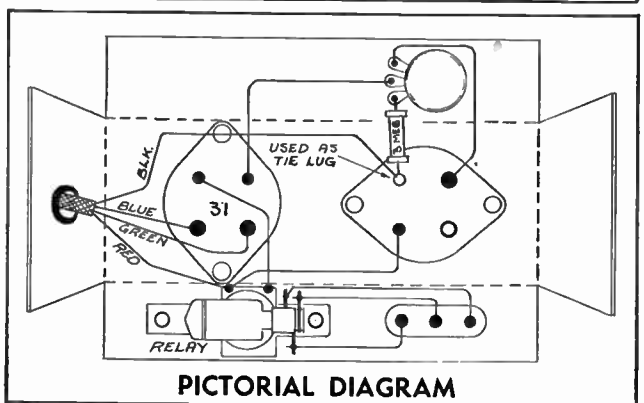
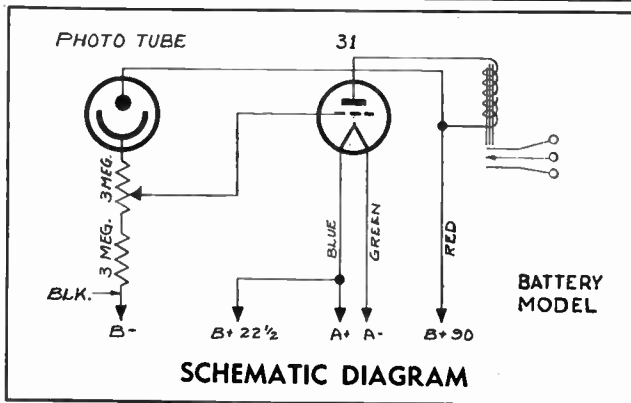
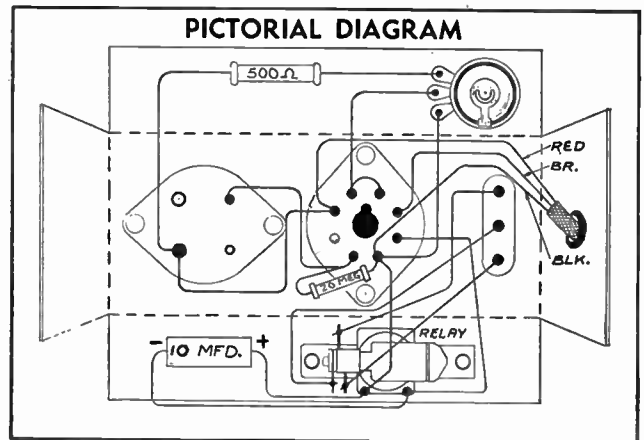
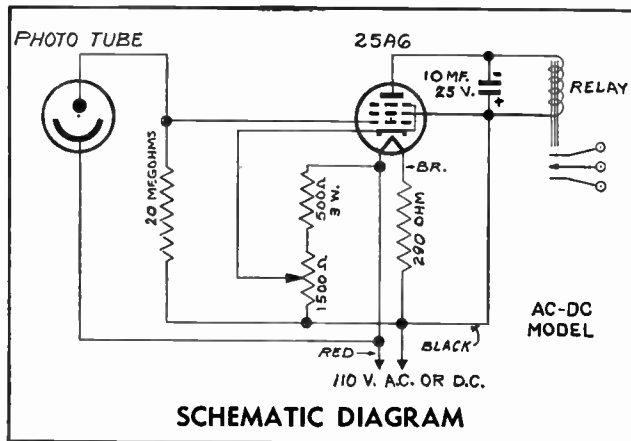


Photo-Electric Cell Circuits

THE photo-electric tube is becoming increasingly important in industry as a medium for protection and for precision control. Some of its common uses are in the burglar alarm and the anti-sabotage system, for smoke control, counting of all types, color and size matching, punch press safety control, and television.

The two circuits are basically alike, but one is for operation from batteries, the other from a 110-volt AC or DC line voltage.


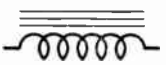








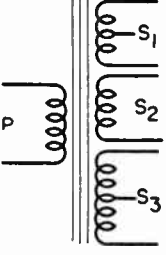










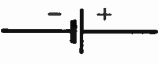



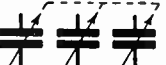








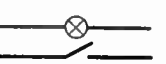
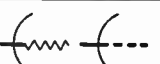


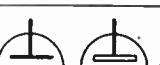

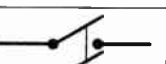
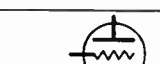
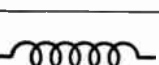
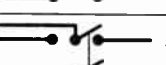
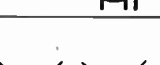
The triode or pentode tube is operated with a grid bias at nearly the cut-off point. That is, the negative potential on the grid is such that very little, if any, plate current flows in the plate circuit. With no excitation for the relay, the armature remains open. When the amount of negative bias on the grid of the tube is reduced, plate current begins to flow. Below a certain negative potential, depending upon the tube used, sufficient current will pass through the plate circuit to close the relay and actuate a control or alarm.

