PRICE $5.00

D

BASIC RADIO

PART 1

HEATHKIT

EDUCATIONAL SERIES

MODEL EK-2A

595-310

HEATH COMPANY BENTON HARBOR, MICHIGAN

RESISTOR AND CAPACITOR COLOR CODES

RESISTORS

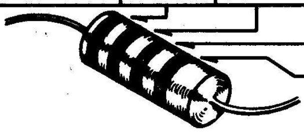
The colored bands around the body of a color coded resistor represent its value in ohms. These colored bands are grouped toward one end of the resistor body. Starting with this end of the resistor, the first band represents the first digit of the resistance value; the second band represents the second digit; the third band represents the number by which the first two digits are multiplied. A fourth band of gold or silver represents a tolerance of ±5% or ±10% respectively. The absence of a fourth band indicates a tolerance of ±20%.

The physical size of a composition resistor is related to its wattage rating. Size increases progressively as the wattage rating is increased. The diameters of 1/2 watt, 1 watt and 2 watt resistors are approximately 1/8", 1/4" and 5/16", respectively.

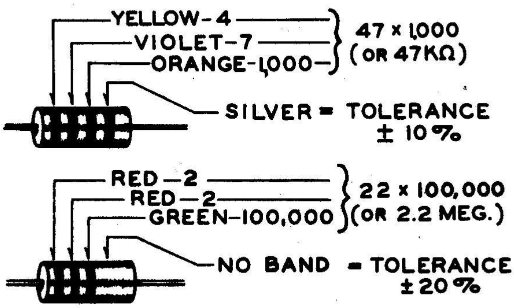
The color code chart and examples which follow provide the information required to identify color coded resistors.

CODE

COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER
BLACK	0	0	1
BROWN	1	1	10
RED	2	2	100
ORANGE	3	3	1,000
YELLOW	4	4	10,000
GREEN	5	5	100,000
BLUE	6	6	1,000,000
VIOLET	7	7	10,000,000
GRAY	8	8	100,000,000
WHITE	9	9	1,000,000,000
GOLD	-	-	.1
SILVER	-	-	.01



EXAMPLES



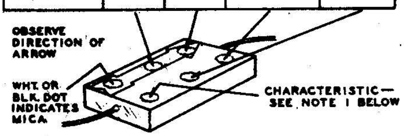
CAPACITORS

Generally, only mica and tubular ceramic capacitors, used in modern equipment, are color coded. The color codes differ somewhat among capacitor manufacturers, however the codes shown below apply to practically all of the mica and tubular ceramic capacitors that are in common use. These codes comply with EIA (Electronics Industries Association) Standards.

MICA

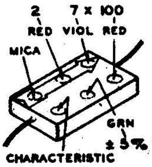
CODE

COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLER.%
BLACK	0	0	1	±20
BROWN	1	1	10	—
RED	2	2	100	± 2
ORANGE	3	3	1,000	± 3
YELLOW	4	4	10,000	—
GREEN	5	5	—	± 5
BLUE	6	6	—	—
VIOLET	7	7	—	—
GRAY	8	8	—	—
WHITE	9	9	—	—
GOLD	-	-	.1	—
SILVER	-	-	.01	± 10



(VALUE IN μμf—SEE NOTE 3 BELOW)

EXAMPLE



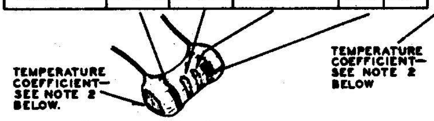
2,700μμf ±5%
OR .0027μfd

TUBULAR CERAMIC

Place the group of rings or dots to the left and read from left to right.

CODE

COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLER. % [illegible]	TOLER. % [illegible]
BLACK	0	0	1	±20	±20
BROWN	1	1	10	±0.1	±1
RED	2	2	100	—	±2
ORANGE	3	3	1,000	—	±2.5
YELLOW	4	4	10,000	—	—
GREEN	5	5	—	±0.5	±5
BLUE	6	6	—	—	—
VIOLET	7	7	—	—	—
GRAY	8	8	—	±0.25	—
WHITE	9	9	—	±1.0	±10



(VALUE IN μμf—SEE NOTE 3 BELOW)

EXAMPLE

33μμf ±5%

NOTES:

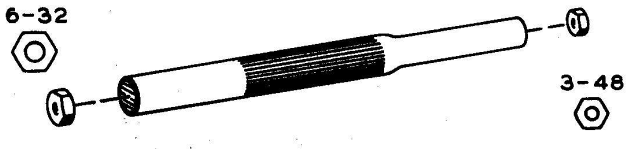
1. The characteristic of a mica capacitor is the temperature coefficient, drift capacitance and insulation resistance. This information is not usually needed to identify a capacitor but, if desired, it can be obtained by referring to EIA Standard, RS-153 (a Standard of Electronic Industries Association.)

2. The temperature coefficient of a capacitor is the predictable change in capacitance with temperature change and is expressed in parts per million per degree centigrade. Refer to EIA Standard, RS-198 (a Standard of Electronic Industries Association.)

3. The farad is the basic unit of capacitance, however capacitor values are generally expressed in terms of μfd (micro-farad, .000001 farad) and μμf (micro-micro-farad, .000001 μfd); therefore, 1,000 μμf = .001 μfd, 1,000,000 μμf = 1μfd. The designation pf is sometimes used for μμf.

USING A PLASTIC NUT STARTER

A plastic nut starter offers a convenient method of starting the most used sizes: 3/16" and 1/4" (3-48 and 6-32). When the correct end is pushed down over a nut, the pliable tool conforms to the shape of the nut and the nut is gently held while it is being picked up and started on the screw. The tool should only be used to start the nut.



BASIC RADIO

PART 1

★ ★

One of a series of Learn-by-Doing
EDUCATIONAL KITS
prepared especially for
Individual Home Study
or
Group Classroom Instruction

★ ★

HEATH COMPANY
Benton Harbor, Michigan

PRINTED IN THE UNITED STATES

OF AMERICA

December 1960

7/8/66

INTRODUCTION

Understanding radio communication today is just another part of understanding the modern world around us. The time is long past when electronics and radio could be put aside as a very specialized field of knowledge affecting only a very few people. Radio communication has become such a dominant element in our daily lives that some understanding of its fundamentals is almost essential. Just as most of us understand the basic principles involved in the operation of an automobile engine, so it is important that we have the same understanding about radio. We still take our automobiles to a mechanic when repairs and adjustments are needed, since knowing the fundamentals of what goes on under the hood does not necessarily make us all mechanics. By the same token, having a basic understanding of electronics and radio does not necessarily mean that all of us will be our own radio and TV repairmen.

Knowledge of the principles involved in the phenomenon of radio transmission is a great asset for anyone to have, and the EK-2A and EK-2B Kits are designed to give you just this kind of understanding and background.

The fact that this manual is now in your possession is an indication of genuine interest on your part in the "why" of electronics and radio, and you are to be congratulated for pursuing this interest as far as you have already. Your curiosity will be rewarded by the delight and satisfaction of actually assembling and operating various types of radio circuits, and learning how and why such circuits operate.

The basic principles underlying broadcast radio communication also apply to television, FM, radar, military communication, etc., so that familiarity with these principles will open the door for you to the broader field of electronics in general.

Each lesson in your manual will explain in simple terms the "how it works" information you need to understand an experiment. Then you will actually build circuits to demonstrate these principles, and prove theoretical points by experimenting.

You are due for an exciting, learn-by-doing experience, so set a relaxed pace for yourself and take the time necessary to think through each point as you work with this material. It's more fun that way too!

TABLE OF CONTENTS

CONSTRUCTION NOTES

Refer to the "Kit Builders Guide" for complete information on unpacking, parts identification, tools, wiring, soldering, and step-by-step assembly procedures.

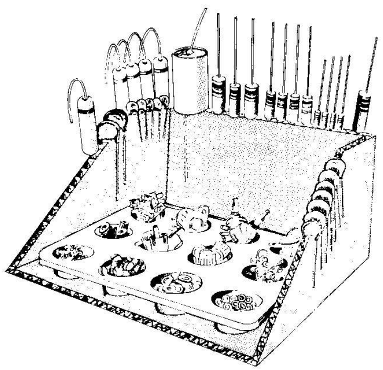
UNPACK THE KIT CAREFULLY AND CHECK EACH PART AGAINST THE PARTS LIST. In so doing, you will become acquainted with the parts. Refer to the information on the inside cover of the manual and in the Kit Builders Guide to help you identify the components. If some shortage or parts damage is found in checking the Parts List, please read the REPLACEMENT section and supply the information called for therein.

Resistors generally have a tolerance rating of 10% unless otherwise stated in the Parts List. Tolerances on capacitors are generally even greater. Limits of +100% and -20% are common for electrolytic capacitors.

We suggest that you do the following before work is started:

1. Lay out all parts so that they are readily available. Take special care not to lose or mislay experiment parts while studying the text portions of the lessons.
2. Provide yourself with good quality tools. Basic tool requirements consist of a screwdriver with a 1/4" blade; a small screwdriver with a 1/8" blade; long-nose pliers; wire cutters, preferably separate diagonal cutters; a pen knife or a tool for stripping insulation from wires; a soldering iron (or gun) and rosin core solder. A set of nut drivers and a nut starter, while not necessary, will aid extensively in construction of the kit.

Most kit builders find it helpful to separate the various parts into convenient categories. Muffin tins or molded egg cartons make convenient trays for small parts. Resistors and capacitors may be placed with their lead ends inserted in the edge of a piece of corrugated cardboard until they are needed. Values can be written on the cardboard next to each component. The illustration shows one method that may be used.



PARTS LIST

Use the pictures on the opposite page to help you identify parts.

PART No.	PARTS Per Kit	DESCRIPTION
Resistors		
1-27	1	150 K ohm 1/2 watt (brown-green-yellow)
1-35	1	1 megohm 1/2 watt (brown-black-green)
1-38	1	3.3 megohm 1/2 watt (orange-orange-green)
1B-15	1	1000 ohm 2 watt (brown-black-red)
1B-22	2	12 K ohm 2 watt (brown-red-orange)
Capacitors		
21-9	1	100 μμf ceramic
21-11	1	150 μμf ceramic
21-24	1	800 μμf ceramic
21-27	1	.005 μfd ceramic
21-32	1	47 μμf ceramic
21-71	2	.001 μfd ceramic
25-77	1	40 + 20 μfd, 300 volt electrolytic
26-9	1	2-gang variable
Terminal Strips-Connectors-Sockets		
431-1	2	"T" type terminal strip
431-12	1	4-lug terminal strip
431-6	1	2-lug Screw type connector
434-2	1	Octal socket
434-37	4	Tube socket, 7-lug
434-83	1	Lamp socket
434-85	1	Lamp socket, with wire
Hardware		
250-49	8	3-48 x 1/4" screw
250-89	15	6-32 x 3/8" screw
252-1	8	3-48 nut
252-3	12	6-32 nut
252-4	4	8-32 nut
252-7	2	Control nut
252-39	1	1/4" control nut
253-21	6	Flat washer
254-1	13	#6 lockwasher
254-2	3	#8 lockwasher
254-5	1	Control lockwasher
254-14	1	1/4" control lockwasher
255-2	3	#6 x 3/16" spacer
Hardware (Cont'd.)		
259-1	2	#6 solder lug
259-2	1	#8 solder lug
259-10	1	Control solder lug
Miscellaneous		
10-107	1	Linear control, 200 ohm
19-27	1	Audio control, 1 megohm w/SPST switch
40-303	1	Coil, broadcast regenerative detector
45-3	1	RF choke, 1 mh
54-97	1	Power transformer
56-26	1	Crystal diode
71-6	2	Porcelain insulator
73-4	4	5/16" rubber grommet
73-6	3	7/16" soft rubber grommet
75-24	1	Strain relief insulator
89-1	1	Line cord
200-M250	1	Chassis
205-M261	2	End plate
207-31	1	Ground clamp
340-10	1	Length bare copper antenna wire (antenna)
344-59	1	Length hookup wire
344-21	1	Length red wire; pretinned (lead-in)
346-1	1	Length sleeving
390-93	1	Label sheet (GND. ANT.) (Phones)
1401-36	1	Crystal earphone, single unit
411-3	1	5Y3GT tube
411-4	1	6C4 tube
412-1	2	#47 pilot lamp
436-16	1	Miniature phone jack
438-26	1	Miniature phone plug
462-18	1	Knob, gray
462-112	2	Knob, white
481-2	1	Capacitor mounting wafer
331-6		Solder
595-310	1	Manual

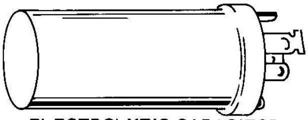
Two standard size "C" flashlight batteries should be purchased at this time to be available when needed.

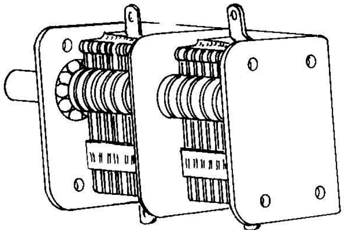
PARTS PICTORIAL

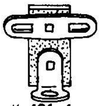

1/2 WATT RESISTOR

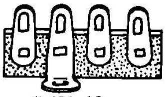

2 WATT RESISTOR

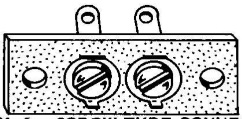

CERAMIC CAPACITOR

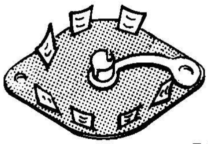

ELECTROLYTIC CAPACITOR

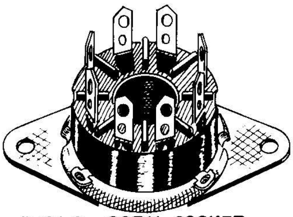

26-9 VARIABLE CAPACITOR

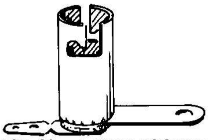

431-1
"T" TYPE
TERMINAL STRIP

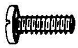

431-12
4-LUG
TERMINAL STRIP


431-6 SCREW TYPE CONNECTOR


434-37 TUBE SOCKET, 7 PRONG


434-2 OCTAL SOCKET

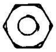

434-83 LAMP SOCKET

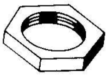

6-32 x 3/8" BHMS

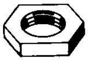

3-48 x 1/4" BHMS

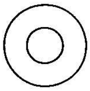

3-48 NUT

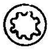

6-32 NUT


8-32 NUT


CONTROL NUT

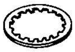

1/4" CONTROL NUT

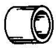

FLAT WASHER,
9/16" OD


#6 LOCKWASHER

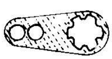

#8 LOCKWASHER

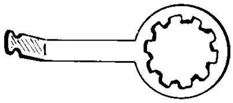

1/4" CONTROL
LOCKWASHER

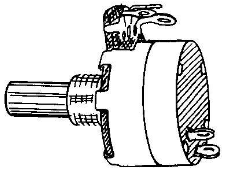

CONTROL LOCKWASHER

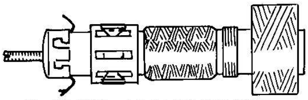

#6 x 3/16" SPACER

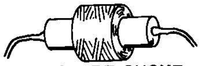

#6 SOLDER LUG


#8 SOLDER LUG


CONTROL SOLDER LUG


19-27
AUDIO CONTROL
W/SPST SWITCH


40-303 DETECTOR COIL

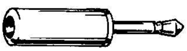

45-3 RF CHOKE

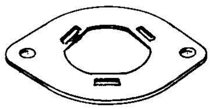
#56-26 CRYSTAL DIODE


73-6
7/16" RUBBER GROMMET


75-24
STRAIN RELIEF INSULATOR


436-16
MINIATURE PHONE JACK


438-26
MINIATURE PHONE PLUG


481-2
CAPACITOR MOUNTING WAFER

PROPER SOLDERING TECHNIQUES

Only a small percentage of HEATHKIT equipment purchasers find it necessary to return an instrument for factory service. Of these instruments, by far the largest portion of malfunctions are due to poor or improper soldering.

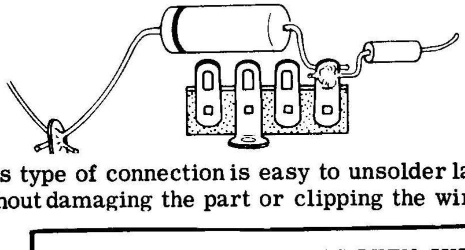
If terminals are bright and clean and free of wax, frayed insulation and other foreign substances, no difficulty will be experienced in soldering. Correctly soldered connections are essential if the performance engineered into a kit is to be fully realized. If you have not already completed kit EK-1 in Basic Electricity, and had the soldering experience it provides, a half hour's practice with some odd lengths of wire may be a worthwhile investment.

For most wiring, a 25 to 100 watt iron or its equivalent in a soldering gun is very satisfactory. A lower wattage iron than this may not heat the connection enough to flow the solder smoothly over the joint. Keep the iron tip clean and bright by wiping it from time to time with a cloth.

CHASSIS WIRING AND SOLDERING

1. SOLDER ALL CONNECTIONS in the experiments of this manual. You will find that the step-by-step instructions provided for each experiment do not tell you when to solder each connection, because the steps are used merely as a check on your work. For instructional purposes, the various experiments should be wired from the schematic and pictorial diagrams if possible. The time to solder each connection then depends on which wires are installed first. Even where you might solder a connection prematurely, however, it is quite easy to add another wire to the terminal if you use temporary soldering techniques.

Instead of hooking and crimping each wire before soldering, simply leave the wire straight and thread it through the hole in the terminal, or lay it across the face of the terminal, and make a temporary "lap" joint. Typical temporary lap joints are shown in the figure below.



This type of connection is easy to unsolder later without damaging the part or clipping the wires. It is not as strong mechanically as a hooked and crimped connection, but it is completely satisfactory from an electrical standpoint, and will simplify the soldering and unsoldering job for you.

2. Unless otherwise indicated, all wire used is the type with colored insulation (hookup wire); the size of the conductor is the same for all colors of hookup wire furnished with this kit. In preparing a length of hookup wire, 1/4" of insulation should be removed from each end unless directed otherwise in the construction step.

3. To avoid breaking internal connections when stripping insulation from the leads of transformers or similar components, care should be taken not to pull directly on the lead. Instead, hold the lead with pliers while it is being stripped.

4. Wherever there is a possibility of bare leads shorting to other parts or to the chassis, the leads should be covered with insulating sleeving. Where the use of sleeving is specifically intended, the phrase "use sleeving" is usually included in the associated construction step. In any case where there is the possibility of an unintentional short circuit, sleeving should be used. Extra sleeving is provided for this purpose.

5. Position the work, if possible, so that gravity will help to keep the solder where you want it.

6. Place a flat side of the soldering iron tip against the joint to be soldered until it is heated sufficiently to melt the solder.

7. Then place the solder against the heated terminal and it will immediately flow over the joint; use only enough solder to thoroughly wet the junction. It is usually not necessary to fill the entire hole in the terminal with solder.

8. Remove the solder and then the iron from the completed junction. Use care not to move the leads until the solder is solidified.

A poor or cold solder joint will usually look crystalline and have a grainy texture, or the solder will stand up in a blob and will not have adhered to the joint. Such joints should be reheated until the solder flows smoothly over the entire junction. In some cases, it may be necessary to add a little more solder to achieve a smooth bright appearance.

ROSIN CORE SOLDER HAS BEEN SUPPLIED WITH THIS KIT. THIS TYPE OF SOLDER MUST BE USED FOR ALL SOLDERING IN THIS KIT. ALL GUARANTEES ARE VOIDED AND WE WILL NOT REPAIR OR SERVICE EQUIPMENT IN WHICH ACID CORE SOLDER OR PASTE FLUXES HAVE BEEN USED. IF ADDITIONAL SOLDER IS NEEDED, BE SURE TO PURCHASE ROSIN CORE (60:40 or 50:50 TIN-LEAD CONTENT) RADIO TYPE SOLDER.

LESSON I

HOW DO VOICE AND MUSIC GET FROM A BROADCAST STUDIO TO YOUR HOME?

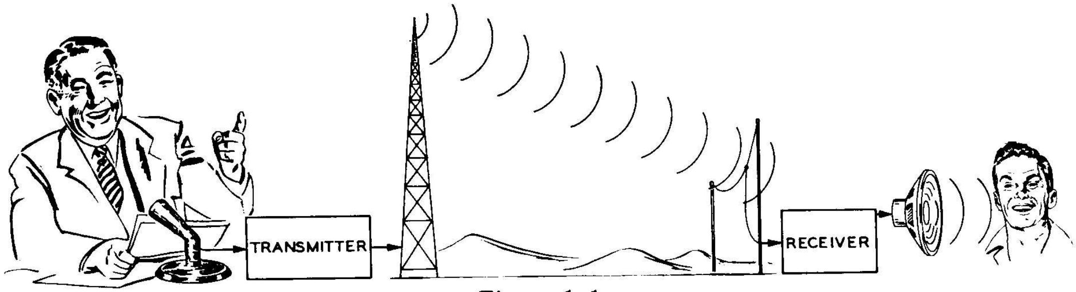


Figure 1-1

An announcer picks up his script, speaks into a microphone, and almost instantly his voice is heard coming from the loudspeaker of thousands of radio receivers, frequently many miles from the studio in which this action takes place. Or, a studio orchestra in front of a microphone strikes up, and in the same way, the melodious tones created are heard in thousands of homes within a radius of many miles. These are amazing occurrences, when you stop to think about them, even though such happenings are taken for granted every day. But simply being "amazed" at this occurrence is not enough...when to satisfy genuine curiosity it is more logical to find out what happens between the time he speaks and the time his voice is heard in your living room!

TRANSMISSION

When an announcer speaks into a microphone in a broadcast radio studio (Figure 1-1), the sound waves created by his voice are picked up by the microphone and converted from mechanical vibrations of the air into electrical vibrations within a wire. The microphone creates what is commonly referred to as an "audio signal." Actually, an audio signal is what may be thought of as "sound in electrical form." The pulsations of electricity produced follow the same pattern as the pulsations of air created by his voice.

This audio signal is fed into the broadcast transmitter. The transmitter "amplifies" this signal to make it stronger, and then transforms it into an electrical form that can be fed to a broadcast antenna, and radiated through space. The details of various functions that occur in the transmitter itself will be left to a later discussion, but it is important that you note at this time two facts about the transmitter. It provides the power to feed the antenna and radiate the signal into space, and it transforms the audio signal into a form suitable for broadcasting. The power of a broadcast station is specified in watts, and this unit of measure indicates the strength of the signal being sent out from the antenna. Broadcast stations in the United States vary in power from about 250 watts up to a maximum of 50,000 watts. In general, the greater the power being radiated from the transmitter antenna, the greater the distance over which the broadcast signal may be received.

RADIATION

Figure 1-1 shows the steps involved in carrying the announcer's voice from the studio to your home, and you will note that the signal is radiated from the transmitting antenna to the receiving antenna through space. This radiation takes place at a speed of 186,000 miles per second (the speed of light), so the time between transmission and reception is practically instantaneous. A broadcast signal is sent out at one particular radio frequency. The broadcast band consists of all the frequencies between about 550 kc and 1600 kc. Since kc is an abbreviation for thousands of cycles per second, the broadcast band is between 550,000 cycles and 1,600,000 cycles, per second. The fact that each broadcast station operates on a different frequency within the broadcast band accounts for your ability to select one station or another with your receiver.

The distance over which the broadcast signal will carry depends on a number of factors. Geography will have an effect, since mountains and other large masses protruding up from the earth's surface tend to block and absorb signals.

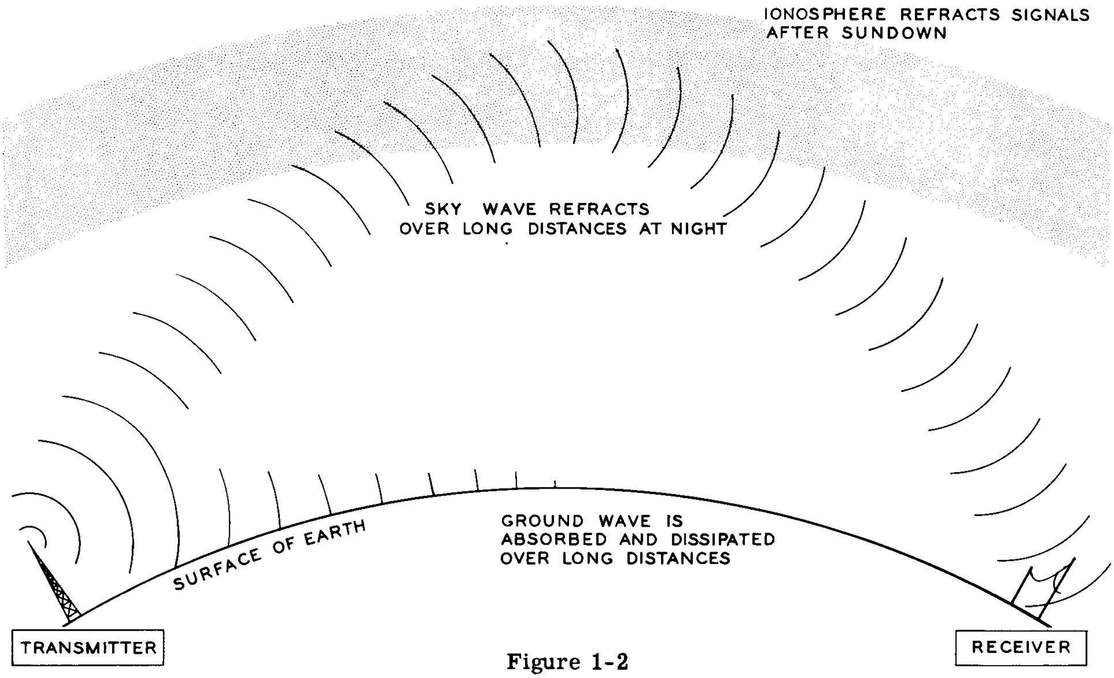


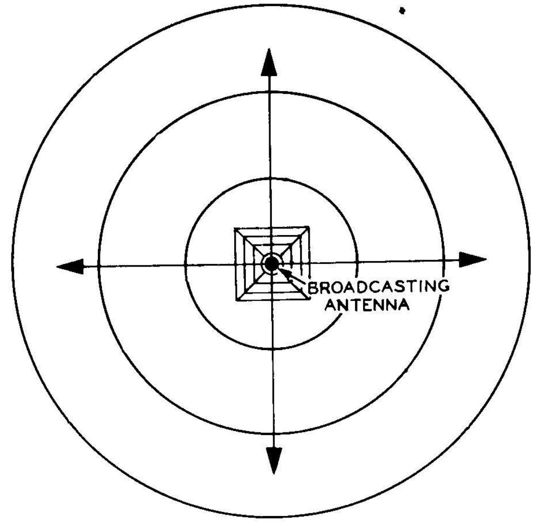
Figure 1-2

If everything else is equal, a broadcast signal will carry further in flat country than in mountainous terrain. Of course, the power of the transmitter, the height of the transmitting antenna, and the time of day or night will also affect the distance over which the signal can be received. This last fact deserves further explanation.

During the daylight hours, radiation from a transmitting antenna to a receiving antenna normally takes place in a horizontal fashion (see Figure 1-2). In other words, a signal is radiated from the transmitting antenna, and a portion of this signal travels along horizontally through the earth's atmosphere until it is picked up on the receiving antenna. If the receiver is too far away, the signal fades out before it reaches the receiver and the station cannot be heard. The portion of this same signal that is radiated upward, away from the earth, travels out into space and serves no useful purpose.

After sundown, however, an electrical layer high above the earth changes in such a way that it will refract (bend) radio signals at an angle that returns them to earth. When this occurs, the signal radiated upwards from a transmitting antenna strikes this layer, called the ionosphere, and is bent back to earth at a greater distance than the signal could have covered in a horizontal direction. This phenomenon is sometimes referred to as "skip", and it accounts for the fact that many more stations are heard on the broadcast band, and for greater distances, during the evening hours after the sun has set. Tuning across your home broadcast receiver during the daylight hours will give you a good idea of your local and semi-local radio situation. You will hear broadcasts within a range of, perhaps, one hundred miles or more. In the evening hours, however, the broadcast band usually becomes crowded with signals, and these stations may be located several hundreds of miles away, and are reaching your receiver purely by way of the "skip" effect involving the ionosphere. Figure 1-2 also illustrates how the skip signal operates.

The radiation pattern of a transmitting antenna is usually equal in all directions. Figure 1-3 is a birds-eye view of a non-directional transmitting antenna showing how the circles of radiated signal go out from the tower in all directions. In some cases, antennas or groups of antennas are arranged so that a broadcast station will send out a directional pattern, sending signals into beams in one or more directions for special coverage. However, most broadcast stations send out an equal signal in all directions around the antenna tower.



CONCENTRIC RADIATION PATTERN EQUAL IN ALL DIRECTIONS.

Figure 1-3

RECEPTION

When a radio signal reaches a receiving antenna, either by way of the ground wave or a sky wave, this signal is rather weak. Radio signals, as a receiving antenna picks them up, amount to very small quantities of energy, and except for very close local stations, these signals are too weak to operate an earphone or speaker. Neither is the signal in the proper electrical form to create sound. Several important functions must be performed on the signal by the receiving set.

A receiver must be able to separate one station from another by tuning, for example. A radio without tuned circuits would pick up many stations at once. But, by employing tuned circuits, a radio can select one station and reject all others, even when these stations are close together on the dial. This quality in a receiver is called "selectivity."

Also, since the radio signals picked up by the receiving antenna are very weak, the receiver must be able to amplify or build up the signals to stronger levels. Vacuum tube amplifiers are normally used to do this. Very weak radio signals are amplified in special receiver circuits to a level great enough to operate loudspeakers, earphones, etc. This quality in a receiving set is commonly called "sensitivity."

Finally, the receiver must be able to transform the radio signal back into an audio signal (sound in electrical form). This transformation is called "detection," and is very necessary if the audio signal developed by the microphone at the broadcast studio, and transformed for broadcast through space, is to be changed back into its original audio signal form again, so that it can operate a loudspeaker or an earphone.

The speaker itself does exactly the opposite job from the microphone. Whereas the microphone changed sound vibrations into electrical vibrations, the speaker changes electrical vibrations back into sound vibrations again, so that the announcer's voice at the studio can be heard in the living room of your home.

HOW TO PLOT YOUR BROADCAST STATION ENVIRONMENT

PURPOSE

TO LISTEN TO A STANDARD BROADCAST RADIO RECEIVER AND, FROM THE INFORMATION OBTAINED, COMPLETE A BROADCAST RADIO INVENTORY CHART SHOWING ALL THE IMPORTANT INFORMATION ABOUT YOUR LOCAL BROADCAST STATION SITUATION. An inventory chart is shown in Figure 1-4, with two sample entries. This information will have a bearing on how you will place the broadcast receiving antenna which you erect in the next lesson.

BROADCAST RADIO INVENTORY

CALL LETTERS	LOCATION (TOWN)	FREQUENCY (IN KC)	POWER (IN WATTS)	DIRECTION (IN DEGREES)	DISTANCE (IN MILES)	STRENGTH (RATED 1 TO 5)
WSJM	St. Joseph	1400	250	45	2	2
WHFB	Benton Harbor	1060	1,000	90	2.6	1

Figure 1-4

BROADCAST RADIO INVENTORY

CALL LETTERS	LOCATION (TOWN)	FREQUENCY (IN KC)	POWER (IN WATTS)	DIRECTION (IN DEGREES)	DISTANCE (IN MILES)	STRENGTH (RATED 1 TO 5)

Figure 1-5

RADIO INVENTORY CHART

You will notice that the chart shown in Figure 1-4 provides space to record the call letters of any stations that can be received in your area, the locations of these stations, their frequencies, power, direction from your receiving point, distance from your receiving point, and relative signal strength as compared to each other. Two sample entries have been made on the chart to show the kind of information desired, and the way in which it should be recorded. A blank chart is provided in Figure 1-5 for you to fill in with the information about your particular broadcast radio signal situation. A standard radio should be used for this purpose and the experiment should be performed during daylight hours!

CALL LETTERS

In tuning across the broadcast band of a receiver, from 550 kc to 1600 kc, you should receive a number of local and semi-local broadcast signals. The call letters of these stations should be recorded in the call letter column of your broadcast inventory. Most stations identify themselves every fifteen minutes, or at least every half hour, so you should have no difficulty obtaining the call letters. Limit your radio inventory to those stations that can be heard during daylight hours, as mentioned earlier, since after sundown the number of stations received will be tremendously increased, and will merely complicate the chart with a large number of stations that cannot be received consistently at all hours. After sundown, stations will be picked up over long distances, but such reception is frequently unreliable and is subject to fading, interference, fluctuation in signal strength, etc.

LOCATION

The town where each station you receive is located should be noted in the second column of the inventory chart. In most cases, the transmitting tower of each station will be located close enough to the center of the town involved that the town itself may be considered the source of the signals being radiated. It is only with stations in your own city or town that the exact location of the transmitting antenna needs to be considered as the source of the signals. Often the tower may be in a suburb, rather than in the downtown section.

FREQUENCY

The frequency of each station received should be recorded in the third column of your radio inventory chart. The approximate frequency can be determined from the dial of the radio on which the station is being received. However, most radio dials are difficult to read accurately, and the exact frequency of the broadcast station should be determined from the station identification announcement in which frequency is given in kilocycles (kc), or from station program schedules which are often published in daily newspapers.

POWER

The power of broadcast stations is measured in watts, or kilowatts (one thousand watts). This information may be a little more difficult to obtain, although most stations announce their power rating at sign-on time in the morning or sign-off time in the evening. If necessary, a phone call to your local station will put you in touch with someone who can give you the power rating of the station, and perhaps even the power rating of other stations in the vicinity. In either case, the power rating in watts should be recorded in the fourth column of the inventory. Keep in mind that one kilowatt equals one thousand watts.

DIRECTION

To find out the direction of various broadcast stations from your particular location, you will need a map of your area. The Chamber of Commerce or a local filling station can provide you with such a map, and you can mark your own location on the map. Then, with a ruler, draw a line out to the locations of the various stations being received. This will let you find the direction of each station from your home.

The most convenient method of showing this direction in the chart would be in degrees. Figure 1-6 will help you to find the angle of the stations from your home. Note that the points of the compass in Figure 1-6 have been divided into degrees, beginning with zero at north, and running around to 360 degrees back at north again. Northeast becomes 45 degrees, east is 90 degrees, southeast is 135 degrees, south is 180 degrees, southwest is 225 degrees, west is 270 degrees, northwest is 315 degrees, and north is, again, either 360 degrees or zero degrees. The 5-degree marks falling between these main divisions are shown so you can locate, within five degrees or so, the direction of all the stations being picked up by your home receiver. Place this angle indicator over or under your map to estimate the degree of angle in each case.

DISTANCE

Finding the distance of any broadcast station from your home can be done rather easily by, again, using the map of your area. Almost all maps have a scale shown, so you can simply measure the distance between your home and the station with a ruler, and then read this distance on the scale provided on the map. It is, of course, the straight-line distance in which you are interested, not the highway distance.

SIGNAL STRENGTH

Rating signal strength is a simple matter of judging the loudness of each station by ear, and recording which stations are strongest in your location of all the stations you can hear across the broadcast band without changing the volume control. An important fact to keep in mind here is that most all receivers such as you will be using for these listening tests use some sort of built-in antenna that has directional characteristics. In other words, the built-in antenna will receive better from one direction than another. Therefore, in comparing signal strength, the sets having a built-in antenna should be rotated for maximum loudness on each station before a comparison is made. It is assumed you will be using some type of table-model radio which is light enough that it can be picked up and turned to "peak" the station being received. Assign the number "1" to the strongest station that can be picked up at your location, the number "2" to the second strongest station, etc. There is no need to go beyond five in your signal strength ratings, since you will not be concerned with the stations

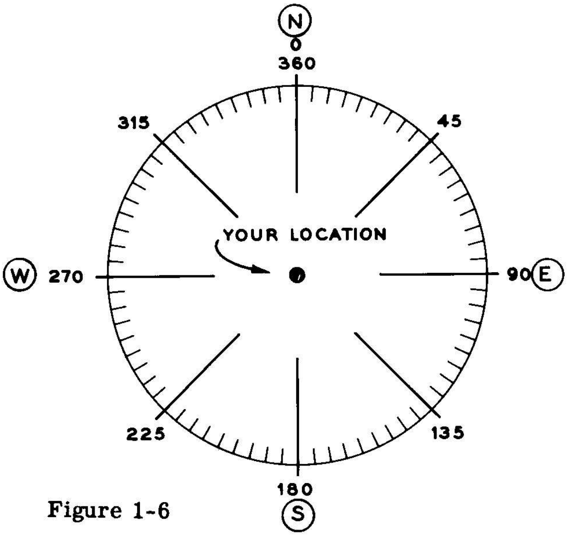


Figure 1-6

with less than a number five rating in future experiments.

When you have the broadcast radio inventory chart (Figure 1-5) completely filled in for all the stations you can pick up in your area, you have a written record of your broadcast radio environment. You should find it interesting to note the effects that distance, power, and geography have on the final signal strength rating of each station.

Now the Broadcast Radio Inventory Chart is ready for future reference and you are prepared for Lesson II.

LESSON I

QUESTIONS

NOTE: Answers to the questions below will be found on Page 84 in the back of your manual.

1. What function is performed by the studio microphone?

2. What two main functions are performed by the transmitter as far as the signal is concerned?

3. The standard broadcast band is between the frequencies of 550 kc and 1600 kc.

4. The abbreviation "kc," standing for kilocycles, is used to mean 1000 cycles per second.

5. Broadcast stations in the United States vary in power from about 25 to 50K watts.

6. The effect that causes long-distance stations to be heard at night that cannot be heard in the daylight hours is commonly referred to as "skip."

7. The three things a receiver must do to signals coming in on an antenna before they are ready to operate a speaker may be summed up in what three words?

8. What function is performed by the loudspeaker?

LESSON II

WHAT IS A BROADCAST RADIO SIGNAL?

You have already learned some of the characteristics of broadcast radio signals. You know that these signals can exist in a wire, or can be radiated through space from a transmitting antenna to a receiving antenna. The details of what is meant by "frequency," "cycle," and "amplitude," still need some explaining, however, and this lesson will attempt to make it completely clear to you what a radio signal is, so that later you will be in a position to understand the various functions that a receiver must perform on a broadcast radio signal before you can hear sound coming from the radio set in your home.

Since radio signals are merely a special form of the current discussed in the lessons of kit EK-1, it would be advisable at this time to review some information about the various forms that electric current can take, as a basis for describing the special form of electric current that is a radio signal.

UNDERSTANDING DC, AC, and PDC CURRENT

The electric current in a wire or the nature of a radio-wave in space is not easy to visualize. There is just no way to "see" the current because, of course, it is invisible. Yet these currents can be understood better if they are somehow translated into a form that can be put down on paper and analyzed. This may be done by the use of a graph. Here are some things to keep in mind so that the following graphs of DC, AC, and PDC current will be most meaningful to you.

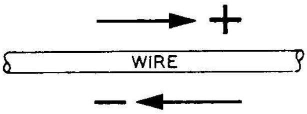
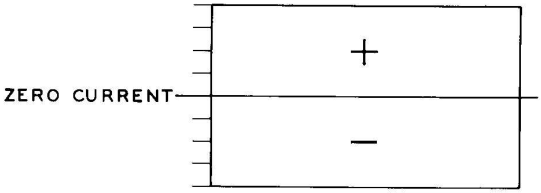


Figure 2-1

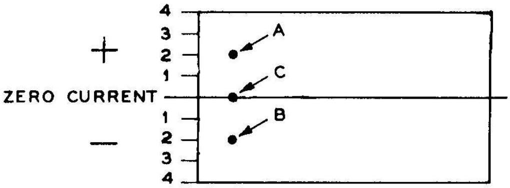
1. Current will be called plus when it flows in one direction within a wire. Current will be called minus when it flows in the opposite direction within a wire. (Refer to Figure 2-1.) Plus and minus currents are equal in energy, and are assigned these plus and minus symbols merely as a way of telling one direction of current flow from another.

2. The zero-current line (Figure 2-2) is used as a base line for the following graphs. So far as these graphs are concerned, current flow in a plus direction will be shown above the zero-current line, and current flow in a minus direction will be shown below the zero-current line.