The reduction in grid voltage is secured by applying

a small amount of positive voltage to the grid of the tube through the photo cell. Note that the photo cell is connected between the grid and a point of the circuit having a higher DC positive potential in relation to the grid. Photo cells operate on the basis that with a greater amount of light falling on the caesium-coated cathode, a greater amount of current is permitted to pass through the cell. Therefore, as light on the photo cell is increased, a positive voltage flows to the grid of the tube. This bucks the negative voltage already there and results in a reduction of the negative voltage, thereby increasing the plate current.

In the AC-DC circuit a filter is unnecessary. To eliminate hum from the relay, a 10-mfd. electrolytic condenser is connected across it. The relay used has a single-pole double-throw contact arrangement which makes it possible to connect external circuits so that action may be either stopped or started on the interruption or application of a beam of light, depending upon the contacts selected.

SCHEMATIC SYMBOLS USED IN RADIO

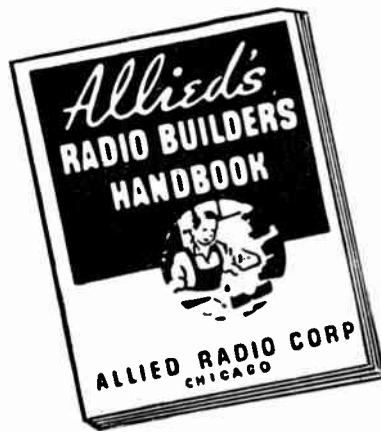
 ANTENNA (AERIAL)	 IRON-CORE CHOKE COIL	 SWITCH (ROTARY OR SELECTOR)
 GROUND (OR CHASSIS CONNECTION)	 R.F. TRANSFORMER (AIR CORE)	 CRYSTAL DETECTOR
 LOOP AERIAL (USUALLY BUILT INTO CABINET OF RECEIVER)	 A.F. TRANSFORMER (IRON CORE)	 LIGHTNING ARRESTER
 CONNECTION	 <p>POWER TRANSFORMER P: 115-VOLT PRIMARY S₁: CENTER-TAPPED SECONDARY FOR FILAMENTS OF SIGNAL CIRCUIT TUBES S₂: SECONDARY WINDING FOR RECTIFIER TUBE FILAMENT S₃: CENTER-TAPPED HIGH-VOLTAGE SECONDARY WINDING</p>	 FUSE
 NO CONNECTION		 PILOT LAMP
 NO CONNECTION (WHEN CONNECTIONS ARE INDICATED BY DOTS)		 HEADPHONES
 CONNECTION (WHEN NO-CONNECTION CROSS-OVERS ARE INDICATED BY HALF-CIRCLES)		 FIXED CONDENSER (MICA OR PAPER)
 TERMINAL	 FIXED CONDENSER (ELECTROLYTIC)	 LOUDSPEAKER, P.M. DYNAMIC
 ONE CELL OR "A" BATTERY	 VARIABLE CONDENSER	 LOUDSPEAKER, ELECTRODYNAMIC
 MULTI-CELL OR "B" BATTERY	 GANG TUNING CONDENSER	 PHONO PICK-UP
 RESISTOR	 TRIMMER AND PADDER CONDENSER	 FILAMENT
 POTENTIOMETER	 I.F. TRANSFORMER (DOUBLE-TUNED)	 CATHODE
 TAPPED RESISTOR OR VOLTAGE DIVIDER	 POWER SWITCH (S.P.S.T.)	 GRID
 RHEOSTAT	 SWITCH (S.P.D.T.)	 PLATE
	 SWITCH (D.P.S.T.)	 3-ELEMENT VACUUM TUBE
 AIR-CORE CHOKE COIL	 SWITCH (D.P.D.T.)	 ALIGNING KEY OF OCTAL BASE

OTHER ALLIED PUBLICATIONS



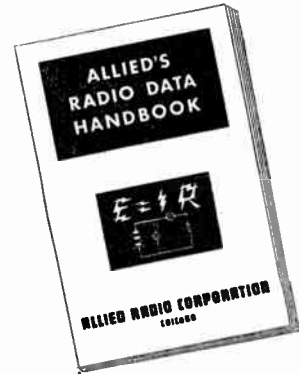
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