DIRECTION OF CURRENT FLOW IS SHOWN BY POSITION ABOVE OR BELOW ZERO-CURRENT LINE.

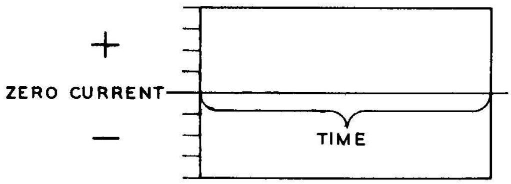
Figure 2-2



DISTANCE ABOVE OR BELOW ZERO-CURRENT LINE SHOWS AMOUNT OF CURRENT.

Figure 2-3

3. The amount of current flowing in the wire (Figure 2-3) will be shown by the distance above or below the zero-current line. For example, plus 2 amperes is at point A in Figure 2-3; minus 2 amperes is at point B; zero current is at point C.



TIME IS SHOWN BY DISTANCE ALONG THE ZERO-CURRENT LINE.

Figure 2-4

4. Time elapsed (Figure 2-4) is shown by the distance along the zero-current line. Any convenient time value can be assigned to this distance, depending on how rapidly the current alternates and what the graph is designed to show.

5. When current reverses its direction of flow (as alternating current does) this alternation usually takes place at a very rapid rate. Because of this fact, you may view a graph as being an ultra-slow-motion-picture of what is taking place.

DC CURRENT

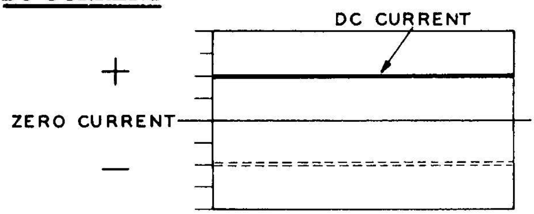


Figure 2-5 GRAPH OF DC CURRENT

DC, or direct current, flows in only one direction. DC current maintains a steady value (constant amplitude), and shows up on a graph as a simple straight line. (See Figure 2-5.) The DC current line could have been graphed below the zero-current line (note dotted line) if it flowed in the opposite (minus) direction.

AC CURRENT

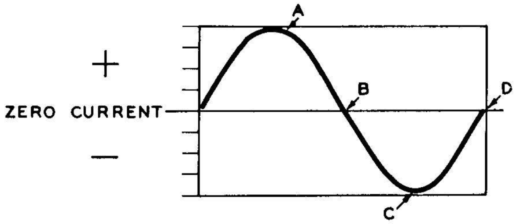


Figure 2-6 GRAPH OF AC CURRENT

AC, or alternating current, flows first in one direction and then in the other, while at the same time rising from zero up to a peak value and then returning to zero again. Following the graphed curve in Figure 2-6 will help you see how the current starts from zero and rises rather steeply to a peak amount of current flow in the plus direction at A, and then decreases back to zero again at B. This much of the current flow has been in one direction only, since this action all took place on the plus side of the zero-current line. Then the current reverses and starts to flow in the opposite (minus) direction. From point B (zero) the current builds up to a peak at point C, and then falls back to zero again at point D. Notice that this latter rise and fall all took place on the minus side of the zero-current line. AC current, then, is doing two things at the same time. It is constantly changing in its direction of flow, and each time it changes direction, the amount of current builds up to a peak and falls back again. One complete cycle of this action is shown in Figure 2-6. Notice that one cycle consists of a rise and fall of current in one direction, then a rise and fall of current in the other direction, returning to zero.

PDC CURRENT

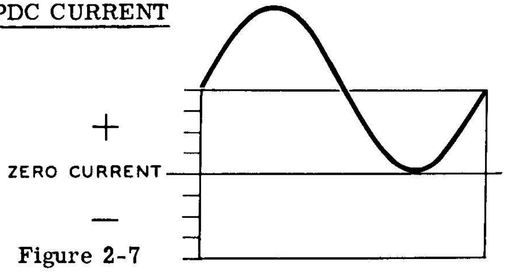


Figure 2-7 CYCLE OF PULSATING DC CURRENT

PDC or pulsating direct current, as its name suggests, is the same as direct current except that it pulsates. (See Figure 2-7.) To put it another way, PDC always flows in the same direction, just like DC current, but is changing in amount, just like AC current. PDC operates in cycles, and has a frequency, but this frequency refers only to how often the current changes in amount, and has nothing to do with any change in the direction of current flow. Notice that although the PDC current of Figure 2-7 rises and declines in amount, it stays above the zero-current line, showing that the current always flows in only one direction.

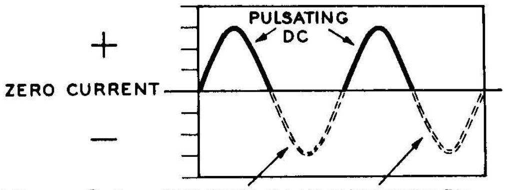
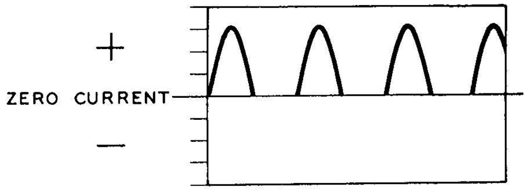


Figure 2-8 PORTIONS OF AC ELIMINATED BY RECTIFIER

The most common example of PDC current looks somewhat different than that shown in the graph of Figure 2-7. This is because the PDC normally encountered in electronics is the one-way current left after AC current has been rectified. Rectification is the process of passing current through a device that will conduct current in only one direction. You will learn more about this process later. It is enough at this time to say that if a two-way current (AC) is fed to a one-way current device, half of the current will be blocked. The PDC that remains after rectifying an AC current is graphed in Figure 2-8. A rectifier will pass current in only one direction, so one half, or the other (plus or minus) of the AC current is blocked, and a pulsating DC current remains. When more cycles are involved the result would appear as in Figure 2-9.

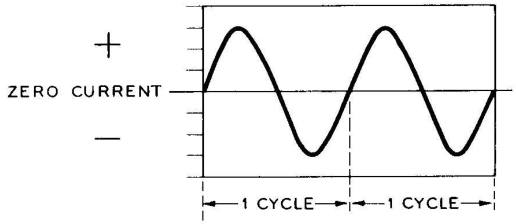


PDC CURRENT FROM RECTIFIED AC CURRENT

Figure 2-9

FREQUENCY

The three basic forms that electric current can take have now been covered under the headings of DC current, AC current, and pulsating DC current. Since AC current occurs in "cycles," and has "frequency," a further discussion of these subjects is in order to see how this alternating and pulsating current is related to a radio signal.



MORE THAN 1 CYCLE OF AC CURRENT

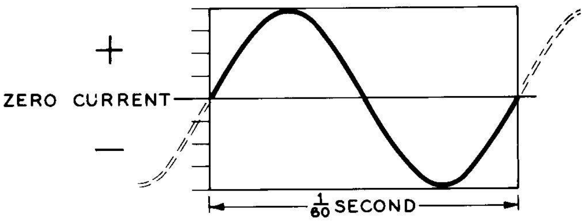
Figure 2-10

Since a plus swing followed by a minus swing, constitutes one cycle of AC current (see Figure 2-10), the frequency of an AC current is determined by the number of cycles that take place in one second. Your 60 cycle AC house current, for example, completes 60 full cycles of direction change combined with amount change, every second! Since 60 cycles take place every second, the time required for one cycle would be 1/60 of a second, and this may be seen on the graph in Figure 2-11, where the time line has been given a definite value. This graph shows one cycle of 60 cps (cycles per second) house current. AC current at a frequency of 60 cps is usually used for house current in the United States.

AC current that ranges in frequency from about 20 cps to 20,000 cps may be heard when connected to a speaker or earphone, and therefore is considered as "sound in electrical form." Electric current with frequency in this range is called audio. The term audio simply refers to the fact that these electrical impulses could be heard if connected to a sound reproducing device, even though not everyone's hearing range extends to these extreme limits. Below 20 cps or above 20,000 cps, the human ear would not detect the sound, even if it were fed to a sound reproducing device that was able to move the air in vibrations at these frequencies.

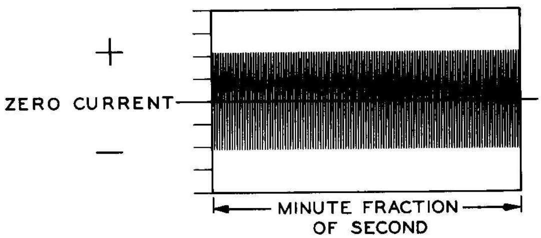
AC current with frequency higher than the audio range will cause radiation through space over long distances, if provided in sufficient power and connected to an antenna tower or other radiating device. Because of this fact, the range of frequencies above the audio limit are referred to as radio frequency currents. The broadcast band, for example, takes in frequencies between approximately 550 kc and 1600 kc (550,000 cps to 1,600,000 cps). The only difference then, between ordinary AC power line current, audio current, and radio current, is the frequency of the AC alternations and amplitude changes. As the frequency gets higher and higher, the behavior of the current changes.

While it would be impossible to graph accurately so many cycles taking place in one second, you can still draw radio waves in graph form by merely showing a great number of cycles occurring along the graph in a very short period of time. A radio frequency AC current is shown in Figure 2-12. Again note that the only difference between this radio frequency AC current and your AC house current is in the greater number of cycles taking place in a short length of time.



1 CYCLE OF 60 CPS AC CURRENT

Figure 2-11



RADIO FREQUENCY AC CURRENT

Figure 2-12

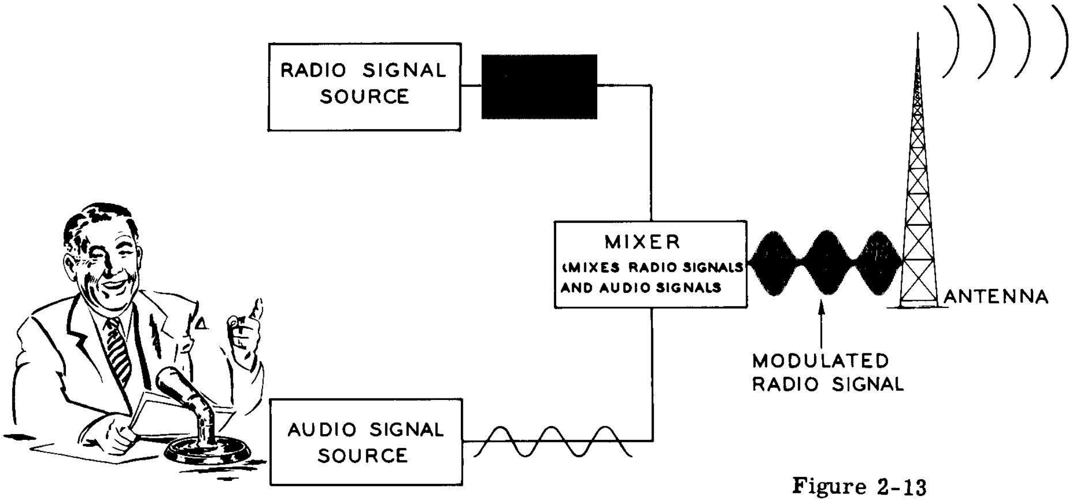


Figure 2-13

SIMPLIFIED DIAGRAM OF HOW A BROADCAST SIGNAL IS CREATED.

SIGNALS

The word signal is used to describe current when the current contains some kind of intelligence. In the case of a broadcast signal, this word suggests that intelligence is carried by this AC current (the voice or music conveyed from the studio to your home). In many cases, therefore, the terms "AC current," and "signal," will mean the same thing, even though DC current could be a "signal" under some circumstances.

An audio signal is an AC current up to 20,000 cps that carries sound in electrical form.

A radio signal is an AC current above 20,000 cps that contains intelligence, either in the form of code (as the signal is turned on and off in such a way that dots and dashes are formed), or contains intelligence in the form of its modulation. This last word requires some explaining.

Figure 2-13 is a much-simplified diagram of a broadcast station transmitter. One section of the transmitter produces a radio frequency signal at, say 1200 kc (1,200,000 cps).

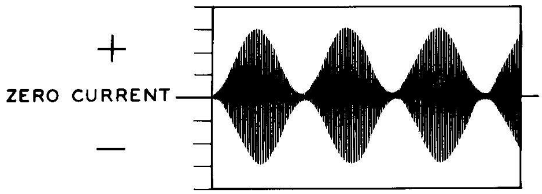
A second section of the transmitter, fed by the microphone, produces an audio signal at, say 1000 cps, as the announcer speaks into the microphone. In reality, of course, the human voice produces a complicated mixture of many audio frequencies in the microphone. A single 1000 cps signal is used merely to simplify this illustration of what happens in a transmitter.

A third section of the transmitter is fed both of these signals and mixes them together in such a way that the resulting modulated radio broadcast signal being fed to the antenna carries in it the signal produced by the announcer's voice in the studio.

The effect that modulation has on the radio signal is shown in Figure 2-13 to be a change in the amplitude of the radio frequency signal (the amount of current). Instead of a 1200 kc radio signal with amplitude that remains steady, the modulation process has produced a 1200 kc signal with uneven amplitude. The radio signal current comes in "swells" in which there is first very little energy and then a lot of energy. These swells were caused by the 1000 cps audio signal.

Notice that modulation has not changed the frequency of the radio signal, but has merely changed its amplitude. The modulation takes place in such a way that the audio signal coming from the microphone is able to control the instantaneous amounts of radio signal going to the antenna. In effect, then, the audio signal is being conveyed through space from the transmitter to the receiver even though audio signals, as such, will not radiate from this antenna. The audio signal exists in the way the radio signal changes in amplitude, and some restoring will have to be done at the receiving end of the communications system to convert these variations in radio frequency energy back into an audio signal again.

Figure 2-14 is an enlarged view of modulated radio signal in which you can see more clearly the variations in amplitude caused by modulation of the radio signal by an audio signal. This, then, is a broadcast radio signal, as it would be graphed to show its make-up. Understanding the nature of a broadcast radio signal is important because all of the functions of a receiver are designed to convert this signal back into usable sound again, and this fundamental idea is essential in understanding the functions of a receiver.



MODULATED RADIO FREQUENCY AC CURRENT (BROADCAST RADIO SIGNAL).

Figure 2-14

HOW TO PUT UP A BROADCAST RECEIVING ANTENNA

PURPOSE

TO PLAN AND CONSTRUCT A LONG-WIRE BROADCAST RECEIVING ANTENNA SUITED TO YOUR PARTICULAR BROADCAST RADIO SITUATION.

MATERIAL REQUIRED

1 75 ft. length of stranded bare antenna wire
1 30 ft. length of insulated wire for antenna lead-in and ground wires
2 Porcelain insulators
1 Ground clamp

STEP 1-CONSIDER ALL THE FACTORS

There are a number of things you should take into consideration as you think about an ideal location for your receiving antenna. Antenna location is quite important since it will affect the results you get with the various receiver circuits built up later. You will want to plan its location carefully by considering the following antenna requirements:

1. A long-wire antenna, such as you will be erecting, receives best off of its sides (broadside) and poorest off of its ends (at frequencies below 10 megacycles). Ideally, your number-one broadcast station (from the inventory chart in Lesson I) should be located off one side of your antenna. If this is not possible, the antenna should be arranged to favor the number-two broadcast station from the chart.

2. The lead-in wire to your work area must be connected to one end of the antenna. You must also provide a ground lead from a cold water pipe to your work area. This means that the selection of a work area in your home will be affected by the antenna location you select, and the availability of a cold water pipe or equivalent grounded object from which to run a ground wire.

3. Two tall objects are required (buildings, trees, poles, etc.) for hanging the antenna.

4. The antenna should be kept away from power lines, rain gutters, metal buildings or other large metal objects that might tend to block, shield, or absorb signals (or cause interference).

5. You have about 75 ft. of stranded wire to use for the antenna and support wires, and 30 ft. of solid insulated wire for use as antenna lead-in and ground wire.

All of the factors listed above will have an effect on the selection of your antenna location, work area, etc.

STEP 2 - PLANNING THE ANTENNA BEST FOR YOU

From the number of factors listed in Step 1 it is easy to see that you must compromise in locating the antenna, depending on your particular situation. You may not have antenna supports that are exactly in the right places, or the work area that is most convenient for your antenna lead-in may not be ideal for your ground wire, etc. It is up to you to find the compromise that best meets the five important antenna requirements listed. This will require some thought and planning, and a map of your situation will prove quite helpful.

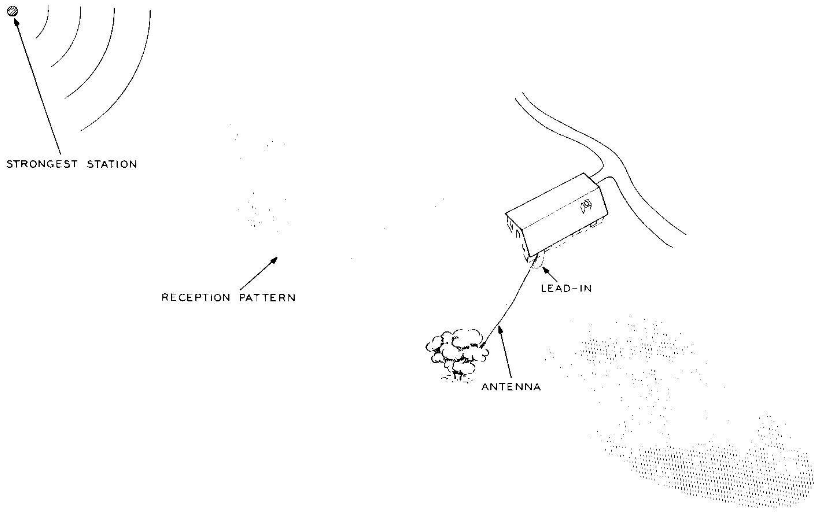


Figure 2-15

A BIRDS-EYE DRAWING HELPS PLAN YOUR BEST ANTENNA LOCATION AND DIRECTION.

Make a birds-eye drawing of your lot, similar to Figure 2-15. On your map show trees, poles, your home, outbuildings, or any other objects to which the antenna might be attached. Also show the location (direction) of your number-one and number-two radio broadcast stations from the inventory chart in Lesson I. This plan drawing need not be a work of art, but it should follow the actual physical situation of your location close enough that the directions and distances are approximately to scale. From this drawing, you should be able to decide on a long-wire antenna location to meet your needs. Note that the antenna should be broadside to the station to be received best. The higher you can put your antenna, the better.

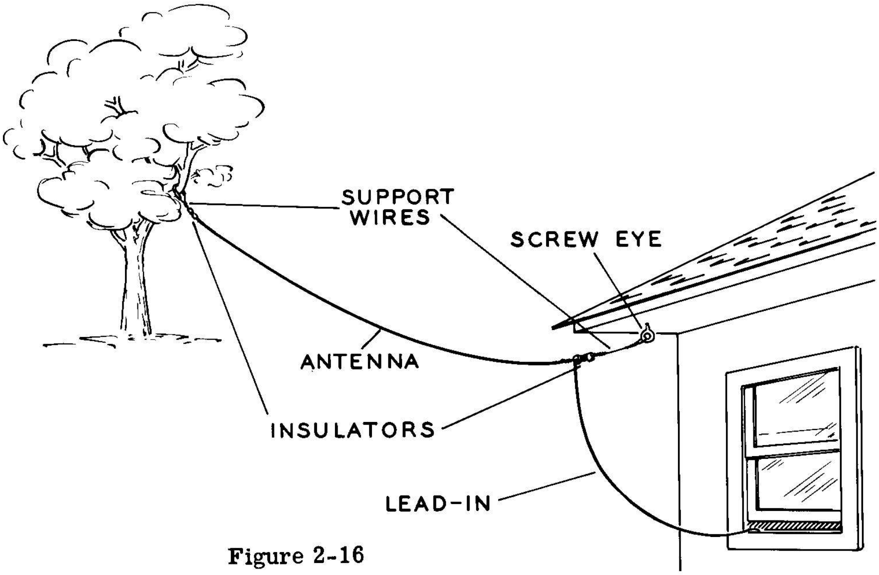


Figure 2-16

ANTENNA LEAD-IN WIRE IS BROUGHT THROUGH A WINDOW OPENING INTO THE WORK AREA.

STEP 3 - INSTALLING THE ANTENNA AND THE GROUND WIRE

Read all the way through this section before starting work in your antenna!

Ideally, one end of your antenna should be supported at your house to minimize the amount of lead-in wire required to reach up to one end of the antenna from your work area. The other end of the antenna should be pointed (as near as possible) 90 degrees away from your number-one or number-two broadcast station. A typical installation might turn out to look like Figure 2-16. Notice that the antenna lead-in wire is brought into the work area under a window. A ground wire must also be provided in the work area.

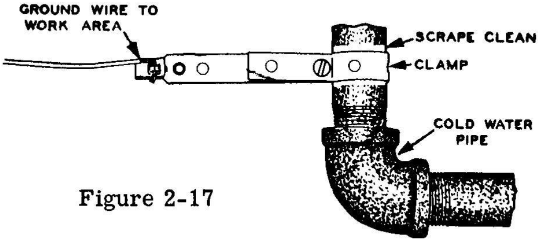


Figure 2-17

GROUND WIRE CONNECTS TO COLD WATER PIPE.

A ground connection is established by attaching one end of a length of wire from the work area, to a cold water pipe with the ground clamp provided. If this is not possible or practical, the connection may be made to any metal object that is eventually connected through to the cold water pipe (for example, a radiator, or pipes in a hot water heating system, etc.). A good electrical connection will be assured if you scrape the object to bare metal under the clamp. Figure 2-17 shows how the ground clamp attaches to the pipe.

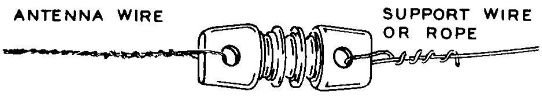
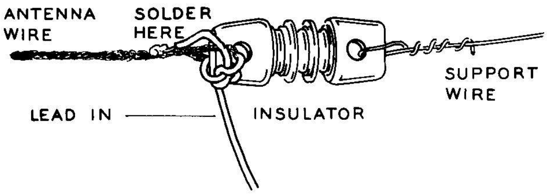


Figure 2-18 INSULATORS SEPARATE ANTENNA WIRE FROM SUPPORT WIRE (OR ROPE).

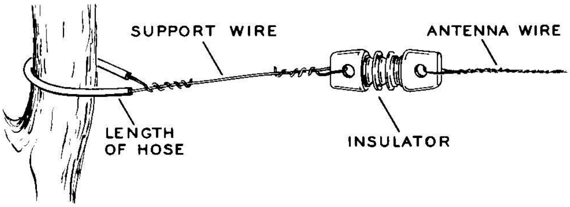
To construct the antenna itself, antenna and support wires are connected through the holes in the insulators and securely twisted as shown in Figure 2-18.



LEAD-IN WIRE IS SOLDERED TO ONE END OF ANTENNA.

Figure 2-19

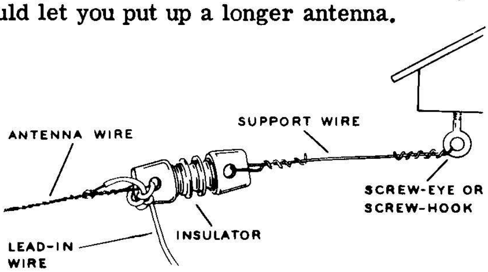
Lead-in wire must be attached and soldered at the end of the antenna nearest your work area. This is illustrated in Figure 2-19. Knotting the lead-in wire will keep it from pulling back through the insulator hole, and will take strain off of the soldered connection.



USE PROTECTION OVER WIRE AND LEAVE SOME SLACK WHEN TYING TO A TREE.

Figure 2-20

When a tree is used as a support for the antenna, the antenna support wire should be tied in such a way that the tree is not injured. A length of rubber hose will serve as a pad. Leave enough slack in the antenna to allow the tree to sway without breaking the wire. Heavy waterproof cord, or rope, may be substituted for the support wire at the ends of the antenna if desired. This would have the advantage of conserving wire for use in the antenna itself, and would let you put up a longer antenna.



USE SCREW-EYE OR SCREW-HOOK WHEN TYING TO BUILDINGS.

Figure 2-21

When attaching the antenna to a building, a heavy screw-eye or screw-hook will do the job. This is shown in Figure 2-21.

When you have considered all the factors, made your drawing and your plan, and have decided exactly where your antenna should be, where your work area will be located, and how the lead-in and ground wires will be run to the work area...you will then be ready to install your broadcast antenna system, complete with ground circuit. Now go right ahead and erect the antenna-ground system in preparation for the experiments to come.

LESSON II

QUESTIONS

NOTE: The answers to the questions for Lesson II will be found in the back of the book on Page 84.

1. AC current is doing two things at the same time. It is changing in ________, while at the same time changing in __________.

2. PDC is like AC in that it changes in amount. It is like DC in that the current is always flowing__________________.

3. Audio frequencies range from about_______ cps to _________cps.

4. Radio frequencies range upwards from ________cps, which can be written ____kc.

5. Radio signals convey intelligence either in the form of _______or by audio________.

6. With a modulated radio signal, the frequency remains constant, and intelligence is conveyed by changes in ____________.

7. Station A is located in a direction broadside to your long-wire antenna, while station B is located in a direction in line with the end of your antenna. If the stations are of equal power, and equal distance, which normally would be picked up stronger on your antenna?

LESSON III

WHAT THREE THINGS MUST A RADIO RECEIVER DO?

In your previous lesson the nature and characteristics of a broadcast radio signal were discussed. (See Figure 3-1.) You found out that a broadcast signal was an AC current alternating at a very high frequency (1200 kc was used as an example) and that the amplitude (amount) of energy in this signal changed up and down in time with the audio signal with which it was modulated (1000 cps was used as an example). The announcer's voice, or the sound of the orchestra playing in the studio, was found to be contained in the broadcast signal in the form of these changes in amplitude.

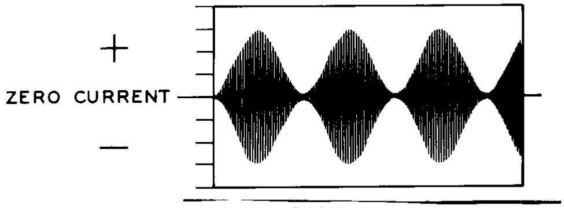


Figure 3-1

Yet, if a loudspeaker were connected to a receiving antenna circuit, no sound would be heard. There are several interesting reasons why a loudspeaker could not produce sound from a radio signal as it is picked up from the antenna.

First, the form of modulated broadcast signal, as sent out by the transmitter, is not such that it will operate a loudspeaker or an earphone. It needs to be "decoded," so to speak, to recover the audio signal that originated in the studio. Remember, only an audio signal can operate a loudspeaker or earphone.

Secondly, the signal on the antenna is so small and weak that it could not operate a speaker, and would be faint in an earphone, even if it were in the proper condition to perform this function.

And finally, since no means of selection is provided, there would not be just one signal involved, but many signals being picked up by the antenna. Even if the signals were strong enough, and were of the proper form to operate a speaker, all stations in the area would be heard at the same time, and would interfere with each other.

This discussion of the deficiencies of a signal when it reaches the antenna must suggest to you the three main functions that a broadcast receiver must perform. It must first select the desired signal, then it must amplify the signal so that its strength is built up, and then it must detect the signal, or in other words, transform modulated radio frequency signal into its original audio signal form. Knowing that these are the three main functions a receiver must perform before the signal is ready to operate a speaker, will help you to understand how a broadcast receiver operates.

RECEIVER CIRCUIT

A much-simplified block diagram of a broadcast receiver with speaker is shown in Figure 3-2. You will notice that the receiver divides roughly into three sections: the radio frequency section, the detector section, and the audio frequency section.

The radio-frequency section (RF section) picks up the signal from the antenna and performs two functions. First it "tunes" the signal. In other words, it selects one signal and rejects all others, so the radio does not pick up more than one station at a time. In addition, the radio-frequency section also amplifies the modulated radio-frequency signal in what are called RF amplifiers. This builds up the signal strength in preparation for sending it on to the next receiver section.

BLOCK DIAGRAM OF BROADCAST RADIO RECEIVER.

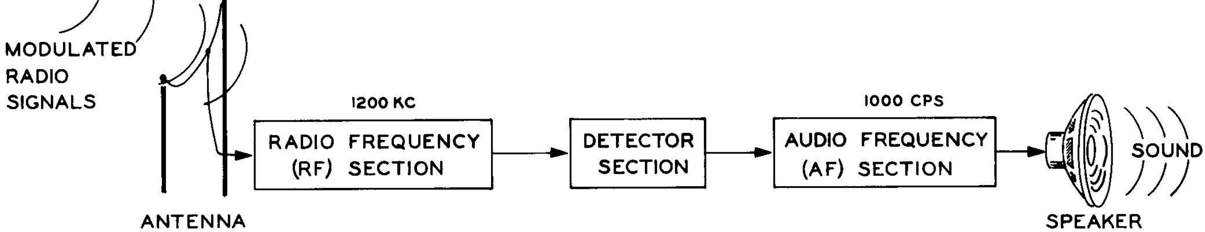


Figure 3-2

The dectector section (still referring to Figure 3-2) restores the audio signal from the modulated RF signal. This section is sometimes called the "demodulator" section. An important point to remember about the detector is that while it is fed a modulated radio frequency signal, its output is an audio frequency signal. The detector is the receiver section where the audio signal (sound in electrical form) from the announcer's voice or the orchestra, is restored to its original form.

Following the detector section is the audio frequency section. The main function this section of the set performs is to amplify the audio signal in strength and power to a level where it is strong enough to operate an earphone or a loudspeaker. Loudspeakers, of course, require more power for operation than earphones. The speaker, then, converts the electrical audio signal back into sound again by vibrating its cone.

TUNING

Figure 3-3 shows the things taking place in the three sections of the receiver in a little more detail.

The RF (radio frequency) section of the average receiver will very likely consist of about three tube circuits, and each circuit, in turn, amplifies and tunes the signal. The tuned circuit at the input of the first radio frequency amplifier, and the tuned circuits at the inputs of the two following amplifiers, are each capable of tuning signals in the broadcast range, and when all three tuned circuits are operating together, the result is sharp signal selection. The more tuned circuits the signal passes through, the sharper the tuning becomes. Each circuit in the RF section must be tuned, since the 1200 kc broadcast signal (the example used earlier) must pass through all three circuits before reaching the detector. Eliminating any one of these three tuned circuits would broaden the tuning of the set.

The broadcast signal, when it reaches the detector, is exactly the same as when it was picked up on the antenna, except that it is now much stronger, and is the only signal reaching the detector because of the rejection accomplished by the tuned circuits. The functions of selection and amplification, have therefore been accomplished by the circuits in the RF section, so far as the incoming signal is concerned.

AMPLIFICATION

After the detector circuit converts the incoming signal back to an audio frequency again (Figure 3-3), this audio signal is still rather small, and is not strong enough to operate a loudspeaker. Therefore, two audio amplification circuits are added to build the signal up to a higher level so it will have the strength to drive the speaker cone and vibrate the air to produce sound. One of the differences between these audio frequency amplifiers and the radio frequency amplifiers is that no tuning is involved in the audio circuits. The signal has already been tuned, and has been converted from a radio frequency down to an audio frequency, by the detector, and these audio amplifiers will pass most frequencies in the audio range.

FUNCTIONAL BLOCK DIAGRAM OF BROADCAST RADIO RECEIVER.

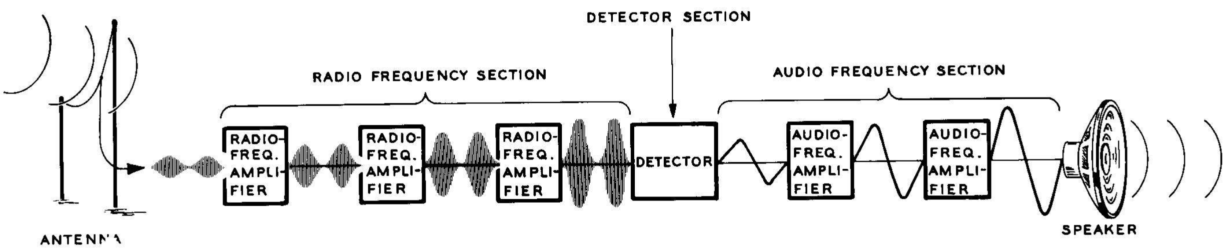


Figure 3-3

DETECTION

Detection is, again, the "decoding" kind of operation that must be performed on the incoming signal if it is to be restored to its original audio signal form. The detector in a receiver may be thought of as the point in the radio circuit where the signal is transformed from modulated RF (radio frequency) to audio, and it is always located between the RF section and the audio section.

Rectification, which was mentioned earlier in connection with the various graphs, is an important part of the detection process. In fact, the experiment that follows lets you demonstrate rectification with a crystal diode. A more detailed explanation of the process of detection will be provided in Lesson IV, following the experiment in rectification.

The important thing to remember at this point is that in order to detect the signal, the signal must be rectified. On this note, your attention should be directed to the experiment that follows.

HOW TO RECTIFY CURRENT AND VOLTAGE WITH A CRYSTAL DIODE

PURPOSE

TO SHOW THAT A RECTIFIER PASSES CURRENT (OR VOLTAGE) IN ONE DIRECTION AND BLOCKS CURRENT (OR VOLTAGE) IN THE OPPOSITE DIRECTION.

MATERIALS REQUIRED

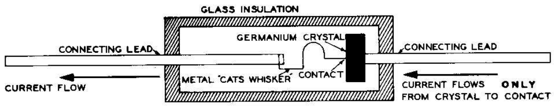
1 12,000 ohm (12 K ohm) resistor

1 Crystal diode

2 "C" cells with battery holders*
Hookup wire
EK-1 Test Set (or equivalent)*

*The items marked with an asterisk in the list of materials required are available to you if you completed the EK-1 Kit. Undoubtedly you did follow this procedure so these materials may be used to conduct this experiment. However, since completion of the EK-1 in Basic Electricity is not a prerequisite to kit EK-2A, a few customers may not have these items. Should this be your case, the "C" cells can simply be soldered together with wires instead of using the battery holders to make up the circuits. Any test set that will measure resistance and DC voltage may be used in place of the EK-1 Test Set in this experiment.

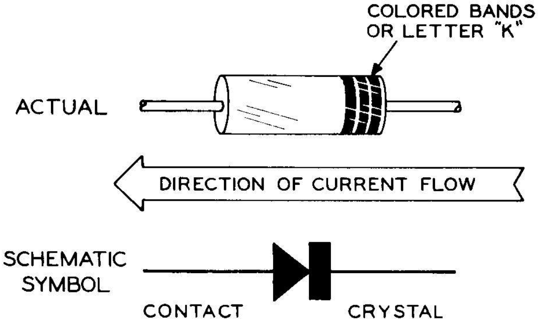
STEP 1 - BECOMING FAMILIAR WITH THE PARTS



FUNCTIONAL DIAGRAM OF CRYSTAL DIODE SHOWING DIRECTION OF CURRENT FLOW.

Figure 3-4

The crystal diode required in this experiment is a rectifier, and is actually a modern version of the old "cats whisker" arrangement used in crystal radios back in the very early days of radio. Figure 3-4 shows the physical construction inside a crystal diode. Inside the glass envelope, which serves as insulation, is a small crystal of germanium material, with a hair-like metal whisker in contact with it. The unusual feature of this small metal point in combination with the crystal, is that current will flow from the crystal into the contact and out through the wire, but will not flow in the reverse direction, from the contact back into the crystal. The physical properties of the crystal material that make this possible are not especially important to you at this time. However, it is important that you understand (and demonstrate) that current can only flow from crystal to contact, and will be blocked if it attempts to flow from contact to crystal.



ONE-WAY CURRENT FLOW IN A CRYSTAL DIODE - ACTUAL, AND SCHEMATIC SYMBOL.
Figure 3-5

Figure 3-5 shows the external physical appearance of the crystal diode, and also the symbol normally used to represent a crystal diode in a schematic circuit. The bands on the outside of the glass diode housing are always at the same end as the crystal. Therefore, current can flow into the banded end of the crystal and out the other end, but will not flow in the reverse direction. The arrow in the schematic symbol for a crystal diode symbolizes the contact whisker, and the block, at the point of the arrow, symbolizes the crystal itself. Therefore, the current can flow only in a direction opposite to the arrow in the schematic symbol (Figure 3-5).

There are many different types of rectifiers. Some are designed for light-duty work (as is your crystal diode rectifier) while others are designed to rectify heavy currents and voltages in power circuits. Some are crystal types, some are vacuum tube types, others are chemical and mechanical in their operation. However, the effect of rectification remains the same. They are all "one-way" current devices.

STEP 2 - TESTING THE ONE-WAY EFFECT WITH YOUR OHMMETER

( ) Use your EK-1 Test Set (or equivalent) as an ohmmeter and connect the crystal diode rectifier to the leads as shown in Figure 3-6 to measure its resistance. Note that the red test lead should connect to the banded end of the rectifier, and the black test lead should connect to the other end.

SPECIAL NOTE: If you are using an ohmmeter other than the EK-1 Test Set, you may find that your results are just the opposite of those given below. This would merely show that the ohmmeter circuit of the tester you are using is reversed to that of the EK-1. The "one-way" characteristic of the diode is still quite apparent even if your readings are reversed.

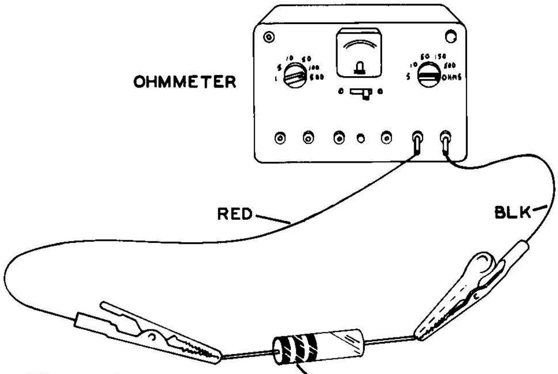


Figure 3-6

( ) Set the range knob to "ohms" and press the "LO" ohms button of the EK-1 Test Set. Observe the resistance reading obtained. It will probably be near 200 ohms. This is the forward resistance of the rectifier.

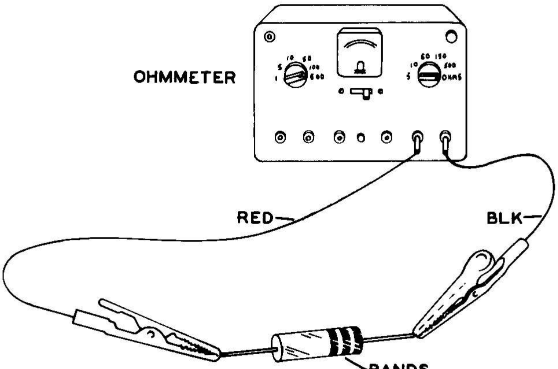


Figure 3-7

( ) Now reverse the connections to the rectifier as shown in Figure 3-7, so the black lead is connected to the banded end of the rectifier, and the red lead to the opposite end.

( ) Again, observe the resistance reading. You should find that it is a very high resistance value, probably beyond the range of your ohmmeter. This is the backward resistance of the rectifier.

STEP 3 - MEASURING VOLTAGE THROUGH A RECTIFIER

( ) Connect two flashlight cells in series, (see Figure 3-8A) using the battery holders from the EK-1 kit, or solder the hookup wire directly to the cells.

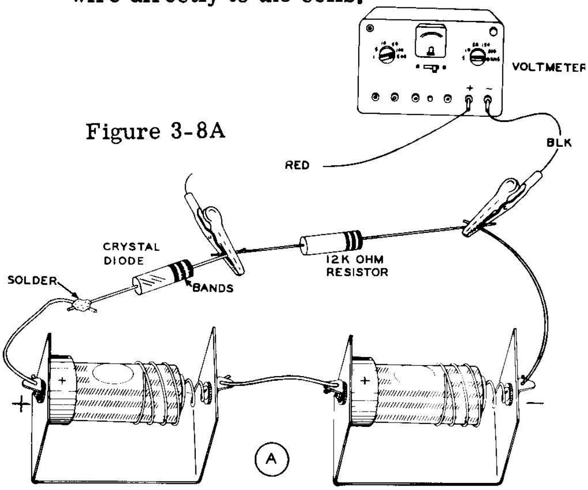


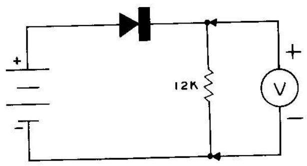
Figure 3-8A

CAUTION: Excessive heat can damage the crystal diode rectifier...so hold the diode lead with long-nosed pliers when soldering so as to conduct heat away from the body of the part. This procedure should be followed whenever crystal diode leads are soldered in any of the experiments.

( ) Connect the unmarked lead of the crystal rectifier to the plus battery lead. (See Figure 3-8A.)

( ) Connect a 12 K ohm (12,000 ohm) resistor from the banded end of the crystal rectifier to the minus battery lead, as shown in Figure 3-8A.

( ) Adjust the EK-1 Test Set for voltage measurements on the 5 V range and connect the black lead to the minus battery lead and the red voltmeter lead to the crystal rectifier lead as shown in Figure 3-8A. A schematic of this circuit is shown in Figure 3-8B.



(B) Figure 3-8B

( ) Note the voltage indicated by the meter. This is the reading you get when measuring voltage across the 12 K resistor (in series with the crystal rectifier) with the rectifier connected properly to pass current through the resistor.

( ) Reverse the connection of the crystal rectifier in the circuit as shown in Figure 3-9A.

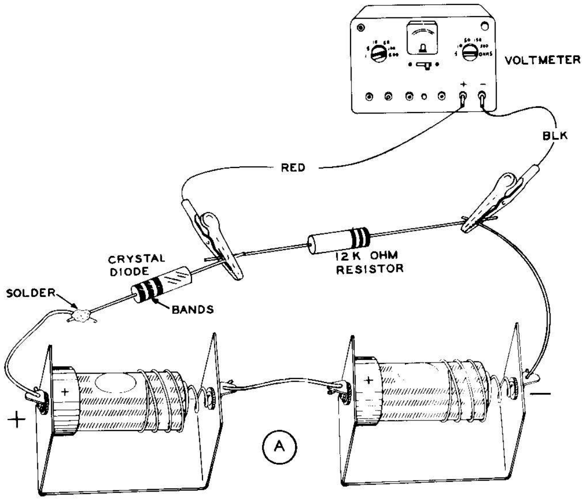
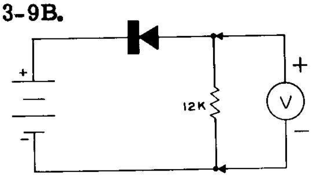


Figure 3-9A

A schematic of this circuit is shown in Figure 3-9B.



(B) Figure 3-9B

( ) Again, connect the test leads as shown and observe the meter. This is the result you get when attempting to measure voltage across the 12 K series resistor with the rectifier connected to block current through the resistor.

( ) You may now disassemble this circuit since this completes the experiments in this lesson.

DISCUSSION

The experiments just conducted prove quite clearly that a crystal rectifier is a "one-way" device.

Measuring the resistance of the rectifier in one direction shows a forward resistance of only about 200 ohms. This low resistance value can be ignored in most circuits in which a rectifier of this type would be used, and the rectifier can be considered as a fairly good conductor.

Measuring the resistance of the rectifier in the opposite direction shows a very high resistance reading, practically equivalent to an open circuit. A crystal diode, therefore, acts like a conductor when current flows in one direction, and like an open circuit when current attempts to flow in the opposite direction. This is what makes it a "rectifier."

In the voltage part of the experiment, your results show that (with the crystal rectifier connected one way) the crystal passes current through the series circuit, causing voltage to appear across the 12 K resistor due to the current flow through it. But when the crystal rectifier is reversed (so it blocks current) no voltage appears across the resistor because no current flows in the circuit.

A crystal rectifier is clearly a one-way device for current, and this characteristic of the part is quite important in electronic circuits. An AC current, for example, in which current flows first in one direction and then in the other, can be passed through a rectifier and one direction of current flow will be blocked, eliminating half of the waveform. Detection in a radio receiver depends on rectification to eliminate one half of the AC signal being fed to the detector stage, from the RF section of the set.

You are now ready to proceed with the next lesson and find out more details about detection and detector circuits.

LESSON III

QUESTIONS

NOTE: The answers to the questions on Lesson III will be found in the back of the book on Page 84.

1. What are the three things a receiver must do? Select amplify detect change to sound vibration

2. What are the three main sections of a radio receiver? RF Det, AF

3. What two main things does the RF section do? Select, Amplify

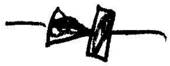
4. What one main thing does the detector do? Change to audio

5. What one main thing does the audio section do? amplify & change

6. Current will flow through your crystal diode rectifier from:

   Contact to crystal?
   Crystal to contact? ✓

7. Draw the schematic symbol for a crystal diode rectifier.



8. The banded end of your crystal diode rectifier is the end connected to the:
   Crystal? ✓
   Whisker contact?

9. AC current that has been rectified becomes:

   DC? PDC? ✓

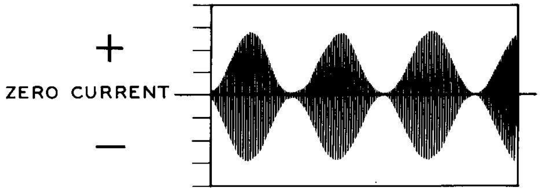
Direction – → +

LESSON IV

WHAT IS A DETECTOR CIRCUIT?

You have learned many facts so far about the composition of a radio broadcast signal, including the way the radio frequency is modulated by the audio frequency. You have seen how a radio receiver must tune and amplify this signal to build up its strength, and then how (after detection) the audio signal is amplified again, to operate the speaker. You learned that the detector is the part of the set that translates the incoming broadcast signal back into an audio signal again, and in this lesson you will find out more about how a detector operates. As the experiment for this lesson you will actually build a detector circuit and connect it to your antenna to pick up local broadcast stations.

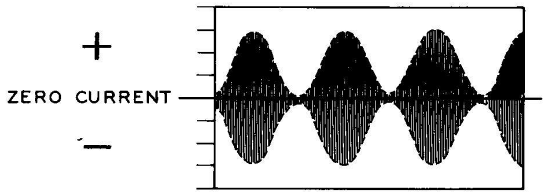
DETECTION



MODULATED BROADCAST SIGNAL.

Figure 4-1

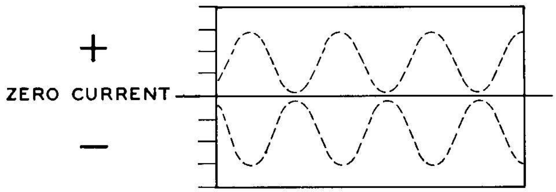
You should recall the graph of a modulated broadcast radio signal from an earlier lesson (Figure 4-1). The current contained in the signal is at an RF frequency within the broadcast band (say 1200 kc) and the amplitude or amount of signal comes in "swells." These swells occur at a frequency in the audio range (say about 1000 cycles per second). The signal you want to hear is represented in the "swells," and the problem is to extract, somehow, this audio signal from the modulated broadcast signal.



CHANGES IN AMPLITUDE OF RADIO SIGNAL PRODUCE THE SHAPE OF AUDIO SIGNAL.

Figure 4-2

The changes in amplitude that constitute the 1000 cps audio signal in the received broadcast signal, increase in both the positive and the negative direction at the same time. If this signal were to be strengthened and fed to an earphone or speaker, the reproducing device would not respond to the individual 1200 kc RF pulsations because the mechanism of an earphone or speaker could not operate that fast. Neither, however, could the speaker or earphone respond to the audio frequency change in signal amplitude, because the changes cancel themselves out. This can be seen if dashed lines are drawn to follow the peaks of the RF pulses in the modulated signal (see Figure 4-2). Notice that as the signal swells in the positive direction, it also swells in the negative direction, and these two opposing swells cancel each other because they are exactly equal and opposite.



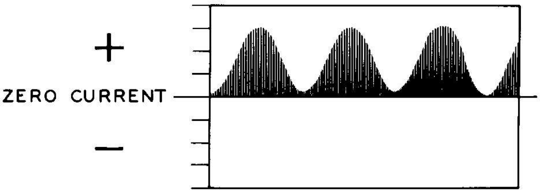
AMPLITUDE CHANGES IN THE SIGNAL ARE DUPLICATED, PLUS AND MINUS, RESULTING IN CANCELLATION.

Figure 4-3

In Figure 4-3 the individual radio frequency cycles have been left out to show more clearly the fact that the changes in amplitude (representing the audio signal) are actually duplicated on the negative side of the graph as well as the positive side, so that effectively there is no audio signal so far as a speaker or an earphone is concerned, because of cancellation.

RECTIFICATION

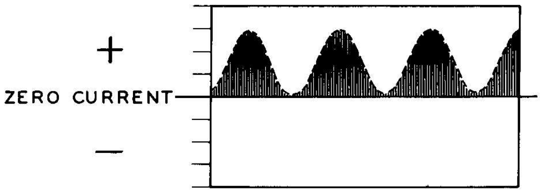
The main step in extracting the audio signal from a modulated broadcast signal is to rectify the signal by passing it through a one-way current device. A crystal diode, like the one described and demonstrated in your last lesson, has the effect of eliminating either the plus or the minus half of the modulated broadcast radio signal. (See Figure 4-4.) The rectifier will permit current to flow in only one direction, and the waveform that results from this process is shown in Figure 4-4. Notice that rectification eliminates one direction of current



RECTIFYING BROADCAST SIGNAL ELIMINATES EITHER PLUS OR MINUS HALF OF RADIO FREQUENCY SIGNAL.

Figure 4-4

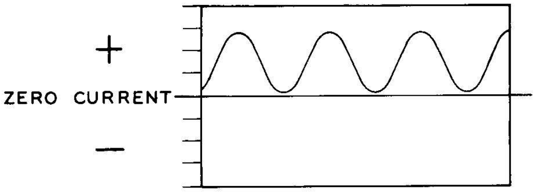
flow in the signal. The "half signal" remaining has all the characteristics of the original broadcast signal, including the changes in amplitude that represent the audio signal. The cancellation observed in the whole signal is not present in the remaining half signal. (Figure 4-4.)



AMPLITUDE CHANGES REPRESENTING THE AUDIO SIGNAL ARE ALL IN ONE DIRECTION AFTER RECTIFICATION.

Figure 4-5

Figure 4-5 shows the rectified half signal with dotted lines tracing out the audio shape of the changes in amplitude. Since all these changes in amplitude of a rectified signal are in the same direction, an earphone or a speaker can respond to these changes by following them up and down. There is now no matching change in the opposite direction to cancel the audio signal. As mentioned before, the earphone or loudspeaker cannot vibrate at 1200 kc (the RF frequency), so it will follow the amplitude changes, which are much slower, and are within the audio frequency range. The earphone and loudspeaker ignore the radio frequency pulsations and respond only to the changes in amplitude. This audio signal causes the speaker or earphone to vibrate air and create sound. In effect, therefore, the signal to which the earphone or loudspeaker responds has the shape of the signal shown in Figure 4-6. (The rectified signal with the radio frequency pulsations eliminated.)



EARPHONE OR SPEAKER RESPONDS ONLY TO SLOWER AUDIO FREQUENCY, EFFECTIVELY ELIMINATING THE RADIO FREQUENCY PULSES.

Figure 4-6

FILTERING

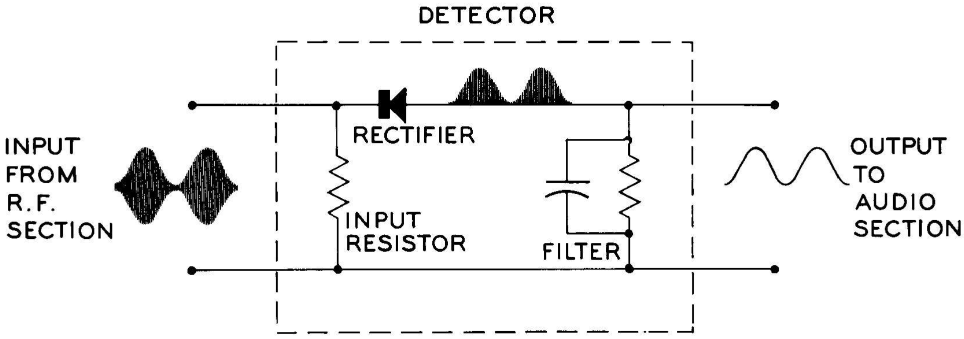
This effect, of the earphone or speaker slurring over from one RF peak to another to round off the quick little radio frequency pulses, is a kind of mechanical filtering. The speaker or earphone has the effect of filtering and "filling-in" the spaces between the quick pulsations, to follow the slower changes in amount of signal. This happens because its mechanism just cannot move fast enough to follow the radio frequency pulsations.

The two functions involved in detection, therefore, are rectification and filtering. In a very simple circuit where an earphone is operated directly from a detector, the detector needs only to perform the operation of rectification. Filtering is taken care of automatically by the response of the earphone or speaker to only the audio signal.

In a more elaborate circuit, however, where an audio amplifier may appear between the detector and the loudspeaker, a capacitor-resistor combination may be added to the circuit to perform this filtering electrically. Filtering helps complete the transformation from a modulated RF signal to an audio frequency signal, by eliminating any RF signal remaining in the detector circuit.

A typical detector circuit schematic is shown in Figure 4-7, along with waveforms showing the detecting process. Notice that the input signal from the RF section, developed across the input resistor, is a modulated RF signal.

The rectified RF signal shows up beyond the crystal rectifier in the circuit...and the audio signal shows up at the output, beyond the resistor-capacitor filter circuit.



THE DETECTOR CIRCUIT RECTIFIES AND FILTERS THE MODULATED RF SIGNAL AND PRODUCES AN AUDIO SIGNAL.

Figure 4-7

Now that you have seen how detection takes place in a radio circuit, by the process of rectification, and then filtering, you can proceed with the experimental section of Lesson IV, to build a simple crystal detector and connect it to your antenna to hear local stations with the earphone.

HOW TO BUILD A RADIO SIGNAL DETECTOR

PURPOSE

TO ASSEMBLE AND OPERATE A SIMPLE RADIO RECEIVER CONSISTING OF A CRYSTAL DETECTOR CIRCUIT, AN EARPHONE, AND THE LONG-WIRE ANTENNA CONSTRUCTED IN LESSON II.

MATERIALS REQUIRED

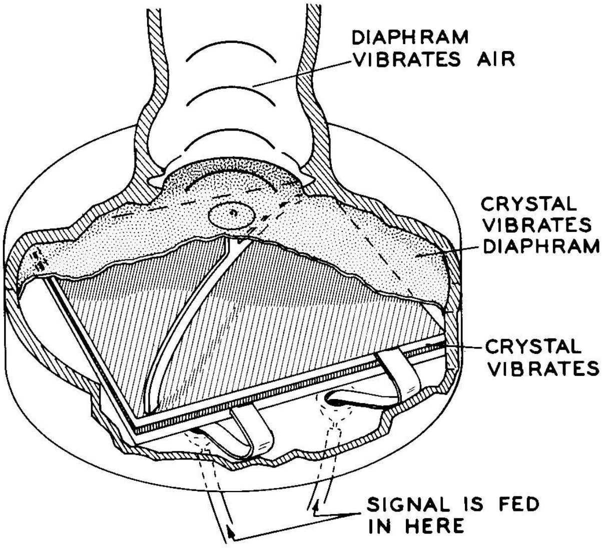
1 3.3 megohm resistor
1 "T" type terminal strip
1 Earphone
1 Earphone jack
1 Earphone plug
1 2-lug, screw-type connector
1 #6 solder lug
7 #6 screws, lockwashers and nuts
1 Chassis
2 Chassis end plates
1 Label sheet

STEP 1 - BECOMING FAMILIAR WITH THE PARTS

The earphone required in this experiment is new to you, and this would be an appropriate time to learn something more about sound reproducers. It is already quite apparent from the discussions that have gone before that when a sound reproducer (speaker, earphone, etc.) is fed an audio signal (sound in electrical form) it is capable of converting this signal into vibrations of the air, or actual sound. Some reproducers accomplish this by magnetic and electromagnetic means, wherein the signal acts in a coil of wire, causing the coil to become an electro-magnet. Since the coil of wire is in the field of a permanent magnet, it will move back and forth (moving the cone of the speaker) in step with the signal applied to it. Other means are employed to achieve this effect also; and the earphone used in your experiments is of the crystal type.

Certain kinds of mineral crystals, both natural and artifically grown, when cut to the proper shape and size, will vibrate when an audio signal is connected to them. The vibrations that result follow very closely the amplitude variations (size changes) of the audio signal being fed to the reproducer. This is how your earphone makes sound.

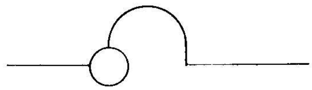
As you can see in Figure 4-8, the crystal in your earphone is tied mechanically to a diaphram designed to vibrate the air reaching your ear, in step with the crystal vibrations. The crystal itself is the element that changes electrical vibrations into mechanical vibrations,



INTERNAL CONSTRUCTION OF THE CRYSTAL-TYPE EARPHONE.

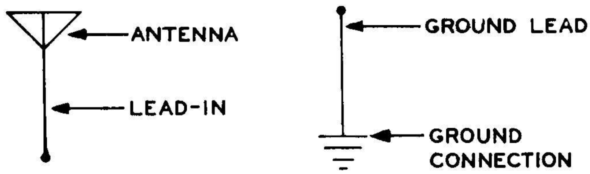
Figure 4-8

so that the earphone can convert an audio signal into sound. This type of earphone is commonly referred to as a "crystal earphone." Its schematic symbol is shown in Figure 4-9. The schematic symbol for the antenna-ground circuit is shown in Figure 4-10. The schematic circuit diagram for the crystal circuit you are about to build is shown in Figure 4-11.



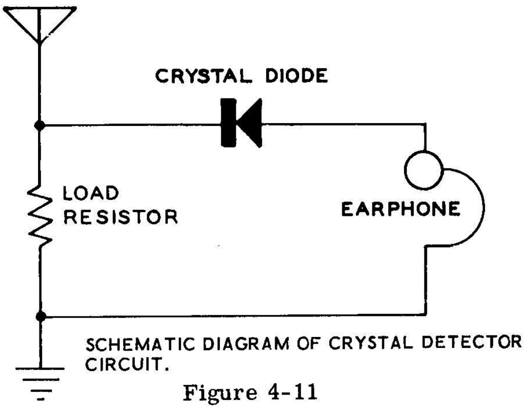
SCHEMATIC SYMBOL FOR EARPHONE.

Figure 4-9



SCHEMATIC SYMBOL FOR ANTENNA-GROUND CIRCUIT.

Figure 4-10



SCHEMATIC DIAGRAM OF CRYSTAL DETECTOR CIRCUIT.

Figure 4-11

STEP 2 - MOUNTING THE PARTS

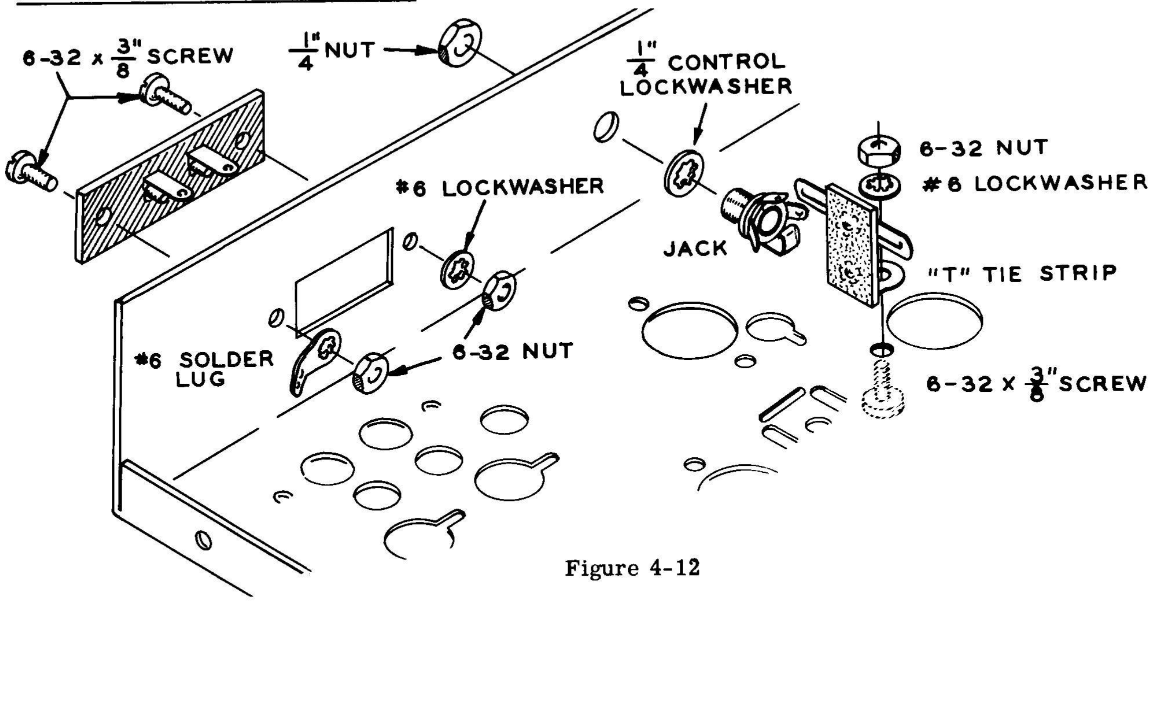


Figure 4-12

( ) Mount the 2-lug, screw-type antenna-ground connector and the phone jack as shown in Figure 4-12. The various hardware used, including the #6 solder lug, is clearly identified in the illustration. Be <u>sure</u> to position the phone jack so the terminals are as shown in Figure 4-12.

( ) Mount a "T" type tie strip, using a 6-32 x 3/8" screw, lockwasher, and nut, as shown in Figure 4-12.

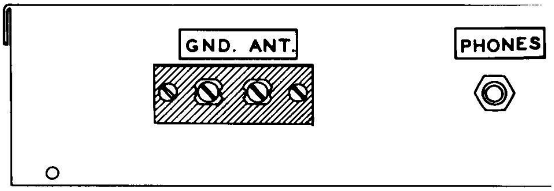


Figure 4-13

( ) Cut the "GND. ANT." label from the label sheet. Remove the backing from the label and press it in place above the antenna-ground connector as shown in Figure 4-13.

( ) Also place the "PHONES" label as shown in Figure 4-13.

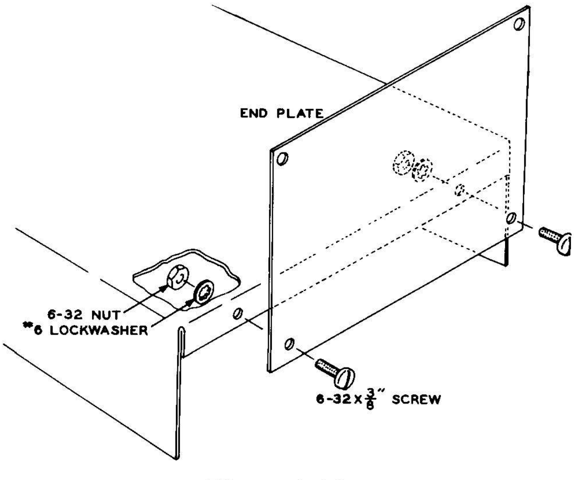
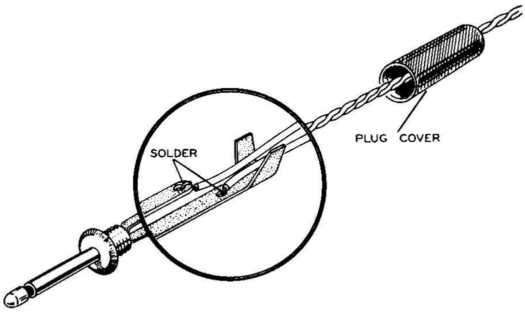


Figure 4-14

( ) Mount the metal end plates on each end of the chassis using 6-32 screws, lockwashers, and nuts. (See Figure 4-14.)

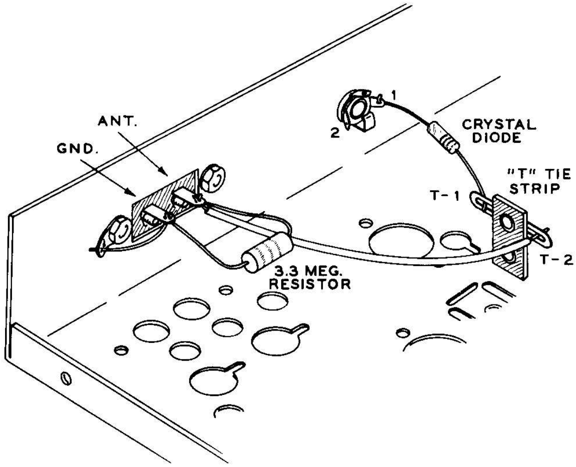


CONNECT EARPHONE LEADS TO PHONE PLUG.

Figure 4-15

STEP 3 - WIRING THE CIRCUIT

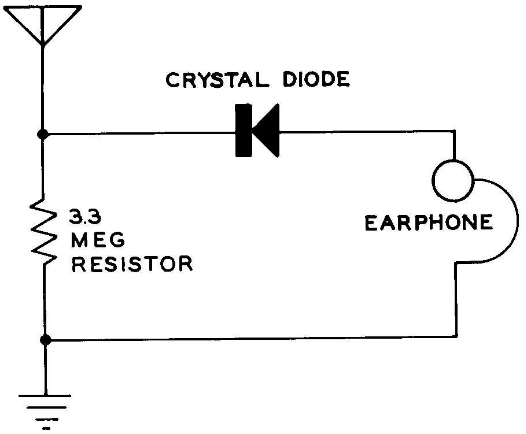
( ) Connect the earphone wires to the phone plug by first unscrewing the plug cover from the plug, and sliding this over the earphone wires. Then solder either wire to the center terminal of the plug, and the other wire to the outside terminal. (See Figure 4-15.)



PICTORIAL VIEW OF CRYSTAL DETECTOR.

Figure 4-16

The circuit of this experiment should be wired by following the pictorial diagram in Figure 4-16, and the schematic diagram of the circuit in Figure 4-17. In addition, step-by-step instructions are provided to suggest the order of assembling the components. You will profit most from the experience of wiring the circuit if you check your work not only against the pictorial dia-



ANTENNA-GROUND CURRENT THROUGH 3.3 MEGOHM RESISTOR DEVELOPS SIGNAL VOLTAGE FOR DETECTOR

Figure 4-17

gram, but also against the schematic, so that the relationship between the schematic drawing and the actual wiring under the chassis will be appreciated. The step-by-step instructions are merely to assist you in remembering to put in every part and wire. Actually, you can wire directly from the pictorial and the schematic, and merely use the step-by-step instructions as a check on your work, after the wiring has been completed.

( ) Connect a short length of bare wire between the "GND."terminal of the 2-lug antenna-ground connector, and the ground lug adjacent to it. (See Figure 4-16.)

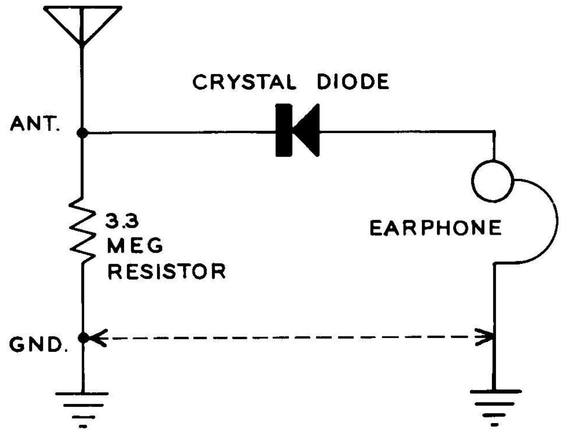
( ) Connect a 3.3 megohm resistor (orange-orange-green) between the "GND." and "ANT." terminals of the screw-type connector. Resistor color code is explained on the inside cover of your manual.

( ) Connect one end of a wire to the "ANT." terminal of this same connector, and the other end of the wire to terminal T2 of the "T" tie-strip. (See Figure 4-16.)

( ) Connect the crystal diode between terminal T-1 of the "T" tie-strip and terminal 1 of the earphone receptacle, as shown. CAUTION: The crystal diode leads should not be shortened when it is connected into the circuit. The banded end of the diode connects to T-1. Do not overheat the diode when soldering.

This completes the wiring of the circuit.

You will observe that one portion of the circuit is completed through the chassis itself. The schematic shows a connection between one side of the earphone and the ground lug of the antenna-ground connector strip. Yet no wire is provided between these two points because the construction of the earphone receptacle is such that the shaft of the earphone plug is in contact with the bushing, and this bushing, in turn, connects to the chassis. The ground lug of the terminal strip is also connected to the chassis through an adjacent solder lug, so that chassis takes the place of a wire between these two points. Compare the schematic to the pictorial diagram and to the actual wiring to clear this up in your mind. The schematic has been redrawn in Figure 4-18 to show how the ground connection effectively completes the circuit.



CIRCUIT COMPLETED THROUGH CHASSIS AS SHOWN BY DASHED LINE.

Figure 4-18

STEP 4 - USING THE CRYSTAL DETECTOR

To operate the crystal detector you have constructed, it is necessary only to plug in the earphone, and connect the antenna and ground leads under the appropriate screws of the antenna-ground connector on the chassis.

If your local broadcast situation is such that you are picking up a strong signal on your antenna, you should be able to hear the station in the earphone. If the signals in your area are weak, you may not hear a station in this experiment. On the other hand, if you have several very strong signals in your locality, you may hear several stations at the same time when listening through the earphone. Disconnect the antenna and ground leads and remove the earphone plug after you have completed these listening tests.

DISCUSSION

Only fair performance should be expected from the circuit just completed because, after all, it represents merely the detector section of a receiver. It provides no tuning, no RF amplification, and no audio amplification. It could only be considered satisfactory as a radio if your location were such that there were a single strong station that could be picked up without interference from other stations. Even then, listening would be limited to one person at a time by the earphone.

This experiment does serve to demonstrate, however, that an antenna, a detector, and an earphone, can function as a very limited kind of "radio," without tubes, batteries, coils, power line voltage, or any of the more complicated electronic components normally associated with a radio set.

A quick review of the principles of operation involved would show that the modulated broadcast radio signal is picked up by the antenna, and causes alternating radio frequency current to move back and forth from the antenna to ground, through the 3.3 megohm resistor connected between the antenna and ground. (See Figure 4-18.) This alternating signal current through the resistor causes the signal voltage to appear across the resistor, and this voltage can be considered as the modulated RF broadcast signal. The signal is then rectified in the crystal diode, and is heard as audio in the earphone since "mechanical" filtering is accomplished by the earphone itself in a circuit of this type.

In the experiment of Lesson V you will modify this circuit to improve its performance and extend its functions closer to those of a conventional radio receiver.

LESSON IV

QUESTIONS

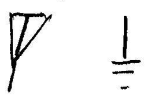
NOTE: The answers to the questions on Lesson IV will be found in the back of the book on Page 84.

1. What main function in the detection process is performed by the crystal diode? charge to audio and rectify current

2. What other function usually must be performed by a resistor-capacitor combination in a detector circuit? filter signal

3. Draw the schematic symbol for an earphone.

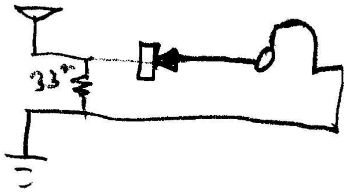
4. Draw the schematic symbols for the antenna-ground circuit.



5. Draw the schematic symbol for a resistor.

6. Draw the schematic symbol for a crystal diode and show the direction in which current will flow (by drawing an arrow beside it).

7. Without referring back to text illustrations, draw the complete schematic diagram of the circuit constructed in this experiment.



8. This experiment shows that, of the three main sections of a radio receiver, a simple receiver can consist of just the detector section, plus an antenna and earphone.

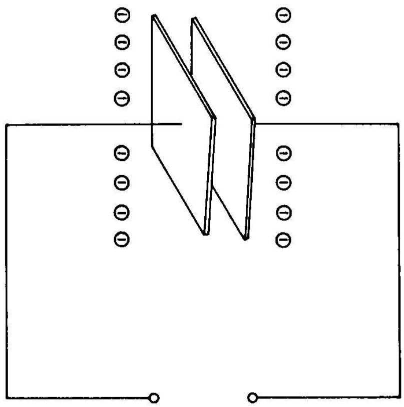
LESSON V

WHAT IS A TUNED CIRCUIT?

Your earlier lessons have attempted to show that "selectivity" is desirable and necessary in a radio receiver. Some means is required, in any receiver, to tune one particular station while others are rejected. The usual "tuned circuit" consists of a coil and a capacitor connected together in such a way that they are "resonant" at a certain frequency. Under these conditions, the circuit will accept a broadcast radio signal at the "resonant" frequency, but will reduce the level of all other signals.

The idea of "resonance," and the characteristics of capacitors and coils that make tuned circuits possible, need some further explaining. You should be familiar with these ideas before constructing the tuned circuit and adding it to the detector circuit built up in the previous lesson.

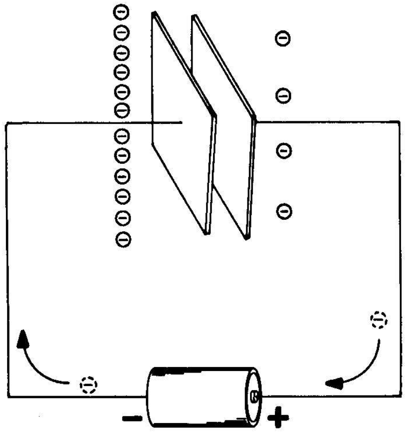
CAPACITORS AND CAPACITY



A SIMPLE CAPACITOR CONSISTING OF TWO METAL PLATES FACING EACH OTHER BUT NOT TOUCHING.

Figure 5-1

A very simple capacitor can consist of two closely-spaced (but not touching) metal plates, as shown in Figure 5-1. Since the wires connected to these metal plates are not connected to any source of electrical energy, it may be assumed that the plates are "in balance" as far as electrical charge is concerned. Both metal plates contain normal numbers of electrons (symbolized by the minus signs next to each plate). Air acts as the insulation between the two plates.



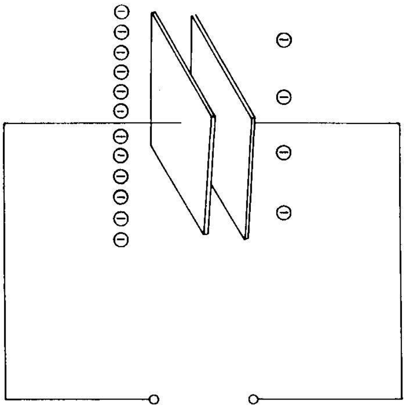
ELECTRICAL PRESSURE FROM BATTERY "CHARGES" CAPACITOR.

Figure 5-2

One of the unusual things about a capacitor is that when a source of electrical energy is connected to its plates (for example, the battery in Figure 5-2), the electrical pressure in the battery causes electrons to pile up on one plate, and move away from the other plate. The two plates are not in contact with each other, so the circuit is actually "open" as far as the battery is concerned... yet current does flow in the circuit for a short instant, as the electrical pressure in the battery attempts to force the current around the circuit in the direction indicated by the arrows. This short impulse of current "charges" the capacitor in the sense that extra electrons are accumulated on one plate and drawn away from the other plate. This "unbalanced" condition is shown in Figure 5-2 by the minus signs symbolizing negative charge.

As soon as the battery has exerted all the pressure it can in the circuit, and has moved as many electrons onto one capacitor plate and away from the other plate as it can, the "charged" condition is reached, and no further current flows.

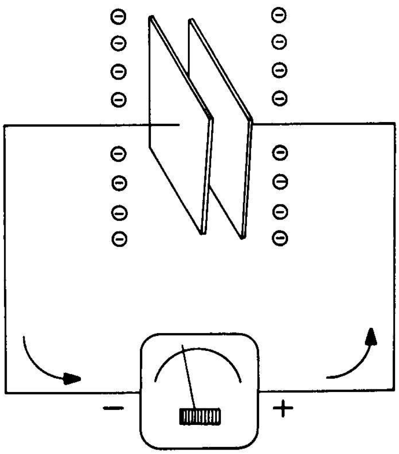
If the battery is then removed from the circuit (Figure 5-3), the charge remains on the capacitor even though the source of energy has been taken away. The charge of the capacitor will remain (barring some leakage through the air) until a circuit is provided to connect the



A CAPACITOR HOLDS THE "CHARGE" PUT ON ITS PLATES.

Figure 5-3

plates together and equalize them again. The capacitor will remain charged, in other words, until a circuit is provided through which current can flow to discharge it. In a sense, a charged capacitor is like a miniature battery since it has energy of its own which it will dispense very quickly as soon as a circuit is provided through which it can discharge.



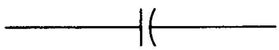
A CAPACITOR DISCHARGES AND NEUTRALIZES ITS PLATES AS SOON AS A CIRCUIT IS PROVIDED.

Figure 5-4

Figure 5-4 shows what happens when a discharge circuit is provided so the capacitor plates may return to "balance" again, with equal amounts of electrons. A meter, connected to complete the circuit from one capacitor plate to the other, would provide a path for the two plates to equalize their charge. Current would flow from the plate with an excess of electrons, around to the plate with a deficiency of electrons (indicated by the arrows) and the meter would actually register a pulse of current as this discharge action took place. The direction of discharge current flow (arrows in Figure 5-4) is just the opposite from the direction of current flow that took place in charging the capacitor (Figure 5-2).

A capacitor, therefore, reacts to circuit current by becoming charged, and then has the capacity to provide current of its own in the process of discharging back through the circuit. If a series of pulses were fed to a capacitor, (and the circuit were closed between pulses to provide a path for the capacitor to discharge), the capacitor would "answer" current pulses by returning "kick-back" pulses of its own.

To put it another way, a quick surge of current applied to a capacitor causes electrons to pile up on one plate and move away from the other plate. The capacitor is thereby charged. When the surge of current stops, the capacitor can send its own surge of current back around the circuit to equalize its plates again. You should keep this important characteristic of capacitors in mind, since the action of a capacitor in a tuned circuit is related to its ability to answer current pulses with pulse reactions of its own. The schematic symbol for a fixed capacitor is shown in Figure 5-5.



SCHEMATIC SYMBOL FOR FIXED CAPACITOR.

Figure 5-5

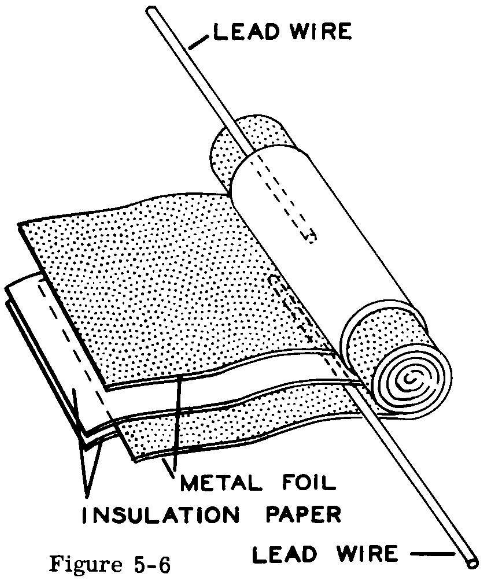
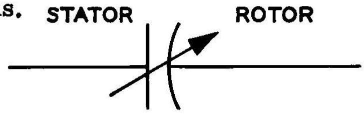


Figure 5-6

ACTUAL CAPACITORS ARE FREQUENTLY MADE OF METAL FOIL AND INSULATING PAPER, WOUND TOGETHER IN A ROLL.

Figure 5-6 shows how the effect of large capacitor plates spaced closely together, but not touching, is achieved in some actual capacitors. A sandwich made of two sheets of metal foil, separated by insulating paper, is wound into a roll to give a large plate area. This keeps the physical size of the capacitor to manageable dimensions.



SCHEMATIC SYMBOL FOR VARIABLE CAPACITOR.

Figure 5-7

The schematic symbol for a variable capacitor is shown in Figure 5-7. You will observe a diagonal arrow across the plates. This symbolizes the fact that the size of the capacitor may be varied.

The physical construction of a common type of variable capacitor is shown in Figure 5-8. Most variable capacitors of this type use air as the insulator between the two plates, and one plate

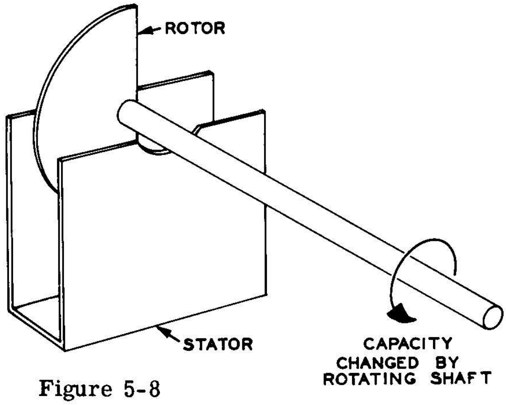


Figure 5-8

VARIABLE TUNING CAPACITOR.

is so arranged that it can be moved in and out of the space between the two opposing plates.

Capacitors are rated in farads, which is a measure of the capacitor's ability to take a charge. The main factors in determining a capacitor's electrical size are the amount of effective plate area, and the distance between the two plates. The closer the plates are together (without touching), and the larger the plate area, the higher the capacity.

The actual capacitors used in electronics are only small fractions of a farad in size, so the terms microfarad (one millionth of a farad), and micromicrofarad (one millionth of a millionth of a farad) are commonly used. As an example of this relationship, note that 1000 micromicrofarads is equal to .001 microfarad, which is equal to .000,000,001 farads. Microfarad is abbreviated mfd, μf or μfd, and micromicrofarad is abbreviated mmf, mmfd, or $\mu\mu$f.

COILS AND INDUCTANCE

When a length of wire is spiralled into a series of circular loops or turns it is referred to as a "coil." Coils have different electrical values depending upon the size of wire, the diameter of the turns, the number of turns, the nature of the material used in the core of the coil, etc. The simplest kind of coil would consist of several turns of wire wound in a circular shape as shown in Figure 5-9.

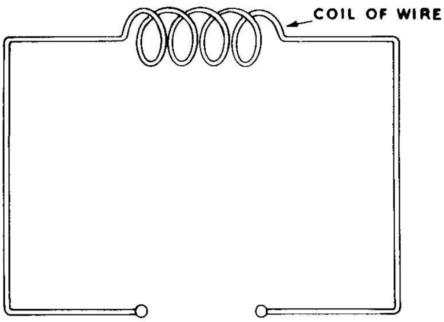


Figure 5-9

If a battery is connected to a coil to cause current flow through it, as in Figure 5-10, a magnetic field springs up through and around the coil, as shown in the illustration. This is the principle put to use in electromagnets, relays, solenoids, etc. The magnetic field surrounding a coil is frequently made to perform work.

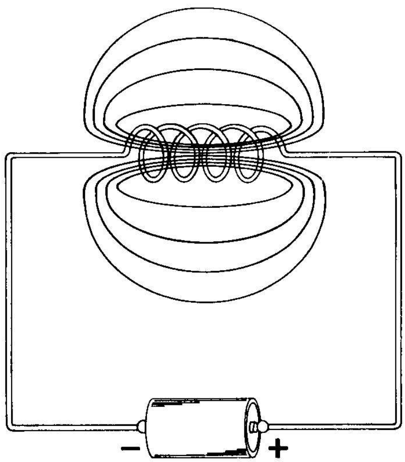


Figure 5-10

The important point to observe here, however, is that so long as the battery is connected to the coil leads, a magnetic field exists through the center of the coil winding, and around the outside of the coil, much like the magnetic field surrounding the north and south poles of a bar magnet.

When the battery is removed from the circuit, the magnetic field around and through the coil collapses. If a complete circuit exists, the magnetic field in the process of collapsing, causes a current to flow through the coil and the rest of the circuit for an instant.

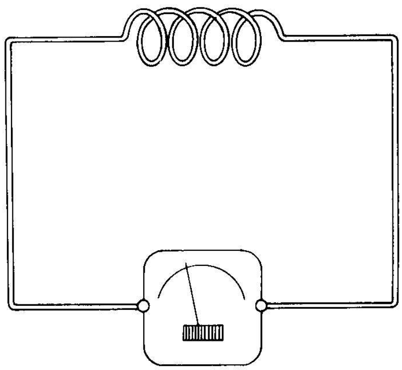
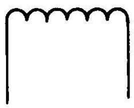


Figure 5-11

If a meter could be inserted in the coil circuit at the same instant that the battery was removed (see Figure 5-11), it would measure a "kick-back" current in the circuit, caused by the collapsing magnetic field. For an instant, the coil itself acts as a source of current and shoots a pulse of its own through the circuit as the magnetic field collapses. If a series of pulses were fed to this coil, instead of the steady DC battery current, you could see that coils have the ability to answer current pulses with pulse reactions of their own. Although the effect takes place for different reasons, coils are similar to capacitors in that they have the same ability to "answer" current pulses with pulse reactions of their own. This principle should be kept in mind as the theory of tuned circuits is examined further.

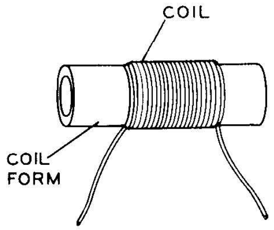
The electrical characteristic of a coil that influences this kick-back action is called inductance. The inductance of a coil depends on the nature of the core on which it is wound, the number of turns, the way the turns are wound, the diameter of the turns, etc. Inductance is measured in "henrys," and most radio frequency coils found in radio circuits are of a size that is measured in millihenrys (thousandths of henrys) or microhenrys (millionths of henrys). Note that 1000 microhenrys (μh) = 1 millihenry (mh) = .001 henry (h).



SCHEMATIC SYMBOL FOR FIXED-INDUCTANCE COIL.

Figure 5-12

The schematic symbol for a fixed-inductance coil is shown in Figure 5-12, and the physical appearance of a typical radio-frequency coil is shown in Figure 5-13.



SIMPLE RADIO FREQUENCY COIL.

Figure 5-13

A variable-inductance coil is shown schematically in Figure 5-14. The arrow drawn through the coil shows that its inductance can be changed. This may be accomplished in a number of ways, but a method frequently used in radio circuits is to vary the core material by moving a powdered iron core in and out of the coil winding. Such a coil, with a variable core, is shown on Figure 5-15. Notice that a screwdriver adjustment is provided to move the core in and out of the coil and thereby change its inductance.

SCHEMATIC SYMBOL FOR VARIABLE-INDUCTANCE COIL.

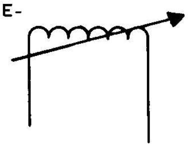
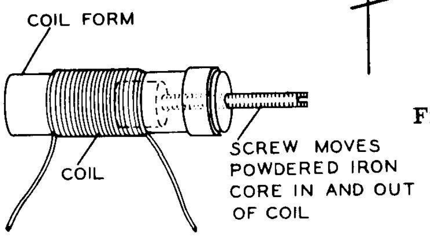


Figure 5-14

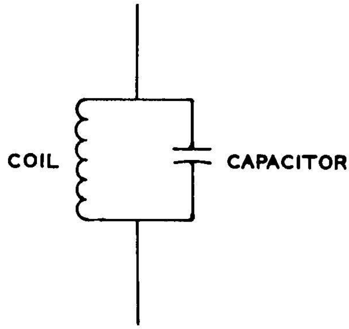


VARIABLE-INDUCTANCE RADIO FREQUENCY COIL.

Figure 5-15

The ability of both coils and capacitors to "kick-back" a pulse, in response to a pulse applied to them, is an important point to remember from this discussion of coil and capacitor characteristics. You will find that this kick-back action is what makes a tuned circuit work, when a coil and a capacitor are connected together.

TUNING



PARALLEL TUNED CIRCUIT.

Figure 5-16

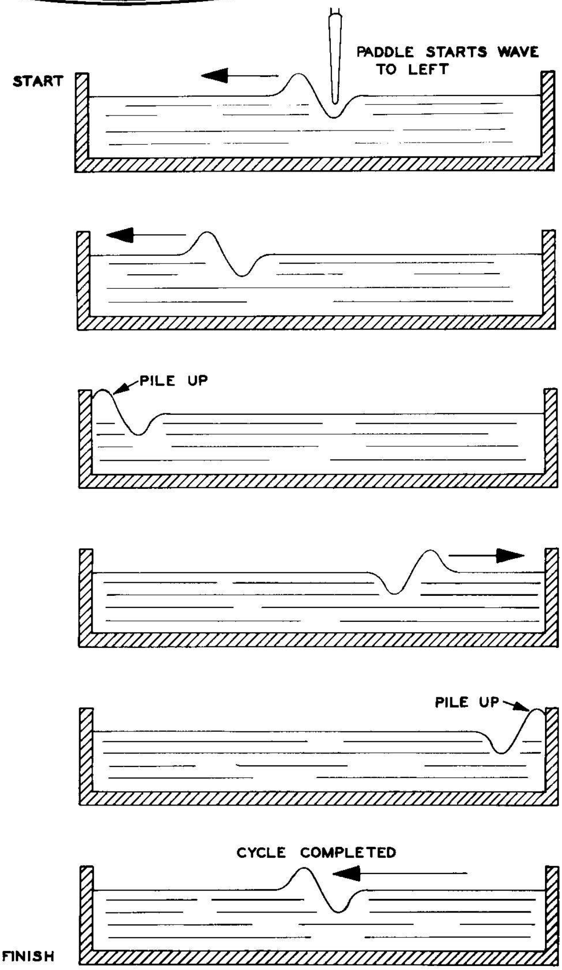
When the "kick-back" action of a capacitor is combined properly with the "kick-back" of a coil, a tuned circuit results. A parallel tuned circuit (the type employed in the experiment to follow), consists of a coil and a capacitor connected in parallel (see Figure 5-16). The size of the capacitor and coil (capacitance of capacitor and inductance of coil), in a tuned circuit must be such that, at a certain frequency, the capacitor kick-back, the coil kick-back, and the frequency being fed to the circuit, are all three synchronized. The result is an "oscillating" action within the tuned circuit, stimulated by pulses from the incoming frequency, which enables the circuit to "tune" this one frequency and reduce its response to all others. This synchronized action occurs only at the resonant frequency of the tuned circuit.

The resonant frequency of a tuned circuit depends on the value of the coil and capacitor used. Changing the value of either part (the capacity of the capacitor or the inductance of the coil) changes the resonant frequency of the circuit. Most circuits of this type are tuned with a variable capacitor. In the circuit you will build, the shaft of a variable capacitor is rotated to change its value.

An example of physical resonance (involving a tank of water), might help you to understand even more clearly what electrical resonance means in a tuned circuit.

RESONANCE

Water moving in a trough (Figure 5-17), is like a tuned circuit in some ways, and you can investigate its action to help visualize resonance in a tuned circuit.



WAVE ACTION IN TANK OF WATER HELPS YOU UNDERSTAND TUNED CIRCUITS.

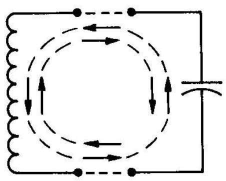
Figure 5-17

If a paddle gave the imaginary water in a tank a push to the left as shown in Figure 5-17, and was then removed, you would see a wave travel to the left end of the tank, pile up for a moment there, travel back to the other end of the tank, pile up for a moment, and move back to the left side of the tank again, etc. Each time the wave travels back and forth, it decreases in size because of the resistance it meets in trying to flow back and forth. However, assistance from the paddle, if it were synchronized, could keep this wave action moving back and forth indefinitely.

At the natural resonant frequency of the tank, little effort would be required from the paddle to keep the wave motion going continuously. A paddle motion in time with tank resonance would require slight exertion, whereas much greater effort would be needed to push a wave motion that was either faster or slower than the natural resonant frequency of the tank. Shortening the tank would increase its resonant frequency, or lengthening the tank would decrease its resonant frequency!

An electrical tuned circuit is much like the tank of water. The coil on one side and capacitor on the other side (like the ends of the tank), act to answer each others pulses, and cause circulating current at the resonant frequency of the circuit. The resonant frequency is determined by the electrical size of the coil and capacitor. Only little stimulation from an outside circuit (equivalent to the paddle) is necessary to keep this circulating current going at the resonant frequency.

If either the coil, or the capacitor, is made larger, the resonant frequency of the circuit decreases, while if either part is made smaller, the resonant frequency increases. Tuning is accomplished by changing the value of either part, but the capacitor is usually the element changed to tune the circuit to various resonant frequencies.



CURRENT CIRCULATES OR "OSCILLATES" BACK AND FORTH FROM CAPACITOR TO COIL AND COIL TO CAPACITOR, AT RESONANCE.

Figure 5-18

Figure 5-18 shows how the circulating currents move back and forth from capacitor to coil, and coil to capacitor again. This circulating current dies out if not stimulated by current from outside the parallel tuned circuit.

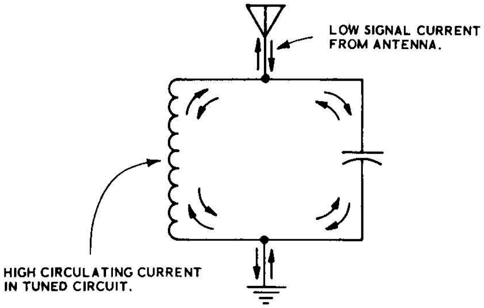


Figure 5-19

Figure 5-19 shows a tuned circuit connected into the antenna-ground circuit so that the incoming signal stimulates circulating current when the tuned circuit is exactly resonated to the frequency of the incoming signal. Notice that the current flowing up and down the antenna-ground circuit, caused by an incoming signal, acts on the tuned circuit to keep it oscillating. Only a small amount of incoming signal, therefore, can stimulate a relatively strong circulating current in the tuned circuit at its natural frequency, thereby adding to signal strength, and "favoring" the tuned signal over signals at other frequencies not matching the resonant frequency of the circuit. The idea of a capacitor and a coil operating together as a tuned circuit is a very fundamental one in electronics. There are many types of tuned circuits, used in practically all equipment designed to handle radio frequency signals. The fundamental principles of tuned circuit operation remain the same even though different frequencies may be involved, or the physical appearance of the coils or capacitors may not be the same.

As the capacitor of your tuned circuit is changed, the resonant frequency of the circuit changes and sweeps across the broadcast band to select first one, and then another of the stations being picked up on the antenna. When the resonant frequency of the tuned circuit is matched to the frequency of the incoming signal, the signal will be passed on to the rest of the circuit, and other signals will be reduced in amplitude. This effect will be demonstrated in the experiment that follows. You will add a tuned circuit to the detector circuit built in the previous lesson, so that your basic "radio" will have some degree of "selectivity."

HOW TO BUILD A TUNED CIRCUIT FOR RADIO SIGNALS

PURPOSE

TO ADD A TUNED CIRCUIT TO THE CRYSTAL DETECTOR SET AND INCREASE ITS SELECTIVITY

PREPARING THE CHASSIS FOR THIS EXPERIMENT

Remove the 3.3 megohm resistor, the crystal rectifier, and the hookup wire between T-2 and the antenna post. The chassis is now prepared for construction of this experiment.

MATERIALS REQUIRED

1 47 mmf ceramic capacitor
1 Regenerative detector coil
1 Two-gang tuning capacitor
3 Rubber grommets, 7/16" diameter
4 Rubber grommets, 5/16" diameter
1 #6 solder lug
6 #6 flat washers
3 #6-32 screws
1 Knob, (gray)
3 Spacers
1 Length insulating sleeving
1 Crystal diode rectifier, from previous experiment

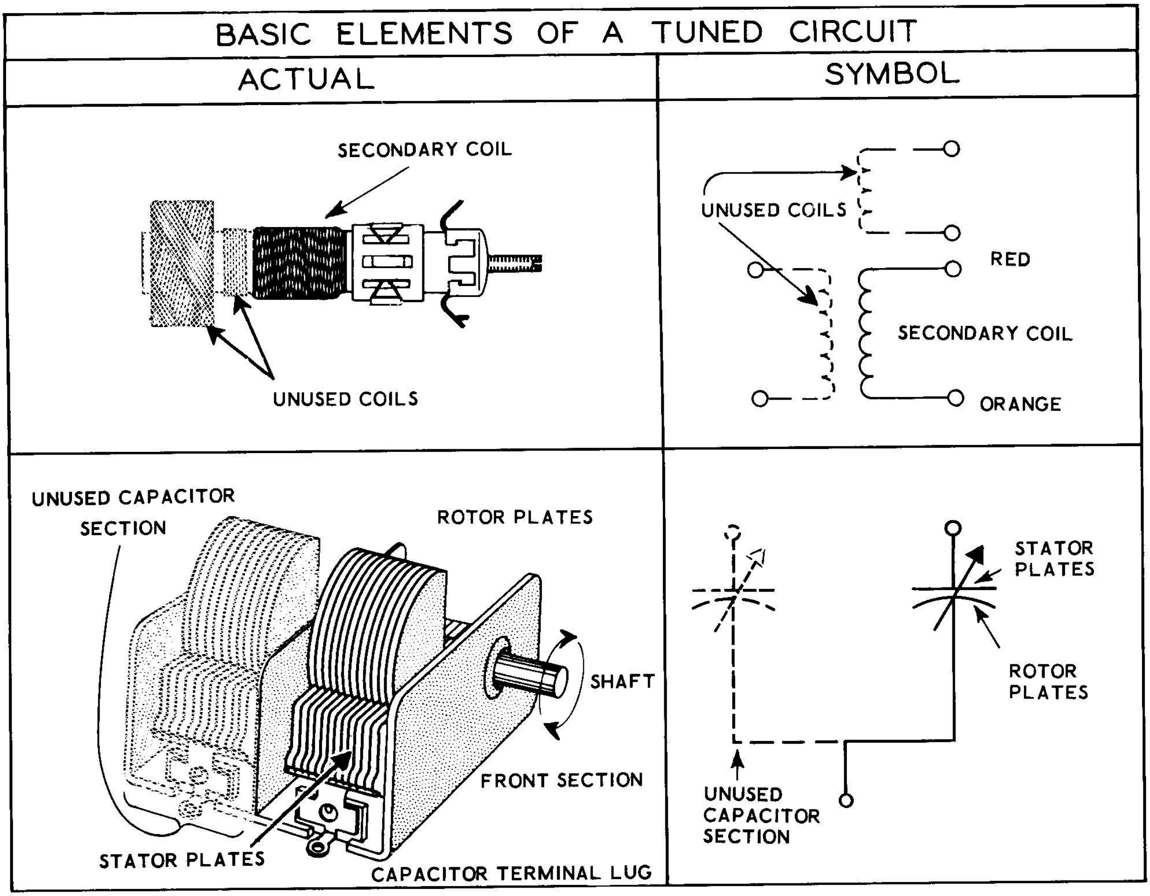


Figure 5-20

STEP 1 - BECOMING FAMILIAR WITH THE PARTS

The components that are new in this experiment are the two-gang tuning capacitor (two variable capacitors tied together mechanically), and the regenerative detector coil.

The characteristics of coils and capacitors have been covered rather thoroughly already in this lesson. However, the physical characteristics of this particular capacitor and coil combination can be further explained if you will refer to Figure 5-20, which shows the two parts as compared to their schematic symbols.

Handle the tuning capacitor with care so that the stator or rotor plates are not bent or damaged. These plates must be insulated from each other. Keeping the capacitor plates closed when you are handling it and constructing the various circuits will help to prevent damage.

Locate the tuning capacitor and look it over carefully. You will note that the rotor plates turn with the rotating shaft and are electrically connected to the capacitor frame through the shaft bearing. In most circuits, the frame of the tuning capacitor is fastened directly to the chassis, thus electrically grounding the rotor plates. This particular tuning capacitor will be mounted on rubber grommets to isolate it mechanically from the chassis, but electrical contact with the chassis will be made by a wire connected to one mounting bolt.

The stator plates are insulated from the capacitor frame, and electrical connections to these plates are made by way of terminal lugs for each section of the plates.

For practice, you can use your EK-1 Test Set, or any other test set with an ohmmeter circuit, to check the variable capacitor for short circuits between rotor and stator plates. Rotate

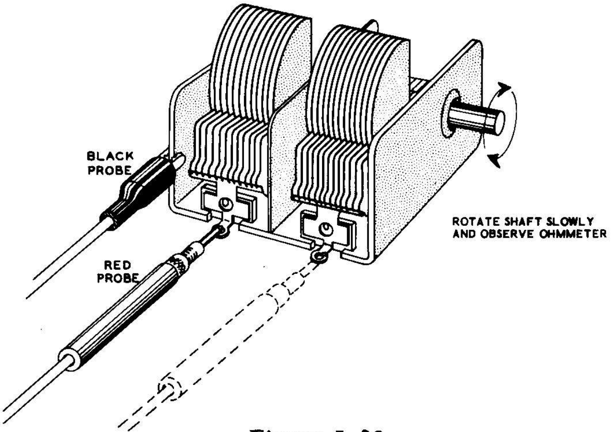


Figure 5-22

the capacitor shaft while observing the ohmmeter reading with the instrument connected to measure the resistance between each of the stator terminals and the capacitor frame (see Figure 5-22). The ohmmeter should show an "open" circuit in each case if the capacitor is in good operating condition.

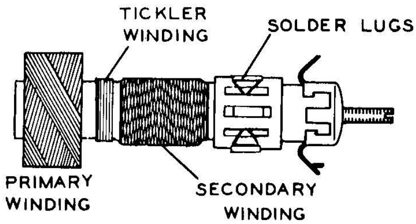


Figure 5-23

Locate your regenerative detector coil (given this name because of its later use) and compare it to Figure 5-23 in which the various windings are identified. Notice that the terminals on the coil are color-coded so you can tell one winding from another. The schematic diagram in Figure 5-24 shows how the windings are connected to the colored terminals, and gives the name of each winding for future reference.

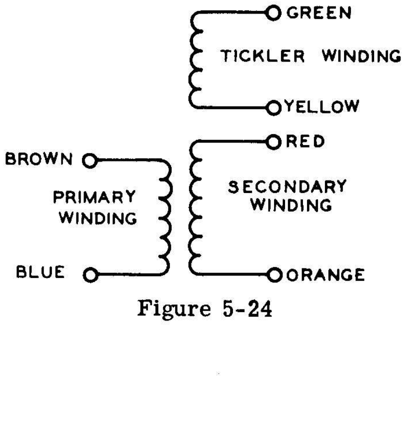
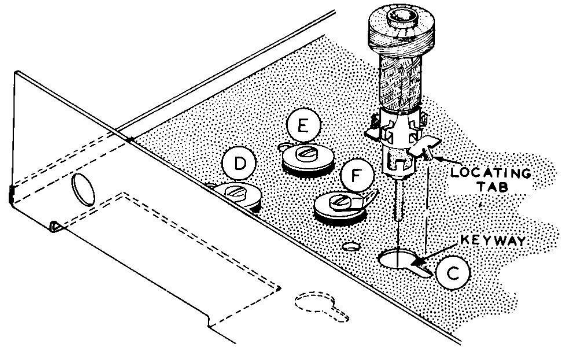


Figure 5-24

Again, you can use an ohmmeter to check the continuity of the coil windings, to be sure that each winding is continuous, and that no two windings are shorted together.

WARNING: The screw adjustment of this coil is preset to a particular inductance value. <u>Do not</u> adjust the screwdriver-slotted shaft at this time!

STEP 2 - MOUNT THE PARTS



MOUNTING THE REGENERATIVE DETECTOR COIL.

Figure 5-25

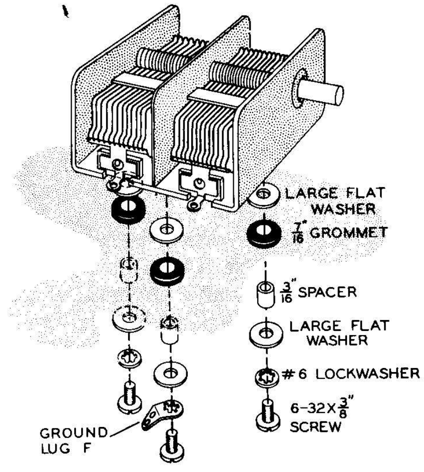
( ) Mount the regenerative detector coil in hole "C" (see Figure 5-28). Be sure to observe the locating tab and the keyway in mounting the coil as shown in Figure 5-25. Push the coil against the chassis hole until you hear it snap in place.

( ) Insert the three 7/16" soft rubber grommets in the capacitor mounting holes (D, E, and F, in Figure 5-28).

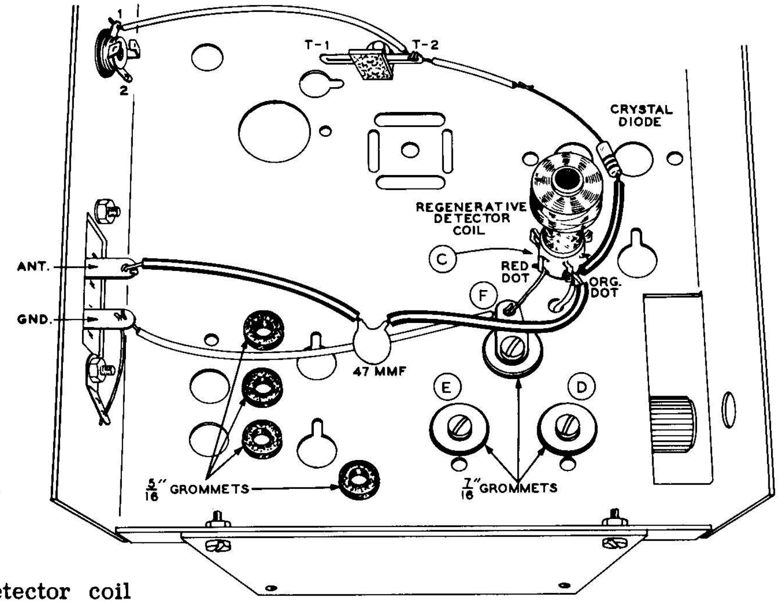
( ) Mount the tuning capacitor as illustrated in Figure 5-26. Use 6-32 x 3/8" BHMS screws, large flat washers, and lockwashers, at holes E and D. Use a solder lug in place of a lockwasher at hole F. Position the solder lug as shown in Figure 5-28. Note that 3/16" spacers are used on all three screws as shown in Figure 5-26.

( ) Place the gray knob on the shaft of the variable capacitor and tighten the setscrew.

( ) Mount the four 5/16" rubber grommets in the chassis holes shown in Figure 5-28.



MOUNTING THE TUNING CAPACITOR.
Figure 5-26

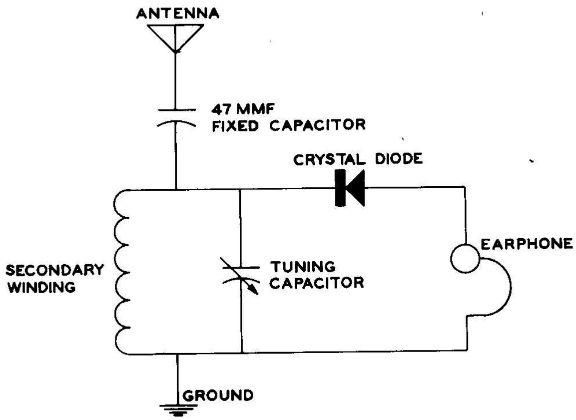


PICTORIAL DIAGRAM OF CIRCUIT WIRING.
Figure 5-28

STEP 3 - WIRING THE CIRCUIT

NOTE: While the regenerative detector coil actually has three separate coil windings, only the secondary winding (the red and orange terminals) will be used in this experiment.

The circuit of this experiment should be wired by following the pictorial diagram in Figure 5-28, and the schematic diagram in Figure 5-29. Step-by-step instructions are provided to remind you of the various parts and wires to be installed, but it will be up to you to check each step against the pictorial to make sure that the parts and wires are being positioned properly, etc. It is also a good idea to follow the schematic diagram as the wiring is installed. This will help you to understand the relationship between the schematic and the actual wiring in a circuit.



SCHEMATIC DIAGRAM OF CIRCUIT WIRING.
Figure 5-29

(✓) Connect a wire between ground lug F and the ground lug of the antenna strip.

(✓) Connect a short bare wire from ground lug F to the red terminal of the coil.

(✓) Connect a wire from the orange terminal of the coil, through the chassis hole next to the orange terminal, to the stator terminal of the tuning capacitor.

(✓) Connect the 47 mmf capacitor between the orange terminal of the coil, and the "ANT." lug. Use insulating sleeving on both leads of the capacitor. Lengthen the capacitor lead with a piece of wire, if necessary, to reach between these two points.

(✓) Connect the banded end of the crystal rectifier to the orange terminal of the coil, and connect the other end to T-2 by adding a length of wire to extend the crystal rectifier wire as shown.

(✓) Connect a wire from T-2 to the phone jack, using terminal 1, as shown.

This should complete the wiring of your circuit. Check your work carefully against the schematic and the pictorial diagrams.

STEP 4 - USING THE TUNED CIRCUIT AND CRYSTAL DETECTOR

Once the wiring is completed, your crystal detector circuit with a tuned circuit can be put into operation by simply connecting the antenna and the ground leads to the appropriate screw terminals, and by inserting the earphone plug.

Slowly rotate the tuning knob on the variable capacitor while listening in the earphone. If you received stations with the circuit of Lesson IV, you should receive the same stations now, except that the tuned circuit should give you some degree of selectivity in tuning in one station and tuning out another.

Notice that the higher frequencies in the broadcast band are tuned when the variable capacitor plates are almost all the way unmeshed, showing that as the capacity in the tuned circuit is made smaller, the resonant frequency is higher. Conversely, stations at the lower end of the broadcast band will be tuned when the plates are almost all the way meshed, indicating that as the capacity of the tuned circuit is increased, the resonant frequency is lower.

Signal strength of the stations picked up with this circuit should be slightly greater than for the circuit of Lesson IV because the high circulating current in the tuned circuit tends to feed a slightly stronger signal to the crystal diode and earphone.

Should you find that there are no strong stations in your locality and that no signals are picked up with this circuit, or the circuit of Lesson IV, you might try listening during the evening hours, when a strong signal may be picked up by way of "skip" action. Intermittent fading might be experienced with such a long-distance signal, but at least it would be strong enough at times to demonstrate that your "tuned" detector circuit functions properly.

You may disconnect the antenna and ground leads, and remove the earphone plug when you have completed these listening and tuning tests. However, the circuit can be left assembled until you are ready to start Lesson VI, in case you want to come back and listen to stations picked up by this "radio" in the meantime.

DISCUSSION

The performance of this circuit will be only slightly better than that experienced in Lesson IV. It must be remembered that you are still dealing with only the detector circuit of a receiver, to which you have added a tuned circuit to select incoming signals. The addition of a tuned circuit should clearly improve the selectivity of the circuit, by allowing you to "peak" the desired signal as compared to other signals being picked up by the antenna. Also, the tuned circuit should increase the signal strength slightly, because of the higher circulating current in the tuned circuit as mentioned previously. Still, the performance of the circuit will not compare to that of a complete radio receiver, such as you will build later.

Referring to the schematic diagram in Figure 5-29 again, you will observe that there is a 47 mmf fixed capacitor in the circuit that does not fit in with any of the information presented so far, and apparently has no logical reason for being in the circuit. Your attention should be focused on this part, for the moment, to learn its actual function in the circuit.

The 47 mmf fixed capacitor is not a functional part of either the tuning or the detection circuits explained earlier, except that it has been placed in the circuit to prevent the antenna itself from interfering with normal circuit action. This capacitor is connected in series with the capacity of the antenna itself, to minimize the effect of the antenna capacity on the tuned circuit.

Figure 5-30

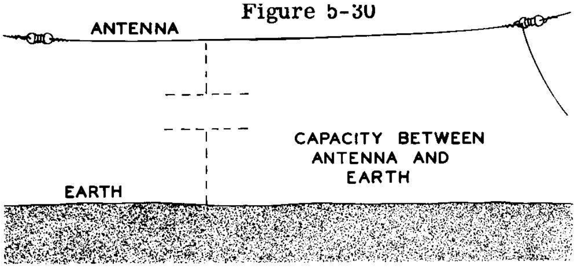
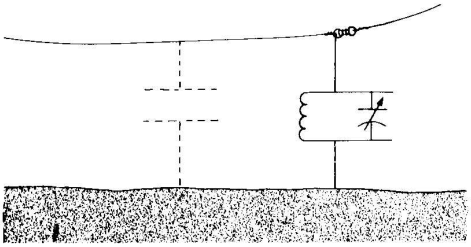
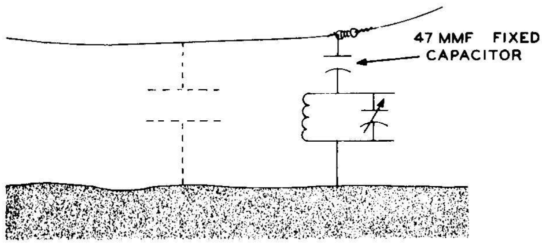


Figure 5-30 shows how capacity develops between your antenna (acting as one capacitor plate) and the earth (acting as the other capacitor plate). The capacity developed in this fashion is a very real electrical quantity, even though no "capacitor" in the usual sense of the



ANTENNA CAPACITY ADDS TO VARIABLE CAPACITOR AND DISTURBS CIRCUIT TUNING.

Figure 5-31



SMALL CAPACITOR IN SERIES WITH ANTENNA CAPACITY MINIMIZES EFFECT ON TUNED CIRCUIT.

Figure 5-32

word appears in the circuit. The effect of this extra capacity which appears across the tuned circuit (Figure 5-31), is that it changes the tuned circuit. The antenna capacity adds to the variable capacitor value, making it less effective as a tuning device. If this condition were left to prevail, the tuning capacitor would not tune the broadcast band properly, but would tune a more restricted range of frequencies because the antenna capacity would change the resonant frequency range of the tuned circuit.

However, connecting a very small capacitor (47 mmf) in series with the antenna (and thereby in series with the antenna capacity), reduces the effect of the antenna capacity to a small enough value that the tuned circuit is not appreciably disturbed. (See Figure 5-32.) When two resistors are connected in parallel, the combined resistance of the pair is smaller than the resistance of the smaller resistor. In the realm of capacitors, this same rule holds true, except that it applies in a series circuit. In other words, when two capacitors are connected in series, the total capacity of the pair is smaller than the capacity of the smaller capacitor. This principle makes it possible to minimize the effect of antenna capacity by connecting the small capacitor in series with it. If it helps to clarify your understanding, you may think of the 47 mmf capacitor as part of the antenna circuit, rather than an extra part added to the tuned circuit or the detector circuit. You may find it less confusing that way.

This concludes the discussion of this experiment. In Lesson VI, you will substitute a vacuum-tube rectifier for the crystal rectifier in this circuit to demonstrate how a vacuum tube diode functions in a detector circuit.

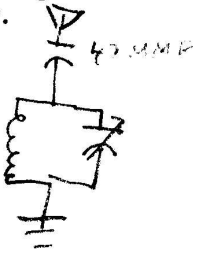
LESSON V
QUESTIONS

NOTE: The answers to the questions on Lesson V will be found in the back of the book on Page 85.

1. The two components used to make a tuned circuit are a Coil and a Condenser
2. Draw the schematic symbol for a fixed-value coil.

3. Draw the schematic symbol for a variable capacitor.

4. Draw the schematic of a parallel tuned circuit using a fixed coil and a variable capacitor.



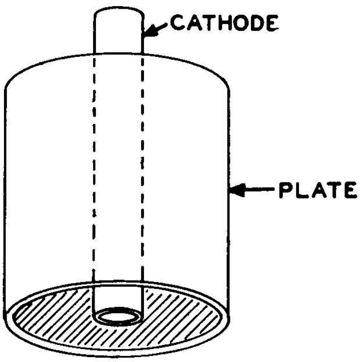
5. The basic unit of measurement for capacity is the Farad.
6. The basic unit of measurement for inductance is the Henry.
7. Tuning in a 1200 kc broadcast signal would require a tuned circuit with a resonant frequency of 1200 kc.
8. If the capacity is decreased in a tuned circuit, the resonant frequency increase
9. If the inductance of a coil is increased in a tuned circuit, the resonant frequency decrease
10. Capacity between the antenna and earth, that might disturb tuned circuit action, is minimized by connecting a [illegible] in series with the antenna.

LESSON VI

HOW DO DIODE VACUUM TUBES WORK ?

You have already seen how current is rectified in a crystal diode, and how rectification is put to use in a detector circuit. As mentioned earlier, there are other types of rectifiers besides the crystal type, and the most commonly used of these is the vacuum tube rectifier. This is a one-way current device, just as a crystal diode is a one-way current device. While the principle of operation in a diode vacuum tube is different, the total effect is essentially the same. A further investigation of vacuum tubes and their principles of operation will help clarify this for you.

THE DIODE TUBE

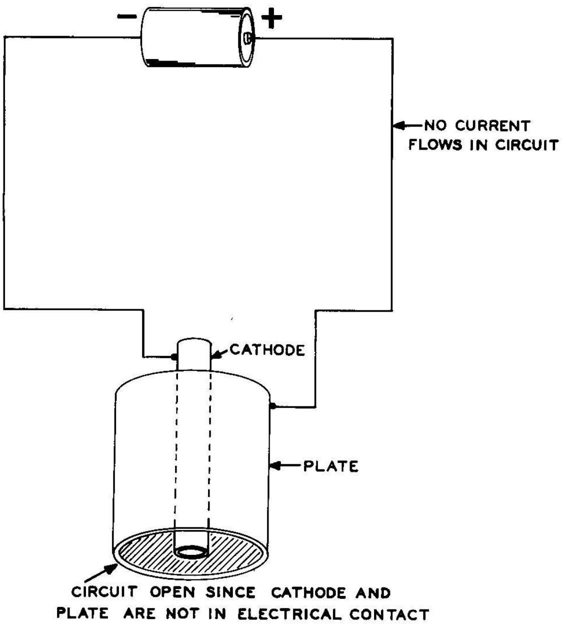


THE TWO MAIN ELEMENTS OF A DIODE TUBE ARE THE CATHODE AND THE PLATE.

Figure 6-1

The term "diode" when applied to a vacuum tube means that the tube has just two elements; a cathode, and a plate. The "cathode" is a small-diameter metal tube located in the center of a larger-diameter metal tube called the "plate." The cathode and plate elements of a diode vacuum tube are shown in Figure 6-1. Both metal cylinders are open at each end, and are positioned in the tube so they do not touch each other at any point.

If a battery were connected between the plate and the cathode (Figure 6-2), no current would flow (ignoring a small amount of capacity between the two elements) because the circuit is "open" between the two metal cylinders.



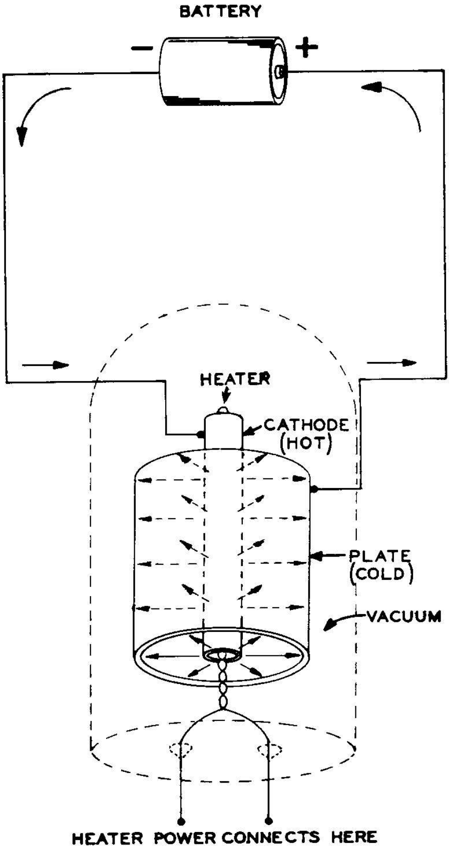
NO CURRENT WILL FLOW BETWEEN THESE ELEMENTS (BECAUSE THEY DO NOT TOUCH) UNLESS CERTAIN CONDITIONS ARE MET.

Figure 6-2

Two additional conditions must be met before current can flow in the circuit.

First, the cathode must be heated to a very high temperature so it will "boil off" electrons into the space surrounding it. This is done by inserting a heater into the hollow cathode cylinder to raise its temperature. This heater is much like the filament in a light bulb, except that it is designed primarily to produce heat, rather than light. The heater will cause the cathode cylinder to become red-hot and boil off free electrons into the space surrounding it. Heating the cathode, therefore, is one important condition that must be met for vacuum tube operation. (See Figure 6-3).

The other condition required is that the cathode, the plate, and the heater must be enclosed in a vacuum. Placing these elements in a glass envelope, pumped free of air, accomplishes this.

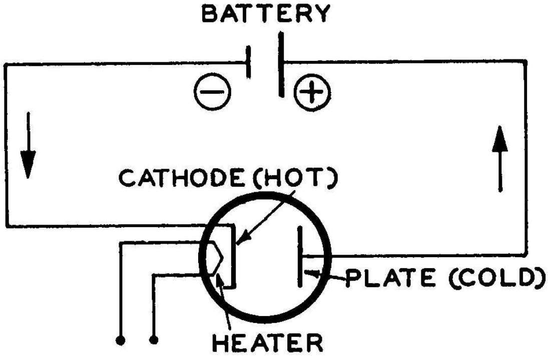


CURRENT FLOWS IN THE CIRCUIT WHEN:

1. CATHODE IS HEATED.
2. BOTH ELEMENTS ARE ENCLOSED IN A VACUUM.

Figure 6-3

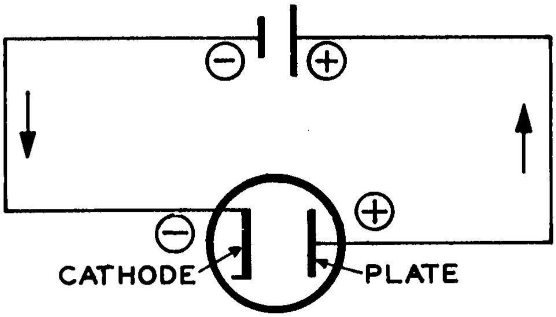
Now, with the plate and the cathode enclosed in a vacuum, and the cathode raised to an extremely high temperature, electrons will travel around the circuit as shown in Figure 6-3. Current from the negative side of the battery moves around the circuit to the cathode where electrons are boiled off and travel to the plate, so that the current can continue from the plate on around the circuit to the positive terminal of the battery. This effect can occur only when the cathode is hot and when the plate and the cathode are enclosed in a vacuum. If air were to enter the tube envelope, or if the voltage supplying the heater were cut off, all circuit current would stop. The current from the battery to the cathode, across to the plate and back to the other battery terminal, is an independent circuit, entirely separate from the heater circuit which merely heats up the cathode. Heater wires are insulated and do not come into electrical contact with the cathode cylinder, so the heater circuit, and the cathode-to-plate circuit, are isolated from each other. The cathode-to-plate circuit is the important one so far as electronics is concerned, and the heater circuit is just a necessary means to this end.



SCHEMATIC OF DIODE TUBE IN A BATTERY CIRCUIT SHOWING HEATER.

Figure 6-4

The schematic symbol for a diode tube is shown in Figure 6-4. Notice that the heater or "filament" is a separate circuit. Figure 6-5 shows how the heater circuit may be left out of the tube schematic symbol in order to place emphasis on the circuit connected to the main tube elements. You will frequently find that the heater circuit is not shown in tube diagrams, and is merely taken for granted. The heater seldom has any connection with the vacuum tube circuit except to raise the temperature of the cathode to a high enough level that emission of electrons from the cathode can take place.

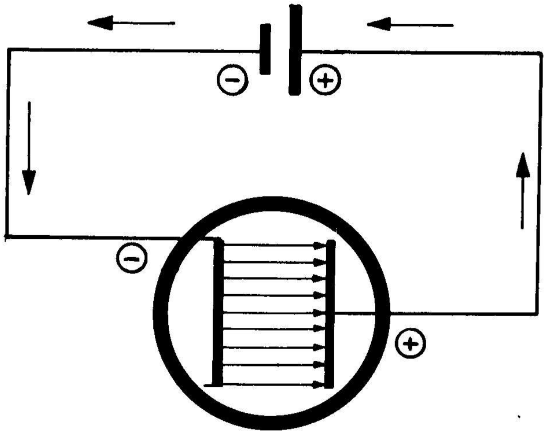


SIMPLIFIED SCHEMATIC OF DIODE TUBE IN BATTERY CIRCUIT IN WHICH HEATER IS TAKEN FOR GRANTED AND LEFT OUT OF DIAGRAM FOR CLARITY.

Figure 6-5

RECTIFICATION

Referring again to Figure 6-5, it may be seen that electrons pass from the hot metal cathode to the cold metal plate in a vacuum tube as the extremely high heat frees electrons to boil off the surface of the cathode. The battery plays an important part in this action, also, since the electrical pressure from the battery (having an excess of electrons at its negative terminal, and a deficiency of electrons at its positive terminal), forces electrons around the circuit and off of the hot cathode. The cold plate, connected to the positive battery terminal, attracts these electrons being emitted from the cathode. The cathode must be negative, and the plate must be positive to cause current flow around the circuit.

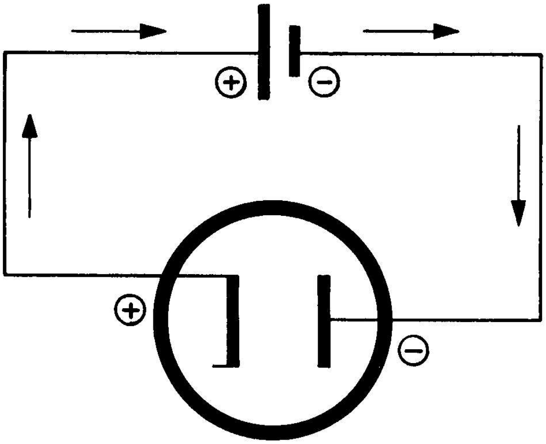


CELL CURRENT FLOWS AROUND CIRCUIT BECAUSE ELECTRONS EMITTED FROM HOT CATHODE (-) ARE ATTRACTED TO COLD PLATE (+).

Figure 6-6

The enlarged tube schematic symbol in Figure 6-6 uses arrows to show how the cathode must be negative (have an excess of electrons), and the plate must be positive (have a deficiency of electrons), in order for the electrons to move from cathode to plate. The battery in the circuit provides this difference of polarity, and the electrical pressure necessary, to cause current to flow in the circuit.

When the battery is reversed, as shown in Figure 6-7, the cathode becomes positive and the plate becomes negative. The electrical pres-



REVERSE CURRENT WILL NOT FLOW BECAUSE ELECTRONS WILL NOT MOVE FROM COLD PLATE (-) TO HOT CATHODE (+).

Figure 6-7

sure of the battery is such that it is attempting to force electrons off of the plate and onto the cathode, as indicated by the direction of the arrows in the circuit. Under such conditions, the diode vacuum tube acts like an "open" circuit because only the cathode can emit electrons to be attracted to the plate; the cold plate cannot emit electrons, nor can the hot cathode attract them. In effect, then, the vacuum tube diode is acting just like the crystal diode in your earlier lesson. When it is placed in a circuit, it will pass electrons flowing from the cathode to the plate, but will block electrons attempting to flow from the plate to the cathode. It, too, is a "one-way" current device. You will be able to demonstrate this in the experiment to follow.

Smaller vacuum tubes, with low current ratings, do a rectifying job comparable to that performed by the crystal rectifier. However, while the crystal rectifier is limited to light duty, large vacuum tube rectifiers can handle heavy current in high-power circuits. The large "power tube" in your home radio or television set is a rectifier tube in the power supply circuit.

Of course, a vacuum-tube rectifier does require heater voltage for operation, whereas a crystal rectifier needs no external source of power to perform its rectification function.

HOW TO BUILD A VACUUM TUBE SIGNAL DETECTOR

PURPOSE

TO MEASURE THE ONE-WAY CURRENT EFFECT OF A VACUUM TUBE RECTIFIER WITH AN OHMMETER; AND TO CONNECT THE VACUUM TUBE DIODE IN PLACE OF THE CRYSTAL DIODE IN THE TUNED DETECTOR CIRCUIT FROM LESSON IV.

MATERIALS REQUIRED

1 Power transformer
4 7-prong wafer sockets
1 Strain relief insulator
1 Line cord
1 150 K ohm (brown-green-yellow) resistor
2 .001 mfd ceramic capacitors
1 #47 lamp
1 4-lug terminal strip
1 Lamp socket with lead
8 3-48 x 1/4" screws and nuts
4 8-32 nuts
3 #8 lockwashers
1 #8 solder lug
1 6C4 radio tube
1 1 megohm control (with switch)
1 Knob, white
The circuit already wired from Lesson V

PREPARING THE CHASSIS FOR THIS EXPERIMENT (See Figure 5-28 on Page 37.)

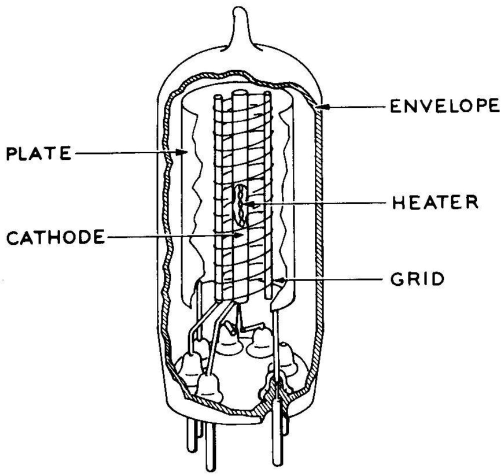
(✓) Remove the short length of wire between T-2 and the crystal rectifier lead, leaving the rectifier lead free for a future experiment.

( ) Remove the wire between ground lug F and the ground terminal of the GND.-ANT. strip.

Leave the other parts mounted and in place, since the same components will be used in this circuit.

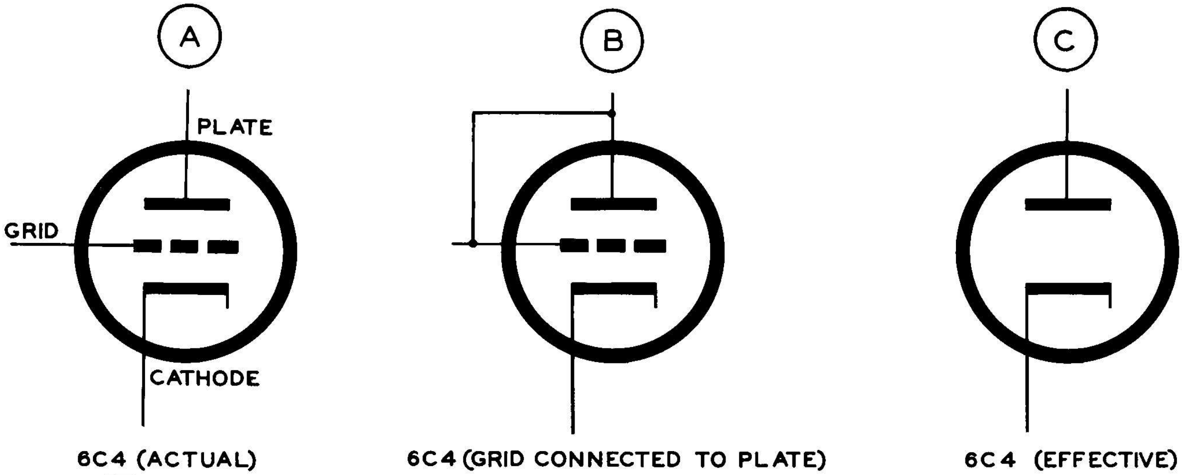
STEP 1 - BECOMING FAMILIAR WITH THE PARTS

The internal construction of the type 6C4 tube to be used in this experiment is shown in Figure 6-8. You should have no trouble identifying the heater, the cathode, and the plate inside the glass tube envelope, although you will find an extra element in the tube not mentioned in the previous discussion of diodes. This element is a spiral of wire positioned between the cathode and the plate within the tube, and it is called the grid. A further discussion of the grid and its function in a vacuum tube will be covered in your next lesson. For the present, it is sufficient for you to understand that a type 6C4 tube is a triode (three elements), and not a diode. However, the tube will be used as a diode in this experiment by connecting the grid to the plate, to make the grid ineffective.



PHYSICAL CONSTRUCTION OF 6C4 TUBE.

Figure 6-8



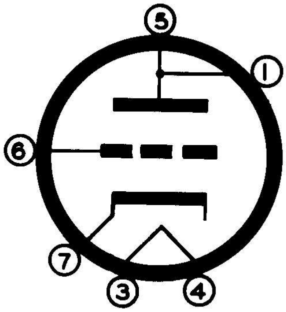
6C4 TRIODE TUBE ACTS AS DIODE WHEN GRID IS CONNECTED TO PLATE.

Figure 6-9

Figure 6-9A shows the schematic symbol for a triode tube, having a cathode, a grid, and a plate.

Figure 6-9B shows how the grid of the 6C4 is connected to the plate, making the grid ineffective as a third element, so that it acts as part of the plate.

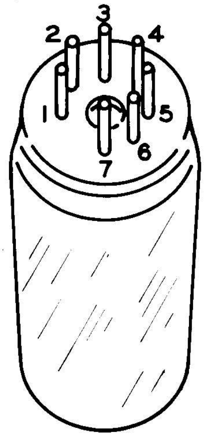
Figure 6-9C shows the schematic symbol for a diode tube, which can be applied to the 6C4 tube, when its grid is connected to its plate.



ELEMENT PIN NUMBERS FOR 6C4.

Figure 6-10

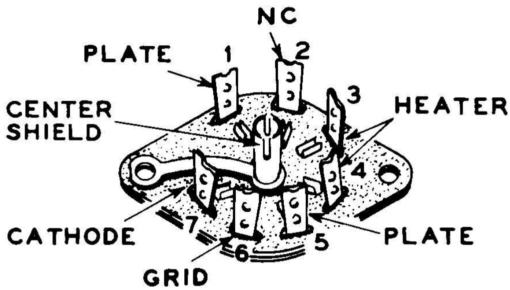
Figure 6-10 is a true schematic diagram of the 6C4 showing the terminal numbers of each element. The pins of the tube are numbered from 1 to 7 in a clockwise direction, starting at the wide space on the tube base. Viewing the tube from the bottom, the terminals are numbered as indicated in Figure 6-11, and the



BOTTOM VIEW OF TUBE SHOWS CLOCKWISE PIN NUMBERING STARTING AT WIDE SPACE BETWEEN 1 AND 7.

Figure 6-11

elements within the tube are connected to the pins indicated by the numbers in Figure 6-10.



THE TUBE SOCKET IS ALSO NUMBERED CLOCKWISE FROM THE BOTTOM.

Figure 6-12

Figure 6-12 is a bottom view of the tube socket, showing how the tube elements are connected to the socket terminal lugs. The tube is plugged into the socket by observing the wide space between pins 1 and 7. The center shield of the tube socket is grounded by being in contact with one of the tube socket mounting screws, making electrical contact with the chassis. The center shield provides a convenient ground for circuit wiring.

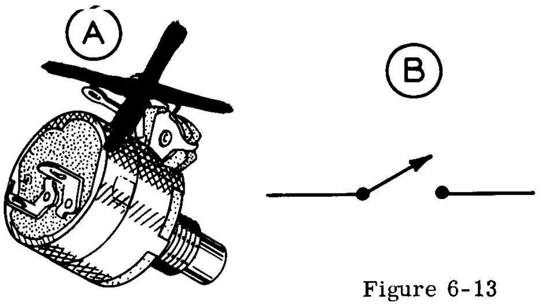
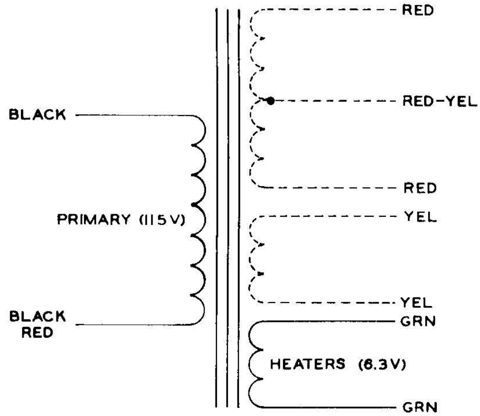


Figure 6-13

The 1 megohm control is another of the new parts introduced in this experiment. However, only the "ON-OFF" switch on this control will be used at this time. Figure 6-13A shows the control. Note that the three top terminals will not be used. Only the two terminals at the rear of the switch will be employed in this circuit. A schematic diagram of a switch is shown in Figure 6-13B.

Since the 6C4 vacuum tube will be used in this experiment, and vacuum tubes require heater voltage, the power transformer also will be used in this experiment to supply the 6C4 heater. The details of how a power transformer operates will be covered in a later lesson. It is sufficient, at this time, to simply say that the power transformer is a device for stepping up or stepping down your 117 volt AC power line to produce more (or less) voltage, for use in a circuit. One winding of a power transformer (the primary) will be connected to your power line by means of the line cord and plug. Another winding of the transformer, with an output of 6.3 volts AC, will be connected to power the heater in the 6C4 tube. The other transformer windings will not be used at this time. Your assembly instructions will explain how to identify the leads from the transformer so these connections can be made properly. A pilot lamp will be connected in series with the 6C4 tube heater to reduce the heater voltage down to about three volts, for best performance of the tube when it is connected to operate as a diode.



SCHEMATIC SYMBOL FOR POWER TRANSFORMER.

Figure 6-14

The schematic symbol for your power transformer is shown in Figure 6-14. Only the two windings you will use are drawn in solid. The windings drawn as dashed lines will not be used until a later experiment.

Although only one 7-lug wafer socket is required in this experiment, all four 7-lug sockets will be mounted and the heater circuits wired, at this time.

Unused leads from the power transformer will be bent back and taped until required in a later experiment.

STEP 2 - MOUNTING THE PARTS

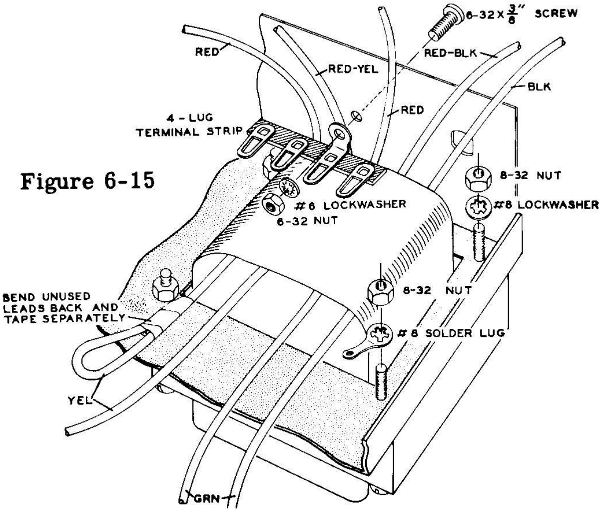


Figure 6-15

MOUNTING THE POWER TRANSFORMER.

( ) Mount the power transformer in the large rectangular chassis hole, using 8-32 lockwashers and nuts, and one #8 solder lug, as shown in Figure 6-15.

( ) Bend back and separately tape each of the two yellow leads, each of the two red leads, and the red-yellow lead, as shown in Figure 6-15. This keeps the leads from shorting together or shorting to the chassis, and also protects you from the high voltage.

( ) Mount the 4-lug terminal strip using a 6-32 screw, lockwasher, and nut, as shown in Figure 6-15.

NOTE: When mounting wafer tube sockets, be sure to mount each socket from the bottom of the chassis. If, by mistake, the sockets are mounted so the lugs pass through the chassis, they will short to the chassis where they pass through the mounting hole.

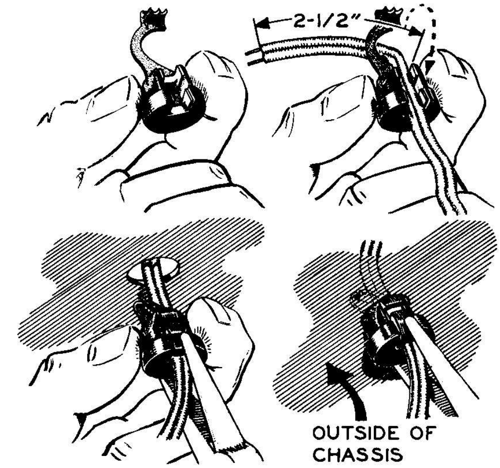
( ) Mount the four 7-lug miniature tube sockets using 3-48 screws and nuts. Be sure to position each socket as shown in Figure 6-16 on Page 48.

( ) To be sure of good ground connections, solder the center post of each tube socket to its ground strap, as shown in the inset illustration on Figure 6-16. Use only a small amount of solder.

CAUTION:
In the next step you will install the line cord. Once this is done, the potential danger of electrical shock is present if the line cord is plugged into the wall socket. Do not plug in the line cord until instructed to do so!

It is important to remember that work should be performed under the chassis only with the plug removed from the wall socket. Do not touch any under-chassis terminals or parts while the line cord is plugged in, even if the switch is "OFF." Instructions are provided to remind you when to insert or remove the line cord plug, for your own safety in conducting the experiments.

( ) Install the line cord through the chassis apron hole near the power transformer. Use the strain-relief insulator as shown in Figures 6-16 and 6-17. Leave approximately 2-1/2" of wire extending inside the chassis.



INSTALLING THE LINE CORD. Figure 6-17

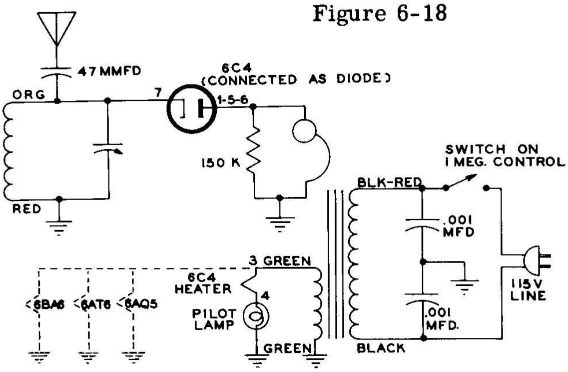
( ) **Install the 1 megohm control as shown in Figure 6-16, using a control lockwasher inside the chassis and a control nut on the outside of the chassis. Install a white knob on the control shaft.**

( ) **Insert the pilot lamp in its socket and clip the socket to the chassis as shown; Figure 6-16.**

STEP 3 - WIRING THE CIRCUIT

Follow the pictorial diagram in Figure 6-16, the schematic diagram in Figure 6-18, and the following wiring steps, in wiring the circuit for this experiment. Notice that the circuit schematic in Figure 6-18 shows the heater and power transformer wiring separately, since it is easier to follow the circuit if the heater wiring is apart from the signal wiring. As discussed previously, this can be done logically, because the heater circuit merely serves to raise the temperature of the cathode in the 6C4 tube.

Figure 6-18



SCHEMATIC DIAGRAM (SHOWING HEATER CIRCUIT SEPARATELY).

When instructions call for wiring from one of the tube socket terminals to the center shield of the socket, use bare wire for this purpose. Bare wire is obtained by merely stripping the insulation from regular hookup wire.

The heater circuit, from the power transformer to the heater terminals of each tube socket, is wired first.

As mentioned earlier, all connections should be soldered as the circuit is wired, unless otherwise specified. Wires can be added to a terminal rather easily at any time if temporary-type lap joints are used.

( ) Connect one green transformer lead to the #8 ground lug next to the transformer, and the other green lead to lug 4 of the first tube socket closest to the transformer. See Figure 6-16.

( ) Connect a length of hookup wire from lug 4 of this same tube socket to lug 3 of the second socket.

( ) Connect another length of hookup wire from lug 3 of the second tube socket to lug 3 of the third tube socket (follow Figure 6-16 for this wiring from socket to socket).

( ) Connect a length of hookup wire from lug 3 of the third socket, over to lug 4 of the fourth tube socket.

( ) Connect a short length of bare wire from the center post of the second tube socket to lug 4 on this socket. (See Figure 6-16.)

( ) Connect a short length of bare wire from the center post to lug 3 on the first and fourth tube sockets.

( ) Connect a length of wire from the center post of the fourth tube socket to ground lug F.

( ) The third tube socket (which is the 6C4 socket at the moment) does not use a ground jumper wire at this time. Connect the long lead from the pilot lamp to lug 4 of the 6C4 socket by passing it through the chassis hole next to this terminal. (See Figure 6-16.)

( ) Connect a bare jumper wire between lugs 5 and 6 of the 6C4 (3rd) socket.

( ) Connect a wire from the orange solder lug of the regenerative detector coil over to lug 7 of the 6C4 tube socket.

( ) Connect a wire that is long enough to reach T-2, to lug 5 of the 6C4 socket. Do not connect this wire to the "T" terminal strip at this time, since it must be disconnected later for a test.

( ) Twist two 7" lengths of hookup wire together and run them between the two switch terminals on the back of the 1 megohm control, and L-3 and L-4 of the 4-lug terminal strip near the power transformer.

( ) Connect the two .001 mfd ceramic capacitors between L-1, L-2 and L-3 of the 4-lug strip as shown in Figure 6-16.

( ) Connect the black and red-black transformer leads to L-1 and L-3 of the 4-lug terminal strip as shown.

( ) Split the line cord leads and connect one to L-1 and the other to L-4 of the 4-lug strip as shown.

( ) Connect the 150 K ohm (brown-green-yellow) resistor across terminals 1 and 2 of the earphone socket as shown in Figure 6-16.

This completes the wiring of this experiment. All connections should be soldered except the free lead from lug 5 of the 6C4 socket and the free crystal diode lead.

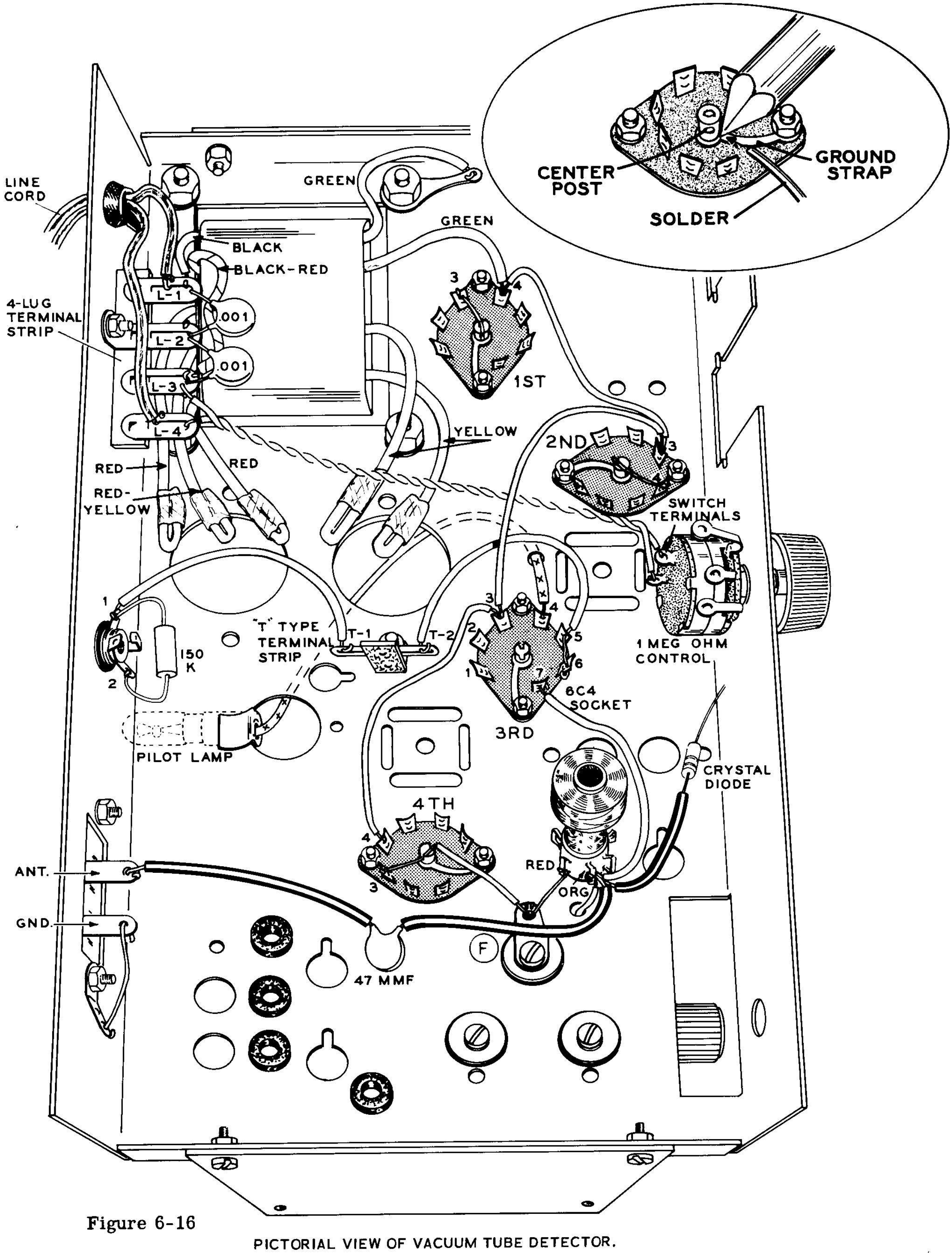


Figure 6-16

PICTORIAL VIEW OF VACUUM TUBE DETECTOR.

STEP 4 - CHECKING HEATER CIRCUIT

You will now check the circuit you have just constructed by applying power to it with the 6C4 tube in each of the 7-pin sockets to be sure the filament circuit is wired properly.

CAUTION: The power transformer in this circuit will operate on 105-125 volts AC power only. It will not function on DC power or on AC power of a frequency other than 50 or 60 cps. If there is any question in your mind about the suitability of the power available in your home, check with your local power company before plugging in the set. Practically all homes in the United States are supplied with 117 volt AC power at 60 cps.

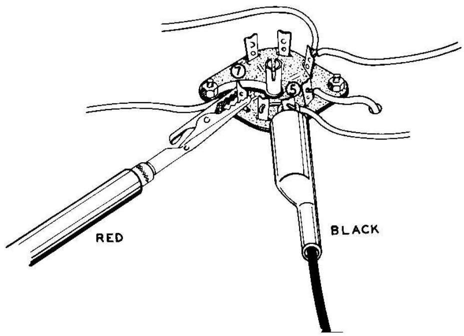
A reminder....do not work under the chassis with the line cord plugged in!

(✓) Plug in your line plug, and rotate the 1 megohm control shaft to snap the switch "ON." This applies your power line voltage to the primary winding of the transformer and thereby should apply heater voltage to each of the tube sockets.

(✓) Plug the 6C4 tube into each of the four tube sockets, to be sure that it lights up in each socket indicating that heater voltage is reaching the tube. You can observe, after about a 20-second warmup period, if the tube is lighting or not. The red glow will not be as bright at the 6C4 tube socket as it is at the others, since the pilot lamp is connected in series with this particular heater circuit to reduce the heater voltage temporarily for this experiment. You will notice, however, that the pilot lamp lights when the tube is inserted in the 6C4 tube socket, showing that current is being drawn through it. Should you encounter any difficulty in checking the heater circuit, go back and compare your wiring to the pictorial diagram, Figure 6-16, to be sure all the wires are connected properly.

Leave the 6C4 tube plugged into the 6C4 socket and turn the switch "OFF." Remove the line cord plug from the power socket.

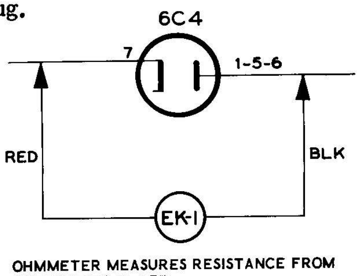
STEP 5 - MEASURING THE ONE-WAY EFFECT OF A DIODE TUBE WITH AN OHMMETER



MEASURING FORWARD RESISTANCE OF DIODE TUBE.

Figure 6-19

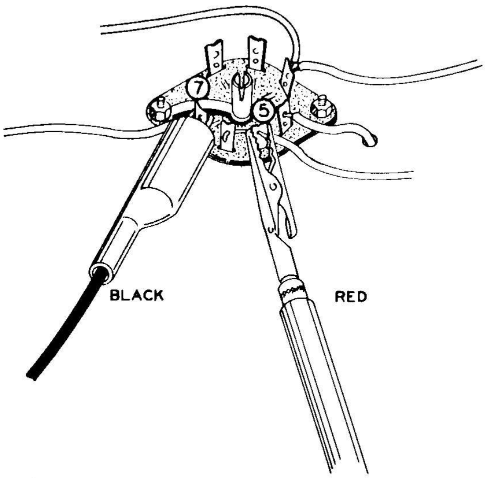
(✓) Connect the red test lead of the EK-1 Test Set to lug 7 of the 6C4 socket, and the black test lead to lug 5, lug 1, or lug 6 of the socket. These three lugs are all connected to the plate. Figure 6-19 shows how these connections are made. A schematic diagram of this test is shown in Figure 6-20. Plug in the line cord, set the tester to measure resistance, and turn the circuit switch "ON" and allow 20 seconds for the 6C4 tube to warm up. Push the lo-ohms button on the EK-1 Test Set and you should get a low resistance reading showing that the diode tube is definitely a conductor when electrons are flowing from cathode to plate. Turn the circuit off and remove the power plug.



OHMMETER MEASURES RESISTANCE FROM CATHODE TO PLATE

SCHEMATIC OF FORWARD OHMMETER TEST.

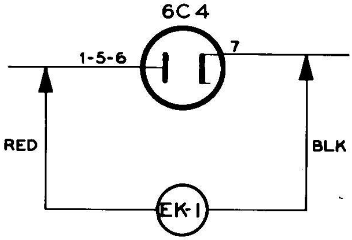
Figure 6-20



MEASURING BACKWARD RESISTANCE OF DIODE TUBE.

Figure 6-21 .

( ) Now, reverse the red and black test leads (as shown in Figure 6-21) to measure the backward resistance of the diode rectifier. This test is shown schematically in Figure 6-22. Plug in the line cord, turn the circuit switch "ON," allowing the tube to warm up, and you should get a high resistance reading indicating that the diode rectifier is "open" as far as DC current is concerned when the current is in the reverse direction. Current does not flow from plate to cathode. Now remove the line cord plug and turn the circuit "OFF."



OHMMETER MEASURES RESISTANCE FROM PLATE TO CATHODE.

SCHEMATIC OF BACKWARD OHMMETER TEST.

Figure 6-22

( ) Unclip the test leads, and connect the lead from lug 5 of the 6C4 tube socket to T-2 of the "T" type terminal strip, and solder it.

STEP 6 - USING A VACUUM TUBE DIODE IN THE TUNED DETECTOR CIRCUIT

This circuit is now ready for operation as a radio signal detector. Connect the antenna and ground leads to the appropriate screw terminals and insert the earphone plug. Now plug in the line cord, rotate the power switch to the "ON" position, and tune for reception of your local stations, as you did with this circuit previously. This circuit is performing the same function as it did in the last experiment (Lesson V) except that you are using a vacuum tube diode to perform rectification in the detector circuit, instead of a crystal diode. You should find little difference in the performance of the circuit, since the vacuum tube and the crystal diode do approximately the same kind of rectifying job. Take another look at the schematic diagram in Figure 6-18 to refresh your mind on the circuit to which you are listening.

DISCUSSION

In this experiment, you have been able to demonstrate the one-way effect of a diode vacuum tube with an ohmmeter, and you have substituted such a diode in the detector circuit to show that it performs the same function in the circuit as the crystal diode. The fact that vacuum tubes require heater voltage to raise the cathode temperature high enough for operation has been made clear. In fact, you should notice how the signal being received will fade away when the power is turned "OFF," showing that diode current diminishes as the cathode cools off.

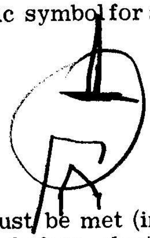
This circuit is identical with that of Lesson V except for the addition of a 150 K ohm resistor to increase the current flow through the diode and improve its performance. In your next lesson, you will learn more about vacuum tubes and amplification.

LESSON VI

QUESTIONS

NOTE: The answers to the questions for Lesson VI will be found in the back of the book on Page 85.

1. Draw the schematic symbol for a diode tube (showing heater).

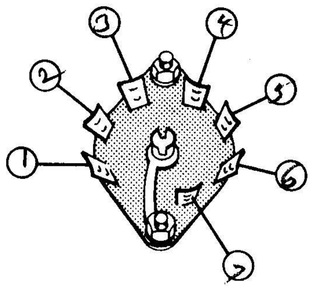


2. What condition must be met (in addition to having a vacuum) before electrons from a battery can flow through a diode vacuum tube? heat on cathode

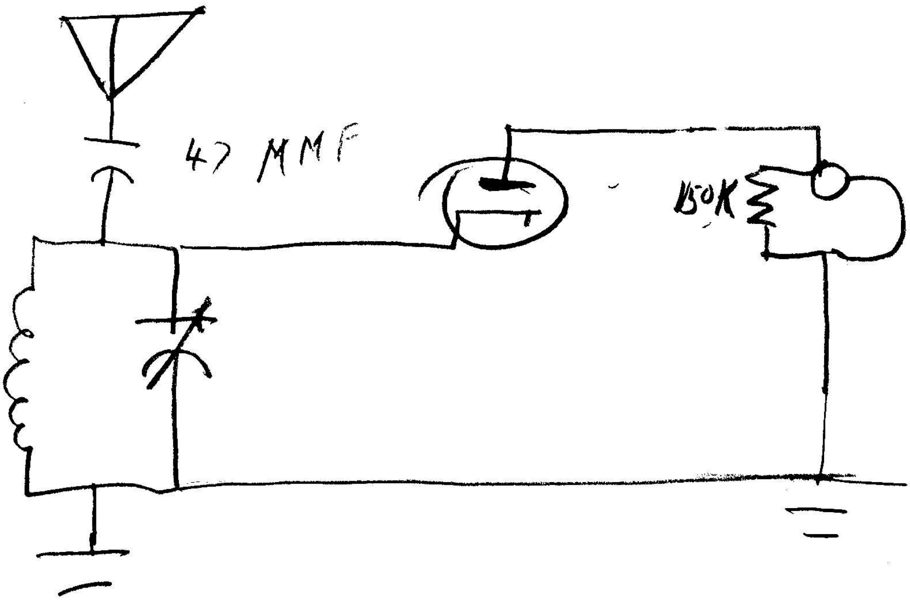
3. Electrons can flow in only one direction in a diode tube, and that is from cathode to plate.

4. To connect a diode vacuum tube into a battery circuit so current will flow, the cathode is connected to the — battery terminal, and the plate is connected to the + battery terminal.

5. Mark the lug number in the circle next to each terminal on this 7-lug tube socket.



6. From memory (and omitting the heater circuit) draw a schematic of the tuned-detector circuit with vacuum tube diode.



LESSON VII

WHAT DOES THE GRID IN A VACUUM TUBE DO?

The effect of the grid in a vacuum tube is an extremely important fundamental concept in the field of electronics, and the operation of practically all vacuum tube circuits is based on this grid-circuit, plate-circuit, relationship. This lesson will help you to understand how vacuum tube amplifiers work, through an examination of grid action in a triode tube.

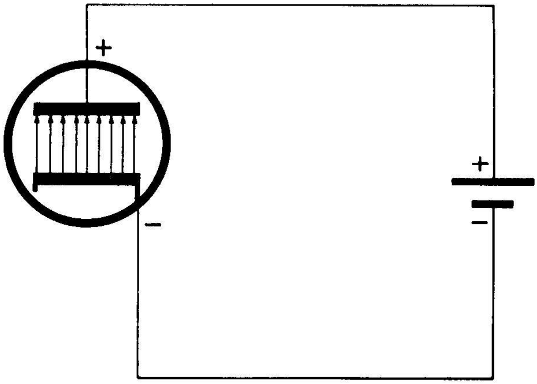


Figure 7-1

Figure 7-1 will refresh your memory on diode tube operation, in a battery circuit. Notice that the circuit is completed from the negative battery terminal to the positive battery terminal, through the diode tube, and that electrons move from the cathode to the plate, permitting current flow around the entire circuit. Observe too, that the cathode is always negative and the plate is always positive. The electrons are pushed off of the negative cathode and attracted to the positive plate by the electrical pressure of the battery.

While the circuit of Figure 7-1 was quite helpful as a means of explaining diode vacuum tube theory, it is not a very practical circuit. The battery would be shorted by the tube, because the tube connects directly across the battery leads. This circuit has been redrawn in Figure 7-2 to add a resistor in series with the vacuum tube and the battery. This resistor acts as a "load" in the circuit, and limits the current so that the vacuum tube is not shorting the battery when it conducts. Arrows have also been added to the diagram to show how current flows around the series circuit. When current flows through a

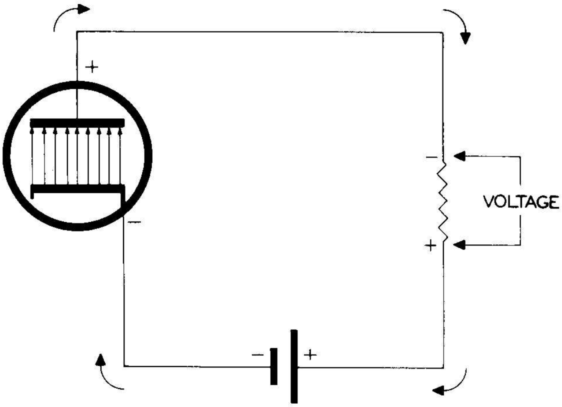
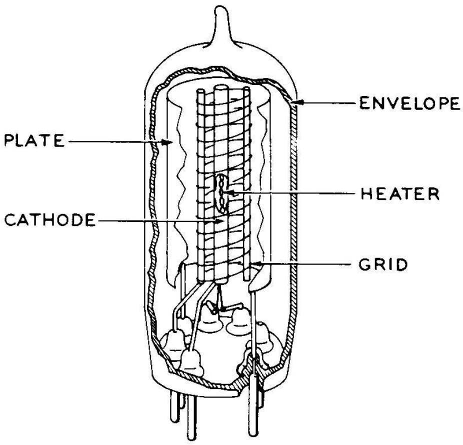


Figure 7-2

resistor, voltage is developed across it. This voltage is measured across the resistor as shown in the illustration.

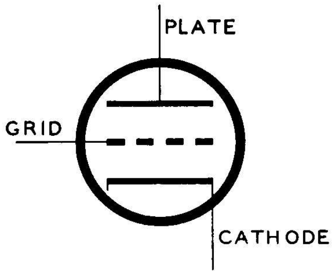
THE TRIODE TUBE



PHYSICAL CONSTRUCTION OF 6C4 TUBE

Figure 7-3

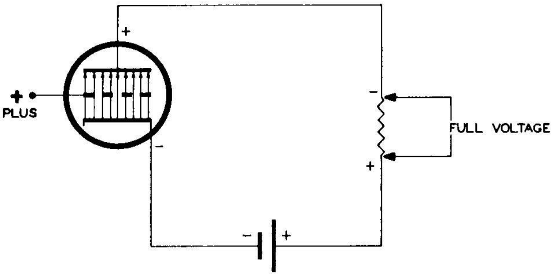
A triode tube has three elements, as contrasted to the diode tube with only two. Take another look at the internal construction of the 6C4 triode tube in Figure 7-3. Note that the third element (grid) is a spiral of wire positioned between the cathode and the plate, so electrons moving from cathode to plate must pass through it. The schematic symbol for a triode



SCHEMATIC SYMBOL OF A TRIODE TUBE.

Figure 7-4

tube in Figure 7-4 also shows the grid positioned between the cathode and the plate, so that electrons moving through the vacuum tube must pass through the grid to reach the plate.

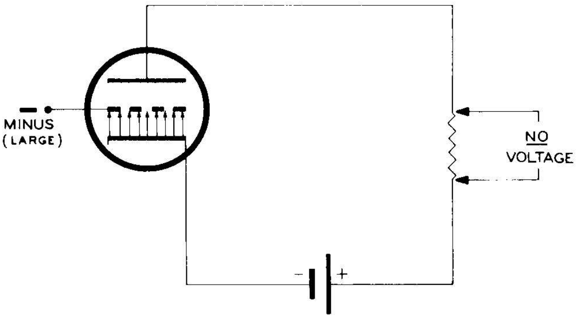


POSITIVE GRID AIDS ELECTRON MOVEMENT FROM CATHODE TO PLATE.

Figure 7-5

If a triode tube were substituted for the diode tube in the simple circuit of Figure 7-2, the circuit would appear as in Figure 7-5. If the triode grid is then connected to a positive voltage, it will act to assist the plate in pulling electrons across the vacuum in the tube, and the circuit will function as it did when a simple diode was used. Current flows from the negative terminal of the battery, through the tube from cathode to plate, through the resistor, and back to the positive terminal of the battery. In the process of helping the plate attract the electrons away from the cathode, the positive grid also accumulates some of the electrons on its spiral wires. However, this effect will be ignored for the present since the grid's limited surface area accumulates a much smaller number of electrons than the plate, and because this particular action is not essential to the basic idea of grid control to be discussed in this lesson.

GRID CONTROL OF CATHODE-TO-PLATE CIRCUIT



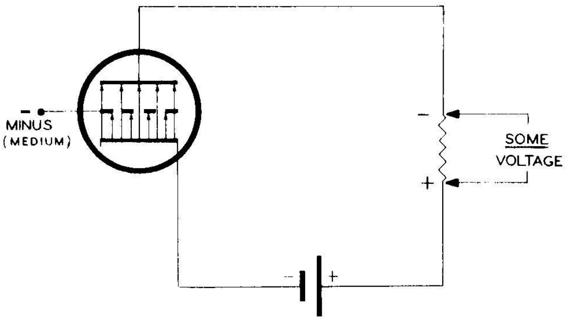
VERY NEGATIVE GRID STOPS ELECTRON MOVEMENT FROM CATHODE TO PLATE.

Figure 7-6

If the grid in a vacuum tube is connected to a highly negative voltage, this voltage will actually block the flow of electrons from cathode to plate. High negative grid voltage repels electrons and forces them back to the cathode. This keeps electrons from passing through the grid to reach the plate (see Figure 7-6). Under this condition, the grid, with a high negative voltage, is actually causing the cathode-to-grid circuit to become "open" so far as the battery is concerned. No current can then flow from the battery around the circuit, because it is blocked at the vacuum tube. Neither is any voltage developed across the resistor in the circuit because no current flows through it.

It seems quite clear that the grid in the vacuum tube can, in effect, turn the cathode-to-plate circuit off or on, depending on the voltage applied to the grid. When the grid is positive, it aids and accelerates the movement of electrons from the cathode to plate (Figure 7-5), while when it is highly negative, it can actually block the movement of electrons from cathode to plate (Figure 7-6). In a sense, the grid acts as a "switch" in these two extreme conditions. The grid has been given the name control grid for this reason.

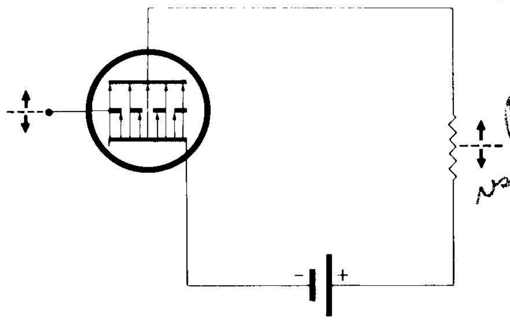
Between the condition where the control grid is highly negative and stops all current flow, and the condition where it is positive and assists current flow, there is a range of grid voltage that cuts down on the movement of electrons from cathode to plate but does not stop this



MODERATELY NEGATIVE GRID CONTROLS THE AMOUNT OF ELECTRON MOVEMENT FROM CATHODE TO PLATE.

Figure 7-7

movement entirely. This might be called the "usable range" of grid voltage so far as vacuum tube amplification is concerned, and is illustrated in Figure 7-7. Notice that the grid does hold back many electrons in the cathode-to-plate circuit, but allows enough electrons to get through so that the circuit can still function. Electrical pressure from the battery causes current to flow in this circuit, but the current is less than maximum and, therefore, the voltage appearing across the resistor in the circuit is lower than full battery voltage. It is by this means that the grid voltage controls the voltage across the load resistor in the plate circuit.



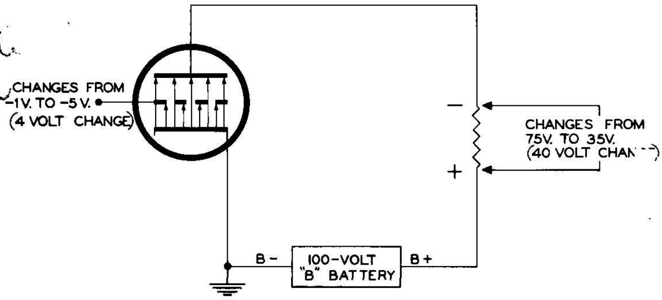
CHANGES IN GRID VOLTAGE CAUSE CHANGES IN VOLTAGE ACROSS PLATE RESISTOR.

Figure 7-8

To pursue this idea further, refer to Figure 7-8. The arrows at the control grid symbolize increases and decreases in grid voltage, while the arrows next to the resistor in the cathode-to-plate circuit (you may call this the plate resistor) symbolize increases and decreases in the voltage appearing across this resistor. If the control grid is made slightly negative, the voltage across the plate resistor will decrease slightly, as the control grid limits the number of electrons reaching the plate. If the grid is made even more negative, the voltage appearing across the plate resistor will be reduced even more. If the control grid is made very negative, it may shut off all electron movement so that the voltage across the plate resistor drops to zero. On the other hand, if the control grid is very negative and is made less negative, the voltage across the plate resistor will increase, etc. As the voltage on the control grid changes up and down, the voltage across the plate resistor also changes up and down, in step.

AMPLIFICATION

To illustrate the idea of amplification more dramatically, the simple circuit being used for discussion purposes has been changed slightly (see Figure 7-9). First, the single cell that was shown as a source of electrical energy has been replaced by a 100-volt battery. This may be called the "B battery" since this is the name that has traditionally been used to describe the battery supplying the cathode-to-plate circuit. Second, the cathode has been connected to ground (chassis), which in no way affects the basic operation of the simple circuit, but which merely follows convention in grounding the negative side of the power source (B-) to the chassis.



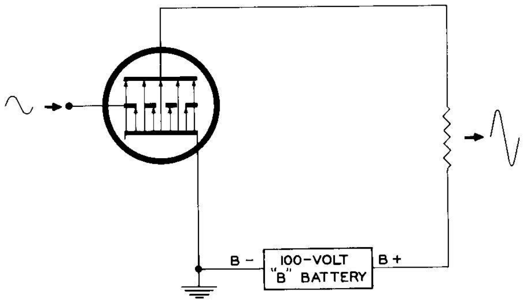
4 VOLT CHANGE IN GRID VOLTAGE CAUSES 40 VOLT CHANGE ACROSS PLATE RESISTOR.

Figure 7-9

Notice that all circuit relationships are still the same. The battery, the vacuum tube, and the resistor, are still connected in series, and the grid is between the cathode and the plate to control electron movement between these two tube elements.

As the control grid voltage is changed, say, from minus 1 volt, to minus 5 volts, the voltage appearing across the plate resistor might change from 75 volts down to 35 volts. It could then be said that a 4-volt change in grid voltage caused a 40-volt change (the difference between 35 volts and 75 volts) across the plate resistor. This is the basic concept of amplification. A small change in grid voltage can cause a large change in the cathode-to-plate current and, therefore, a large change in voltage across the plate resistor. The large-size battery in the cathode-to-plate circuit supplies the extra voltage necessary for this dramatic 40-volt swing, yet this large amount of voltage may be controlled by a small change in grid voltage. This is the real advantage of a vacuum tube, and the characteristic of vacuum tubes that practically revolutionized our modern world by opening up possibilities of electronic control, amplification and long-range communication, that were virtually impossible before the device was discovered.

As changing grid voltage causes a larger changing voltage across the plate resistor, so it is also true that a very small signal voltage applied to the grid of the vacuum tube can produce a much larger signal voltage in the cathode-to-plate circuit (across the plate resistor) that follows the same pattern of change. See Figure 7-10. An audio signal, for example, can be applied to the grid of an amplifier and it will appear across the plate resistor in the amplifier in much larger form, but in the same shape and pattern, so that the intelligence contained by the signal has not been altered.



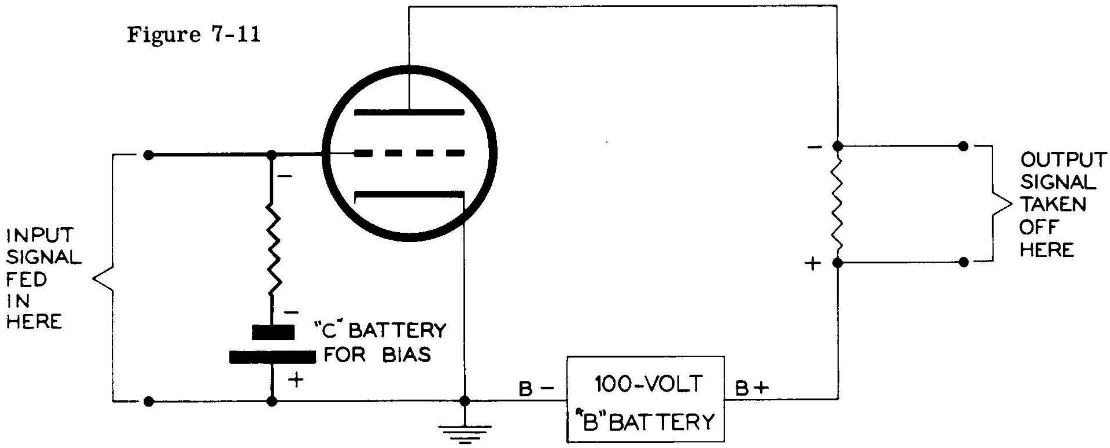
GRID SIGNAL APPEARS ACROSS PLATE RESISTOR IN ENLARGED FORM.

Figure 7-10

GRID BIAS

As mentioned earlier in this discussion, the ideal operating range for the grid voltage is somewhere between the two extremes of its control. The grid should not be so negative that it cuts off electron movement from cathode to plate entirely...but on the other hand, it should not be positive either, since this causes the grid to attract some of the electrons away from the plate, because the grid is positive also. This "in-between" range, where the grid does the best job of controlling the cathode-to-plate current, requires that the grid be made slightly negative to start with. This is so a signal can be applied to the grid without causing the grid to become positive, even though the signal is swinging up and down in voltage. Placing an initial negative voltage on the control grid is called "biasing" the tube. A biasing circuit is shown in Figure 7-11. Notice that the circuit

Figure 7-11



BIAS BATTERY ("C" BATTERY) KEEPS GRID OPERATING IN OPTIMUM VOLTAGE RANGE.

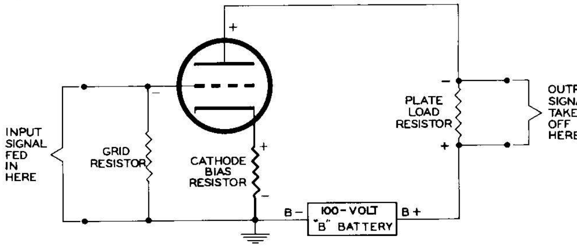
is the same as in previous illustrations, except that a battery has been connected between the cathode and the grid, with the positive end of the battery connected to the cathode, and the negative end connected to the grid, through a resistor. The resistor can be ignored for the moment, and you may consider that the battery is effectively connected directly from the grid to the cathode. This makes the grid negative as compared to the cathode, keeping grid operation in the range where it will have the most effective control over plate resistor voltage. Most radios in the early days used "C" batteries to provide bias for amplifier circuits, although different means are used in today's modern sets. A small signal fed into the circuit of Figure 7-11, would be amplified and would appear in larger form across the plate resistor. There would be a minimum amount of "distortion," since the tube is biased to prevent the control grid from going positive. Ideally, the output signal of an amplifier should be identical to the input signal, except in size. Distortion occurs when the signal is changed or distorted by the circuit that is amplifying it.

The resistor shown in series with the "C" battery performs no function so far as bias is concerned, but is inserted in the circuit to prevent shorting the incoming signal. Without this resistor, the signal would be shorted through the battery itself, and would not reach the grid.

"B" batteries were mentioned as the supply for the cathode-to-plate circuit, "C" batteries have been identified as the source of bias for the grid circuit in old-style radios...so "A" batteries should be mentioned too. An "A" battery supplies power for the tube filaments in a battery-operated radio. Even modern vacuum tube portable radios still use "A" and "B" batteries, although the need for separate "C" batteries has declined over the years.

SELF-BIAS

Providing an extra battery merely to bias the tubes in a radio was not a very convenient arrangement, and some means was desirable to eliminate the "C" battery if possible. Such an answer was developed, and the technique of "self-bias" eventually replaced the "C" battery in radios. Figure 7-12 shows how self-bias operates.



"SELF-BIAS" WITH A CATHODE BIAS RESISTOR REPLACES THE "C" BATTERY.

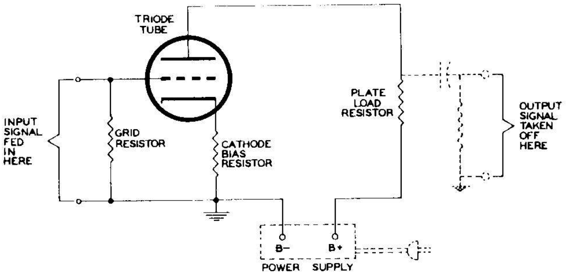
Figure 7-12

Instead of using a separate "C" battery to make the grid negative as compared to the cathode, to keep the tube operating in the correct range of the grid voltage, a resistor was inserted in the cathode circuit to accomplish this same purpose. The direction of current flow in the "B" battery circuit (from the negative battery terminal up through the cathode resistor, across from the cathode to plate, down through the plate resistor, and back to the positive battery terminal) is such that the small voltage developed across the cathode resistor (which is a smaller resistor value than the plate resistor) has the polarity shown in Figure 7-12. Notice that the top end of the resistor (connected to the cathode) is positive, while the bottom end of the resistor is negative. Note, also, that the negative end of the resistor connects around to the control grid. The resistor from the control grid to ground can be ignored in the same sense as the grid resistor in the previous circuit was ignored. It is installed at this point merely to convey the negative voltage to the grid, and to prevent the incoming signal from being shorted. So far as this explanation is concerned, you can think of the control grid as being at exactly the same voltage potential as the bottom end of the cathode resistor.

The unusual thing about this "self-bias" idea is that to make the grid more negative than the cathode, the cathode was merely made more positive. The relationship between the cathode and grid is then the same as if the grid had been made more negative. You may have to think about this for a few moments, but when you consider that the objective to be achieved is to make the grid more negative than the cathode, this can be done just as easily by making the cathode more positive as it can by making the grid more negative. It is not a very obvious idea, just off hand, and perhaps that is why it was not used originally in the early radio sets, but was to be discovered later.

The circuit of Figure 7-12 functions just like the simplified examples given previously. A small incoming signal is amplified in the circuit and appears as a much larger signal, having the same shape, across the plate resistor.

PRACTICAL CIRCUITS



POWER SUPPLY REPLACES "B" BATTERY.

Figure 7-13

If you were to look at the schematic diagram of a modern radio receiver, and locate one of the amplifier stages, you would probably see something that looks like Figure 7-13. The main difference between this circuit and the one just discussed in Figure 7-12, is that a power supply has been used instead of a "B" battery. Of course, portable radios still use batteries...but most home radios are designed to operate from the power line, and a power supply circuit substitutes for the battery in providing the electrical pressure for the cathode-to-plate circuit. You can still trace out the circuit functions in Figure 7-13 by observing how electrical pressure causes the current to flow from the negative side of the power supply (called B minus) up through the cathode resistor, across from cathode-to-plate through the grid, down through the plate resistor, to the positive (B plus) terminal of the power supply again. The incoming signal is applied across the grid resistor and causes the control grid to regulate the amount of voltage across the plate load resistor.

This discussion of vacuum tubes and amplification is probably the biggest step you have taken in the lessons of your EK-2A kit so far. Since much of this material is new to you, a thorough rereading of this section of the manual might be in order. Do not hesitate to take the time necessary to study this lesson again, before going ahead with the experiment, because basic vacuum tube operation is quite important to all the lessons that follow, and is a concept you will want to have firmly fixed in your mind. You might allow several days to elapse before coming back to reread this section, and you may be surprised at how some ideas that may seem slightly "vague" to you at the moment will clear up with several readings.

When you have done this, you are ready to conduct the experiment of this lesson, in which you actually build a vacuum tube amplifier and use it to listen to the local stations being picked up on your crystal detector.

HOW TO BUILD A VACUUM TUBE AMPLIFIER

PURPOSE

TO BUILD A TRIODE VACUUM TUBE AMPLIFIER AND DEMONSTRATE GRID CONTROL OVER THE CATHODE-TO-PLATE CIRCUIT; AND TO CONNECT THIS CIRCUIT TO AMPLIFY THE OUTPUT OF THE CRYSTAL DETECTOR.

MATERIALS REQUIRED

1 1000 ohm 2 watt resistor
1 1 megohm 1/2 watt resistor
1 3.3 megohm resistor
1 .005 mfd ceramic capacitor
1 40 and 20 mfd, 300 volt electrolytic capacitor
1 5Y3 rectifier tube
1 #47 pilot lamp
1 Pilot lamp socket
1 Octal tube socket
1 Capacitor mounting wafer
4 #6 screws, lockwashers and nuts
2 12,000 ohm 2 watt resistors
EK-1 or equivalent.
Assembled experiment from Lesson VI.

PREPARING THE CHASSIS FOR THIS EXPERIMENT (See Figure 6-16 on Page 48.)

( ) Remove the line cord plug from the wall socket.

( ) Disconnect the antenna and the ground leads from the screw terminals at the back of the chassis.

( ) Remove the wire between lug 7 of the 6C4 tube socket and the orange terminal of the regenerative detector coil.

( ) Remove the jumper wire between lugs 5 and 6 of the 6C4 socket.

( ) Remove the 150 Kohm resistor from across lugs 1 and 2 of the phone jack.

( ) Remove the lead from between phone jack lug 1 and T-1.

( ) Disconnect the wire from T-2 and leave it hang free temporarily.

( ) Disconnect the pilot lamp lead from lug 4 of the 6C4 tube socket.

( ) Leave the other parts mounted and in place, since the same components will be used in this circuit.

STEP 1 - BECOMING FAMILIAR WITH THE PARTS

You have undoubtedly noticed already that the resistors you have used so far are the same size physically, even though they vary in resistance value. In this experiment you will use a 1000 ohm resistor and two 12,000 ohm resistors that are larger than usual. While the physical size of a resistor has no bearing on its resistance value, it does relate to its power rating (the amount of current it is capable of handling at any given voltage). The larger the resistor, the higher the power rating. Power is measured in watts, and is the product of multiplying the current through the resistor by the voltage across it, or multiplying the square of the current times the resistance. The resistors you have been using up to now have been rated at 1/2 watt, while the three resistors mentioned in this experiment are rated at two watts.

Several other parts that are new to you are used in this experiment, including the 40-20 mfd electrolytic capacitors, the 5Y3 tube, etc. These components are used in the power supply which you build up as a preliminary step in constructing this circuit. The main objective of the experiment is not to go into the "how and why" of power supplies at this time. A full explanation of these new parts will be postponed to a later experiment when the subject of power supplies is covered in depth. For the moment, go right ahead and use these parts as specified in the manual even though you are not fully acquainted with their function in the circuit or the part they play in power supply operation.

The power supply is a circuit designed to operate from your AC power line and produce DC power comparable to that obtained from a battery. The power supply is, in a sense, a battery eliminator, and it will be used in the circuit you are about to build to provide higher DC voltage without using a large battery as a source of power.

The 5Y3 is an octal type tube, and employs a larger tube socket, with more terminals, than the sockets you have already installed. The lugs of the octal socket are numbered in a clockwise direction as viewed from the bottom, beginning at the "keyway" in the center hole of the socket. Figure 7-14 illustrates the socket terminal identification for wiring purposes, as viewed from the bottom.

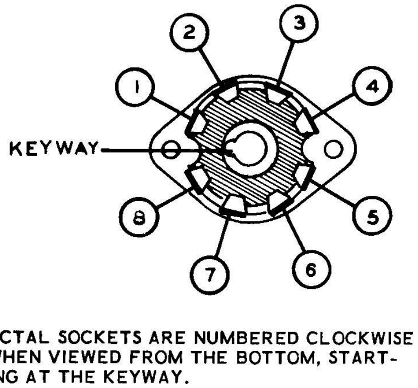


Figure 7-14

The other parts employed in this experiment are resistors and capacitors similar to those you have already used, so no special explanation is required.

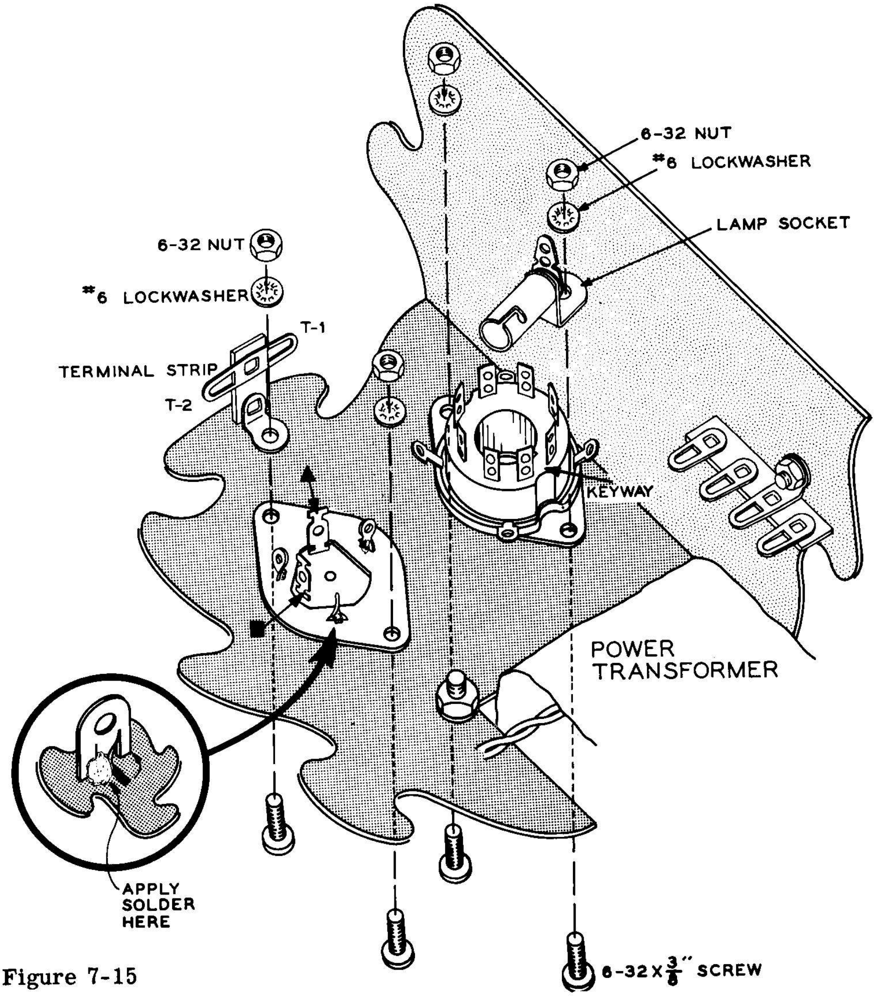


Figure 7-15

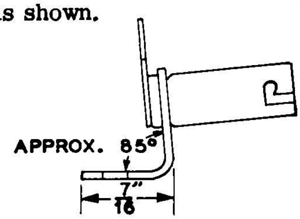
MOUNTING THE CAPACITOR, TUBE SOCKET, AND LAMP SOCKET.

STEP 2 - MOUNTING THE PARTS

Follow the pictorial diagram in Figure 7-15 in mounting the octal socket, the capacitor, and the pilot lamp under the chassis, as specified below.

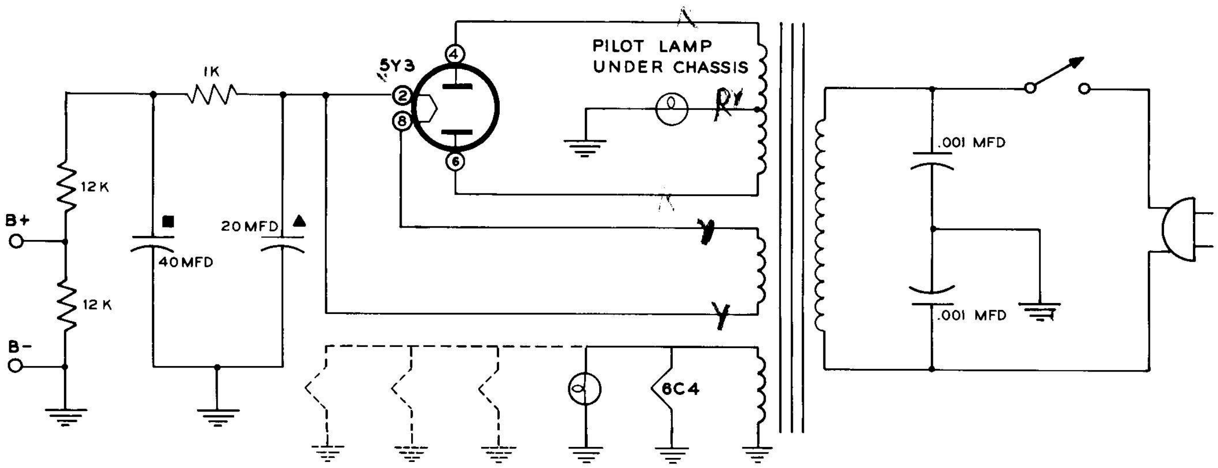
(✓) Install the capacitor mounting wafer first, as shown in the pictorial diagram, using 6-32 screws, lockwashers and nuts. Position the wafer and remount the "T" type terminal strip as shown. Note the position of the slots in the wafer.

(✓) Mount the electrolytic capacitor itself, from the top of the chassis through the slots in the mounting wafer. Make sure the terminals of the capacitor are positioned as shown in Figure 7-15, and hold the capacitor tight against the wafer while twisting the mounting tabs (not more than 1/4 turn) as shown in Figure 7-15. Solder one mounting tab to the wafer as shown.



PREPARING THE LAMP SOCKET FOR MOUNTING.
Figure 7-16

(✓) Bend the bracket on the pilot lamp socket as shown in Figure 7-16 and then mount it while mounting the octal tube socket, as shown in Figure 7-15. Note the position of the keyway when mounting the octal socket. Use 6-32 screws, lockwashers and nuts.



POWER SUPPLY TAKES THE PLACE OF BATTERY, SUPPLYING B+ AND B-.

Figure 7-17

STEP 3 - WIRING THE POWER SUPPLY CIRCUIT

The schematic diagram of the power supply in Figure 7-17 and the pictorial diagram in Figure 7-18 should be followed in wiring this section of the circuit. Position the wires as close as possible to the locations shown in the illustration. You are not expected to understand the function of the power supply circuit at this time, so the schematic diagram is purely for informational purposes. Notice that the power supply consists of the power transformer (which was already mounted in a previous experiment), a type 5Y3 rectifier tube, a two-section electrolytic capacitor, and a 1000 ohm 2-watt filter resistor, along with a pair of 12,000 ohm resistors.

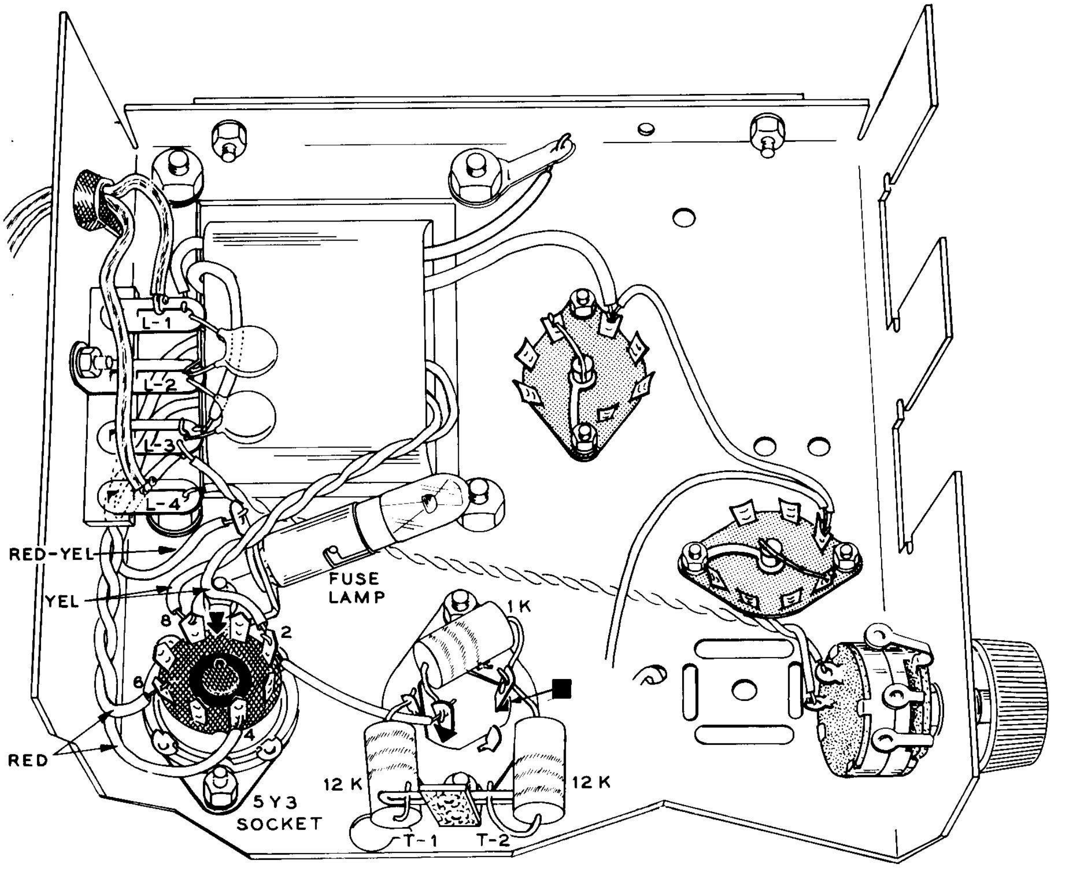
( ) Twist the two red transformer leads loosely together and connect one to lug 4 and the other to lug 6 of the 5Y3 tube socket.

( ) Twist the two yellow transformer leads loosely together and connect one to lug 2 and the other to lug 8 of the 5Y3 socket.

( ) Connect the red-yellow transformer lead to the terminal of the pilot lamp mounted beside the 5Y3 socket.

( ) Install the pilot lamp in its socket.

( ) Connect a length of hookup wire from lug 2 of the octal socket to the ▲ terminal of the filter capacitor. It is important at this time that you look closely at the two terminals of the electrolytic capacitor. You will notice two cutouts in the fiber insulation, one next to the base of each terminal; one forms a triangle (▲) and the other a square (■). These cutouts identify the terminals, and will be referred to in the text.



PICTORIAL VIEW OF POWER SUPPLY WIRING.

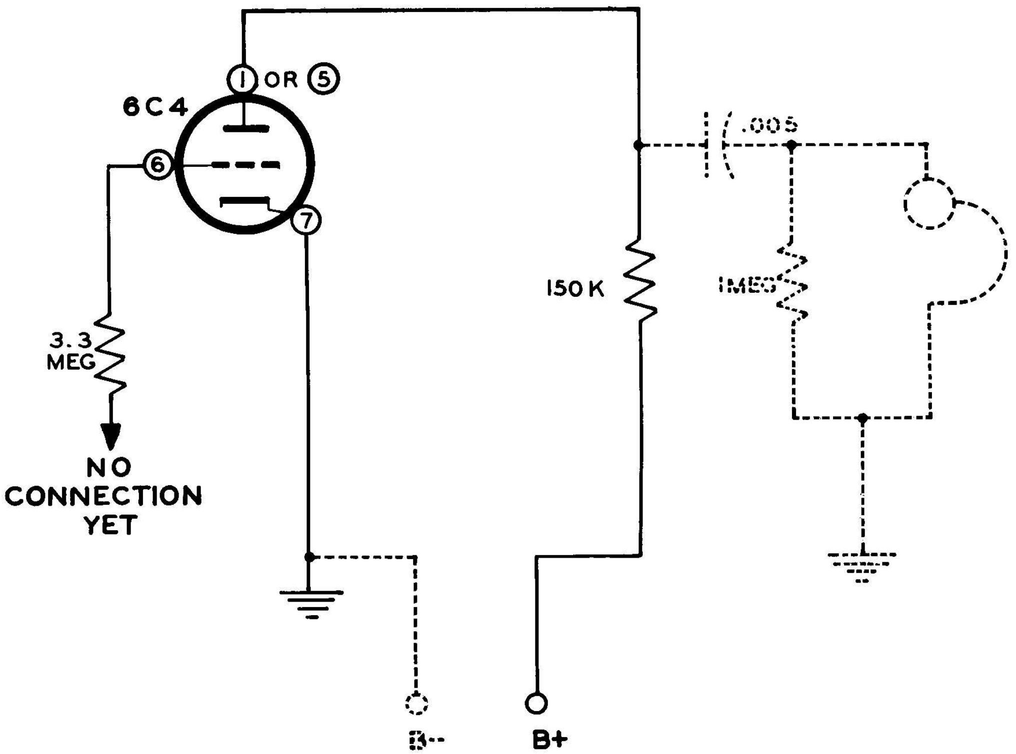
Figure 7-18

( ) Connect the 1000 ohm (brown-black-red) 2 watt resistor between the ▲ and ■ terminals of the filter capacitor.

( ) Connect a 12 K ohm (brown-red-orange) 2 watt resistor from the ■ capacitor terminal to T-2.

( ) Connect the other 12 K ohm (brown-red-orange) 2 watt resistor from T-1 to the capacitor ground lug (see Figure 7-18).

These steps complete the wiring of the power supply section of the circuit. The power supply can be viewed, at this point, strictly as a substitute for a battery. The negative terminal of this "battery" (B-) is the chassis itself, and the plus terminal of the battery (B+) is T-1 or T-2. You will want to keep this in mind as you perform the experiment.



SCHEMATIC OF AMPLIFIER CIRCUIT.

Figure 7-19

STEP 4 - WIRING THE AMPLIFIER CIRCUIT

The wiring for this section of the experiment can be performed while following the schematic diagram of the amplifier circuit in Figure 7-19, and the pictorial diagram in Figure 7-20.

( ) Connect a jumper wire at the 6C4 tube socket, from the center ground post over to lug 7, and from the center ground post over to lug 4.

( ) Connect a 150 KΩ (brown-green-yellow) resistor between lug 5 of the 6C4 socket and T-2.

( ) Connect the .005 mfd capacitor between lug 1 of the phone socket and the free end of the wire still connected to lug 5 of the 6C4 socket, as in Figure 7-20.

( ) Connect the 1 megohm resistor (brown-black-green) across lugs 1 and 2 of the phone socket. (See Figure 7-20.)

( ) Connect the lead from the pilot lamp above the chassis to lug 3 of the 6C4 tube socket, after passing it through the chassis hole as in the last experiment. The pilot lamp, this time, will be operating as a warning light to let you know when the power supply is turned "on."

( ) Connect one end of the 3.3 megohm resistor (orange-orange-green) to lug 6 of the 6C4 tube socket, solder a 12" length of hookup wire to the other resistor lead, and leave this hookup wire hanging free.

( ) Install the 5Y3 tube in the octal socket.

This completes the wiring for the amplifier section of this experiment.

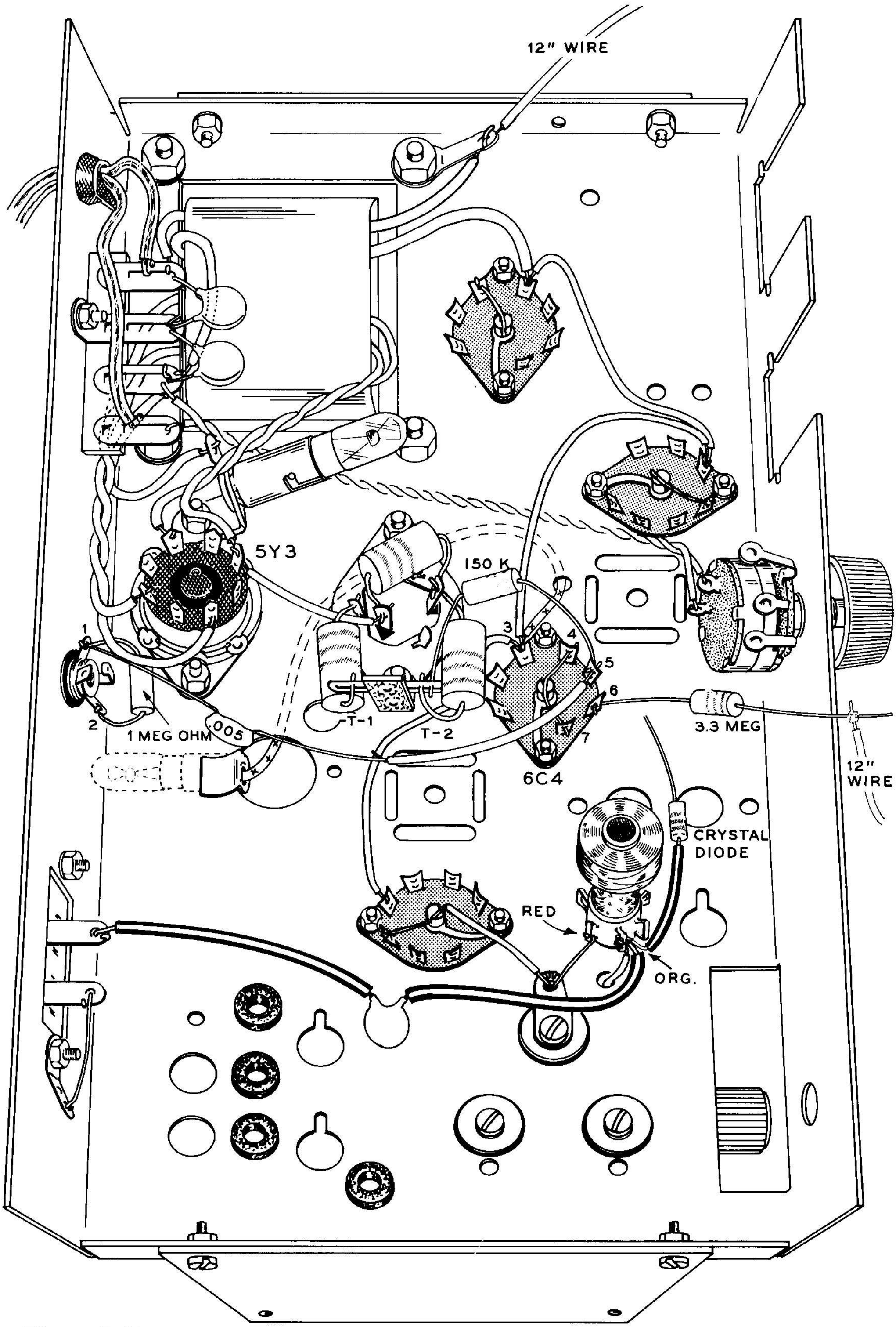


Figure 7-20

PICTORIAL OF AMPLIFIER CIRCUIT (AND POWER SUPPLY).

CAUTION

The wiring you have just completed includes a power supply capable of producing voltages higher than your power line voltage. Any danger to your person from electrical shock can be minimized, however, if you will follow a few simple procedures in handling the circuit. In addition to pulling the line plug between actual demonstrations, as instructed previously:

1. Do not touch any terminals below the chassis when the switch is in the "ON" position.

2. Watch the pilot lamp on top of the chassis as a warning of when the high voltage is on. This precaution includes any measurements you might make with the EK-1 Test Set. You can hold the insulated part of the red test probe to make a measurement, but you should not touch the metal part of the probe, nor should you touch the alligator clip on the black test lead, unless you first turn the switch "OFF."

3. Any time you make a measurement, or change something under the chassis, perform these operations with the switch "OFF," and then turn the circuit "ON" again for your test.

STEP 5 - DEMONSTRATING GRID CONTROL OF THE PLATE CIRCUIT

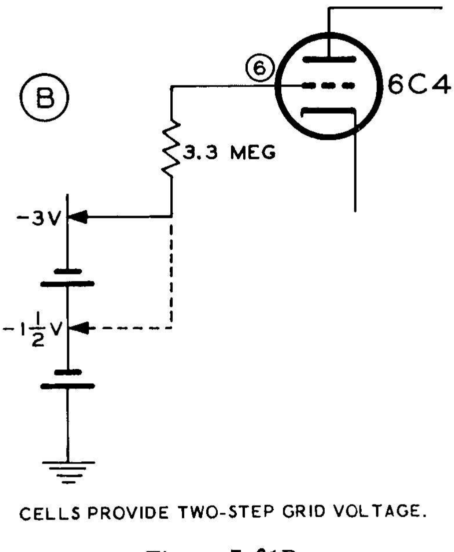


Figure 7-21B

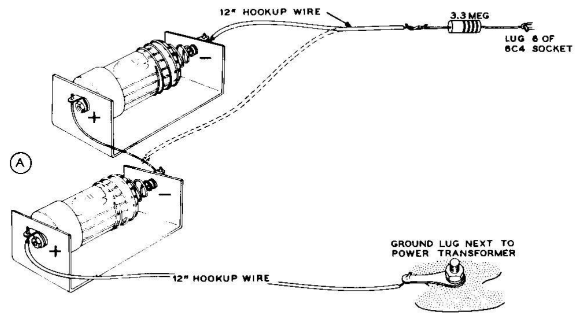


Figure 7-21A

Flashlight cells will be used in this experiment to change grid voltage. Your EK-1 Test Set (or its equivalent) will be used to measure the change in voltage across the plate resistor. Figure 7-21A is a pictorial diagram of how two flashlight cells are connected in series between ground (the chassis) and the free end of the 12" length of hookup wire connected to the 3.3 megohm resistor. This arrangement in the grid circuit is shown schematically in Figure 7-21B. Your ground connection to the chassis can be made conveniently by using another 12" length of hookup wire connected to the ground lug next to the power transformer.

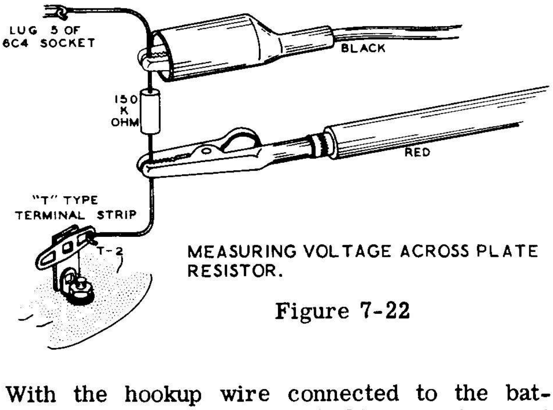


Figure 7-22

With the hookup wire connected to the batteries, as shown in Figure 7-21A, and the EK-1 Test Set connected to measure voltage across the plate resistor (Figure 7-22), switch the EK-1 selector switch to the 100 volt range and turn the entire circuit "on" by plugging in the line cord and rotating the EK-2A control switch. Record your reading in the "1st TEST" box of the chart in Figure 7-23. This is the plate resistor voltage reading for -3 volts bias (both batteries connected in series to the grid).

GRID VOLTAGE	PLATE RESISTOR VOLTAGE	
-3	32.0	1 ST TEST
-1 1/2	67.0	2 ND TEST
1 1/2	35.0	DIFFERENCE

RECORDING PLATE RESISTOR VOLTAGE MEASUREMENTS AS GRID VOLTAGE IS CHANGED.

Figure 7-23

Now turn off the power, pull the line plug, leave the EK-1 Test Set as it is, and remove the length of hookup wire from its connection at the negative battery terminal and connect it to the junction between the two batteries, so that only one battery is in the grid circuit. Now plug in the line plug and turn on the power again. Read the EK-1 meter after the circuit warms up. Record this result in the "2nd TEST" box of the chart in Figure 7-23. The "DIFFERENCE" box in the chart of Figure 7-23 will not be filled in at this time.

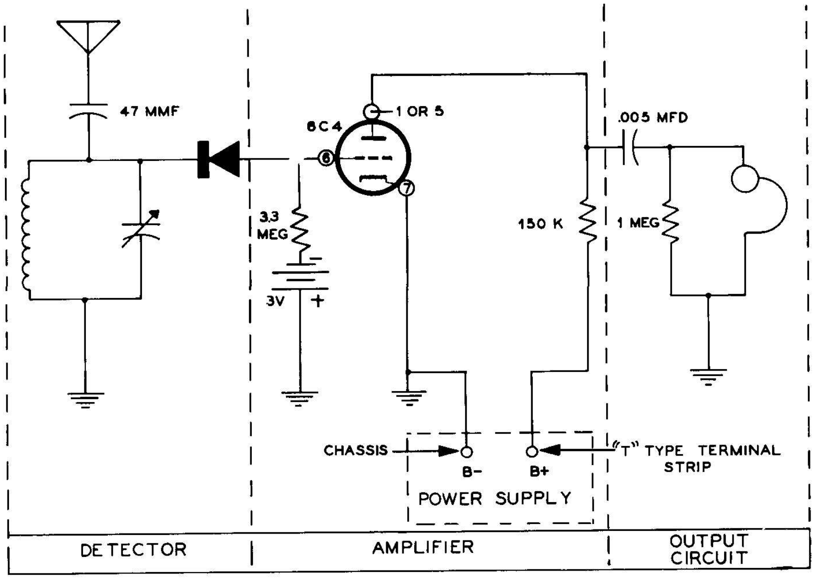
The reading you have just made is the plate resistor voltage when the grid voltage is reduced from -3 volts to only -1-1/2 volts (for a change of 1-1/2 volts at the grid. You will see the significance of these tests later in the "discussion." Now turn the circuit "off," and pull the line plug.

STEP 6 - AMPLIFYING THE OUTPUT OF THE CRYSTAL DETECTOR

( ) Connect the 12" length of hookup wire (connected to the 3.3 megohm resistor), back to the negative terminal of the second cell again, so you have a full -3 volts of bias on the 6C4 tube.

( ) Now, connect the free end of the crystal diode to pin 6 of the 6C4 tube socket. This connects the output of your crystal detector circuit to the input of the amplifier you have just constructed, instead of directly to the earphone as it was connected before. This can be seen schematically in Figure 7-24.

( ) With the circuit still "off," connect the antenna and ground leads to the appropriate screw terminals on the back of the chassis and plug in the earphone. Now plug in the line plug and turn the entire circuit "on." You should be able to hear the same stations you have listened to in previous listening tests, but with greater volume because of the amplification provided by the amplifier circuit you have constructed. You may even find that you can hear a station or two that you were unable to pick up before because the volume was too low. Turn "off" the circuit and pull the line plug.



SCHEMATIC OF DETECTOR AND AMPLIFIER CIRCUITS COMBINED.

Figure 7-24

DISCUSSION

Going back to the readings you recorded in Step 5, when you were demonstrating grid control of the plate resistor voltage, you can now take the difference between the two readings to record the "difference" voltage in the chart of Figure 7-23. The difference voltage already provided in the left column is 1-1/2 volts, and this represents the amount of voltage change that took place on the grid. The difference voltage in the right-hand column is found by subtracting the reading in the 1st TEST from the reading in the 2nd TEST. Record the difference voltage in the chart. This represents the amount of voltage change that took place across the plate resistor.

You should find that the change in plate resistor voltage is in the neighborhood of 10 to 20 volts. This is a considerably greater change than the 1-1/2 volt change in grid voltage that caused it. It may be seen that the triode tube truly amplifies changing voltage, since a grid change of only 1-1/2 volts, produced a plate resistor voltage change of approximately 15 volts.

In Step 6 of this experiment, the output of the crystal detector circuit was fed to the amplifier to build up its size so that the signal could be heard louder in the earphone. Referring to Figure 7-24, you can see that the basic circuit functions remain the same as in previous experiments, in that the tuned circuit selects the signal, the crystal diode detects the signal and produces an audio signal from the modulated RF signal fed into it, and then this audio signal is amplified in the 6C4 triode circuit. The signal is then fed to the earphone through a coupling capacitor. You have constructed an audio amplifier, since this is the use to which the added 6C4 circuit is being put.

The function of the .005 mfd coupling capacitor is to prevent the high DC voltage in the plate circuit from getting into the earphone. A capacitor, as you have seen previously, will not pass DC current and, therefore, it acts as a block as far as plate current is concerned. A capacitor will have the effect of passing AC signals, however, through its charge and discharge action, and this unique property of the part is put to use in this circuit.

There should be a noticeable difference in the volume of the stations picked up by the antenna, as heard through this improved, one-tube, "radio" circuit.

The function of the pilot lamp on top of the chassis is to act as a warning device to let you know when the circuit is "on." The lamp under the chassis is functioning as a fuse. It is connected in series with the high voltage supply and will burn out if the high voltage is accidentally shorted. This protects other components in the power supply from damage.

In your next experiment you will see how a triode vacuum tube can be connected so that it not only amplifies an incoming signal but performs the detection function as well!

Your present circuit can be left assembled for listening enjoyment and for demonstration to your friends and family, until you are ready to start the next experiment. Always be sure to turn the switch "off" when the circuit is not in use, and be very careful about the high voltage under the chassis.

LESSON VII

QUESTIONS

NOTE: The answers to the questions for Lesson VII will be found at the back of the book on Page 85.

1. Draw the schematic symbol for a triode tube (with heater).

2. What function does the control grid in a vacuum tube perform? as a gate for electrons from the cathode to plate

3. When the grid in a triode tube is made more negative, the electron flow from cathode to plate decreases (increases or decreases)?

4. When a tube circuit is amplifying, the voltage change across the plate resistor is: ________ (greater than - smaller than) the voltage change at the grid.

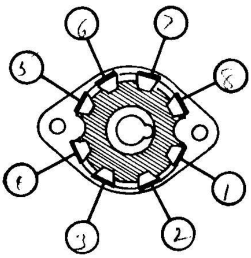
5. Grid bias in a vacuum tube circuit makes the grid more ________ (negative - positive) than the cathode.

6. If a "B" battery supplies power to the cathode-to-plate circuit, and a "C" battery supplies bias to the grid circuit, what does an "A" battery do? heat filament

7. Self-bias in an amplifier circuit is accomplished by putting a resistor in the cathode circuit to make the grid more negative than the cathode (or the cathode) more positive than the grid).

8. A power supply takes the place of B batteries in most home radios.

9. Identify the terminal numbers on this octal socket.



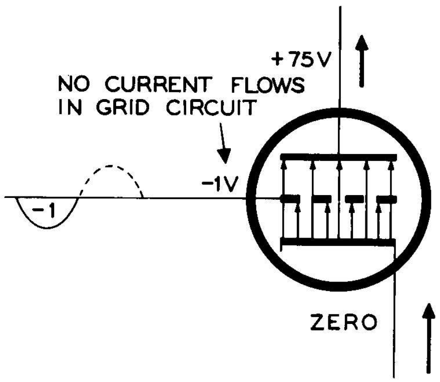
LESSON VIII

CAN ONE VACUUM TUBE DO TWO THINGS AT ONCE?

The 6C4 tube in your last experiment was operated as an audio amplifier to build up the signal volume in the earphone. The signal was detected in the circuit employing the crystal detector, although this same function could have been accomplished with another vacuum tube in the circuit. In either case, however, you would be requiring two tubes, or a tube and a crystal diode, to detect and amplify the signal.

Actually, both detection and amplification can be performed by one triode tube under certain circumstances. This lesson will explain how a single triode tube can detect a modulated broadcast signal, and amplify the remaining audio signal, both at the same time.

MINUS AND PLUS GRID VOLTAGE



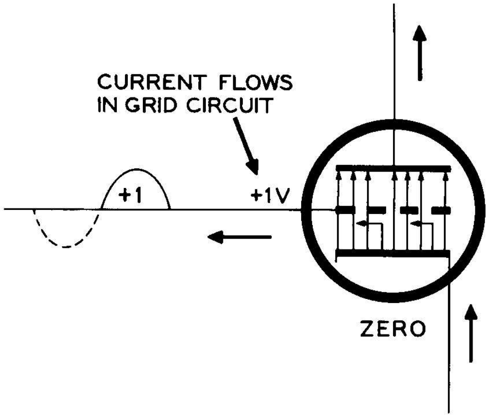
NO GRID CURRENT FLOWS AS LONG AS THE GRID IS MORE NEGATIVE THAN THE CATHODE.

Figure 8-1

Figure 8-1 illustrates the relationship between the three elements in the triode tube when an alternating (plus and minus) signal is applied to the control grid. This diagram shows the condition for the first half-cycle of an alternating voltage, when the voltage is swinging in a negative direction.

If you use the cathode as a "zero voltage" reference, it may be said that the control grid of this tube is at a potential of -1 volt due to the signal applied to it. The plate voltage may be said to be +75 volts, as compared to the cathode (zero), because it is connected to the plus terminal of a B battery through the plate resistor.

As in the examples given before, the control grid (being more negative than the cathode), tends to repel electrons and limit the electron flow from cathode to plate. No current flows in the grid circuit itself, however, since it is repelling electrons, not attracting them. These are the tube conditions for the first half-cycle of an alternating signal applied to the grid.



GRID DRAWS CURRENT WHEN IT IS MORE POSITIVE THAN THE CATHODE.

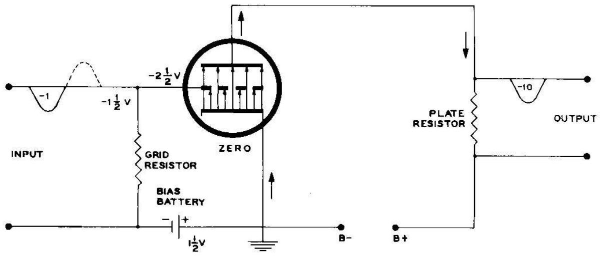
Figure 8-2

Figure 8-2 shows the relationship between the triode tube elements when the grid signal swings positive, making the control grid voltage +1 volt. The control grid is now more positive than the cathode, although it is still not as positive as the plate. What is significant about this condition is that, as soon as the grid becomes positive, even to a small degree, it begins to accumulate some of the electrons flowing from the cathode, and current then begins to flow out from the grid lead. When the grid becomes more positive than the cathode, as it is on the positive half-signal, it begins to attract electrons, instead of repelling them.

So long as the control grid of a triode tube is negative, no grid current flows. As soon as the control grid becomes positive, however, grid current flows, and the consequences of current flow in the grid circuit are considerable, and may be considered either "good" or "bad," depending on what the tube circuit is intended to do.

In a conventional amplifier circuit, for example, grid current is undesirable, and bias voltage is used in a deliberate attempt to prevent the control grid from ever becoming positive when an alternating (plus and minus) signal is applied to it. Grid current causes distortion in a conventional audio amplifier circuit.

BIAS VOLTAGE KEEPS GRID NEGATIVE

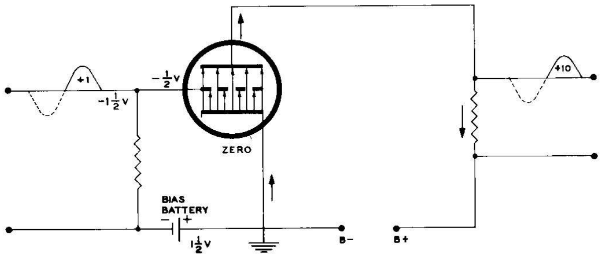


NEGATIVE SIGNAL VOLTAGE ADDS TO NEGATIVE BIAS VOLTAGE FOR MINUS 2-1/2 VOLTS ON GRID.

Figure 8-3

Figures 8-3 and 8-4 show how a conventional amplifier (with bias) operates on each half-cycle of an incoming signal, and illustrate the fact that the grid never becomes positive, and therefore no grid current flows in a conventional amplifier circuit.

The circuit of Figure 8-3 follows the example of triode circuits used in previous lessons, and you can see that a 1-1/2 volt battery is used between the grid and the cathode to apply an initial negative voltage to the grid. As the incoming signal swings to -1 volt on its first half cycle, this -1 volt adds to the -1-1/2 volt bias already on the grid, resulting in a total grid voltage of -2-1/2 volts. This negative grid voltage reduces the electron flow from cathode to plate, and the voltage drop across the plate load resistor is reduced, to follow the shape of the incoming signal.

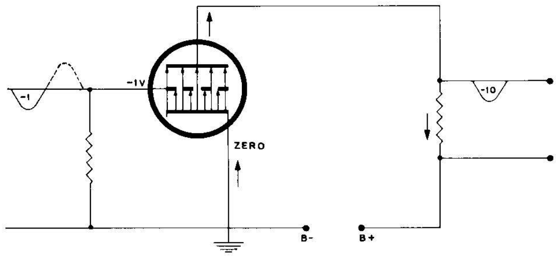


POSITIVE SIGNAL VOLTAGE SUBTRACTS FROM NEGATIVE BIAS VOLTAGE FOR MINUS 1/2 VOLT ON GRID.

Figure 8-4

On the positive swing of the incoming signal (+1 volt) shown in Figure 8-4, the +1 volt voltage cancels part of the -1-1/2 volt bias, so that the resultant grid voltage is minus 1/2 volt. While the control grid is not as negative as it was for the first half of the signal, it still has not become positive, and therefore there is still no grid current flowing. The -1/2 volt remaining on the grid still reduces electron flow from cathode to plate, but not as much as in the previous condition, so the voltage drop across the plate load resistor increases, as indicated by the half signal shown in the plate circuit of Figure 8-4.

Even though the signal applied to a vacuum tube amplifier swings plus and minus, the grid remains negative because of the negative bias voltage applied to it with a battery. This explanation also makes it clear that the amount of bias voltage applied to a vacuum tube grid should always be at least half as much as the value of the incoming signal, or the alternating signal could exceed the bias and still cause the grid to become positive.



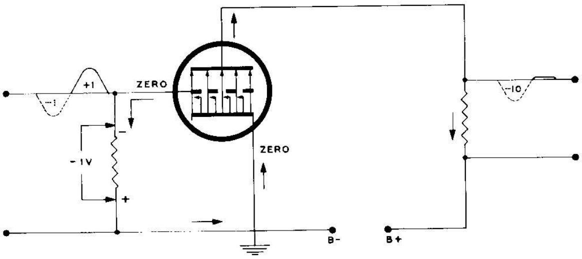
AMPLIFIER WITHOUT BIAS HANDLES NEGATIVE SIGNAL VOLTAGE OKAY.

Figure 8-5

LACK OF BIAS CAUSES RECTIFICATION

When bias voltage is removed from an amplifier circuit (as in Figure 8-5) it can no longer be said that the grid is always negative with respect to the cathode, or that no grid current ever flows in the circuit.

On the negative half cycle of the incoming signal, the grid will be negative, and the relationship between the grid circuit and the cathode-to-plate circuit will be normal as described in the previous examples. The negative swing of the signal applied to the grid will be reproduced in larger form across the resistor. However, on the positive half-cycle, where the grid actually starts to become positive with respect to the cathode, an entirely different situation exists.



AMPLIFIER WITHOUT BIAS DOES NOT AMPLIFY POSITIVE SIGNAL VOLTAGE.

Figure 8-6

Figure 8-6 shows what happens on the positive half-cycle of the grid signal in a triode vacuum tube circuit without bias voltage. As soon as the incoming signal begins to cause the control grid to swing positive with respect to the cathode, the control grid starts attracting electrons that would normally move on to the plate. This causes current to flow out of the grid, down through the very large grid resistor, and around to the cathode, where the electrons originated. When current flows through the grid resistor, a voltage is developed across it. The voltage has the polarity indicated in Figure 8-6, so that the voltage developed across the grid resistor puts a negative potential on the grid, which stops any increase in electron flow from cathode to plate. This condition exists so long as the signal is trying to make the grid positive. A positive signal pulse on the grid causes grid current, and grid current means a negative voltage will be developed across the grid resistor as current flows through it, canceling the positive signal voltage on the grid.

The net effect of this phenomenon (still referring to Figure 8-6), is that very little change occurs in the voltage across the plate resistor while the positive half-cycle of signal is applied to the grid. The negative voltage developed across the grid resistor just about cancels the positive swing of the signal, and the total effect in the amplifier circuit is that the voltage across the plate resistor hardly changes at all. The amplifier, therefore, is not amplifying and reproducing the signal on the positive half-cycle, but only on the negative half-cycle of the incoming signal.

This means that, while an alternating (plus and minus swinging) signal may be applied to the grid of an unbiased amplifier circuit, only the negative half-cycle of this signal will appear in the plate circuit. The positive half-cycle is cancelled out by the grid current flow that occurs when a grid is made more positive than the cathode. When half of a signal has been eliminated, the signal has been rectified. The amplifier circuit has then become a "one-way" device very much like a diode tube or a crystal rectifier.

The rectification that occurs in this way is not "perfect," in that the positive half-cycle is not eliminated entirely. There is still a slight rise above the zero line (Figure 8-6) at the plate resistor as the grid attempts to swing positive. However, enough of the positive part of the signal has been eliminated that the negative half signal becomes predominant, and the signal is essentially "rectified."

The negative half-cycle passes through this circuit and is amplified faithfully, since it does not cause the grid to become positive.

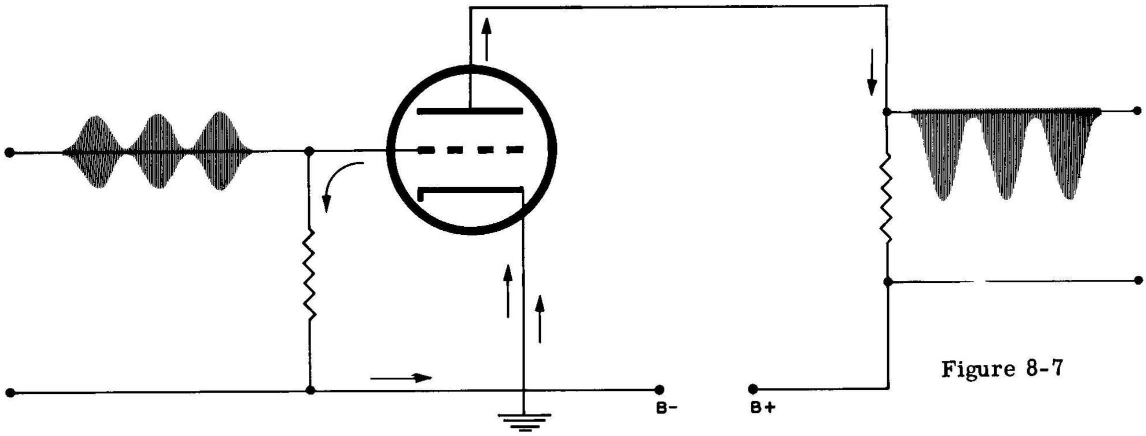


Figure 8-7

MODULATED BROADCAST SIGNAL IS AMPLIFIED AND RECTIFIED IN UNBIASED AMPLIFIER CIRCUIT.

THE DETECTOR-AMPLIFIER

Figure 8-7 shows the total effect of what happens in an amplifier without bias, or a detector-amplifier (sometimes called grid leak detector). Notice that a modulated RF voltage is applied to the grid of this triode amplifier. Its output, from the plate load resistor, consists of just one-half of the signal that was fed in. This half signal is larger than it was on the grid, however, so it is being amplified. The other half signal has been eliminated almost entirely, so the signal is also detected to the extent that it is ready to operate an earphone.

The obvious advantage of this type of detector-amplifier is its amplification. It not only detects the signal, but it builds up the strength of the signal at the same time. This kind of circuit is quite useful in some receivers where amplification cannot be conveniently obtained any other way.

The disadvantage of such a circuit is that the detection job it does is not quite as good as that achieved in a diode tube. As mentioned previously, it does not eliminate all of the positive half-cycle, and this introduces a degree of distortion in the resulting audio signal. In a circuit where the fidelity of the detected signal is extremely important, a detector-amplifier would not be ideal. Better results would be obtained with a separate diode detector circuit, and then a conventional amplifier (with bias) to reproduce faithfully the signal fed to it. The detector-amplifier is, however, a fine circuit for many ordinary applications.

As the experiment in this lesson you will modify the amplifier built in Lesson VII to make it a detector-amplifier, thus eliminating the need for the crystal rectifier in the circuit.

HOW TO BUILD A DETECTOR-AMPLIFIER

PURPOSE

TO CONVERT THE SEPARATE DETECTOR AND AMPLIFIER CIRCUITS OF LESSON VII TO A COMBINATION DETECTOR-AMPLIFIER CIRCUIT.

MATERIALS REQUIRED

1 100 mmf capacitor
The assembled circuit from Lesson VII

PREPARING THE CHASSIS FOR THIS EXPERIMENT (See Figure 7-20 on Page 63.)

(✓) Remove the line cord from the wall socket and disconnect the GND.-ANT. wires.

(✓) Remove the crystal rectifier from the circuit entirely. Put it in a safe place for use in the future.

(✓) Disconnect the 12" length of hookup wire from one end of the 3.3 megohm resistor.

(✓) Disconnect the 12" length of hookup wire from the ground lug next to the power transformer. The batteries will not be used in this experiment.

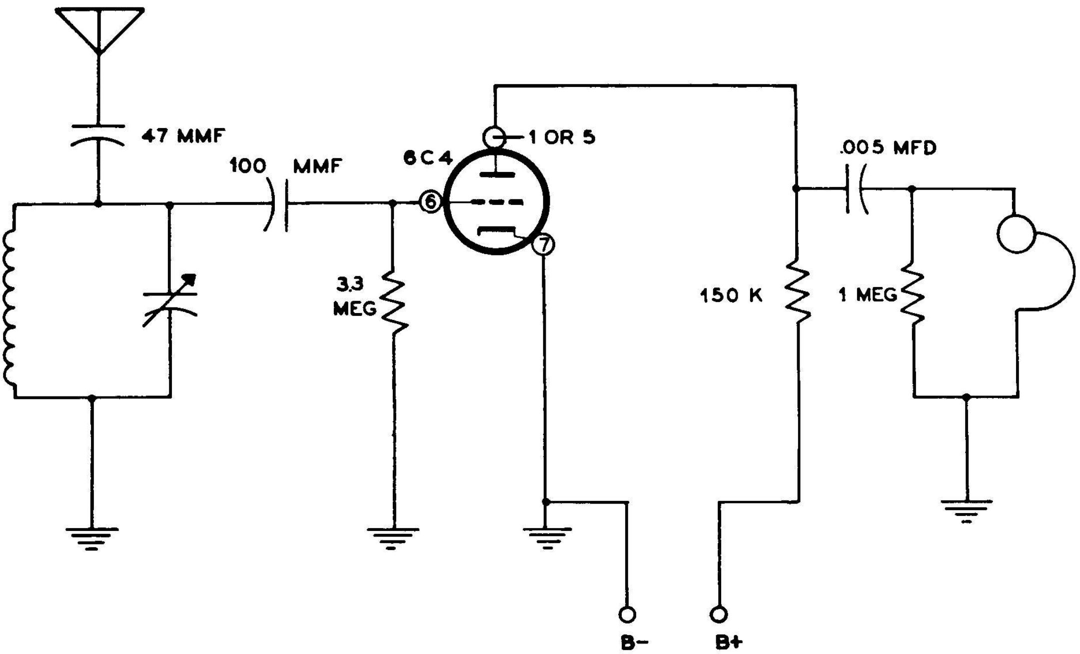
MODIFYING THE CIRCUIT

(✓) Connect the free end of the 3.3 megohm resistor to terminal 4 of the 6C4 tube socket. The resistor will now be between terminals 4 and 6 of the 6C4 tube.

(✓) Connect the 100 mmf capacitor where the crystal was connected previously (between the orange terminal of the regenerative detector coil and terminal 6 of the 6C4 tube socket. Use insulating sleeving.

These simple changes complete the wiring of the circuit for this experiment. The circuit has been converted to a detector-amplifier by merely removing the battery bias from the circuit, and by replacing the crystal rectifier with a coupling capacitor. No pictorial diagram is required for these minor changes, but a schematic diagram is shown in Figure 8-8. The differences can be seen readily by comparing the circuit to the schematic of Lesson VII.

This circuit may now be operated to listen to your local broadcast stations by reconnecting the antenna and ground leads, inserting the power plug in the wall socket, plugging in the earphone, and turning the switch on.



CIRCUIT FROM PREVIOUS EXPERIMENT CONVERTED TO DETECTOR-AMPLIFIER BY REMOVAL OF BATTERY BIAS, AND SUBSTITUTION OF 100 MMF CAPACITOR IN PLACE OF CRYSTAL RECTIFIER.

Figure 8-8

DISCUSSION

You should find that the operation of this detector-amplifier is very similar to that of the separate detector and amplifier circuits of Lesson VII. The importance of the experiment is that you have proved that the unbiased amplifier circuit is detecting the signal while it is also amplifying it. The crystal rectifier has been removed from the circuit, yet the circuit still functions satisfactorily.

This completes the experiment of Lesson VIII. In Lesson IX you will modify this circuit further to increase the amplification of the signal even more, and bring up the volume of stations as heard in the earphone.

LESSON VIII

QUESTIONS

NOTE: The answers to the questions for Lesson VIII will be found at the back of the book on Page 86.

1. What grid condition is the bias in a conventional amplifier designed to prevent?

2. How much (at least) negative bias would be desirable in an amplifier designed to handle a signal that swings 2 volts negative and 2 volts positive? 4

3. As long as the grid remains negative as compared to the cathode, grid current_____ (does - does not) flow in a conventional amplifier circuit.

4. In the circuit of Figure 8-6, the negative half of the signal is amplified satisfactorily, and the positive half of the signal________ (doubles - is cancelled out).

5. Give one advantage of the detector-amplifier as compared to a diode detector.

6. Give one advantage of a separate diode detector and separate amplifier over the combination detector-amplifier.

LESSON IX

HOW IS FEEDBACK USED FOR EXTRA AMPLIFICATION?

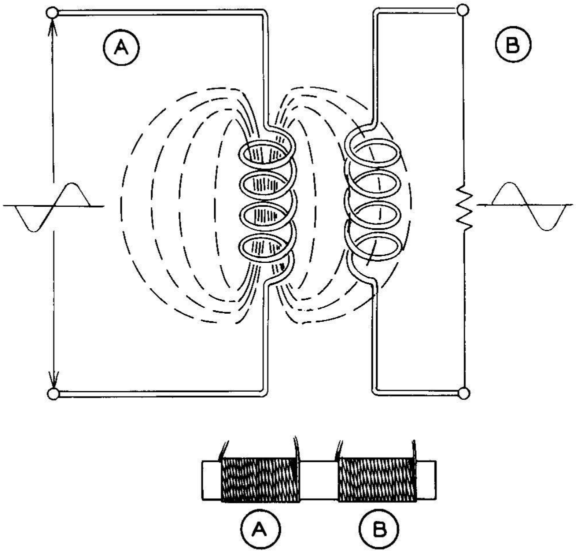
While the detector-amplifier constructed in Lesson VIII does a rather good job for a one-tube circuit, its performance can still be improved, and its amplification increased, by making the circuit regenerative. "Regeneration" is the technique of increasing the amplification of a circuit by causing it to "reamplify" signals. The term "feedback" is very descriptive of this process, since regeneration does consist of feeding part of a circuit's output back to its input, so the signal is amplified more than once in the same amplifier circuit. Such a feedback arrangement can be added to the detector-amplifier you built in the last experiment, and it will reamplify the incoming signal to build up its strength even beyond that achieved as a straight detector-amplifier.

Regeneration is another of those qualities in an electronic circuit that can be either "good" or "bad," depending on what the circuit is supposed to do. The irritating whistle and scream of a public address system with the volume turned up too high is an excellent example of undesirable regeneration. With excessive volume, sound coming from the PA speakers is picked up by the microphone ... and this feedback of the output sound to the input mike causes the entire system to oscillate. Oscillation is the natural consequence in a highly regenerative circuit, but is undesirable in a PA system.

On the other hand, if a circuit were designed for some other purpose...if the objective were to design a code practice oscillator, or an audio tone generator, then this oscillation would be desirable.

The objective in adding feedback to your detector-amplifier circuit is to increase the amplification of the circuit through regeneration, but not to cause oscillation. It is for this reason that a regeneration control is added to the circuit, so the amount of feedback can be controlled to give additional amplification, but to fall short of making the circuit oscillate.

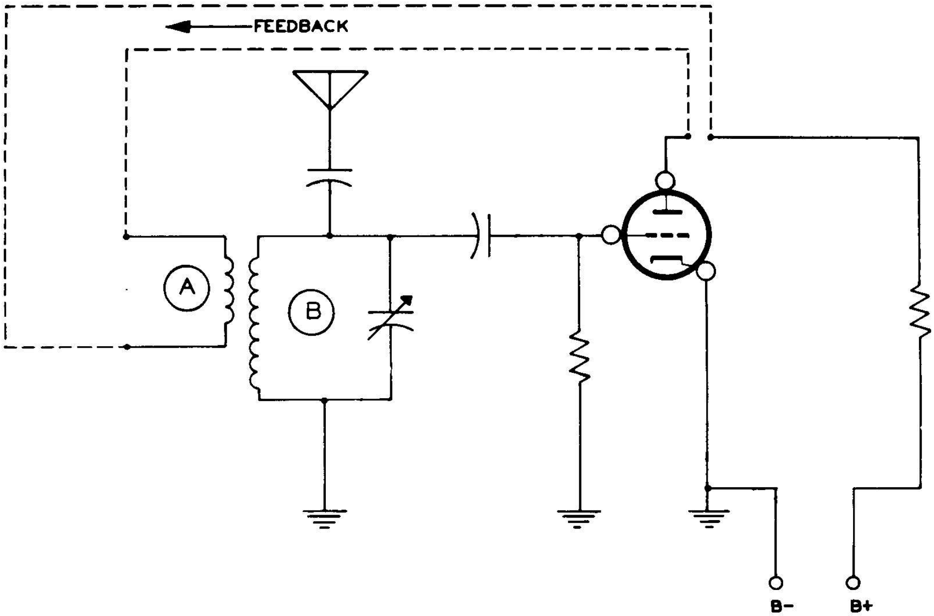
A transformer will be used as a device for feeding back the signal in your circuit. Transformers will be explained in more detail in your next experiment (Kit EK-2B). Just one fundamental concept needs explaining right now, and that is the effect of two coils wound on the same coil form and positioned closely together. Figure 9-1 shows this situation schematically and pictorially.



TWO COILS WOUND CLOSE TOGETHER MAKE A TRANSFORMER DUE TO THE MAGNETIC COUPLING.

Figure 9-1

As you learned in previous lessons, when current passes through a coil of wire there is a magnetic field set up around the coil and through its core. If another coil is positioned so that it is in the magnetic field of the first coil, current will be induced in the second coil by the first coil, and energy can be transferred from one coil to the other, even though there is no electrical contact between the two coils of wire. Coil A in Figure 9-1, for example, can cause current to flow in coil B, purely through the fact that the coils are positioned closely together, and coil B is in the magnetic field of coil A. A changing signal voltage (AC) applied to coil A will appear across the terminals of coil B, although a steady



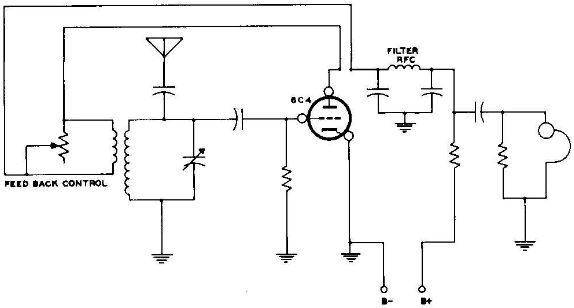
FEEDBACK FROM OUTPUT TO INPUT CAUSES CIRCUIT TO "REAMPLIFY" SIGNALS.

Figure 9-2

DC current through coil A will not appear across coil B. It is only as the magnetic field is changing that it induces current into coil B. A signal causes the magnetic field to build up and collapse very rapidly, and each fluctuation of the field induces current in coil B. A steady DC current does not cause the field to fluctuate, so no effect is evident across coil B. It is for this reason that a transformer has the effect of blocking DC, and passing AC.

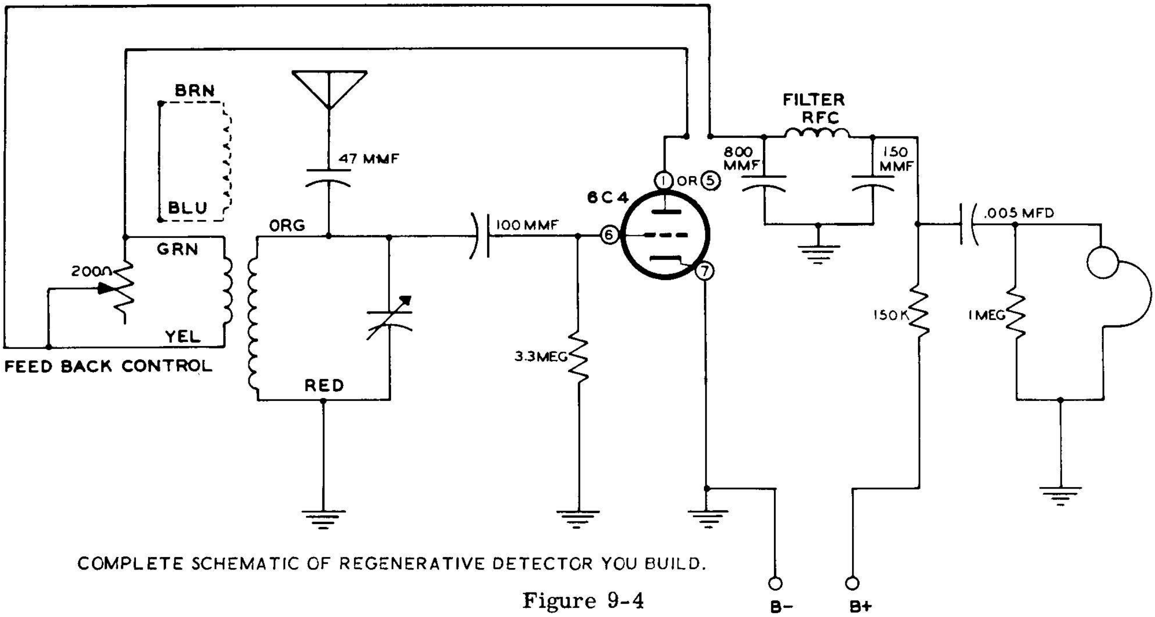
This idea may become clearer as you refer to a schematic diagram of a simplified circuit employing feedback (see Figure 9-2). Notice that one coil (A) is connected into the plate circuit of the amplifier to pick up the output of the circuit. This coil is closely coupled to a second coil (B) so that the two coils together make a transformer. The signal current flowing through coil A feeds some of the output signal back into the input of the amplifier circuit through coil B. The high DC plate voltage, however, does not pass through from coil A to coil B of the transformer. The high DC plate voltage is kept out of the input circuit by the transformer, so the high voltage cannot upset signal and bias conditions.

The overall effect of this kind of circuit is that the signal is amplified and reamplified to build up its strength far beyond what would be possible with normal amplification. The trick is to keep the circuit operating just below the point of oscillation. If the feedback becomes too great, the circuit simply oscillates and produces its own signal, while if the feedback is controlled in some way, and is kept just below the point of oscillation, this "reamplification" effect is achieved and the circuit becomes very efficient.



FEEDBACK CONTROL AND RADIO FREQUENCY FILTER ARE ADDED TO IMPROVE CIRCUIT OPERATION.

Figure 9-3



COMPLETE SCHEMATIC OF REGENERATIVE DETECTOR YOU BUILD.

Figure 9-4

Figure 9-3 shows a more realistic regenerative detector circuit. You will notice two main changes between this circuit and the one in Figure 9-2.

First, a variable resistor has been installed across the feedback coil so that the amount of feedback can be controlled. If the control is adjusted all the way in one direction it actually shorts out the feedback coil, while in the other extreme position the variable resistor places a high resistance across the coil so that the coil can still function as a feedback device. Various degrees of feedback are then possible by adjusting this variable resistor.

You will also notice that another coil and two capacitors have been added in the plate circuit of the amplifier tube. This is a filter circuit designed to eliminate any remaining radio frequency signal before the audio signal reaches the earphone. You may recall from an earlier discussion of detection, that the process of detection consists of two main functions. The modulated RF signal picked up by the antenna must be rectified, and it also must be filtered. The function of filtering can often be ignored when only a small amount of RF is involved, since an earphone or a speaker has a tendency to respond only to the audio component of the signal and such a sound reproducing device will ignore the RF pulsations. In a circuit of this type, however, where the signal amplitude is being built up excessively by feedback, a considerable amount of RF signal is generated, and this must be filtered out and blocked from the earphone. The coil (called a radio frequency choke) and the two capacitors, make up a filter circuit that blocks RF current from passing through the plate circuit to the earphone. This shorts the RF signals to ground without affecting the audio signal.

Figure 9-4 shows the actual circuit you will construct in the experiment of this lesson. The values of the various parts are given, and the coil terminals are identified by color code. Note that a third winding on the regenerative detector coil (shown with dashed lines) is disabled for this particular experiment by connecting a wire across it to short it out.

You should note, too, that this is exactly the same circuit as you were using in the previous lesson, except for the addition of the feedback circuit, (using another winding of the regenerative detector coil) and except for the addition of the filter in the plate circuit to block excessive radio frequency signal from getting to the earphone.

You will probably be surprised at the extra amplification this circuit provides in the experiment of this lesson.

HOW TO BUILD A REGENERATIVE DETECTOR-AMPLIFIER

PURPOSE

TO DEMONSTRATE IMPROVED CIRCUIT PERFORMANCE WHEN THE DETECTOR-AMPLIFIER IS MADE REGENERATIVE, AND TO DEMONSTRATE FURTHER IMPROVEMENT WHEN THE PLATE SUPPLY VOLTAGE IS DOUBLED.

MATERIALS REQUIRED

1 200 ohm control (variable resistor)
1 Knob, white
1 150 mmf ceramic capacitor
1 800 mmf ceramic capacitor
1 Radio frequency choke coil
1 Control ground lug
1 "T" type terminal strip
Circuit from Lesson VIII
EK-1 Test Set or equivalent

PREPARING THE CHASSIS FOR THIS EXPERIMENT

( ) Remove the power plug from the wall socket and then remove the antenna and ground connections.

( ) Disconnect the 150 K ohm resistor lead and the hookup wire from lug 5 of the 6C4 tube socket. This should leave lug 5 with no connections.

The chassis is now ready for the changes necessary to convert the detector-amplifier of Lesson VIII to the regenerative detector-amplifier of Lesson IX.

STEP 1 - BECOMING FAMILIAR WITH THE PARTS

The regenerative detector coil is not one of the new parts introduced in this experiment. However, in the previous experiments you have used only one winding of this coil, and all three windings will have connections made to them in this experiment.

Figure 9-5A, B, and C will provide you with more information on the regenerative detector coil. Figure 9-5A is a schematic of the three windings on the coil form, giving the name for each winding, and the color termination of the winding connections. Figure 9-5B is a pictorial diagram locating the colored terminals on the coil, as viewed from under the chassis as the coil is now mounted. Figure 9-5C identifies the three coils as they are located on the coil form.

A new part introduced in this experiment is the 200 ohm control. This component is actually a variable resistor. The size of the resistor can be changed smoothly from zero ohms to 200 ohms by rotating the shaft of the control. Figure 9-6A will give you some idea of the physical construction of this part. The resistance element itself is horse-shoe shaped, and a sliding "wiper" contact moves around the resistor as the shaft is turned, thereby controlling the amount of resistance between the center terminal of the control and either outside terminal. Figure 9-6B shows the schematic symbol for the variable resistor.

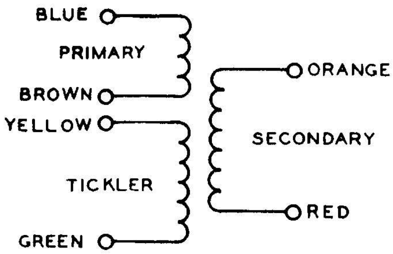


Figure 9-5A

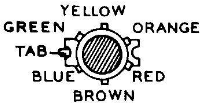


Figure 9-5B

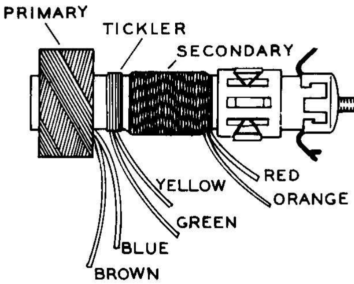
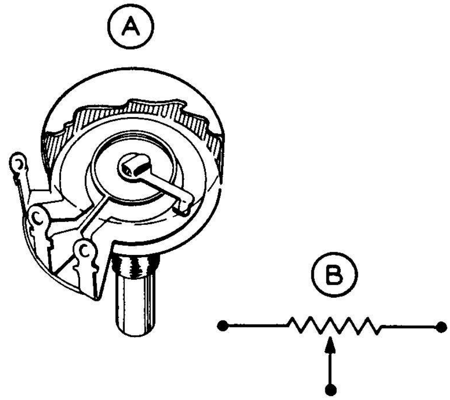


Figure 9-5C

IDENTIFICATION OF REGENERATIVE DETECTOR COIL WINDINGS.



INTERNAL CONSTRUCTION AND SCHEMATIC SYMBOL FOR VARIABLE RESISTOR (SOMETIMES CALLED POTENTIOMETER).

Figure 9-6

The radio frequency choke coil is merely a coil wound in such a way that it will offer maximum opposition to the flow of radio frequency signals. Such a coil tends to "block" the passage of RF signals in a circuit, if an alternate path (through a capacitor to ground) is provided to dispose of the unwanted RF signal. The schematic symbol for a radio frequency choke is the same as for a single winding coil, except that the letters RFC usually appear to identify the function of the part.

The balance of the parts used in this experiment are either the same ones used previously, or are of the same general type, so that no special explanation is necessary.

STEP 2 - MOUNTING THE PARTS

( ) Install the 200 ohm control in the appropriate chassis hole as shown in Figure 9-7, using a large control ground lug instead of a lockwasher inside, and a control nut outside. Position the control terminals and the ground lug as shown.

( ) Install the white knob on the control shaft.

( ) Mount another "T" type terminal strip in the appropriate chassis hole "G" using a 6-32 screw, lockwasher and nut as shown in Figure 9-7. Position the terminal strip as shown.

This completes the mounting of the parts for this experiment.

STEP 3 - WIRING THE CIRCUIT

This experimental circuit can be wired by following the schematic diagram of Figure 9-4 and the pictorial diagram of Figure 9-7. At this stage in your educational progress you should be quite familiar with schematic diagrams and their interpretation. You might find it challenging and instructive to wire the changes in this final experimental circuit in Kit EK-2A by following only the schematic diagram. This will test your understanding of schematics and the wiring pattern they illustrate. You can use the pictorial diagram in Figure 9-7 merely as a check on your work, after the wiring has been completed.

By the same token, although a step-by-step wiring procedure follows, it is suggested that you use this step-by-step outline merely as a check on your work, after you have completed the wiring from the schematic.

( ) Connect a wire from the yellow terminal of the regenerative detector coil to the center terminal (2) of the 200 ohm control.

( ) Connect a wire from the green terminal of the regenerative detector coil to the terminal of the 200 ohm control closest to the chassis (terminal 1).

( ) Connect another wire from the green terminal of the coil to lug 5 of the 6C4 tube socket.

( ) Connect the length of hookup wire (the other end of which is connected to the .005 mfd capacitor) to T-3 of the "T" terminal opposite the 200 ohm control.

( ) Connect the free end of the 150 K ohm resistor to T-3.

( ) Connect the RF choke coil from T-4, over to the center terminal (2) of the 200 ohm control.

( ) Connect the 800 mmf capacitor between the control ground lug, and the center terminal (2) of the 200 ohm control. See Figure 9-7.

( ) Connect the 150 mmf capacitor between T-4 and the ground solder lug.

( ) Connect a short length of wire between the brown and blue terminals of the regenerative detector coil to short out the winding not used in this experiment.

NOTE: The blue and white identification label shows the Model Number and Production Series Number of your kit. Refer to these numbers in any communications with the Heath Company; this assures you that you will receive the most complete and up-to-date information in return.

( ) Install the identification label in the following manner:

1. Select a location for the label where it can easily be seen when needed, but will not show when the unit is in operation. This location might be on the rear panel or the top of the chassis, or on the rear or bottom of the cabinet.

2. Carefully peel away the backing paper. Then press the label into position.

This completes the wiring of the regenerative detector-amplifier.

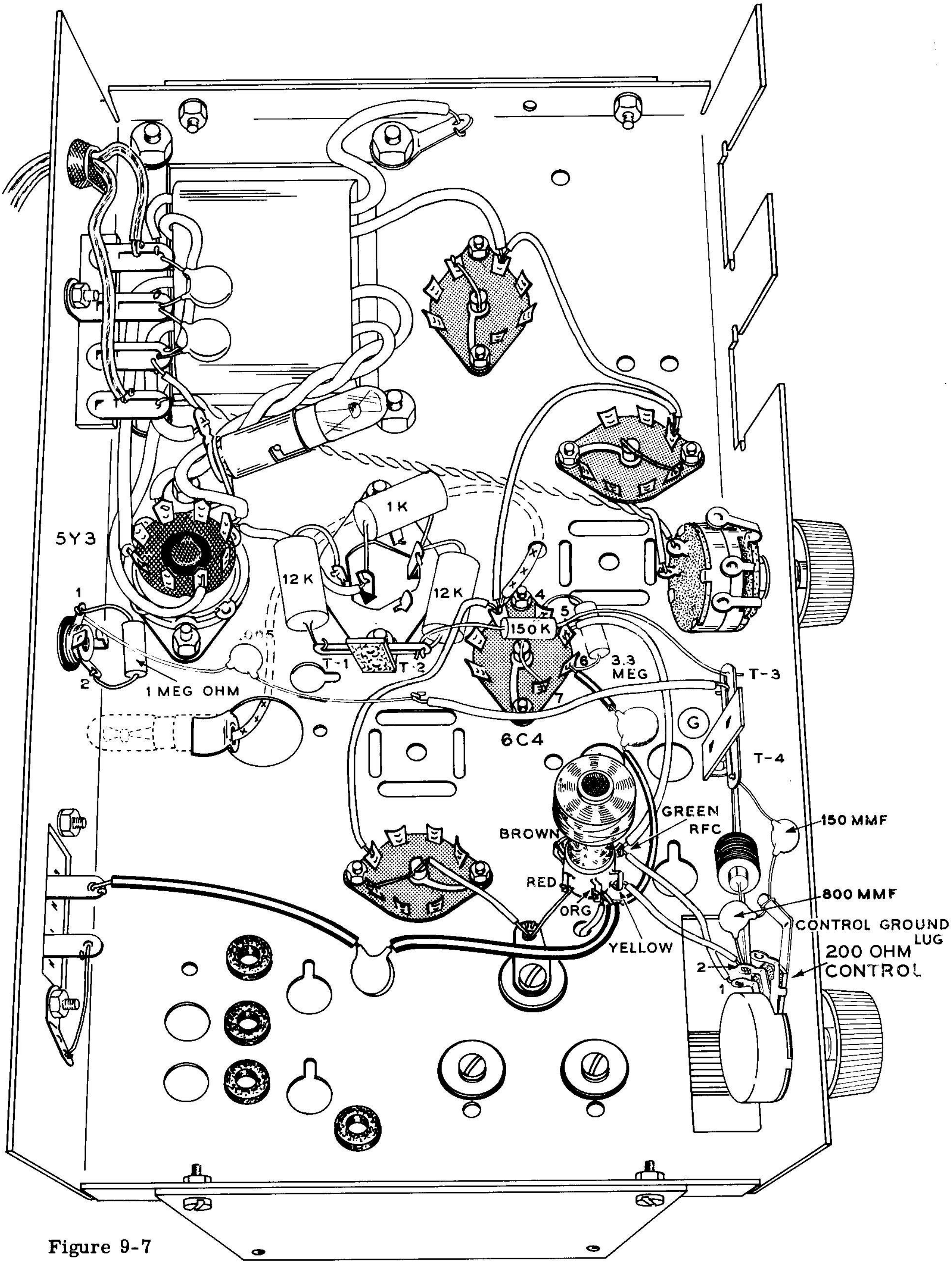

5Y3
1
2
1 MEG OHM
.005
12 K
1 K
12 K
T-1
T-2
150 K
4
5
6
7
3.3 MEG
6C4
T-3
T-4
G
GREEN
RFC
BROWN
RED
ORG
YELLOW
150 MMF
800 MMF
CONTROL GROUND LUG
200 OHM CONTROL
2
1

Figure 9-7

STEP 4 - USING THE CIRCUIT

Reconnect the antenna and ground leads, insert the wall plug, and plug in the earphone, to prepare this experiment for operation.

The 200 ohm regeneration control is connected so that the regeneration in the circuit is increased when the control is turned in a clockwise direction, and decreased when the control is turned in a counterclockwise direction. For now, set the regeneration control at its full counterclockwise position.

Now turn the circuit "on" and tune in one of the stations picked up by your antenna. Then slowly rotate the regeneration control in a clockwise direction to increase regeneration in the circuit. You should find that the signal increases in strength as the control is rotated.

When the regeneration control has been increased too far, the detector-amplifier circuit will go into "oscillation." This will be recognized by a whistling or hissing sound in the earphone. The loudest and clearest signal will be received just before the set breaks into oscillation. Back off on the regeneration control until oscillation just stops. At this point, slight retuning of the station may be necessary, and you will find stations should be retuned each time the setting of the regeneration control is changed. After some practice you will become very familiar with handling the tuning and regeneration controls to bring in the best signal quickly.

A warning is in order concerning operation of the regenerative detector-amplifier. Whenever this circuit is in oscillation it is acting as a transmitter, and is actually radiating a radio frequency signal from your receiving antenna.

This kind of radiation can cause considerable interference to other receivers in the neighborhood, so it is simply good courtesy to keep the operation of the regenerative receiver just below the point of oscillation.

You will find the performance of this circuit to be considerably improved over the previous circuits, dramatically demonstrating the advantage of regeneration in a detector circuit.

STEP 5 - INCREASING THE PLATE VOLTAGE

The experiment thus far has demonstrated that the performance of the detector-amplifier is improved with regeneration. The performance of this circuit can be improved even further by increasing the plate voltage applied to the 6C4 tube. The plate voltage is now obtained from T-2 through the 150 K ohm resistor. The voltage at this point represents half of the output of the power supply. (See Figure 9-8A.) By moving the connection of the 150 K ohm resistor to secure the full output of the power supply, the plate voltage will be doubled and the overall performance of the circuit will be improved.

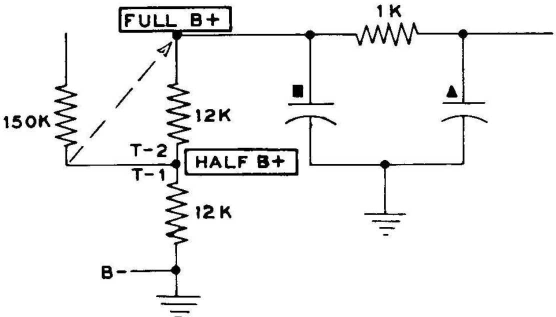
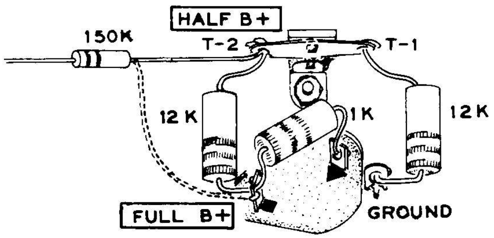


Figure 9-8A



SCHEMATIC AND PICTORIAL DIAGRAMS OF CHANGE IN CONNECTION OF 150 K RESISTOR TO DOUBLE B+ VOLTAGE.

Figure 9-8B

Since the change involves handling the high voltage circuit, make sure that the line plug is removed and the switch is turned "off." Disconnect one lead of the 150 K ohm resistor from T-2 and solder the lead to the junction point of the 1000 ohm resistor and 12,000 ohm resistor at terminal ■ of the filter capacitor. (See Figure 9-8B.)

The EK-1 Test Set may be used to measure this change in supply voltage and confirm the increase in plate circuit supply voltage from the power supply.

With the circuit still "off" and the power plug removed, connect the red test lead of the EK-1 Test Set to the junction point of the two 12,000 ohm resistors (T-2). Set the test set to its 500 V range, and connect the black test lead to the chassis. The test set should be arranged to measure DC voltage, the power plug should be reinstalled, and the circuit turned "on." The reading you get for this test represents 1/2 of the full supply voltage (the amount of voltage you have been using to supply the cathode-to-plate circuit in all the experiments so far). It should be in the neighborhood of 110 volts DC.

Turn the circuit "off" again, pull the plug, and move the red test lead to the ■ terminal of the electrolytic capacitor. Again turn "on" the power and plug in the power line (with the EK-1 Test Set on the 500 V range) and you will measure the full output of the power supply that will now be used to power the regenerative detector-amplifier. This reading should be in the neighborhood of 220 volts DC. Turn off the power, pull the line plug, and remove both test leads from the circuit. Now reinsert the line cord, turn the circuit "on," and you should find a great improvement in performance.

This demonstration makes it rather clear that (up to a certain point, at least) increasing the plate voltage supplied to a vacuum tube increase the amplification in the tube stage.

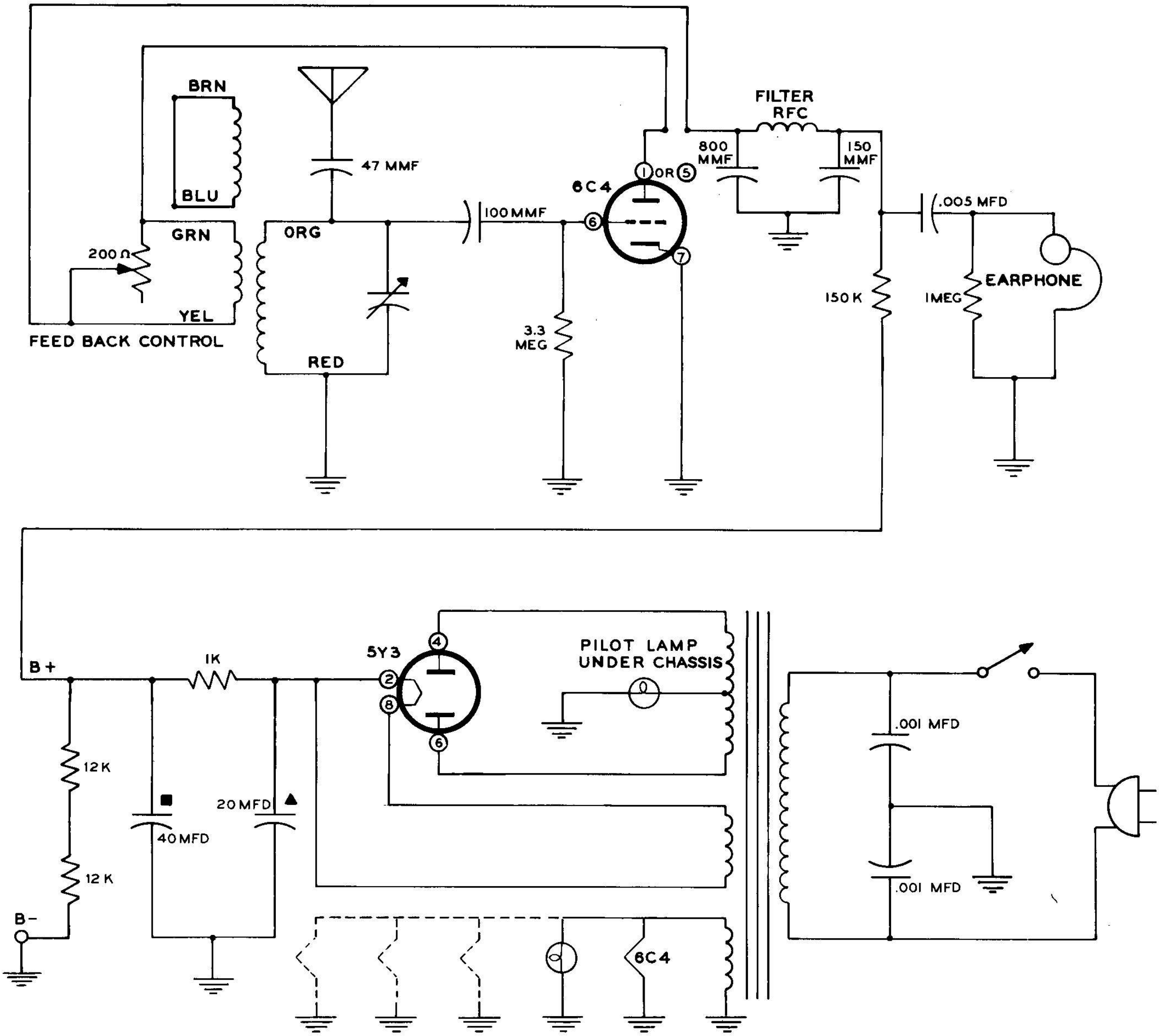
This completes the experiment of Lesson IX.

DISCUSSION

A complete schematic diagram of the power supply and regenerative detector-amplifier circuits is provided in Figure 9-9. This is the final circuit set-up of your EK-2A kit, and will be the "radio" you will be using until you move on to the EK-2B Kit.

The one tube (plus rectifier) circuit of this experiment is one of the most efficient one-tube receiver circuits possible. It has been improved by regeneration, and by increased plate voltage, over the regular detector-amplifier...and the detector-amplifier was a big improvement over the straight diode detector, so you are getting a great deal of performance from a single vacuum tube operating as a receiver on the broadcast band. You should have a lot of fun with this receiving set, and it should be of considerable satisfaction to you, to realize that you understand the basic fundamentals of operation in the circuit.

You are to be congratulated for the effort you have expended in arriving at this final experiment in the EK-2A Kit.



COMPLETE SCHEMATIC DIAGRAM OF FINAL EK-2A CIRCUIT.
Figure 9-9

LESSON IX

QUESTIONS

NOTE: The answers to the questions for Lesson IX will be found at the back of the book on Page 86.

1. The basic idea of regeneration is to feed part of the output of a circuit back to the input

2. Draw the schematic symbol of a feedback transformer (as is used in your experiment).

3. Draw the schematic symbol of a radio frequency choke coil.

4. For best operation, the regeneration control of your experiment should be set:
(just above the point of oscillation)
(just below the point of oscillation)
(just at the point of oscillation)

5. Increasing the supply voltage to the cathode-to-plate circuit of your regeneration detector-amplifier caused the earphone volume to: decrease, increase.

WHERE DO YOU GO FROM HERE?

Basic Radio, Part II (Kit EK-2B), picks up where this kit leaves off. The interesting experiments in the next kit let you actually build a complete two-band superheterodyne receiver with a speaker!

The basic explanation of various radio circuits will continue in the same pattern as has been developed in this kit, and the following are typical of the questions that will be answered for you in Kit EK-2B: What are transformers and how are they used? What does a receiver power supply do? How do amplifiers use operating voltages? What does a receiver audio section do? What does the receiver detector section do? What does the receiver RF section do? What is a local oscillator and how does it work? What is a mixer circuit for? What does alignment mean? What are short wave and CW signals? Etc.

Basic Radio, Part II, will help you learn how to step-up or step-down voltage with a transformer, how to build various kinds of power supplies, how to measure operating voltages with the EK-1 Test Set, and how to build and test audio, RF, and mixer circuits. The principle of superheterodyne operation will be explained, as will receiver alignment, and short-wave operation.

Practically all of the parts of the EK-2A Kit will be used again in the EK-2B Kit, but the new kit will consist of many additional parts, including the speaker, vacuum tubes, IF transformers, a tuning dial, etc. As the final experiment in the EK-2B Kit, you will construct a complete 5-tube (plus rectifier) 2-band superheterodyne receiver with AVC (automatic volume control) and speaker or earphone output. Keep this manual and all the EK-2A parts for use in all later experiments.

Basic Radio, Part II, is the next logical step in your pursuit of knowledge in the Electronics Field. Order your EK-2B kit now, while the material covered in this manual is still fresh in your mind!

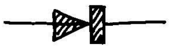
ANSWERS FOR LESSON I

1. Converts sound vibrations into electrical vibrations.
2. Provides the power for the signal, and transforms the signal into an electrical form that will radiate from an antenna.
3. Between 550 kc and 1600 kc.
4. 1000 cycles per second.
5. 250 watts to 50,000 watts.
6. "Skip."
7. Select (or tune), amplify (or build up), and detect (or transform back to audio).
8. Converts electrical vibrations into sound vibrations. (Just the opposite of microphone!)

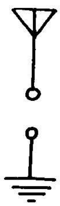
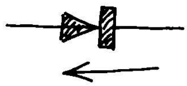
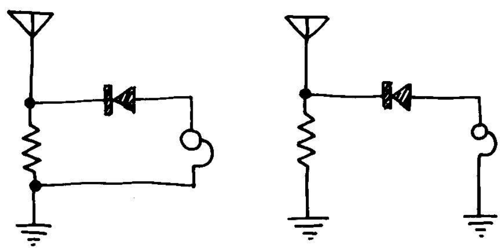
ANSWERS FOR LESSON II

1. Changing in direction, while at the same time changing in amount.
2. Flowing in the same direction.
3. 20 cps to 20,000 cps.
4. 20,000 cps, which can be written 20 kc.
5. The form of code or by audio modulation.
6. Amplitude or amount.
7. Station A.

ANSWERS FOR LESSON III

1. Select (or tune), amplify (or build up), detect (or demodulate).
2. RF (radio frequency) section, detector section, audio section.
3. Tunes (or selects) and amplifies radio signals.
4. Change modulated RF signal to audio signal.
5. Amplify audio signal.
6. From crystal to contact.
7. 
8. Crystal.
9. PDC (pulsating direct current).

ANSWERS FOR LESSON IV

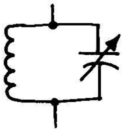
1. Rectification.
2. RF filtering.
3. 
4. 
5. 
6. 
7. 
8. Just the detector section, plus an antenna and earphone.

ANSWERS FOR LESSON V

1. Coil and a capacitor.

2. 

3. 

4. 

5. Farad.

6. Henry.

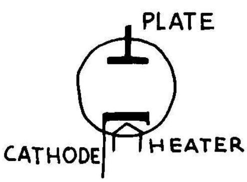
7. 1200 kc.

8. Increases.

9. Decreases.

10. Small capacitor.

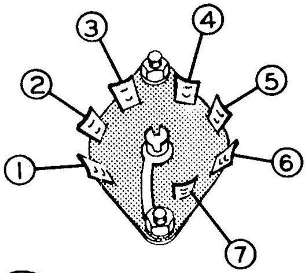
ANSWERS FOR LESSON VI

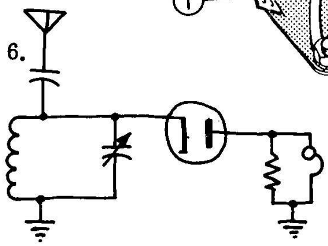
1. 

2. Cathode must be heated.

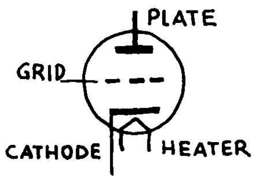
3. From cathode to plate.

4. Cathode is connected to the minus battery terminal and plate is connected to the plus battery terminal.

5. 

6. 

ANSWERS FOR LESSON VII

1. 

2. Regulates or controls the electron movement from cathode to plate.

3. Decreases.

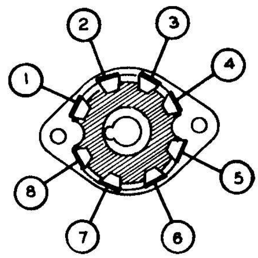
4. Greater than the voltage change at the grid.

5. More negative than the cathode.

6. Supplies power to the heater circuit.

7. Resistor.

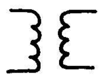
8. Batteries.

9. 

ANSWERS FOR LESSON VIII

1. To prevent the grid from becoming positive and drawing current.
2. At least minus 2 volts.
3. Does not.
4. Is cancelled out.
5. It amplifies the signal, whereas the diode detector does not.
6. Better detection, less distortion, higher fidelity.

ANSWERS FOR LESSON IX

1. To feed part of the output of a circuit back to the input.
2. 
3. 

4. Just below the point of oscillation.
5. Increase.

SERVICE INFORMATION

SERVICE

In event continued operational difficulties of the completed experimental equipment is experienced, the facilities of the Heath Company Service Department are at your disposal, or you may contact our Technical Consultation Department by mail. Local Service is available in some areas through authorized HEATHKIT Dealers. Due to the simplicity of this kit, no minimum service fee has been fixed; the charges will be determined by the amount of time needed to service the instrument and the price of any additional material that may be required. THESE SERVICE POLICIES APPLY ONLY TO THE COMPLETED CIRCUIT OF LESSON IX, CONSTRUCTED IN ACCORDANCE WITH THE INSTRUCTIONS AS STATED IN THE MANUAL. Experiments that are not entirely completed or that are modified in design will not be accepted for repair. Experiments showing evidence of acid core solder or paste fluxes will be returned NOT repaired.

REPLACEMENTS

Material supplied with HEATHKIT products has been carefully selected to meet design requirements and ordinarily will fulfill its function without difficulty. Occasionally improper instrument operation can be traced to a faulty component. Should inspection reveal the necessity for replacement, write to the Heath Company and supply all of the following information:

A. Thoroughly identify the part in question by using the part number and description found in the manual Parts List.

B. Identify the kit Model Number and Series Number.

C. Mention date of purchase.

D. Describe the nature of defect or reason for requesting replacement.

The Heath Company will promptly supply the necessary replacement. Please do not return the original component until specifically requested to do so. Do not dismantel the component in question as this will void the guarantee. This replacement policy does not cover the free replacement of parts that may have been broken or damaged through carelessness on the part of the kit builder.

SHIPPING INSTRUCTIONS

In the event that your completed kit must be returned for service, these instructions should be carefully followed.

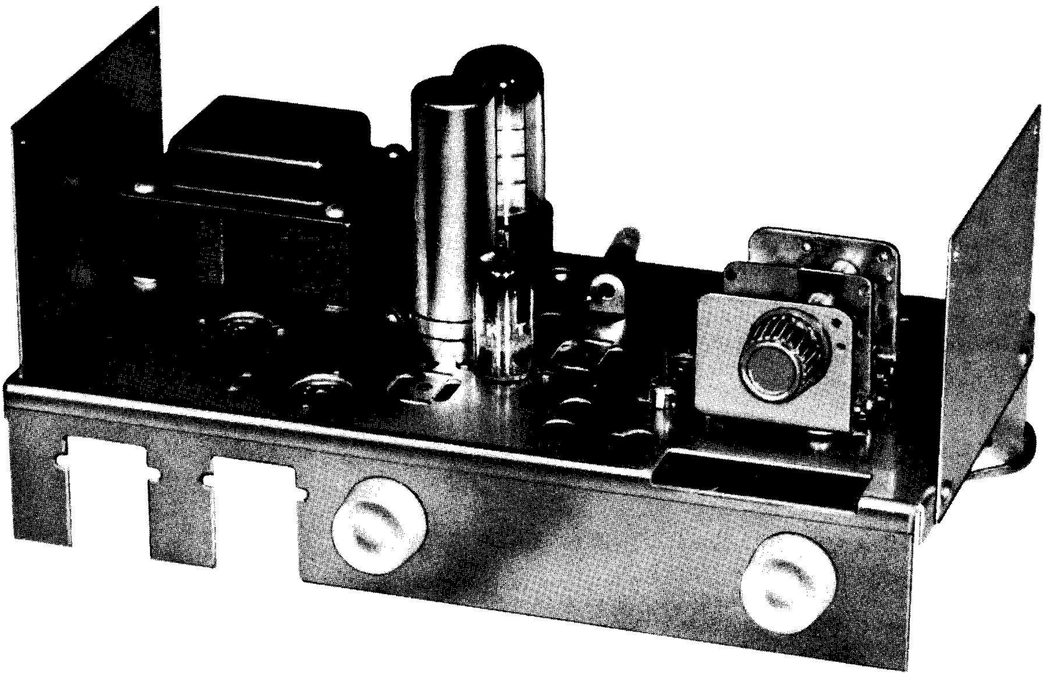
ATTACH A TAG TO THE CHASSIS BEARING YOUR NAME, COMPLETE ADDRESS, INVOICE NUMBER ON WHICH THE KIT WAS PURCHASED, AND A BRIEF DESCRIPTION OF THE DIFFICULTY ENCOUNTERED. Wrap the chassis in heavy paper, exercising care to prevent damage. Place the wrapped chassis in a stout carton of such size that at least three inches of shredded paper, excelsior, or other resilient packing material can be placed between all sides of the chassis and the carton. Close and seal the carton with gummed paper tape, or alternately, tie securely with stout cord. Clearly print the address on the carton as follows:

To: HEATH COMPANY
Benton Harbor, Mich. 49022

Include your name and return address on the outside of the carton. Preferably affix one or more "Fragile" or "Handle With Care" labels to the carton, or otherwise so mark with a crayon of bright color. Ship by insured parcel post or prepaid express; note that a carrier cannot be held responsible for damage in transit, if in HIS OPINION, the article is inadequately packed for shipment. Your chassis will be returned by express collect.

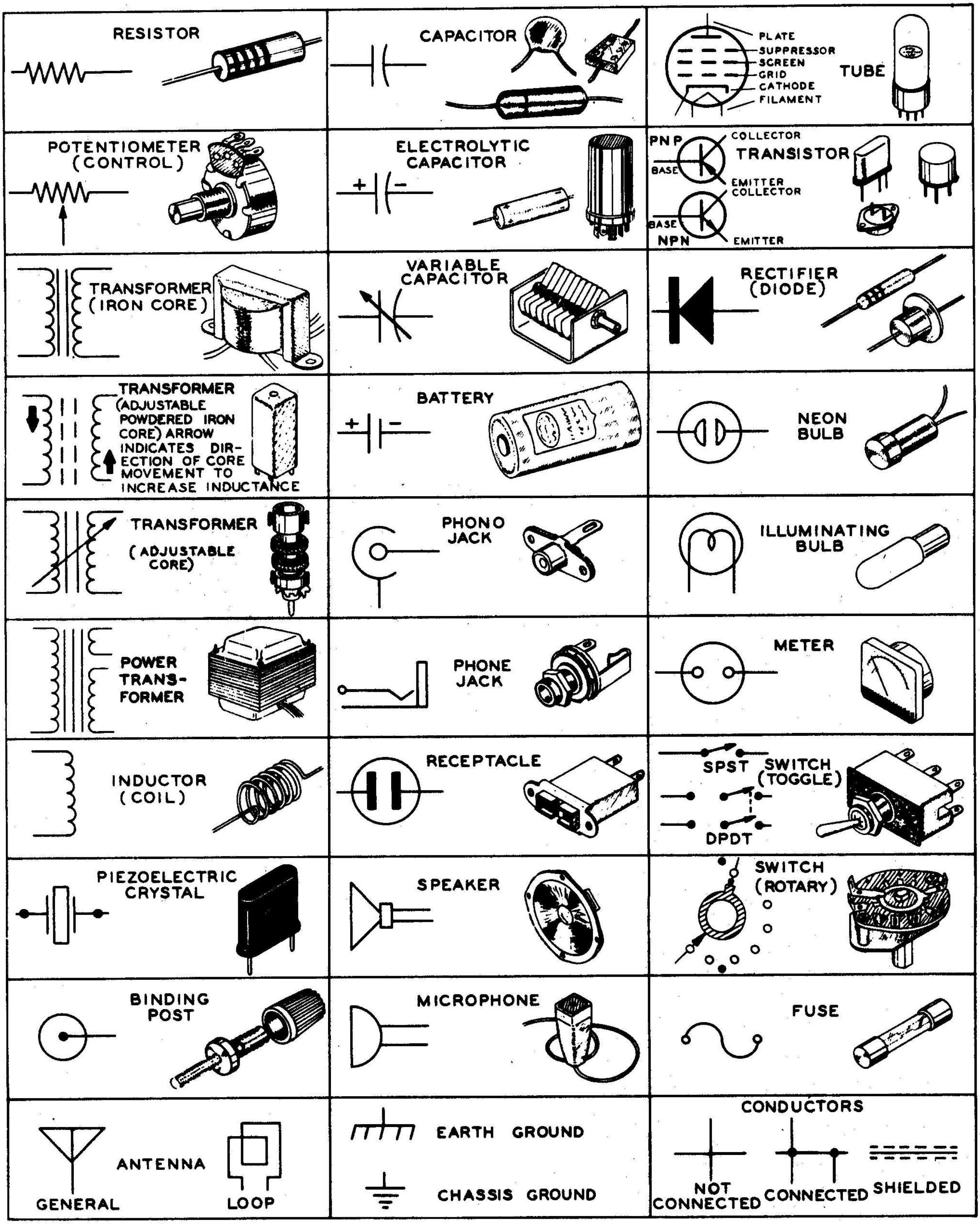
SPECIFICATION CHANGES

All prices are subject to change without notice. The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.



TYPICAL COMPONENT TYPES

This chart is a guide to commonly used types of electronic components. The symbols and related illustrations should prove helpful in identifying most parts and reading the schematic diagrams.



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